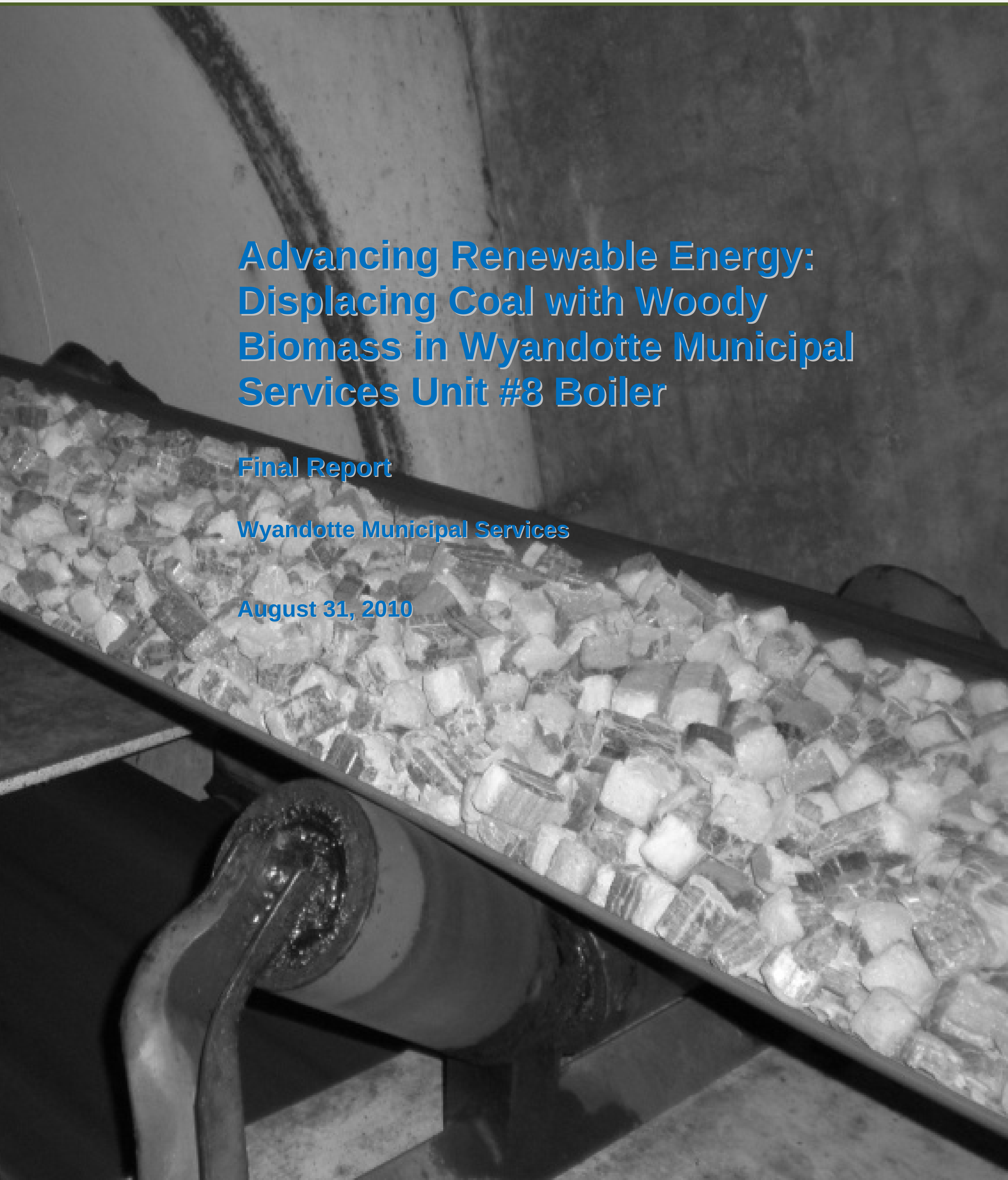

Advancing Renewable Energy: Displacing Coal with Woody Biomass in Wyandotte Municipal Services Unit #8 Boiler

Final Report

Wyandotte Municipal Services

August 31, 2010

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Unit #8 Woody Biomass Test Burn Final Report

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Executive Summary

The Michigan Department of Energy, Labor & Economic Growth (DELEG) awarded Wyandotte Municipal Services (WMS) a grant to demonstrate the feasibility of co-firing biomass fuel in its existing Unit #8 – a 25Megawatt (MW) circulating fluidized-bed boiler. The WMS project investigated the logistics of acquiring and handling various woody biomass fuels and conducted a test burn of the proposed fuel to identify any technical challenges and develop recommendations for future use.

