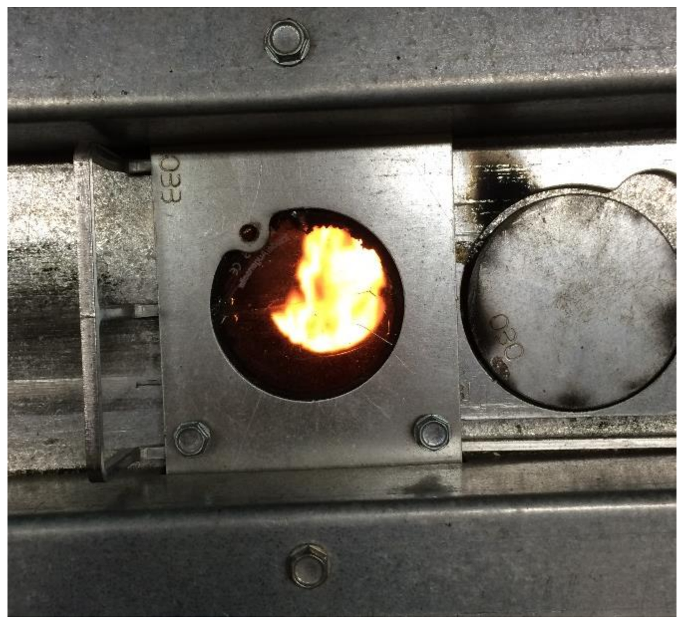
Biomass Boiler Installation at The Vermont Farmers Food Center



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12 Gauge Electric

Lohsen Plumbing and Heating

Phelps Plumbing and Heating

Summary

This report summarizes a recent installation of a 341,200 BTU/hr (output) multi-fuel biomass boiler at the Vermont Farmers Food Center (VFFC) in Rutland, VT. The boiler heated the Farmer's Hall building using several alternative fuels to displace propane. The boiler was fueled primarily on wood pellets but was also able to feed and burn grass biomass pucks. This demonstration project carried a cost premium when compared to a typical propane heater installation. That premium is paid back over time due to recurring fuel cost savings. A simple payback period of 2.2 to 8.0 years is feasible against a cost premium of $51,255 for the boiler depending on the fuel used and the amount of use.

Background

The VFFC is a 501(c)(3) nonprofit educational organization located on the west side of Rutland, VT. VFFC's mission is to increase access and availability of locally produced food through the development of the infrastructure, educational programs and markets necessary for the growth of a vibrant and sustainable regional agricultural system that has the capacity to feed its citizens regardless of economic status, increase the personal health of the population, and add to the economic well-being of the community.

The VFFC is housed at the 2.9 acre former Mintzer Brother's site on West Street. Since the purchase of the property in 2012, the site has benefited from sustained and visionary rehabilitation to support the region's food system. Key accomplishments include the revitalization of the main building (15,640 ft2) to become the "Farmer's Hall" (host site for the 86 vendors that comprise the Rutland Winter Farmer's Market), development of plans for a shared aggregation, packing and storage facility in the pole barn on the north of the property (4,480 ft2) and development of longer-term plans for a commercial kitchen in yet another building onsite. The group recently completed the installation of a 13 kW solar photovoltaic array on the pole barn.

Although Farmer's Hall has historically been heated with propane unit heaters, the thermostats are set low to conserve fuel and minimize operating costs. This project resulted in the installation of a 341,200 BTU/hr EvoWorld HC100 Eco biomass boiler at the VFFC site to heat the Farmer's Hall in order to provide an improved customer and vendor experience. This boiler is capable of using a variety of coarse biomass including pellets, chips and densified pucks made from grass and other ag residue.

This installation is the second of this boiler type in Vermont, following a successful early adoption and demonstration at the Meach Cove Trust in Shelburne. The lessons learned from Meach Cove were applied at VFFC. The work at Meach Cove focused on solid grass biomass fuels was part of a larger US DOE funded program, The Vermont Bioenergy Initiative (VBI), which has the mission of significantly reducing Vermont's dependence on imported, non-renewable fuels. VFFC became interested in grass fuels due to the organizations' integration with the local farming community and the future potential of 1) heating the facility with a renewable fuel, 2) possibly helping to produce the fuel with a densifying system hosted at VFFC for use by partner farms and 3) having both of these things be part of an alternate food and agriculture model where farms are part of their own fuel supply chain.

