Final Technical Report
Cedar Falls Utilities
Biomass Energy Generation Project
DE-EE0000398

Cedar Falls Utilities
Cedar Falls, Iowa

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Author: Edward Olthoff

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Executive Summary:

The Municipal Electric Utility of the City of Cedar Falls (dba Cedar Falls Utilities or CFU) received a congressionally directed grant funded through DOE-EERE to run three short (4 hour) duration test burns and one long (10 day) duration test burn to test the viability of renewable fuels in Streeter Station Boiler #6, a stoker coal fired electric generation unit. Seven additional short text burns were considered when the results of two of the three proposed test burns were unsuccessful. Eight short test burns were actually completed, with two densification options showing potential suitability for the long duration test burn, a 5/8-inch diameter corn stover pellets and a 1-inch diameter corn stover pellets. Both producer of the suitable pellets were not capable of a production run of the approximately 2000 tons of pellets needed for the long test burn, and no other producers were available, thus the long test burn was not completed. The long test burn was intended to test supply chain assumptions, optimize boiler combustion and assess the effects of a longer duration burn of biomass on the boiler.

Project Overview:

The Municipal Electric Utility of the City of Cedar Falls is one of four municipal utilities doing business as Cedar Falls Utilities and providing utility services to the City of Cedar Falls, Iowa. The electric utility is a vertically integrated utility which owns generation and distribution assets in Cedar Falls, Iowa. Streeter Station, one of the generating assets in Cedar Falls, is a coal and natural gas fired generating facility which consists of two generating units, Unit #6 and Unit #7. Unit #6 is a stoker boiler, which has the potential capacity to generate electricity with 100% renewable bio-based fuels, not blended with coal. The electric utility undertook feasibility studies as early as 2004 when they began a series of short (4 hour) 100% renewable fuel test burns using different densification configurations to determine if the renewable fuel could be handled and burned just like coal.

After the initial series of burns, the utility requested financial assistance to continue with three additional short test burns and one long duration (10 day) test burn to advance the study. The three short burns were proposed, a 1¼ inch cubed fuel harvested from local native prairie restoration plots, sugar cane bagasse densified into a 4 cm diameter "bripell", and a ¼ inch pellet from mixed agricultural byproducts. The fuel chosen for the long duration burn would be based on the results of the short test burns.

The poor performance of the cubed prairie grass biomass led to three additional test burns based on corn stover, cubed Indiana stover with bentonite binder, cubed California stover with calcium carbonate binder, and 1¼ inch diameter pelleted Minnesota stover. None of these test burns were considered successful. An extruded stover alternative with plastic binder was proposed, but rejected by the Iowa Department of Natural Resources.

The sugar cane bagasse "bripell" product, sourced and produced in Louisiana, was outside of dimension specifications, and could not be conveyed. After discussions with the manufacture, this option was eliminated.

The ¼ inch pellets performed the best of the three options, but the mass of the ¼ inch pellet is of concern for stoking efficiency. A larger mass pellet would throw to the rear of the boiler better and fully burn before conveying out in the ash.

Commercial producers of larger diameter pellets were sought for additional test burns. A commercial Pellet manufacturer offered 5/8-inch diameter pellets. Simultaneously, a large quantity of "energy crop" was available for harvest. 200 tons of "energy crop" was harvested for pelleting, but pelleting challenges in the production of the 5/8 inch diameter pellet resulted in 40 tons of ¼-inch diameter pellets instead. In an effort to test 5/8-inch diameter pellets, 100 tons of Iowa stover was pelleted into 5/8 inch pellets. At the insistence of the Iowa Department of Natural Resources, stack testing was done on these two fuels, which exhausted the supply, but demonstrated potential viability of the 5/8-inch diameter pellet. Another pellet option was offered by a new pellet manufacturer. This was a 1-inch diameter pellet produced by the same densification equipment that produced the 1¼-inch cubes. A quantity sufficient for a short test burn was produces, and this option was also considered to be viable for a long test burn. Neither manufacturer could produce the quantity needed for the long test burn, and that test was not performed.

INTRODUCTION:

On the 12th day of March, the year of our Lord 2003, The Board of Trustees of the Municipal Electric Utility of the City of Cedar Falls adopted Resolution No. 3670. This resolution set a long-term goal for the electric utility to obtain a 10% renewable generation portfolio by 2010. In 1997, the utility had invested in the Iowa Distributed Wind Generation Project, a small windfarm co-owned by 7 utilities and located near Algona, Iowa. This provided approximately 1% of the electric utility's annual delivery to the generation portfolio. In 2003, a second investment in wind power at the Hancock County Wind Farm supplied another 3% renewable to the generation portfolio.

This resolution did not limit the renewable portfolio to additional wind generation, but also included renewable solid fuels, hydroelectric, compressed air storage, landfill gas and sewage biomass. Some of these options (hydroelectric, landfill gas and sewage biomass) were explored and found to be economically and technically impractical or did not develop as anticipated (compressed air storage). The renewable solid fuel option did have promise as an alternative to coal for dispatchable generation, and prompted further investigated.

The Municipal Electric Utility of the City of Cedar Falls is a vertically integrated utility providing electric service to the City of Cedar Falls, Iowa. One of the Utility's generating resources id Streeter Station, the coal fired electric generating resource located in Cedar Falls. Streeter Station had two operating coal and natural gas fired boilers powering steam turbines driving GE electric generators. Unit #6 is a Wickes stoker coal fired boiler powering a 16.5 MW generator, and Unit #7 is a Babcock and Wilcox pulverized coal-fired boiler powering a 35 MW generator. Densified renewable solid fuel could be blended with coal or fed directly in Unit #6. A separate biomass burner would be needed for Unit #7 to inject ground renewable solid fuel into the boiler, or densified renewable solid fuel could be blended with coal and pulverized in the existing coal mills. The feasibility of pulverizing blended fuels in the coal mills is the subject of another research topic.

Design and construction of modifications needed to prepare Unit #7 for renewable solid fuel combustion would delay implementation, and incur additional costs and possibly require permitting. Unit #6 could begin test burns without modifications, and thus became the subject of the renewable solid fuel research.

Construction of Unit #6 was proposed in October of 1960. Construction bids were opened in April of 1961. Construction began in March, 1962. Unit #6 was brought on line in August of 1963. The boiler was a 165,000 pounds per hour Wickes boiler with a 20' x20' traveling grate. The six mechanical stokers were supplied by Firite. The coal handling equipment began at the coal pit west of the plant, which could unload rail cars or dump trucks. A flight conveyor transferred the coal from the pit to the bucket elevator. The bucket elevator carried the coal to the top of the coal bunkers on the seventh floor of the plant. Conveyors moved the coal from the elevator into the coal bunker. The bunker has a capacity of approximately 200 tons of coal. At the bottom, the bunker bifurcates into two hoppers, each supplying a coal scale. Each coal scale feeds three stokers. The stokers scatter the fuel on the grate, where it burns. Forced draft and induced draft fans supply air to the fire. Boiler tubes filled with water surround the combustion chamber, absorb the heat and produce the steam used to drive the turbine. If renewable solid fuel options could be densified into a product similar to coal, in theory the boiler should operate without modifications.