Several biomass suppliers were identified during the fuel supplier review, but renewaFUEL was selected for the supply of biomass for the WMS test burn. RenewaFUEL was selected due to their densified wood cube product, size of the cube, and their availability to supply large quantities of this product. Testing concluded that the densified wood cubes traveled well through the existing conveying system. Dust was an issue during the loading process, but for the purpose of the test burn, good general housekeeping was maintained to mitigate this issue.

The testing consisted of three test burns – a baseline test, 15 percent by heat input biomass test, and a 30 percent by heat input biomass test. The first test which was a baseline test was completed on May 14, 2010. The baseline test was done operating the boiler as normally operated burning a coal/TDF mixture. The data from this test was compared to the results from the biomass tests to try to determine operating differences. The 30 percent biomass test was completed on June 9, 2010, and the 15% biomass test was completed on June 10, 2010. The boiler was operated for eight hours at the respective biomass input before testing proceeded. This was done to “season” the bed in the attempt to get more accurate testing results. During testing, the boiler reacted well to the introduction of biomass and was capable of providing a steady 160,000 lb/hr of steam flow while burning 15 percent and 30 percent biomass by heat input.

Conventional field testing protocols and reference methods were used to determine boiler efficiency, emissions, and fly ash properties. The WMS facility PI Historian Systems, Continuous Emissions Monitoring System and physical fuel and ash sample results were used to record the results of the biomass test burns. No noticeable changes in boiler efficiency, emissions, or fly ash properties were detected during the testing. It was concluded that the boiler operated successfully using the renewaFUEL biomass and that biomass could be an option for future fuel at the WMS facility. Further testing is required to fully determine the impacts on emissions and boiler efficiency when burning biomass.

1 Introduction

The City of Wyandotte's Department of Municipal Services is a community owned and operated entity that provides electricity, water, telephone, internet, and cable television services to residents of Wyandotte. The electricity is generated by Wyandotte Municipal Services (WMS). The power plant is located on the western shore of the Detroit River, just north of the downtown area of Wyandotte.

WMS generates and delivers roughly 275,000 MWh of electricity annually to more than 10,000 homes and 1,000 businesses within the City of Wyandotte. Today, WMS relies on two coal-fired boilers and sources roughly 85 percent of its power from coal. WMS is striving to diversify its generation portfolio and use of renewable energy and energy efficiency.

DELEG awarded WMS a grant for a biomass energy demonstration project, with an expected completion date of July 31, 2010. This grant was provided by DELEG to demonstrate the feasibility of co-firing biomass fuel in their existing generating facility. The goals of the WMS project were to investigate the logistics of acquiring and handling various woody biomass fuels and to conduct a test burn of the proposed fuel(s) to identify any technical challenges and develop recommendations for future use. The evaluation and subsequent use of biomass-derived fuel as a partial replacement for coal could help WMS reach its respective renewable portfolio standards in a timely manner. Under PA 295, all the electric utilities in the state of Michigan are required to meet a renewable portfolio standard of 10 percent of renewable energy by the year 2015.

WMS has three boilers at this site, identified as Units #5, #7 and #8. Unit #5 is a 22.5 MW natural-gas-fired boiler that is used as a back-up boiler to the other two boilers. Unit #7 is a 32.5 MW wall-fired pulverized-coal-fired boiler that is capable of firing coal, natural gas, and propane. WMS selected Boiler Unit #8; a 25 Megawatt (MW) circulating fluidized-bed boiler capable of firing coal, untreated virgin wood chip waste, and tire-derived fuel (TDF) for the DELEG co-firing grant. The use of this grant to co-fire biomass fuel in WMS's Unit #8 boiler will lay out the pathway for replacing some of its current coal intake with biomass fuel and TDF beginning in 2012.

The specific goals for this project were to:

1. Understand the market for biomass fuel suppliers (what and where) that will be available within a feasible transportation range to WMS, so that WMS will be able to secure a consistent supply of high quality, sustainably-sourced biofuel to fuel Unit #8 boiler for up to 7MW of electricity production by 2025.

2. Identify the infrastructure upgrade requirements and costs for Boiler #8 that will be necessary to store, handle, and feed biomass fuel into the boiler.
3. Verify that selected biomass fuel sources and handling equipment will effectively and consistently work to generate high-quality, low-emission electricity for WMS's customers.