Project Outline & Methods

The proposed project concept included several phases:

1. **Site Work** – General cleanup, Light demolition, Grading of site near boiler room, Layout of boiler room and fuel bin.
2. **Boiler Room Renovation & Bin Construction / Install** – Repair walls and roof, Install new person and equipment door (north), Construct or install fuel bin (west), Masonry repair as needed. Electrical and plumbing mains routed to the boiler room.
3. **Boiler and Buffer Tank Install** – Receive boiler, fuel augers, primary circulator, and buffer tank from RER / EvoWorld USA and install.
4. **Balance of Plant and Heat Distribution** – Specify, procure and install necessary plumbing, valves, thermostat controls, unit heaters, baseboard, & circulation pumps to enable operation of the boiler to heat the buffer tank and to distribute heat to the building.
5. **Commissioning and Test Burns** – Confirm installation of all parts, integrate the system, commission sub-systems and overall system, run boiler on wood pellets to start and tune, and run alternative fuels based on learning from Meach Cove.

Results

The project delivery followed the outlined plan as noted below.

1. **Site Work** – The boiler room was cleared of debris and basic demolition included cutting a new doorway on the north side. The fuel bin was laid out by the team in consideration of primary feed auger length, site layout, snow clearance requirements, maintenance access and future bulk fuel deliveries. This resulted in a 9'x10'x12' fuel bin being constructed on the west side of the boiler room using standard framing construction. This will allow for approximately 16 tons of storage capacity on site. The primary feed auger length was adjusted to 10' (increased from the standard 8') to provide for easier integration of the fuel bin as dimensioned. The boiler room was roughly laid out to allow for a second boiler in the future; favoring the installation of the first to one side allowing room for a second. The buffer tank, expansion tank and balance of plant were to be placed along the east wall allowing maintenance access and leaving as much floor space as possible open for future development.
2. **Boiler Room Renovation & Bin Construction / Install** – The walls of the boiler room were repaired with repointing (CMU construction). A new roof deck was installed above the original steel structural frame and a TPO membrane roof was installed. A new double door was installed on the north wall providing personnel access and also future equipment access. The fuel bin was constructed per plan on the west side of the boiler room and plans are in hand for allowance of future bulk deliveries. Electrical and water mains were routed to the boiler room.
3. **Boiler and Buffer Tank Install** – The boiler (EvoWorld HC100 Eco, 341,200 BTU/hr output) was delivered on schedule by RER along with a 600-gallon buffer tank, expansion tank, mixing valve and circulation pump. The primary feed auger and combustion feed auger were also delivered at the same time. This allowed for basic, "dry" fitup and boiler room layout confirmation. Initially, the boiler-to-tank circulation loop was plumbed backwards, i.e. with hot (supply) coming in the bottom of the tank and cold (return) coming in the top of the tank. This was resolved prior to startup following a walk-through inspection by the team.