The following objectives were defined for the project:

- The solid renewable fuel should mimic coal.
- No modifications to the coal handling/conveying equipment or the boiler would be required, eliminating capital investments and permit modifications.
- The preferred option was 100% biomass, requiring no blending with coal.
- The optimal source of the renewable fuel was locally available agriculture residue or byproducts, and harvesting, transporting and processing would be done locally to reduce transportation costs and bolster the local economy.
- If possible, no binders would be required to produce a robust densified fuel.

INITIAL TEST BURNS

Corn Cob Pellets

Best Cob is a supplier of ground corn cobs densified into a ¼ inch diameter pellet to improve handling and storage. The company is headquartered in Rock Falls, Illinois, and their production facility is in Independence, Iowa. Two truckloads of pellets was purchased and test burned on July 23, 2004

Wood Pellets

Fuel King was a supplier of wood pellets for wood pellet stoves used for home comfort heating. The manufacturing location is Spencer, Iowa. 10 tons of bagged wood pellets were purchased and test burned on March 23, 2005.

Corn Stover Pellets

The utility requested custom manufacture of 3/8 inch diameter corn stover pellets. After numerous production complications, 12 tons of pellets were produced and test burned on March 23, 2005.

Corn Stover Cubes

The utility chose to investigate another densification option available. Warren and Baerg (W&B), in Dinuba, California, manufactures cubers which densify agricultural crops like hay into 1 ¼ inch cubes. The utility proposed shipping corn stover to California for densification, but the California Department of Agriculture refused to grant permission. W&B had a mobile cuber, which was then rented and moved to Cedar Falls. 70 tons of Iowa corn stover cubes were produced and test burned on March 22, 2006. Stack testing was attempted during this test burn, but combustion of only the stover was not sustainable without supplemental natural gas combustion, and the test was not done.

Switchgrass Cubes

At the same time, Iowa switchgrass was purchased and cubed. 70 tons of switchgrass cubes were produced and test burned on March 24, 2006. Stack testing was performed during this test burn.

Oat Hull Pellets

At the same time, ground oat hulls were purchased from Quaker Oats in Cedar Rapids. An attempt to cube the oat hulls was unsuccessful. Instead, 90 tons of ¼ inch pelleted oat hulls was purchased from a

Canadian supplier and test burned on March 23, 2006. Stack testing was performed during this test burn.

Summary:

Initial test burns indicate compatibility of Unit #6 with combustion of densified renewable solid fuels for electric generation. Densification options are crucial, and need to be further investigated. The ¼ inch pellets are robust in the coal handling system, but the stokers are not able to throw them to the back of the grate. A larger diameter would be ideal to increase the mass of the pellets. The cubes were not robust enough to survive the coal handling system, burned up too quickly, and were very susceptible to deterioration during storage. The Firite stokers were replaced with Detroit underthrow stokers. The Firites were obsolete and repair parts were not available. EPA's Boiler MACT rule, proposed in March of 2004, set tighter particulate emission standards on Unit #6. A fabric filter baghouse was constructed in 2007 to comply with the new standard. The baghouse has been troubled by operational limitations. The filtration efficiency is more than sufficient to meet the standard, but the baghouse is undersized and cannot keep up with the dust loading at maximum output. Modifications to the baghouse have been suggested, but, to date, no changes have been made. This restriction would hamper the long test burn of renewable solid fuels when the unit would be operated at maximum load for an extended period of time (proposed 10 days).

DOE SUPPORTED TEST BURNS

The Electric Utility proposed three short test burns to test performance of the replacement stokers with different densification options and try three additional renewable solid fuel options in three different densification options, and follow with one long test burn to assess the viability of the collection, densification and transportation option assumptions, optimize combustion in the boiler, achieve maximum electric generation capacity, and, after completion of the test, inspect the boiler for any noticeable long range effects of renewable solid fuel combustion. The three solid fuel options proposed were native grasses in a W&B cube, mixed agricultural byproducts in a ¼ inch pellet, and sugar cane bagasse in a "bripell". The most viable fuel would be determined from the short test burns, and a sufficient quantity would be obtained (approximately 2000 tons) to perform the long test burn.

Grass Cubes

The electric utility investigated another source of renewable solid fuel. Native prairies, prairie restoration, DOA set aside acres and DOT roadsides are all planted with native prairie grass or prairie grass and forb seed mixes. This biomass can potentially be harvested and densified as a renewable solid fuel. The utility approached the Black Hawk County Conservation Board, owner of three local native prairie or prairie restoration sites and the Iowa Department of Transportation, owner of one local prairie restoration site, to discuss harvest options at these sites. After months of discussion and negotiations, arrangements were made to harvest and bale a plot planted with a seed mix of three native grasses at a prairie restoration site owned by the Black Hawk County Conservation Board. The field was mowed and the grasses baled in April of 2009. The harvest yield of 1.3 tons/acre was below the target yield of 2 tons/acre. This harvested fuel was trucked to Indiana for densification on W&B equipment by Pro Hay. The grasses did not densify well. The cube manufacturer reported that "the material went into the cuber like chopped grass and came out of the cuber like chopped grass". Bentonite was added during a portion of the production run, and lignin was added during another portion of the production run, with no apparent improvement in quality. The densified product was trucked back to Streeter Station and the densified fuel was test burned on October 19, 2009. The quality of the finished cubes after production was marginally acceptable (50% densified, 50% fines), and the cubes deteriorated significantly after production and during shipping and handling. When the cubes were burned, there was little densified fuel remaining. The stokers could not inject a sufficient quantity of fuel into the boiler, resulting in an unsustainable burn. With additional natural gas firing during the burn the generator output was 3 MW.

Indiana Corn Stover Cubes

The electric utility contracted with Pro Hay for the production of 20 tons of cubed corn stover for a second test burn. This production run included bentonite as a binding agent at the rate of 7 pounds per ton of corn stover. Production quality was very favorable, with 95% intact cubes. These cubes waited for a month at the production site, and then were loaded on a hopper trailer for transportation to Cedar Falls. The cubes unloaded with 90% survival. However, they were handled several extra times due to a mechanical failure in the coal conveying system, eventually conveyed into the coal bunkers and held for several weeks when rainfall was abundant and the humidity was high. When the cubes were burned on June 30, 2010, 70% had deteriorated to fines and 30% remained as cubes. Another unsustainable burn followed, with a generator output of 4 MW.