This report presents results of the densified wood biomass testing conducted on Unit #8 at the WMS power plant in Wyandotte, MI. This report includes the following sections:

- Discussion of the biomass fuel suppliers
- Description of the verification approach and parameters
- Description of sampling and analytical procedures
- Test results
- Evaluation
- Appendices

2 Biomass Fuel Suppliers

2.1 Existing Biomass Fuel Supply

Per the Wyandotte Municipal Services proposal response[1] to the Michigan Bureau of Energy Systems *Biomass Energy Demonstration Grant* RFP, the specific goals for the project regarding biomass fuel supply are to:

- Develop a list of potential biomass suppliers that could feasibly, consistently, and cost effectively provide biomass fuel for WMS
- Understand the supplier's products, determine their capacities, evaluate their product in terms of biomass and process type (chipped, grinder, pellet, cube), fuel characteristics, and fuel delivery distance from WMS facility

[1]Wyandotte Municipal Services proposal, *Advancing Renewable Energy: Displacing Coal with Woody Biomass in Wyandotte*; Section E, pages 3-4.

2.2 Existing Biomass Fuel Supply

Table 1 displays a list of potential biomass fuel suppliers identified as being capable of providing biomass fuel, their contact information, the type of biomass and feedstock produced, and their production capabilities.

Table 1 Biomass Wood Fuel Suppliers

Company Phone Number & Website	Shipping Method	Type of biomass fuel	Size of Biomass	Production rate as of first quarter of 2010 (tons/year)	Miles to Plant	Location
renewaFUEL 216-694-5700 www.renewafuelllc.com	Truck	Densified Wood Cubes	+ 2 inch	60,000 – 3rd quarter will reach 210,000	120	Battle Creek
TTS Chips North, Inc 231-690-4684 www.ttschipsnorthinc.com	Truck, Ship or Rail Car	Wood Chips	< 2 inch	700,000	250	Manistee
Mid-Michigan Recycling 810-785-4515 www.mid-michiganrecycling.com	Truck	Wood Chips	< 2 inch	400,000	46 or 23	Macomb, Livonia
Michigan Wood Pellet Fuel, LLC 616-355-4955 www.michiganwoodpellets.com	Truck	Wood Pellets	< 1 inch	50,000	190	Holland
Fiber By Products 269-482-0066 www.fiberby-products.com	Truck	Wood Pellets/ Shavings	< 1 inch	40,000	140	White Pigeon
Beninati Contracting Services 586-243-4452	Truck	Wood Chips	< 2 inch	40,000	35	Shelby Township
Brink Wood Products, Inc. 616-878-9190 www.brinkwoodproducts.net	Truck	Wood Chips	< 2 inch	30,000	153	Byron Center
Harry Fox Inc. 586-772-0300	Truck	Wood Chips	< 2 inch	10,000	24	Roseville

Note: TTS Chips North, Inc. plans to implement wood pellet plants in the near future that may be capable of supplying varying sizes of pellets by 2011(according to William Timmons, CEO of TTS Chips North, Inc.)

As shown in the Table 1, all but three of the suppliers are small-scale operations with production rates of 50,000 tons per year or less. WMS's ultimate goal of co-firing 30 percent woody biomass by 2025 would require approximately 39,055 tons per year. This eliminates all but three of the suppliers, due to risk in availability.

According to the U.S. Department of Energy, “One of the most important keys to a successful co-firing operation is to appropriately and consistently size the biomass according to the requirements of the type of boiler used. Biomass that does not meet these specifications is likely to cause flow problems in the fuel handling equipment or incomplete burnout in the boiler.”[2] General biomass sizing requirements for each boiler type, as reported by the U.S. Department of Energy, are shown in Table 2.

Table 2 Biomass Sizing Requirements

Existing Type of Boiler	Size Required (inches)
Pulverized Coal	≤ 1/4
Stoker	≤ 3
Cyclone	≤ 1.2
Fluidized Bed	≤3

The biomass was added on top of the circulating fluidized bed for the test burn. Due to the operation of a fluidized bed boiler a larger fuel size is required to keep the fuel within the bed as opposed to burning above the bed or from being carried further down the flue gas stream and possibly burning in the ductwork.   During the biomass fuel supplier review it was determined that the renewaFUEL product would be the best and possibly only product that would meet the size requirements for the WMS Unit #8 test burn. The renewaFUEL product size also removed the requirement for material handling modifications to perform the test burn. All other fuel products would have required large monetary investment in order to feed the product into the boiler. This was a limiting factor in the decision making process for WMS and therefore left only the renewaFUEL product as a feasible biomass supplier for this test.