4. **Balance of Plant and Heat Distribution** – Cast iron unit heaters were salvaged from another building on the property. These unit heaters are capable of approximately 450,000 BTU/hr of cumulative capacity, but not all were used. Instead, each was pressure tested and had the air fan tested to determine the subset of units to be used initially for the project. Ultimately, approximately 280,000 BTU/hr of heating capacity was installed in the form of 3 unit heaters. Additional heating capacity will be installed with additional unit heaters and baseboard heating units. Balance of plant plumbing, controls, valves and pumps were procured and installed as needed to support the overall installation. This portion of the project involved a great deal of hired labor which was initially intended to be in-kind contributions. This resulted in the project cost being higher than budgeted in this budget category.
5. **Commissioning and Test Burns** – RER provided boiler integration and initial commissioning. This was done with support from the manufacturer, EvoWorld USA / Troy Boiler Works. This work included final electrical connections of main power and control signals. All other plumbing integration work was done by the project team plumbing lead, Lohsen Plumbing. Electrical mains were provided by 12 Gauge Electric. Initial commissioning and tuning of the boiler was done on wood pellets due to the desire of VFFC to run on this proven fuel in the first year. Initial commissioning identified only one issue, the combustion feed auger was running with higher than normal current intermittently. This resulted in precautionary, intermittent shutdowns by boiler control system. The issue was linked to a mechanical interference between the feed auger and the sleeve it rotates in. A new part was ordered and installed to alleviate the issue. Operation of the boiler during cold weather also helped to identify output (BTU/hr) below what was expected of the unit. Comparing the boiler's ability to heat water in the tank and the rejection of heat from the unit heaters indicated a higher firing rate was possible and needed. Additional primary air was provided with a minor adjustment to tuning and resulted in improved output. We confirmed the output was approximately 330,000 BTU/hr with a simple tank temperature vs. time calculation. During this time the project team also ran alternative fuels through the boiler including pucks made from 50% Miscanthus / 50% wood and pucks made from Ag Biomass / Field Residue. A project notebook, including a settings log, has been assembled and is kept onsite in the boiler room to track settings and future changes as needed.

Project Cost and Performance to Budget

The total cost of the project was $119,481, versus a budgeted project cost of $109,636. The higher expenses were associated with the plumbing of the heating distribution system which required hiring more labor than anticipated to be completed.

Key expenses were:

- Site work, boiler room renovations and fuel bin $15,054 (13%)
- The boiler, augers, buffer tank and near boiler BOP $53,500 (45%)
- Heat distribution and controls..$31,089 (26%)
- Fuel.. $1,586 (1%)
- Project administration $18,252 (15%)

Key funding sources were split between sponsors (55%) and VFFC (45%):

- VSJF, VAAFM, Anonymous Donor $64,000 (54%)
- VFFC Cash..$15,359 (13%)
- VFFC & Partners In-kind $40,122 (33%)

A detailed budget report is provided in Table 1.