California Corn Stover Cubes

After two unsuccessful test burns with W&B equipment, the electric utility contacted Warren and Baerg, the manufacturer of the cubing equipment, to discuss process modifications for better cubes. Warren and Baerg recommended using two way dies for densification and calcium carbonate for binding. Warren and Baerg offered to manufacture the denser cubes at their production facilities in California, using California corn stover. CFU requested production of a 20 ton lot of cubes for a test burn. The cubes were manufactured at a production site in Buttonwillow, California, and shipped to Streeter Station on October 26, 2010. The cubes were longer than the usual length of 2-3 inches, and very dense. After resolving a rotational misalignment in the stokers which caused the distributor paddles to jamb on the extremely dense cubes, the fuel was test burned on November 18, 2010. The cubes were able to sustain combustion during the test burn without the assistance of additional heat input from the gas burners, but at maximum stoker feed capacity, the maximum generation capacity was 4 MW. The larger dimensions of the cubed limited the stoker feed rates. The ash pancaked on the grate, reducing combustion efficiency and challenged the ash handling and disposal equipment.

Sugar Cane Bagasse Bripells

This test burn was planned for the summer of 2010. After production delays in the past year, the fuel manufacturer has begun production and was able to supply a 20 ton quantity of densified bagasse for a test burn. This densification option is a 4 cm diameter sugar cane bagasse pellet, 4-5 cm in length, with a finished density of 43 pounds per cubic foot. The fuel was received on July 7, 2011. The fuel received did not meet specifications. Many bripells were longer than the specified length of 5 cm, some up to 20 cm in length, and extremely dense, and they jammed and damaged the coal pit flight conveyor. The test burn was aborted until the conveyor could be repaired and a decision made about the fuel specifications. After discussions about manual and mechanical sorting options to remove the larger pieces from the fuel, no agreeable solution was found. The test burn was permanently postponed until another lot could be produced which met specifications. The off-specification fuel which was received was shipped to other locations for test burns. Another test lot was not produced.

Agricultural Residue Pellets

The electric utility purchased 22.54 tons of agricultural waste pellets from Show Me Energy Cooperative. The pelleted fuel was received and burned on October 27, 2010. The ¼ inch diameter pellets are very robust, and were easily handled by the existing conveying and stoking equipment. After stabilization of the operating parameters and development of an adequate ash bed, generation was gradually increased to 9 MW until the fuel supply ran out. This fuel easily transitioned from gas backup firing to sustainable combustion, with sufficient additional stoking capacity to potentially run the generator up to full generation capacity. This biofuels option was deemed the most promising of all the test burns performed to date.

The major constraint for this product is the physical size of the pellet. The replacement stokers handle the fuel much better than the original stokers, but the size affects the trajectory of the fuel in the boiler. A piece of fuel with more mass will be thrown to the back of the grate where ignition occurs and the fuel burns out as it travels forward on the grate. The smaller size scatters over the entire grate rather than accumulating in the back. The pellets which fall on the burned out ash at the front of the grate do not ignite, and are lost in the ash as the grate conveys the ash to the front of the boiler and into the ash hopper. This loss has not been quantified, but it was observable during the test burn.

Corn Stover Pellets

Corn stover pellets produced by W&B in California resulted in barely sustainable combustion, limited by the capacity of the stokers to feed the cubed stover into the boiler. The dimensions of the cubes were 1 ¼ inch by 1 ¼ inch and up to 5 inches long. Warren and Baerg had developed a 1 ¼ inch diameter cylindrical die for use in their densification equipment, with a 2 inch limit on the length of the extruded pellet. A private owner of a W&B cuber could produce approximately 25 tons for a test burn in a trial run of the process. Plans were made for installation of the dies in an existing densifier in upstate New York, processing a 25 ton lot of corn stover, and shipping the finished fuel to Streeter Station for a test burn. This test burn was planned for June, 2011. The production run was scheduled, but the baled corn stover available as raw material was excessively wet and no drying equipment was available. After a difficult production run which produced a wheelbarrow of pellets, the run was terminated. Another private owner of a W&B cuber in Montana with round dies offered to produce the fuel. The modified plan was to procure drier Midwest sourced corn stover, ship it to Montana, and schedule a production run in October. Suitable corn stover from the fall 2011 harvest was located in Redwood Falls, Minnesota. One semi load of 30 round bales was shipped from Redwood Falls to Miles City, Montana on November 2, the stover was densified without any binding agent into 1 ¼ inch diameter pellets on November 4, then shipped to Streeter Station on November 8. The test burn followed on November 11, 2011. The freshly densified fuel handled well with minimal degradation during conveying and stoking. The test burn transitioned to sustainable combustion but achieved a maximum of 8 MW of generation at maximum fuel feed rate. Options to increase the maximum feed rate mechanically or electrically will be investigated with the stoker manufacturer, but this densification configuration appears too large to perform with the design of the stokers. The fuel burned without slagging, but the high ash content created an extremely thick ash bed on the grate.

Energy Crop Pellets

All test burns with cubed fuel did not achieving the required handling or performance metrics, and the electric utility agreed that an extended test burn with cubed biofuels is not feasible without further testing of densification options. Cost, size of densified product and equipment availability initially favored the cubed configuration. Pelleted fuel handled and performed well in the test burn. However, the mass of the ¼ inch pellet was not large enough for the stokers to consistently throw the fuel to the back of the grate. A larger diameter pellet with more mass would perform better in the stokers without creating problems in the fuel handling and conveying system.

A larger diameter pellet option is available for a potential 2 day test burn. The raw material for this burn is an energy crop harvested from test plots planted by the University of Northern Iowa Tallgrass Prairie Center. The energy crop is a group of native prairie plans selected for their ability to produce a large quantity of annually harvestable biomass. This fuel was harvested and baled in the spring of 2012, and approximately 200 tons of material was available. Several densification options were possibilities. Idaho National Lab in Idaho Falls, Idaho has built a prototype portable densification system which is designed for any bio-based raw material and produces ¼ inch diameter pellets. Show Me Energy , Centerview, Missouri, processes agricultural based raw materials into ¼ inch pellets. Pellet Technologies processes agricultural based raw materials into various sized pellets. Pellet Technologies is capable of providing larger diameter pellets. They are located closer than the other options, in Gretna, Nebraska, reducing transportation costs. The entire lot of harvested fuel was to be initially ground at the harvest site, transported to Pellet Technologies for pelleting, and return shipped to Streeter Station. The densified fuel would be test burned over a two day period, and stack testing planned during full capacity operation of the unit. The test burn was tentatively scheduled for the end of August or early September, 2012. The entire quantity of harvested fuel was to be prepared for this two day burn.

