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Gasification of Alternative Fuels to Convert Waste Materials to Energy
Phase Two

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MILESTONE FOUR REPORT

Executive Summary

This project is the next demonstrative step of gasification technology that was initially tested in a previous Excel Renewable Energy Fund project. To achieve the primary goal of this project, a gasifier has been installed at P & J Products to convert turkey litter, flock mortalities, and/or various other locally available biomass materials, separately or combined, to energy. When complete the project will demonstrate a complete gasification system, a small micro-turbine that will generate electricity, and the auxiliary equipment determined to best meet the heat and power needs of the industry partner and the fuel. Milestone Four includes operating the system to collect data and determine the best operating scenario, the benefits derived from operating the system, collect emissions data, and to identify any operational issues that need to be resolved.

There were several tasks completed during Milestone Four. While the initial installation and commissioning was completed in Milestone Three in March of 2010, there were additional features added to the system to make long term operation easier and more cost effective. The tasks to be completed during this Milestone were:

- Sample and analyze litter and ash to determine nitrogen and other nutrient values
- Sample and analyze material that included zeolite in the feed to determine any value added by the use of zeolite
- Operate system and determine any operating issues or changes to be made
- Conduct emissions testing to verify emissions control
- Analyze benefits provided by system – energy value into the barn, benefits to heating system in the barn, and ash (biochar) value. When the project began, the value of the biochar was included as a deliverable. During the progress of the project, this project and others have demonstrated that the value of the biochar may be the most significant economic driver for

projects of this type and scale. Therefore, additional work has been done and is continuing in this area even though it was not specifically identified as a deliverable of the project.

Technical Progress

The basic gasification system was installed and operated in March 2009. The energy application was added in March of 2010 and the system was operated at that time to commission the additional equipment and determine the effectiveness of the system. Since that time, additional work has been done to provide auxiliary equipment to improve the operation, the system has been operated, and data has been collected.

The initial installation included a feed system that required periodic filling by an endloader. During the time period this milestone was completed, additional storage capacity and material handling equipment was installed. A storage hopper with approximately 10 to 12 tons of capacity was installed and an elevating belt conveyor was installed to convey the material from the storage hopper to the feed hopper on the gasifier. The drive mechanism for the entire system was synchronized to allow for a steady flow of material. The storage hopper is tarped to prevent additional moisture during bad weather – the belt conveyor will be covered before the end of the summer.

There was additional construction with the ash removal system as well. A second auger was installed to elevate the discharge and allow the material to be placed directly into a variety of containers – presently, one-ton supersacks are being used, but other systems can be used depending on the needs of the purchaser of the biochar.

The primary goal of Milestone Four was to operate the system and collect data to determine the value of the process. The concept of on-site energy projects clearly has advantages, but also has some disadvantages; and the revenue streams must be defined to determine the economic viability. One of the most misunderstood facts about biomass energy projects is that they typically can not survive as energy projects alone. There must be multiple benefits and revenue streams in order to make the economics viable. The advantages of on-site versus large scale projects providing minimal or no transportation, minimal biosecurity risks, and improved farm environmental impact are offset by higher operating costs per unit of energy produced, higher auxiliary equipment costs per unit of energy produced, and general overall efficiency losses simply due to the fact that there are economies of scale for larger equipment and projects. Additionally, it is the goal of the milestone to identify the ability to consistently provide those benefits – either heating in the barn, improved environment in the barn, higher quality manure through use of zeolite, or valuable biochar; as well as the reliability of the system to perform as expected.

Results

There are several parameters to be met to state that the system is successful and provides an improvement over the status quo. The major components are:

- Energy application – one of the benefits is the ability to replace the cost of propane as a heating source. It is impossible to completely replace the use of propane as there are too many occasions where the propane heaters will be needed on an intermittent basis, and the gasifier will not be operated for short periods just to provide that heat. But the goal of the work in this Milestone was to identify the ability to heat the barn, the quality of that heat, and the ability to control the heat and effectively operate the system. The design of the hot oil system makes it very easy to provide heat to the barn. The fan controls allow energy to be sent to the hot oil or bypassed, so regulating the heat is also fairly easy. The distribution sock inside of the barn also provides a very even temperature distribution. The graphs of the temperature profile in the barn will be included in the final report to demonstrate the consistency of the heating. Air temperatures as high as 175 degrees F. were blown into the barn while the barn was empty to experiment with the value of drying out the barn before the birds entered. An increase of 100 degrees over ambient temperature was easily attained, so there will be no issues with replacing the heating need when applicable.
- Remote operation– the system is designed to operate without a dedicated operator and is set up for off-site monitoring with telemetry which has alarms that signal when there is an issue that must be attended to. There is a big difference between not requiring an operator to constantly monitor the system versus being able to leave the unit overnight or for several hours without monitoring the conditions. The system has proven that it doesn't require constant attention and can be left alone. The ability to leave the system overnight has huge benefits to the farmer. This means the mechanics of the system need to be reliable and the controls also must be able to adjust to changing conditions. During the completion of Milestone Four, this benefit was tested. The system was constantly left alone for periods of an hour or so, so it would be easy to have someone on the farm operate the unit as one of their normal duties, without requiring an extra person. The goal of the feed system addition was to be able to store up to 24 hours of fuel in the hopper, so the unit could be left for longer periods. Both the fuel and ash systems can easily be left for several hours, enough to leave it alone overnight. The system is web-based, remote accessed, so it can be monitored off-site; but this still requires someone at a remote location who is available to do so. One of the tests performed during this task was to operate the system and attempt to be able to stop the feed and ash systems and simply operate the fans and continue to heat the barn overnight with the energy contained within the system. For systems that are operating on small single farms with extremely limited labor resources, this is an excellent option as it eliminates virtually all potential risks of failure, as only the fans, hot oil system, and computer controls are required to operate through the night. The controls will continue to be modified to further improve the ability to maximize the benefit, but the system was operated overnight without fuel addition or ash removal, and the barns were still receiving the proper temperature air the next morning. The fuel feed and ash removal were restarted and the system was able to continue to operate. Ideally, the system would be operated as designed, with the fuel feed and ash removal automatically operating throughout the night. But, in times where there are concerns about the reliability of the mechanical systems, it is very beneficial to be able to continue to heat the barn.
- Animal health benefits – this is an area that will be very difficult to prove. Unlike another Coaltec project, there is no ability to have a control barn on this project, so eliminating the variability of conditions other than the heating source are impossible. However, it is easy to demonstrate that positive pressure heating of the barn eliminates the introduction of cold air

into the barn and forces out the ammonia-rich air from the barn, which is beneficial to the birds. It is also easy to show that the introduction of clean, dry air reduces the relative humidity in the barn – which also reduces the formation of ammonia. This benefit is known, but the quantification of the benefit is difficult to show. The benefit of drying out the barn prior to introducing the turkeys should also have a benefit as it will reduce the potential of bacteria and disease; but that again is difficult to quantify.

- Mortality disposal – during most of the operating periods of the gasifier, the farm mortalities have been included in the fuel. The energy content of the mortalities is not much different from the litter, and the weight percentage is small, so the performance of the system is relatively unchanged. The quality of the ash is somewhat different, but again due to the small volume, it has little to no impact on the quality of the biochar. At this point, the value of mortality disposal is more of nuisance avoidance, but many locations are regulating the process of mortality disposal, so it may become more valuable in the future.
- Emissions levels – the emissions from the stack were monitored during an 8-hour period when the gasifier was operating at steady state. Based on previous experience and the quality of the fuel, the only areas of real interest were the NOx and CO emissions, as the other emissions should not ever present an issue. Through years of operation at Coaltec's test facility, it has been shown that NOx and CO emissions can be controlled to a point by the amount of air added to the reaction and the location and timing of that addition. Gasification occurs in an oxygen-starved zone; the less oxygen available in the primary reaction chamber, the lower the NOx volumes that are produced in that area. When combustion air is added, the amount and location is also critical. If there is not enough air to convert all of the CO to CO2, then CO is present in the emissions. The optimum process will produce a gas stream that contains little or no CO, and minimal NOx. Since the stack emissions on the system at P & J Farms contains a significant amount of dilution air, the emissions levels will be relatively low. During the testing, the NOx and CO emissions ranged from 0 to 5 ppm throughout the day. Even with significant dilution air, these volumes are extremely low and are well below the levels required for permitting, even if the system was operated continuously.
- Benefits of zeolite – some of the benefits of the inclusion of zeolite in the feed ration that were anticipated didn't occur but other potential benefits were found. The final report will include results from laboratory studies from WVU to confirm our finding. As a portion of the testing for this project, a percentage of zeolite was included in the feed of 50% of the finisher birds for one flock. The goal was to capture a higher percentage of nitrogen (N) in the manure. Initial testing indicated a 34% increase of N captured in the litter from birds which were fed zeolite. When that litter was gasified, about 25% of the N remained in the ash/biochar. However, recent studies by Dr. Johannes Lehmann, Cornell University, demonstrate that when litter is gasified, the N is bound in the biochar as is the carbon. The theory that there would be more N available for crops in the biochar which included zeolite evidently is not viable; at a minimum additional studies would be required to determine what percentage might be. It may become available over long periods of time, but it is not immediately available for plants, so the value is very minimal. However, there are other benefits to incorporating zeolite in the feed ration of turkeys. When the dried zeolite-enriched litter is mixed with biochar it should be a more valuable soil amendment when land applied as there will be at least a portion of the N that will be released. Coaltec is involved in additional testing for another project where a controlled laboratory test is being conducted which will confirm these results. The significance of this segment of the project is minimal