Biomass Boiler Installation at The Vermont Farmers Food Center

	VSJF-VBI & Other Funders			VFFC			Total	Split		%
	Cash	In-Kind	Total	Cash	In-Kind	Total		Cash	In-Kind	
Revenue Budget	$ 64,000.00	$ -	$ 64,000.00	$ 6,000.00	$ 39,636.00	$ 45,636.00				
Expense Actual	$ 64,000.00	$ -	$ 64,000.00	$ 15,359.13	$ 40,121.85	$ 55,480.98				
Budget Balance	$ -	$ -	$ -	$ (9,359.13)	$ (485.85)	$ (9,844.98)				
Revenue Sources	$ 64,000.00		$ 64,000.00	$ 6,000.00	$ 39,636.00	$ 45,636.00	$ 109,636.00	$ 70,000.00	$ 39,636.00	
	54%	0%	54%	5%	33%	38%		59%	33%	
Actual Expenses										
Boiler Room										
Site Work	$ -		$ -	$ -	$ 2,000.00	$ 2,000.00	$ 2,000.00			
Demo	$ -		$ -	$ -	$ -	$ -	$ -			
Masonry	$ -		$ -	$ 500.00	$ 2,010.00	$ 2,510.00	$ 2,510.00			
Bin	$ 570.00		$ 570.00	$ 1,788.28	$ 854.85	$ 2,643.13	$ 3,213.13			
Roofing	$ 3,800.00		$ 3,800.00	$ -	$ -	$ -	$ 3,800.00			
Door	$ -		$ -	$ 49.96	$ 700.00	$ 749.96	$ 749.96			
Electrical	$ 295.00		$ 295.00	$ 1,939.10	$ 547.00	$ 2,486.10	$ 2,781.10			
Boiler Room Total	$ 4,665.00	$ -	$ 4,665.00	$ 4,277.34	$ 6,111.85	$ 10,389.19	$ 15,054.19	$ 8,942.34	$ 6,111.85	13%
Boiler										
RER-EvoWorld	$ 53,500.00		$ 53,500.00	$ -	$ -	$ -	$ 53,500.00			
Boiler Total	$ 53,500.00	$ -	$ 53,500.00	$ -	$ -	$ -	$ 53,500.00	$ 53,500.00	$ -	45%
Heat Distribution										
Unit Heaters (reclaimed)	$ -		$ -	$ -	$ 6,890.00	$ 6,890.00	$ 6,890.00			
Hanging Heaters	$ -		$ -	$ -	$ 4,950.00	$ 4,950.00	$ 4,950.00			
Plumbing	$ 4,652.09		$ 4,652.09	$ 10,596.79	$ 4,000.00	$ 14,596.79	$ 19,248.88			
Controls	$ -		$ -	$ -	$ -	$ -	$ -			
Heat Distribution Total	$ 4,652.09	$ -	$ 4,652.09	$ 10,596.79	$ 15,840.00	$ 26,436.79	$ 31,088.88	$ 15,248.88	$ 15,840.00	26%
Fuel										
Wood Pellets	$ 1,101.00		$ 1,101.00	$ 485.00	$ -	$ 485.00	$ 1,586.00			
Fuel Total	$ 1,101.00	$ -	$ 1,101.00	$ 485.00	$ -	$ 485.00	$ 1,586.00	$ 1,586.00	$ -	1%
Project Admin & Design										
G. Cox	$ -		$ -	$ -	$ 4,860.00	$ 4,860.00	$ 4,860.00			
R. Steingress	$ -		$ -	$ -	$ 1,260.00	$ 1,260.00	$ 1,260.00			
R. Levin	$ -		$ -	$ -	$ 50.00	$ 50.00	$ 50.00			
C. Brown	$ 81.91		$ 81.91	$ -	$ 12,000.00	$ 12,000.00	$ 12,081.91			
Project Admin & Design Total	$ 81.91	$ -	$ 81.91	$ -	$ 18,170.00	$ 18,170.00	$ 18,251.91	$ 81.91	$ 18,170.00	15%
Expenses Total	$ 64,000.00	$ -	$ 64,000.00	$ 15,359.13	$ 40,121.85	$ 55,480.98	$ 119,480.98	$ 79,359.13	$ 40,121.85	
	54%	0%	54%	13%	34%	46%		66%	34%	
Balance	$ -	$ -	$ -	$ (9,359.13)	$ (485.85)	$ (9,844.98)	$ (9,844.98)	$ (9,359.13)	$ (485.85)	

Table 1 - Project budget and actual expenses by project area, expense type and source of funds.

Cost / Benefit

The installation of a biomass boiler at VFFC came at a financial premium when compared to a typical boiler as noted in the budget review section above. That premium is the combination of the boiler cost and the bin cost less the cost of a typical propane or fuel oil boiler of similar size. Specifically, the biomass boiler cost was $53,350 and the bin cost was $2,905 resulting in a total “heater” cost of $56,255. A typical 330,000 BTU/hr fuel oil boiler costs $5,000. So the cost premium for this system is $51,255. The basis for this project is that a biomass fuel will result in recurring savings against fossil fuels that will result in “paying back” this premium over time.

The determination of a simple payback period, the number of years to “pay back” the capital premium, depends on considering fuels in normalized energy units. Knowing the cost of a fuel and the heating value of it we can determine the cost per heating unit and more easily compare two very different fuels. The cost of biomass fuels varies. Wood pellets at a price of $200 per ton normalize to $11.6 per million BTU. Wood chips at $56 per green (or wet) ton normalize to $5.7 per million BTU. Grass-based biomass puck / briquette fuel costs have been estimated in the range of $85-228 per ton ($5.2 – 14.4 per million BTU) in other recent work (Callahan, 2016).

Even at relatively low prices today, propane at $2.75 per gallon has a normalized cost of $29.85 per million BTU and fuel oil at $2.01 per gallon has a normalized cost of $14.58 per million BTU (US DOE EIA, 3/12/2016). The normalized savings possible when using pellets, chips or densified grass biomass fuels ranges from nearly zero to $24.65 per million BTU depending on the fuels being compared and current pricing and assuming comparable appliance efficiencies which is reasonable when considering modern designs.