After initial field grinding of the energy crop, a 50 ton lot was shipped to Pellet Technologies for densification. The material proved to be impossible to densify into viable 5/8 inch diameter pellets despite multiple attempts to vary equipment operating conditions and process inputs. Pellet Technologies stated it was impossible for them to produce the requested pellet given their resources of equipment and experience. They were capable of producing a ¼ inch pellet using the energy crop, and rather than lose an opportunity to test burn the energy crop, Pellet Technologies was directed to process the 50 ton lot of energy crop into ¼ inch pellets for a short test burn. Streeter Station received final shipment of a total of 40.13 tons of pelleted fuel by October 23, 2012. This fuel was stored in a railcar on site in Cedar Falls, and was test burned with concurrent stack testing the week of February 25, 2013. The Tallgrass Prairie Center partnered with the electric utility to plan this test burn, and they have paid for all production costs for this fuel.

Corn Stover Pellets

Pellet Technologies has had success densifying corn stover into 5/8 inch pellets, and since the primary objective of the repurposed longer duration test burn was to burn a larger diameter pellet, resources have been redirected to produce a 5/8 inch diameter pellet from corn stover. Koster Grain from Carroll, Iowa was contracted to provide 100 tons of raw materials. Koster Grain had the baled corn stover on hand, and was able to grind and ship the material from Carroll to Gretna, Nebraska. Pellet Technologies processed the corn stover into 5/8 inch diameter pellets, and was able to produce the full amount of 100 tons. The final shipment of pelleted fuel arrived at Streeter Station on December 31, 2012. The pelleted fuel was stored in rail cars at Streeter Station, and a test burn with stack testing was scheduled for the week of February 25, 2013.

Energy Crop and Corn Stover Pellet Test Burn

The test burns were ultimately performed on February 27 and 28, 2013. The first burn was the 100 tons of 5/8 inch corn stover pellets. 25 tons was transferred from the rail car to the bunker with only one minor complication. On Monday evening (2/25), Unit #6 was started on natural gas. Early Tuesday morning (2/26), the transition began from natural gas to pelleted fuel. Within three hours, the unit transitioned from natural gas to sustainable combustion on 100% biofuel. The generation output was raised to 6 MW, stabilized, and stack testing was begun. The remainder of the stover pellets (75 tons) were transferred from railcar storage to the bunker without incident. A snowstorm had begun when stack testing was initiated, and weather conditions deteriorated, making stack testing unsafe. The run was aborted in late morning, and the unit returned to natural gas combustion. The test burn was restarted the next morning (2/27) after conditions were determined to be safe to continue. The unit was easily transitioned back to biofuel combustion, stabilized at 6 MW, and stack testing reinitiated. Testing was successfully completed for the emissions required by the Iowa DNR, and additional stack testing was initiated for chlorine emissions. After two test cycles, the fuel ran out.

The unit was transitioned back to natural gas, and the unit idled until the next morning. On Thursday morning (2/28), the ¼ inch diameter energy crop pellets were unloaded from the railcar into the bunker. The unit was transitioned from natural gas to sustainable combustion of energy crop pellets, and the output was raised to 6 MW. The unit was stabilized and stack testing began. Testing was successfully completed for the emissions required by the Iowa DNR, and additional stack testing was initiated for chlorine emissions. After two test cycles, the fuel ran out again.

Both fuels were stored in rail cars for several months with no noticeable deterioration of the fuel. Both also handled well in the conveying system from the rail car to the bunker, and flowed smoothly from the bunker through the scales and through the stokers. Sustainable combustion was easily achieved at 6 MW generation. This capacity was sustained for sufficient time to perform stack testing, but the fuel ran out during stack testing and no testing was done with either fuel to determine maximum capacity of the unit. The stokers had reserve capacity to feed more fuel and the stoker throats could be adjusted to wider settings, but none of this was accomplished during these test burns.

Both of these test burns were shorter duration than the two day test burn suggested earlier. They are variations on the short test burns but included stack testing at the request of the Iowa DNR.

Larksen Stover Cubes

Another company, Larksen LLC had contacted the electric utility with a proposal for producing a 7/8 inch or 1 inch cube using redesigned Warren and Baerg densifying equipment. They had developed a plan which includes production of a 20 ton lot of densified fuel for a test burn to determine viability of the densification option, and then follow the initial sample with production of sufficient quantity for the 10 day test burn (2,000 tons). Logistics and cost were proposed which were reasonable. If this company could produce the proposed material, they could be the supplier for the originally proposed 10 day burn, and the proposed scope of the project could be achieved. Larksen has initiated testing using the 1 inch dies, but were unable to produce sufficient quantity for a test burn. They worked with Warren and

Baerg to identify and correct the problems and initiate production. This test burn was postponed until the fuel was available.

In July of 2013, Larksen was able to produce a 20 ton lot of the fuel using Warren and Baerg cubing equipment with a 1 1/16 inch die. This fuel was shipped to Streeter Station on September 25, and test burned on the same day. The fuel was received in excellent condition, and was conveyed into the bunkers without major problems. Unit #6 had been started on natural gas, and was transitioned to the densified biofuel. After two hours the unit achieved stable, sustainable biofuel combustion, and the load was increased to determine maximum achievable generation capacity. At close to maximum stoking capacity, the unit achieved 7.7 Mw when the fuel supply ran out. The test burn was successful, and this densification configuration was deemed suitable for an extended test burn.

Both the 5/8 inch diameter corn stover pellets and the 1 1/16 inch diameter W&B cube had successful test burns, and are suitable candidates for the extended test burn. CFU negotiated with both suppliers to plan an extended test burn in the summer of 2014, testing either or both configurations for suitability in the 10 day burn on solid renewable fuel in Unit #6.

SUMMARY

In the end, the proposed three short test burns was extended to eight short test burns, and the long test burn was not performed. A pellet in the range of 5/8 inch to 1 inch in diameter was found to be the most viable configuration to mimic coal. Pellets of this size are robust enough to survive the mechanical coal handling system, heavy enough to throw well with the mechanical stokers, and solid enough to burn slowly on the grate. Short test burns required a 20 ton lot of fuel, sufficient to move the fuel from the truck to the grate, transition from natural gas combustion to solid fuel combustion, establish stabilized combustion and an even ash bed on the grate, and then possibly increase the output of the generator by introducing more fuel. The long test burn would optimize combustion and maximize generation with a fuel known to perform well in the short test burn. However, a variety of factors complicated the performance of the 10 day burn.