at this time for this project; however, it has huge potential in other applications and may become very important in the future. Capture of N does positively impact the quality of the atmosphere in the barn. There was not a real improvement at P & J because of the ventilation system there, but other poultry operations have huge issues with air quality and the capture of nitrogen can have a major impact on their business. There was extensive testing done on the quality of the nutrients after they have gone through the gasification process. The details will be listed below in the topic "biochar" but the bottom line is that while the N content may be higher when using zeolite, the N retained in the biochar is sequestered, much like the carbon.

- Biochar quality and potential uses and benefits of biochar –the key to the development of biomass gasification projects is producing multiple revenue streams. It is very rare to find a project where a single revenue will provide the economics to sustain the project. In various agricultural projects, there have been as many as seven or eight different revenue streams produced; but in almost all cases, the greatest potential has been the value of the ash component or biochar. Individual projects will have characteristics or circumstances that will change the impact of the different revenue streams and make certain streams more or less important – energy needs, environmental situations on the farm, cost of land or business expansion opportunities, etc. But, consistently one of the greatest opportunities is with the biochar. Especially when the projects are on-farm, and as they get smaller, this portion of the project becomes more and more critical. The nutrient content of the ash component from gasification has a value. Poultry litter has the highest nutrient content of any agricultural byproduct, so its value can potentially be the greatest. The ability to produce biochar and enhance the value of those nutrients, as well as sequester the carbon and utilize the characteristics of the carbon char to improve the nutrient utilization of those nutrients already in the soil, offers a very substantial benefit to the farmer. The potential value of biochar has been demonstrated in four distinct areas – soil supplement, animal feed supplement, water filtration medium, and as a litter amendment. While all of these markets are very viable, they are emerging markets and need to be developed. The first step in the development is the production of a consistent, reproducible product, and then the demonstration of the value. Through previous work by Coaltec and others, a range of operating conditions has been identified to produce a quality biochar. Once a repeatable product has been produced, then the lab analysis of the biochar, and the characterization of that product is completed. There are specific nutrients that will remain in the biochar, regardless of the operation; but some are dependent on the operating conditions of the system. And most importantly, the availability of those nutrients for crops or animal growth is dependent on the operating conditions in the gasification process; so developing those processes is critical. In Milestone Four, a consistent product was made. The operating conditions were identified, and the automation of the system can be programmed to maintain many of those conditions within the optimum parameters. A comparison of the litter and biochar analyses indicates that every pound of calcium, phosphorus and potassium is retained in the litter and is concentrated by a factor of approximately four.

	CaO	P_2O_5	K_2O
Litter	5%	4%	2.5%
Biochar	22%	15%	9.6%

The carbon content of the biochar was variable, but typically was between 15 and 20%. One of the most critical components of the biochar process is not only to be able to produce a product with a percentage of carbon char, but to also have the conditions that will produce a carbon char with the proper crystalline structure that produces the beneficial impact of the carbon. This was successfully accomplished in this project. The next step is to develop the market. There was sufficient material produced to conduct further testing as to the value it provides and allow the various markets to be explored. These marketing efforts are not limited to this project alone, but several projects depend on the success of the marketing. There is most certainly a market for the product and it is the pricing of that product that needs to be quantified and will determine the viability of many projects. It may also be the final determining factor in identifying how small an on-farm project can be and still be profitable. The biggest questions mark in all the ag-energy projects is the value of biochar. It is typically the largest revenue stream but in most cases there is the least level of confidence in what it can be. Some biochar is being sold in ten pound sacks for $1.00 per pound in the Chesapeake Bay area. Biochar from an operation similar to P & J has been sold in various quantities and qualities with prices ranging from $200 to $1200 per ton. Although a mature market is not yet established, we are working diligently toward that goal. As that happens the price should stabilize which will also allow a better understanding of the economics of gasification systems. Several questions remain to be answered. Is biochar more valuable as a feed supplement, filtration medium, litter amendment, or soil amendment? For the various products can it be sold in its natural state or does it need to be granulated? What will be the most advantageous biochar marketing plan - sold at retail or in bulk? As a soil supplement is it better to blended it with litter or sell it alone? As we are still in the research stage, not only are we trying to develop a market but also establish credibility in what we are doing. Part of that effort is working with researchers at a number of universities in parallel with what we are doing for this project. To date there have been several lab growth tests performed on soils and crops by universities and the USDA; also animal feed studies have been done to identify the benefit of biochar as a feed supplement. Both efforts are costly and time-consuming as the proper application needs to be identified and then the results must be repeated enough to become statistically relevant. After all that is accomplished and a marketable product or products are identified, the marketing efforts will begin. Thus the compound effect will be that this project is also gaining benefit of all the independent research that is being done. In sum, the most important component going forward will be establishing value for the biochar; that is key to making gasification bioenergy agriculture projects economically viable. The guidelines from this grant did not include marketing of biochar but as we are doing work on that in other areas our finding will be included in the Final Report as value added to this project.