Fuel Costs

Knowing the production and densification costs of grass biomass fuels we can make a comparison to other common fuels in order to determine potential savings in operational costs. A summary of fuel costs, in normalized terms at current pricing, is presented in Table 2.

Fuel	Cost	Cost Units	Energy Content	Energy Units	Normalized Fuel Cost $/million BTU
Propane	2.75	$/gal	92000	BTU/gal	29.8
Fuel Oil	2.01	$/gal	129500	BTU/gal	15.6
Wood Pellets	225.00	$/ton	8600	BTU/lb	13.1
Wood Chips	56.00	$/ton (green)	9.9	mill BTU/ton	5.7
Ag Biomass	85-214	$/ton	8123	BTU/lb	5.2-13.2
Switchgrass	129-228	$/ton	8353	BTU/lb	7.7-13.6
Miscanthus	129-228	$/ton	8105	BTU/lb	8.0-14.0
Reed Canary	129-228	$/ton	7898	BTU/lb	8.2-14.4
Mulch Hay	129-228	$/ton	7952	BTU/lb	8.1-14.3

Table 2 - Comparison of fuel costs in normalized terms.

Potential Fuel Savings

Given the assumed fuel costs above and the potential for modern biomass appliances to operate at efficiencies similar to standard fossil fueled appliances it is possible to achieve 7-82% savings when using densified grass biomass as a combustion fuel. This is a wide range due to the variability in grass biomass production costs and fossil fuel prices. It is likely that propane will be at least $3 per gallon ($32.60 per million BTU) in the future when a mature grass biomass fuel can be produced for $130 per ton ($7.93 per million BTU.) This suggests a future scenario of 75% fuel cost savings potential. The impact of that savings depends significantly on the cost premium of the appliance and the amount of heating load the site has, i.e. how much fuel is used each year.

Cost / Benefit

A building with a peak design load that matches the 341,200 BTU/hr of the EvoWorld boiler in this study would have an overall heat transfer coefficient and area product of 4,739 BTU/hr-°F (-12 °F design temperature for Rutland, VT & 65 °F inside temperature assumed.) This information allows us to estimate annual fuel usage by applying heating degree days. This approach assumes the boiler is sized to run at maximum potential capacity when needed on the "design day" and that it is used to heat the building whenever the outside temperature is below 65 °F.

Using Burlington, VT heating degree days of 7,659 (65 °F basis), annual heat loss is estimated to be 871 million BTU which translates to 1,024 million BTU of fuel input with an assumed heating appliance efficiency of 85%. For reference, the historical, frugal propane use at VFFC equates to 350 million BTU.

At 350 mill BTU per year of fuel input, propane at $2.75 and wood pellets at $200 per ton, the simple payback period is 8.0 years.

If the boiler use is increased to 600 million BTU per year due to, e.g., higher heating set-point in the Farmers Hall, longer winter farmers Market season or addition of tenants, still with propane at $2.75 per gallon but using ag biomass provided at $100 per ton, the simple payback drops to 3.5 years.

At an even higher use of 1,000 million BTU, a slightly higher propane price of $3.00 per gallon and a lower biomass puck cost of $85 per ton, this payback period decreases to 1.9 years.

Simple payback period is summarized for a range of fossil fuel prices, alternative fuel prices and fuel use in Table 3.

Next Steps

The boiler installation at VFFC has served as a second demonstration of the feasibility of solid grass biomass fuels for small commercial and agricultural buildings.

For VFFC, the next steps are:

1. Continue to gain experience and understanding of the boiler system, fuel sourcing and use and overall economics.
2. Work to improve and confirm system reliability with continued monitoring, tuning and fuel quality control.
3. Consider becoming part of the fuel production process by potentially hosting a densification machine and possibly offering processing services to partner farms and others.
4. Leverage the biomass heating experience as part of the overall long-term business and facility planning process as future capital projects are explored, i.e. follow-on boiler system for additional heat load.