- Supply chain logistics: Procurement, transportation, densification, transportation and storage of the solid renewable fuel for a 10 day burn is a logistical challenge. Pellet production rates of 4 tons per hour and processing at distant locations are limiting factors. The proposal optimistically assumed development of the supply chain with higher production rates at a closer location for the 10 day burn. Temporary storage in rail cars proved to be a viable concept.
- Cost: Associated with the logistics challenge was an increase in cost. Production cost of shorter burns more accurately predicted the cost of the 10 day burn, which was 3 to 4 times higher than estimated in the proposal.
- Baghouse: The operational deficiencies of the fabric filter baghouse controlling particulate emissions from Unit #6 have not been resolved. The process is continuing, with modeling studies in progress to determine practical modifications, which could improve performance. No permanent modifications have been incorporated yet. performance period extended once, second request denies without clear plan for long burn, grant closed.
- Environmental Regulations: EPA definition of a renewable fuel has not been clarified. Without a clear definition, continued investigations have little benefit.
- Grant Performance Period: The grant performance period was extended once due to additional short test burns. With no clear path to complete the 10 day burn, a second extension was denied and the contracting parties agreed to terminate the grant

The 10 day burn is still an option which the utility intends to pursue, but it will not be completed as part of this grant.

Attachments:

Fuel analyses

CEDAR FALLS UTILITIES - BIOMASS ENERGY GENERATION PROJECT

Fuel Analysis Comparisons

Biomass		Mixed Grass	IN Stover	CA Stover	Ag. Biproducts	MN Stover	Energy Crop	IA Stover	IA Stover
Manufacturer		Pro-Hay	Pro-Hay	W&B	Show Me	W&B	Pellet Tech	Pellet Tech	Larksen
Date Sampled		9/4/09	1/14/11	11/18/10	11/18/10	11/11/11	10/9/12	12/14/12	9/25/13
Moisture	%	2.63	8.02	6.3	8.07	8.38	12.04	13.67	8.9
Ash	%	7.26	13.8	18.76	10.61	15.62	7.97	18.57	7.21
Volatile	%	67.23		63.54	66.31				
Fixed	%	22.88		11.4	15.01				
BTU/lb	BTU/lb	6707	6306	6069	6874	6233	6561	5466	6751
Carbon	%	40.89	41	39.17	43.93	37.4	36.64	31.77	41.52
Hydrogen	%	6.27	4.44	4.53	4.89	4.82	4.94	4.33	4.95
Nitrogen	%	0.16	0.57	0.52	1.47	0.77	0.16	0.52	0.09
Oxygen	%	42.7	32.11	30.65	30.83	32.94	38.21	31.09	37.31
Sulfur	%	0.09	0.06	0.07	0.2	0.07	0.04	0.05	0.02
Chlorine	%	0.81	0.1	0.225	0.228	0.12	0.03	0.16	0.05
Mercury	ug/g	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.02
Ash									
SiO2	%	76.96		64.69	51.21	73.59	78.65	71.11	49.6
Al2O3	%	3.04		11.03	2.9	8.22	3.53	9.19	2.77
TiO2	%	0.12		0.47	0.22	0.37	0.13	0.67	0.18
Fe2O3	%	1.09		3.64	1.57	2.5	1.09	3.11	1.48
CaO	%	10.72		4.53	11.4	4.56	8.46	4.14	24.23
MgO	%	1.83		3.04	4.31	2.6	1.98	2.84	8.84
K2O	%	2.88	7.24	10.8	20.3	5.39	3.39	5.74	9.2
Na2O	%	0.66		2.08	0.35	1.08	0.64	1.26	0.55
SO3	%	0.66		0.4	3	0.52	0.6	0.6	1.13
P2O5	%	1.78	2.29	1.39	5.86	0.99	1.32	1.07	1.83
SrO	%	0.03				0.02	0.03	0.03	0.03
BaO	%	0.1				0.06	0.07	0.09	0.06
MnO2	%	0.13				0.1	0.11	0.15	0.1

SGS

Analysis Report

September 28, 2009

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: AMY K. SHATEK

Client Sample ID:	BF #1-2009_	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Sep 4, 2009	Sample Taken At:	Cedar Falls Utilities
Date Received:	Sep 9, 2009	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Mixed Grass Cubes
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-0938966-001

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	2.63		
Ash %	ASTM D1102	7.26	7.45	
Volatile Matter %	ASTM D3175	67.23	69.05	
Fixed Carbon (by diff) %	ASTM D3172 (by diff)	22.88	23.50	
Sulfur %	ASTM D4239 Method B	0.09	0.10	
Calorific Value BTU/LB	ASTM D3286	6707	6888	7443
Carbon %	ASTM D5373	40.89	42.00	
Hydrogen %	ASTM D5373	6.27	6.44	
Nitrogen %	ASTM D5373	0.16	0.16	
Oxygen (by difference) %	ASTM D5373 (by diff)	42.70	43.85	

Tests	Result	Unit	Method
Net Calorific Value	6098	Btu/lb	ASTM D3286
FUSION TEMPERATURE OF ASH, REDUCING			
Initial Deformation	2701	øF	ASTM D1857
Softening	2701	øF	ASTM D1857
Hemispherical	2701	øF	ASTM D1857
Fluid	2701	øF	ASTM D1857
FUSION TEMPERATURE OF ASH, OXIDIZING			
Initial Deformation	2701	øF	ASTM D1857
Softening	2701	øF	ASTM D1857
Hemispherical	2701	øF	ASTM D1857
Fluid	2701	øF	ASTM D1857

Vanessa Chambliss

VANESSA_CHAMBLISS

SGS

Analysis Report

September 28, 2009

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: AMY K. SHATEK

Client Sample ID:	BF #1-2009_	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Sep 4, 2009	Sample Taken At:	Cedar Falls Utilities
Date Received:	Sep 9, 2009	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Mixed Grass Cubes
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-0938966-001

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D3682
Silicon Dioxide, SiO2	76.96	%	ASTM D3682
Aluminum Oxide, Al2O3	3.04	%	ASTM D3682
Titanium Dioxide, TiO2	0.12	%	ASTM D3682
Iron Oxide, Fe2O3	1.09	%	ASTM D3682
Calcium Oxide, CaO	10.72	%	ASTM D3682
Magnesium Oxide, MgO	1.83	%	ASTM D3682
Potassium Oxide, K2O	2.88	%	ASTM D3682
Sodium Oxide, Na2O	0.66	%	ASTM D3682
Sulfur Trioxide, SO3	0.66	%	ASTM D3682
Phosphorus Pentoxide, P2O5	1.78	%	ASTM D3682
Strontium Oxide, SrO	0.03	%	ASTM D3682
Barium Oxide, BaO	0.10	%	ASTM D3682
Manganese Oxide, MnO2	0.13	%	ASTM D3682
Undetermined	0.00	%	ASTM D3682
Sum of Oxides	100.00	%	ASTM D3682
Silica Value	84.94	%	ASTM D3682
Base Acid Ratio	0.21	%	ASTM D3682
T250 Temperature	2807	°F	ASTM D3682
Fouling Index	0.66	---	ASTM D3682
Slagging Index	>100	%	ASTM D3682
Type of Ash	LIGNITIC	---	ASTM D3682