- Credit opportunities – at this point, Coaltec has not explored the options for credits in this project. However, other projects have credits as a huge component, so work has been done in that area. The greatest hurdle in establishing credit opportunities is being able to demonstrate the actual capture of specific compounds. The data collected in the work of Milestone Four will serve as the supporting information if credits are sought in the future.
- Operational issues and barriers to overcome – Coaltec has operated gasification systems for several years. However, conducting testing and short term operations do not present the problems and difficulties that commercial operations do. There are issues that exist due to longer periods of operation, as well as the additional complications created by expanding the

system to include bulk feed and ash handling, energy application, and overall systems controls. During the periods of operation in the execution of Milestone Four, the feed and ash systems have performed without problem. The PLC and fans and VFDs also performed well and provided excellent control of the process and distribution of the energy and production of biochar. The hydraulic feed system also performed as designed. The issues encountered and their solutions have been:

1. Hydraulic system – the operating pressure required, especially with the ash system, is higher than the initial relief setting. The relief was set at 2,000 psi and was increased to 3,000 psi to improve performance.
2. Air sock in the barn – this system has been previously used by Coaltec. The farm owner wanted to install a system that could be raised or lowered to provide heat in specific areas, so it was installed on a cable that was mobile. The initial installation was weak in the area where the sock split into two directions, so the support cables for the T were altered and reinforced.
3. Hot oil system – the heat exchanger, pump, piping and controls worked as designed. There were minor leaks in the system that became evident when the hot oil was heated up to operating temperature. The electronic control valves have not been installed and will be changed out when the modifications are done to the piping system when the power generation equipment is added.
4. Refinement of operating controls – the initial control programming works well and the system does what it is supposed to. As the system is operated more and more, there will continue to be refinements. Additional temperature monitoring will be placed in the barn, and the use and benefits of the system will be expanded to maximize the benefit it brings to the farm.
5. Ash removal system – one of the benefits of a demonstration project is to determine challenges and to tweak the system to make it better. The greatest issue in the system is the removal of ash from inside of the gasifier. The system works well the majority of the time; but during extended periods of operation, there are times when the floor does not operate properly. The system continues to work, but requires closer attention than should be necessary. Expansion of the metal components of the floor creates some binding which increases the hydraulic pressure required to operate. Further increase of the operating pressure doesn't resolve the problem, it just hides the result; and eventually will lead to damage to the floor. Small modifications will be made to the floor during subsequent visits and a final solution will be developed.
6. Fuel storage – at this point, the litter on the farm is stored outside, exposed to the weather. This allows for a significant variation in moisture content of the fuel, depending on the recent weather. High moisture content can make the operation of the gasifier more difficult, and variations in moisture content can also create changes in the quality of the biochar. This proved to be a major problem in another Coaltec poultry project located on a chicken broiler operation. However, at P & J the wood content in the litter compensates for the higher moisture in the manure and the higher moisture content that existed in the fuel did not present a problem. Again, the wood component also helps the reaction in the gasifier and minimizes the impact of the moisture on the quality of the biochar. One possibility to the moisture issue would be to tarp the litter however, some moisture will

seep in. The most desirable option is to construct a litter shed to house the fuel and protect it from the elements; however, it has not proven to be extremely critical so far.

Additional Milestones:

The next step is to install and commission a power generation system under Milestone 5. The additional power supply for the module was installed during Milestone 4 as other power work was needed for the addition of the fuel and ash systems. The hot oil system is ready for expansion to include the power module once it is delivered. The system has been ordered and is built, ready to ship.

Project Status

The project is slightly behind schedule and is within budget.

Appendix: Photos

Legal Notice

Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund

Appendix: Photos

Litter is stored in a 12 ton bunker and ash is captured in a supersack .

A conveyor loads a small hopper that feeds the gasifier.

The ash auger fills a super sack to minimize handling.

An air sock distributes the hot air inside the barn. The sock can be lowered or raised to control the temperatures at ground level.