Biomass Boiler Installation at The Vermont Farmers Food Center

Cost Premium **51255** $ in yr 0
Fuel / Energy Use **350** million BTU/yr
22 tons of pucks
3804 gal of propane

	Alternative Fuel						Fossil Fuel				
				1.50	2.25	3.00	3.75	4.50	5.25	6.00	Fuel Oil $/gal
Chips	Pellets	Biomass	Normalized	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Propane $/gal
$/gr ton	$/ton	$/ton	$/mill BTU	10.9	16.3	21.7	27.2	32.6	38.0	43.5	Normalized $/mill BTU
31	54	50	3.1	18.9	11.1	7.9	6.1	5.0	4.2	3.6	
46	81	75	4.7	23.7	12.6	8.6	6.5	5.2	4.4	3.8	
62	108	100	6.3	31.7	14.6	9.5	7.0	5.6	4.6	3.9	
77	134	125	7.8	47.9	17.2	10.5	7.6	5.9	4.8	4.1	
93	161	150	9.4	98.0	21.1	11.8	8.2	6.3	5.1	4.3	
108	188	175	10.9		27.3	13.6	9.0	6.8	5.4	4.5	
124	215	200	12.5		38.5	15.9	10.0	7.3	5.7	4.7	
139	242	225	14.1		65.3	19.1	11.2	7.9	6.1	5.0	
155	269	250	15.6		215.6	24.0	12.7	8.6	6.5	5.3	

Cost Premium **51255** $ in yr 0
Fuel / Energy Use **600** million BTU/yr
38 tons of pucks
6522 gal of propane

	Alternative Fuel						Fossil Fuel				
				1.50	2.25	3.00	3.75	4.50	5.25	6.00	Fuel Oil $/gal
Chips	Pellets	Biomass	Normalized	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Propane $/gal
$/gr ton	$/ton	$/ton	$/mill BTU	10.9	16.3	21.7	27.2	32.6	38.0	43.5	Normalized $/mill BTU
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46	81	75	4.7	13.8	7.4	5.0	3.8	3.1	2.6	2.2	
62	108	100	6.3	18.5	8.5	5.5	4.1	3.2	2.7	2.3	
77	134	125	7.8	27.9	10.1	6.1	4.4	3.4	2.8	2.4	
93	161	150	9.4	57.2	12.3	6.9	4.8	3.7	3.0	2.5	
108	188	175	10.9		15.9	7.9	5.3	3.9	3.2	2.6	
124	215	200	12.5		22.5	9.2	5.8	4.2	3.3	2.8	
139	242	225	14.1		38.1	11.1	6.5	4.6	3.6	2.9	
155	269	250	15.6		125.7	14.0	7.4	5.0	3.8	3.1	

Cost Premium **51255** $ in yr 0
Fuel / Energy Use **1000** million BTU/yr
63 tons of pucks
10870 gal of propane

	Alternative Fuel						Fossil Fuel				
				1.50	2.25	3.00	3.75	4.50	5.25	6.00	Fuel Oil $/gal
Chips	Pellets	Biomass	Normalized	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Propane $/gal
$/gr ton	$/ton	$/ton	$/mill BTU	10.9	16.3	21.7	27.2	32.6	38.0	43.5	Normalized $/mill BTU
31	54	50	3.1	6.6	3.9	2.8	2.1	1.7	1.5	1.3	
46	81	75	4.7	8.3	4.4	3.0	2.3	1.8	1.5	1.3	
62	108	100	6.3	11.1	5.1	3.3	2.4	1.9	1.6	1.4	
77	134	125	7.8	16.8	6.0	3.7	2.6	2.1	1.7	1.4	
93	161	150	9.4	34.3	7.4	4.1	2.9	2.2	1.8	1.5	
108	188	175	10.9		9.6	4.7	3.2	2.4	1.9	1.6	
124	215	200	12.5		13.5	5.5	3.5	2.5	2.0	1.7	
139	242	225	14.1		22.9	6.7	3.9	2.8	2.1	1.7	
155	269	250	15.6		75.4	8.4	4.4	3.0	2.3	1.8	

Table 3 - Payback period tables for different volumes of fuel use (i.e. heat load). The three different tables are for three different volumes of use (350, 600, and 1,000 million BTU per year). The horizontal axis represents different fossil fuel costs and the vertical axis represents different alternative (biomass) fuel costs. The balance of the table is the simple payback period in years for each combination of fuel prices assuming a common appliance cost premium of $51,255. Green cells indicate payback period less than 6 years, yellow is less than 10 years and grey cells project no payback.