Vanessa Chambliss

VANESSA_CHAMBLISS

SGS

Analysis Report

February 11, 2011

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	CUBED STOVER JUN 2010	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Jan 14, 2011	Sample Taken At:	Cedar Falls Utilities
Date Received:	Jan 20, 2011	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1151727-001

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	8.02		
Ash %	ASTM D1102	13.80	15.00	
Sulfur %	ASTM D4239 Method B	0.06	0.06	
Calorific Value BTU/LB	ASTM D3286	6306	6855	8065
Carbon %	ASTM D5373	41.00	44.58	
Hydrogen %	ASTM D5373	4.44	4.83	
Nitrogen %	ASTM D5373	0.57	0.62	
Oxygen (by difference) %	ASTM D5373 (by diff)	32.11	34.91	
Chlorine, Cl %	ASTM E776	0.10	0.11	

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D4326
Phosphorus, P	0.50	%	ASTM D4326
Potassium, K	6.01	%	ASTM D4326
TRACE ELEMENTS - DRY BASIS			
Mercury, Hg	0.03	µg/g	ASTM D6722

Vanessa Chambliss

Vanessa Chambliss
Branch Manager

SGS North America Inc. | Minerals Services Division
16130 Van Drunen Road South Holland t (708) 331-2900 f (708) 333-3060 www.sgs.com/minerals
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HAZEN

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	January 11 2011
HRI Project	009-614
HRI Series No.	L20/10-1
Date Rec'd.	12/07/10
Cust. P.O.#	

Detroit Stoker Company
Bob Morrow
PO Box 732
Monroe, MI 48161-0732

Sample Identification
Switch Grass Pellets
11/18/10 SHOW ME

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	8.07	0.00	8.07
Ash	10.61	11.54	10.61
Volatile	66.31	72.13	66.31
Fixed C	15.01	16.33	15.01
Total	100.00	100.00	100.00
Sulfur	0.202	0.220	0.202
Btu/lb (HHV)	6874	7478	6874
Btu/lb (LHV)	6338		
MMF Btu/lb	7762	8542	
MAF Btu/lb		8453	
Ultimate (%)			
Moisture	8.07	0.00	8.07
Carbon	43.93	47.79	43.93
Hydrogen	4.89	5.32	4.89
Nitrogen	1.47	1.60	1.47
Sulfur	0.20	0.22	0.20
Ash	10.61	11.54	10.61
Oxygen*	30.83	33.53	30.83
Total	100.00	100.00	100.00
Chlorine**	0.228	0.248	0.228

	As Rec'd	Dry
Air Dry Loss (%)		
Forms of Sulfur, as S, (%)		
Sulfate		
Pyritic		
Organic		
Total	0.20	0.22
Water Soluble Alkalies (%)		
Na2O		
K2O		

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	15.43
Lb. SO2/MM Btu=	0.59
Lb. Cl/MM Btu=	0.33
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	10,349

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	January 11 2011
HRI Project	009-614
HRI Series No.	L20/10-1
Date Rec'd.	12/07/10
Cust. P.O.#	

Detroit Stoker Company
Bob Morrow
PO Box 732
Monroe, MI 48161-0732

Sample Identification:
Switch Grass Pellets
11/18/10

Elemental Analysis of Ash (%)

SIO2	51.21
AL2O3	2.90
TIO2	0.22
FE2O3	1.57
CAO	11.40
MGO	4.31
NA2O	0.35
K2O	20.30
P2O5	5.86
SO3	3.00
CL	1.88
CO2	1.42
Total	104.42

Ash Fusion Temperatures (Deg F)

	Oxidizing Atmosphere	Reducing Atmosphere
Initial	2055	1905
Softening	2152	2043
Hemispherical	2240	2203
Fluid	2277	2340

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

Note: The ash was calcined @ 1110 deg F (600 C) prior to analysis

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date January 11 2011
HRI Project 009-614
HRI Series No. L20/10-2
Date Rec'd. 12/07/10
Cust. P.O.#

Detroit Stoker Company
Bob Morrow
PO Box 732
Monroe, MI 48161-0732

Sample Identification
Corn Stover Cube 11/18/10
W+B

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	6.30	0.00	6.30
Ash	18.76	20.02	18.76
Volatile	63.54	67.81	63.54
Fixed C	11.40	12.17	11.40
Total	100.00	100.00	100.00
Sulfur	0.067	0.072	0.067
Btu/lb (HHV)	6069	6477	6069
Btu/lb (LHV)	5585		
MMF Btu/lb	7611	8264	
MAF Btu/lb		8099	
Ultimate (%)			
Moisture	6.30	0.00	6.30
Carbon	39.17	41.80	39.17
Hydrogen	4.53	4.83	4.53
Nitrogen	0.52	0.55	0.52
Sulfur	0.07	0.07	0.07
Ash	18.76	20.02	18.76
Oxygen*	30.65	32.73	30.65
Total	100.00	100.00	100.00
Chlorine**	0.225	0.240	0.225
Air Dry Loss (%)			
Forms of Sulfur, as S, (%)			
Sulfate			
Pyritic			
Organic			
Total	0.07	0.07	
Water Soluble Alkalies (%)			
Na2O			
K2O			

Lb. Alkali Oxide/MM Btu= 3.98
Lb. Ash/MM Btu= 30.91
Lb. SO2/MM Btu= 0.22
Lb. Cl/MM Btu= 0.37
As Rec'd. Sp.Gr.=
Free Swelling Index=
F-Factor(dry), DSCF/MM Btu= 10,283

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	January 11 2011
HRI Project	009-614
HRI Series No.	L20/10-2
Date Rec'd.	12/07/10
Cust. P.O.#	

Detroit Stoker Company
Bob Morrow
PO Box 732
Monroe, MI 48161-0732

Sample Identification:
Corn Stover Cube 11/18/10

Elemental Analysis of Ash (%)

SIO2	64.69
AL2O3	11.03
TIO2	0.47
FE2O3	3.64
CAO	4.53
MGO	3.04
NA2O	2.08
K2O	10.80
P2O5	1.39
SO3	0.40
CL	1.12
CO2	0.26
Total	103.45

Ash Fusion Temperatures (Deg F)

	Oxidizing Atmosphere	Reducing Atmosphere
Initial	2197	2160
Softening	2257	2213
Hemispherical	2277	2250
Fluid	2320	2435

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

Note: The ash was calcined @ 1110 deg F (600 C) prior to analysis

SGS

Analysis Report

December 02, 2011

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

1 1/4" ROUND

Client Sample ID:	Stover111111	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Nov 11, 2011	Sample Taken At:	Cedar Falls Utilities
Date Received:	Nov 17, 2011	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1159235-001

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	8.38		
Ash %	ASTM D1102	15.62	17.05	
Sulfur %	ASTM D4239 Method B	0.07	0.08	
Calorific Value BTU/LB	ASTM D3286	6233	6803	8202
Carbon %	ASTM D5373	37.40	40.82	
Hydrogen %	ASTM D5373	4.82	5.26	
Nitrogen %	ASTM D5373	0.77	0.84	
Oxygen (by difference) %	ASTM D5373 (by diff)	32.94	35.95	
Chlorine, Cl %	ASTM E776	0.12	0.14	
Mercury, Hg UG/G	ASTM D6722	0.03	0.03	

Tests	Result	Unit	Method
FUSION TEMPERATURE OF ASH, REDUCING			
Initial Deformation	2255	°F	ASTM D1857
Softening	2280	°F	ASTM D1857
Hemispherical	2300	°F	ASTM D1857
Fluid	2380	°F	ASTM D1857
FUSION TEMPERATURE OF ASH, OXIDIZING			
Initial Deformation	2360	°F	ASTM D1857
Softening	2500	°F	ASTM D1857
Hemispherical	2640	°F	ASTM D1857
Fluid	2700	°F	ASTM D1857

Vanessa Chambliss

Vanessa Chambliss
Branch Manager

SGS North America Inc. | Minerals Services Division
16130 Van Drunen Road South Holland IL 60473 t (708) 331-2900 f (708) 333-3060 www.sgs.com/minerals

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Analysis Report

December 02, 2011

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	Stover111111	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Nov 11, 2011	Sample Taken At:	Cedar Falls Utilities
Date Received:	Nov 17, 2011	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1159235-001

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D4326
Silicon Dioxide, SiO2	73.59	%	ASTM D4326
Aluminum Oxide, Al2O3	8.22	%	ASTM D4326
Titanium Dioxide, TiO2	0.37	%	ASTM D4326
Iron Oxide, Fe2O3	2.50	%	ASTM D4326
Calcium Oxide, CaO	4.56	%	ASTM D4326
Magnesium Oxide, MgO	2.60	%	ASTM D4326
Potassium Oxide, K2O	5.39	%	ASTM D4326
Sodium Oxide, Na2O	1.08	%	ASTM D4326
Sulfur Trioxide, SO3	0.52	%	ASTM D5016
Phosphorus Pentoxide, P2O5	0.99	%	ASTM D4326
Strontium Oxide, SrO	0.02	%	ASTM D4326
Barium Oxide, BaO	0.06	%	ASTM D4326
Manganese Oxide, MnO2	0.10	%	ASTM D4326
Undetermined	0.00	%	
Sum of Oxides	100.00	%	

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Analysis Report

January 23, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	UNI ENERGY CROP PELLETS	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Oct 9, 2012	Sample Taken At:	Cedar Falls Utilities
Date Received:	Dec 21, 2012	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Biomass
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1268412-002

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	12.04		
Ash %	ASTM D1102	7.97	9.07	
Sulfur %	ASTM D4239 (Method A	0.04	0.04	
Calorific Value BTU/LB	ASTM D5865	6561	7458	8202
Carbon %	ASTM D5373	36.64	41.66	
Hydrogen %	ASTM D5373	4.94	5.61	
Nitrogen %	ASTM D5373	0.16	0.18	
Oxygen (by difference) %	ASTM D5373 (by diff)	38.21	43.44	
Chlorine, Cl %	ASTM E776	0.03	0.04	
Mercury, Hg UG/G	SW-846 7470A		0.02	

Tests	Result	Unit	Method
UOM, Sample Weight	g	---	
Sample Weight	578.6	---	
FUSION TEMPERATURE OF ASH, REDUCING			
Initial Deformation	2300	°F	ASTM D1857
Softening	2380	°F	ASTM D1857
Hemispherical	2495	°F	ASTM D1857
Fluid	2630	°F	ASTM D1857
FUSION TEMPERATURE OF ASH, OXIDIZING			
Initial Deformation	2340	°F	ASTM D1857
Softening	2410	°F	ASTM D1857
Hemispherical	2560	°F	ASTM D1857
Fluid	2701	°F	ASTM D1857

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Branch Manager

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16130 Van Drunen Road South Holland IL 60473 t (708) 331-2900 f (708) 333-3060 www.sgs.com/minerals

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Analysis Report

January 23, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	UNI ENERGY CROP PELLETS	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Oct 9, 2012	Sample Taken At:	Cedar Falls Utilities
Date Received:	Dec 21, 2012	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Biomass
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1268412-002

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D4326
Silicon Dioxide, SiO_2	78.65	%	ASTM D4326
Aluminum Oxide, Al_2O_3	3.53	%	ASTM D4326
Titanium Dioxide, TiO_2	0.13	%	ASTM D4326
Iron Oxide, Fe_2O_3	1.09	%	ASTM D4326
Calcium Oxide, CaO	8.46	%	ASTM D4326
Magnesium Oxide, MgO	1.98	%	ASTM D4326
Potassium Oxide, K_2O	3.39	%	ASTM D4326
Sodium Oxide, Na_2O	0.64	%	ASTM D4326
Sulfur Trioxide, SO_3	0.60	%	ASTM D5016
Phosphorus Pentoxide, P_2O_5	1.32	%	ASTM D4326
Strontium Oxide, SrO	0.03	%	ASTM D4326
Barium Oxide, BaO	0.07	%	ASTM D4326
Manganese Oxide, MnO_2	0.11	%	ASTM D4326
Undetermined	0.00	%	
Sum of Oxides	100.00	%	
Silica Value	87.21	---	
Base Acid Ratio	0.19	---	
T250 Temperature	>2900	°F	
Fouling Index	0.64	---	
Type of Ash	LIGNITIC	---	

Vanessa Chambliss

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Analysis Report

January 23, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	PTSTOVERPELLETS_121412	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Dec 14, 2012	Sample Taken At:	Cedar Falls Utilities
Date Received:	Dec 21, 2012	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Biomass Stover
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1268412-001