APPENDIX A – VAAFM REPORTING FORMAT

Task 1: Biomass – Feedstock & Combustion Analysis

Sub-Task 1 – Logistics Management:

Sub-Task 1.1 – Prepare boiler room and heat distribution system prior to EvoWorld installation.

Outcome: The boiler room is prepared, including structural, envelope, chimney, electrical and mechanical improvements necessary for sustained operation and code compliance. The heat distribution system will also be installed, including hydronic unit heaters, thermostat controls and associated hot water plumbing.

Status: COMPLETE. The boiler room used for this project is a revitalized boiler room from the building's history. The remnants of the old boiler were removed, the boiler room door was moved to the north side, the west side of the boiler room was built out as a fuel bin. A new roof was installed. A flue pipe, thimble and exhaust were installed. Smalley Mechanical (C. Brown) provided code review. The heat distribution system was installed making use of reclaimed cast iron hydronic / steam unit heaters and themostat controls were integrated.

Sub-Task 1.2 – Install EvoWorld HC100 ECO boiler and fuel bin.

Product: Take possession of EvoWorld HC100 ECO boiler (ordered by the Grantee and delivered by Renewable Energy Resources) and install it at the Vermont Farmers Food Center in Rutland. The installation process will be carried out by Smalley Mechanical with oversight by UVM Agricultural Engineer Chris Callahan.

Outcome: The EvoWorld HC100 ECO boiler and fuel bin is installed and connected to balance of plant and utilities.

Status: COMPLETE. The EvoWorld boiler was delivered at the site on 11/4/2015 by RER. The fuel bin was built off of the west end of the boiler room using traditional framing following the delivery to allow for fitup around the primary feed auger and sweep arms.

Sub-Task 1.3 – Receive test quantities of wood chips (from Vermont), wood pellets (from Vermont Wood Pellet Company) and grass pucks (from Renewable Energy Resources -- RER) to be used in EvoWorld boiler commissioning process and testing.

Outcome: Three different fuels on site, ready for use in commissioning the boiler.

Status: COMPLETE. Test quantities of wood pellets, wood chips and grass pucks were delivered to the site for initial commissioning.

Sub-Task 1.4 – Commission the EvoWorld boiler using the three feedstocks above listed, to confirm fuel-specific settings. This work will be conducted by Smalley Mechanical with support from RER/EvoWorld and Chris Callahan.

Outcome: Operating under real load conditions, the tests will inform VFFC and RER as to the combustion characteristics of biomass fuels as well as boiler system operations and maintenance. Data collected will be shared with the Grantee and the State.

Status: COMPLETE. The boiler was commissioned following installation on wood pellets by RER with support from EvoWorld USA (Troy Boiler Works). The settings for use of pellets were further refined by the larger project team to provide full load boiler output by increasing primary air supply which was limited with the default (factory) settings. Biomass pucks made of 50% Miscanthus/50% Wood and pucks made of Ag Biomass / Field Residue (each ~13% moisture content) were also burned successfully in the boiler with minimal adjustment. Wood chips (9% moisture content) were also burned successfully.

Task 2: Project and Solicitation Administration: The grantee will provide the State reports and other deliverables in accordance with the Federal Assistance Reporting Checklist.

Product: One progress report, a draft final report, and a final report will be provided to the State.

Status: A progress report was provided 11/18/2015. A draft report will be reviewed 3/24/2016 and a final report provided thereafter.

APPENDIX B – PICTURES

Figure 1 - An assortment of the fuels that the boiler can burn. Left to Right: wood chips, grass biomass fuel pucks, and wood pellets.

Figure 2 - Near completion of the install. Left to Right: Rob Steingress (VFFC Treasurer), Bill Kretzer (12 Gauge Electric), and Greg Cox (VFFC President).

Figure 3 - Laying out the fuel bin. The measuring tape is set to 10 ft of length to illustrate the rough location of the primary feed auger. Charlie Brown (Smalley Mechanical) provided engineering support of the project.