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	13.67		
Ash %	ASTM D1102	18.57	21.51	
Sulfur %	ASTM D4239 (Method A	0.05	0.06	
Calorific Value BTU/LB	ASTM D5865	5466	6332	8067
Carbon %	ASTM D5373	31.77	36.80	
Hydrogen %	ASTM D5373	4.33	5.01	
Nitrogen %	ASTM D5373	0.52	0.60	
Oxygen (by difference) %	ASTM D5373 (by diff)	31.09	36.02	
Chlorine, Cl %	ASTM E776	0.16	0.19	
Mercury, Hg UG/G	SW-846 7470A		0.02	

Tests	Result	Unit	Method
UOM, Sample Weight	g	---	
Sample Weight	415.0	---	
FUSION TEMPERATURE OF ASH, REDUCING			
Initial Deformation	2150	°F	ASTM D1857
Softening	2230	°F	ASTM D1857
Hemispherical	2390	°F	ASTM D1857
Fluid	2540	°F	ASTM D1857
FUSION TEMPERATURE OF ASH, OXIDIZING			
Initial Deformation	2240	°F	ASTM D1857
Softening	2320	°F	ASTM D1857
Hemispherical	2470	°F	ASTM D1857
Fluid	2660	°F	ASTM D1857

Vanessa Chambliss

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Branch Manager

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Analysis Report

January 23, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: ED OLTHOFF

Client Sample ID:	PTSTOVERPELLETS_121412	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Dec 14, 2012	Sample Taken At:	Cedar Falls Utilities
Date Received:	Dec 21, 2012	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Biomass Stover
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1268412-001

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D4326
Silicon Dioxide, SiO2	71.11	%	ASTM D4326
Aluminum Oxide, Al2O3	9.19	%	ASTM D4326
Titanium Dioxide, TiO2	0.67	%	ASTM D4326
Iron Oxide, Fe2O3	3.11	%	ASTM D4326
Calcium Oxide, CaO	4.14	%	ASTM D4326
Magnesium Oxide, MgO	2.84	%	ASTM D4326
Potassium Oxide, K2O	5.74	%	ASTM D4326
Sodium Oxide, Na2O	1.26	%	ASTM D4326
Sulfur Trioxide, SO3	0.60	%	ASTM D5016
Phosphorus Pentoxide, P2O5	1.07	%	ASTM D4326
Strontium Oxide, SrO	0.03	%	ASTM D4326
Barium Oxide, BaO	0.09	%	ASTM D4326
Manganese Oxide, MnO2	0.15	%	ASTM D4326
Undetermined	0.00	%	
Sum of Oxides	100.00	%	
Silica Value	87.57	---	
Base Acid Ratio	0.21	---	
T250 Temperature	2825	°F	
Fouling Index	1.26	---	
Type of Ash	LIGNITIC	---	

Vanessa Chambliss

Vanessa Chambliss
Branch Manager

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16130 Van Drunen Road South Holland IL 60473 t (708) 331-2900 f (708) 333-3060 www.sgs.com/minerals

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Analysis Report

October 24, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: AMY K. SHATEK

Client Sample ID:	Larksenstover Sep2013	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Sep 25, 2013	Sample Taken At:	Cedar Falls Utilities
Date Received:	Oct 1, 2013	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Stover (Biomass)
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1374264-001

	Method	As Received	Dry	DAF
Moisture, Total %	ASTM D4442(METHOD A	8.90		
Ash %	ASTM D1102	7.21	7.92	
Sulfur %	ASTM D4239 (Method A	0.02	0.03	
Calorific Value Btu/lb	ASTM D5865	6751	7410	8047
Carbon %	ASTM D5373	41.52	45.58	
Hydrogen %	ASTM D5373	4.95	5.44	
Nitrogen %	ASTM D5373	0.09	0.10	
Oxygen (by difference) %	ASTM D5373 (by diff)	37.31	40.93	
Chlorine, Cl %	ASTM E776	0.05	0.06	
Mercury, Hg µg/g	SW-846 7470A		0.02	

Tests	Result	Unit	Method
UOM, Sample Weight	g	---	
Sample Weight	2142.9	---	
FUSION TEMPERATURE OF ASH, REDUCING			
Initial Deformation	2075	°F	ASTM D1857
Softening	2150	°F	ASTM D1857
Hemispherical	2265	°F	ASTM D1857
Fluid	2340	°F	ASTM D1857
FUSION TEMPERATURE OF ASH, OXIDIZING			
Initial Deformation	2100	°F	ASTM D1857
Softening	2160	°F	ASTM D1857
Hemispherical	2300	°F	ASTM D1857
Fluid	2410	°F	ASTM D1857

James P. Nelson
Great Lakes Operations Manager

SGS

Analysis Report

October 24, 2013

CEDAR FALLS UTILITIES
PO BOX 769
CEDAR FALLS IA 50613

ATTN: AMY K. SHATEK

Client Sample ID:	Larksenstover Sep2013	Sample ID By:	Cedar Falls Utilities
Date Sampled:	Sep 25, 2013	Sample Taken At:	Cedar Falls Utilities
Date Received:	Oct 1, 2013	Sample Taken By:	Cedar Falls Utilities
Product Description:	BIOMASS	Sample Type:	Stover (Biomass)
		P. O. #:	BPO1800

SGS Minerals Sample ID: 491-1374264-001

Tests	Result	Unit	Method
ANALYSIS OF ASH			
Basis	IGNITED	---	ASTM D4326
Silicon Dioxide, SiO2	49.60	%	ASTM D4326
Aluminum Oxide, Al2O3	2.77	%	ASTM D4326
Titanium Dioxide, TiO2	0.18	%	ASTM D4326
Iron Oxide, Fe2O3	1.48	%	ASTM D4326
Calcium Oxide, CaO	24.23	%	ASTM D4326
Magnesium Oxide, MgO	8.84	%	ASTM D4326
Potassium Oxide, K2O	9.20	%	ASTM D4326
Sodium Oxide, Na2O	0.55	%	ASTM D4326
Sulfur Trioxide, SO3	1.13	%	ASTM D5016
Phosphorus Pentoxide, P2O5	1.83	%	ASTM D4326
Strontium Oxide, SrO	0.03	%	ASTM D4326
Barium Oxide, BaO	0.06	%	ASTM D4326
Manganese Oxide, MnO2	0.10	%	ASTM D4326
Undetermined	0.00	%	
Sum of Oxides	100.00	%	
Silica Value	58.94	---	
Base Acid Ratio	0.84	---	
T250 Temperature	2178	°F	
Fouling Index	0.55	---	
Type of Ash	LIGNITIC	---	

James P. Nelson
Great Lakes Operations Manager

SGS North America Inc. | Minerals Services Division
16130 Van Drunen Road South Holland IL 60473 t (708) 331-2900 f (708) 333-3060 www.sgs.com/minerals

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