Figure 4 - The exterior of the boiler room after initial cleanup, but prior to new doorway (in place of window) and prior to the construction of the fuel bin (off of the large opening in the center of the view). The bin foot print is outlined in the dirt.

Figure 5 – US DOE Biomass Technology Office Technology Manager, Christy Sterner (center) visits the site along with Alex DePillis (right), Senior Agricultural Development Coordinator with the Vermont Agency of Agriculture, Food and Markets to speak with Greg Cox (VFFC, left).

Figure 6 - The ceiling of the renovated boiler room showing new roof decking on top of the existing steel structure.

Figure 7 - The top of the boiler room showing the new roof. The dip at mid-span is intentional to allow for flow of stormwater off of the roof.

Figure 8 - The boiler, tank, primary auger and combustion feed auger set in place as a "dry fit" prior to final plumbing to allow for locating the boiler in the room.

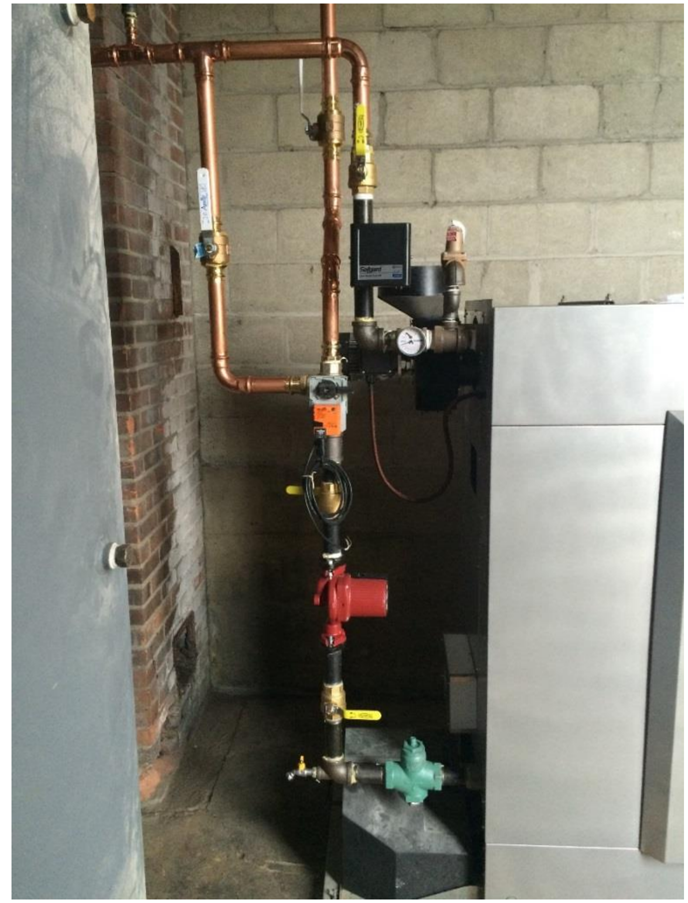

Figure 9 - The primary circulator (red) and mixing valve (grey and orange) control the flow of hot water between the boiler and the buffer tank to ensure the water returning to the boiler is at the right temperature to avoid thermal shock and automatically diverts flow to the tank as the system comes up to temperature.

Figure 10 - The 600 gallon buffer tank (left) allows heat to be transferred to the building as soon as it is needed while the boiler (right) fires up and gets to temperature. The primary circulation loop is between the boiler and the tank. The circulators for heat distribution to the building are the green items in the upper left. This picture was taken prior to insulation of the tank and piping.

Figure 11 - The primary feed auger filled with wood pellets during normal operation of the boiler at VFFC in late Winter 2016.

Figure 12 - Ag biomass pucks made from residue from an idle field used for demonstration burns at VFFC.

Figure 13 - Two of the cast iron hydronic / steam unit heaters salvaged from the site and reused for this new heating system find a new home above Farmer's Hall.

Figure 14 - Several of the salvaged unit heaters prior to pressure testing and electric motor testing.

Figure 15 - Farmer's Hall the VFFC with two of the hydronic unit heaters in place (left).