2.2 Selected Biomass Fuel Supplier

Currently, renewaFUEL is the only wood biomass fuel supplier, discovered during this study, within 120 miles of the WMS facility capable of supplying the densified wood cube in the size (two inches and larger) that meets the sizing requirements for co-firing biomass in a fluidized-bed boiler such as WMS’s Unit#8. The other suppliers listed above are capable of providing either wood chips or wood pellets in various quantities but at sizes smaller than two inches. A photograph of the renewaFUEL product is shown in Figure 1.

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[2] US Department of Energy, “Federal Technology Alert - Biomass Co-firing in Coal-Fired Boilers,” *Energy Efficiency and Renewable Energy*, 26 April 2006, www.eere.energy.gov/femp/

Figure 1 renewaFUEL Cube 100 percent Wood Product

RenewaFUEL, LLC, a subsidiary of Cliffs Natural Resources (NYSE: CLF), is a next-generation-biofuel manufacturer of renewable energy for industrial and institutional applications. Founded in 2005, renewaFUEL aggregates, engineers, processes, and distributes renewable fuels for use in industrial furnaces and boilers that result in substantial environmental benefits compared to fossil fuels. renewaFUEL's products are made from proprietary blends of sustainably collected renewable feedstock including wood, sawdust, corn stover (stalks), straw, grasses, and grain hulls and screenings. renewaFUEL's proprietary products are a blend of sustainably collected renewable feedstock from local businesses. Products include densified cubes that are roughly 2 inches in size ("fuel cubes"). renewaFUEL's products are engineered to have a higher heating value ranging from approximately 7,400 – 8,200 btu/lb (depending on the particular fuel) and to allow immediate use in most existing solid fuel systems. The products are consistent in size, heat value, moisture content, ash content, and other key fuel characteristics. renewaFUEL's products provide approximately 40-50 percent more energy than "green" wood chips.

WMS selected the 100 percent wood fuel cube for this test burn. The 100 percent wood fuel cube was selected due to existing air permit requirements and the grant deadline of July 31st, 2010. With the existing air permit, WMS has the ability to burn virgin, untreated wood in their boiler. Therefore, no modifications were required to the existing permit for the test burn. WMS and Barr Engineering Co. (Barr) worked with the Michigan Department of Natural Resources and Environment (MDNRE) to confirm the renewaFUEL product met the existing permit requirements. The decision was made to proceed with only one fuel type in order to complete the testing prior to the grant deadline.

3 Biomass Fuel Test Burn

3.1 Biomass Test Burn Methodology

One of the project's objectives was to evaluate changes in boiler performance due to co-firing woody biomass fuel with WMS's current fuel blend of 60 percent Powder River Basin (PRB) Coal and 40 percent Tire Derived Fuel (TDF). Boiler operation performance with regard to efficiency, emissions, and fly-ash characteristics were evaluated while combusting 100 percent PRB Coal/TDF fuel blend (Baseline Test) and then reevaluated while co-firing a renewaFUEL woody biomass cubed product made of 100 percent wood at two different rates. The baseline test was performed on May 14th, 2010. The co-firing verification evaluation was performed from June 9th through June 10th. For detailed information of the baseline and verification evaluation, see the Test Burn Procedure in Appendix Q.

The testing of the renewaFUEL product was limited to the following operating points for WMS Unit #8 Boiler:

1) Baseline – Firing 100 percent PRB Coal/TDF fuel blend at a normal operating load of 180,000 lb/hr.
2) Test Burn #1 – Firing 70 percent PRB Coal/TDF fuel blend and 30 percent woody biomass by heat input at an operating load of 160,000 lb/hr.
3) Test Burn #2 – Firing 85 percent PRB Coal/TDF fuel blend and 15 percent woody biomass by heat input at an operating load of 160,000 lb/hr.

Two modifications were made to the original biomass test burn procedure. The original test plan indicated that all tests would be conducted at a steam flow of 180,000 lb/hr. This steam flow rate was selected by WMS because this is where the boiler typically operates on a day-to-day basis. Unfortunately, after the baseline test had been completed and prior to the test burn being conducted, WMS's Turbine #5 tripped. Therefore, WMS was no longer able to run Unit #8 at 180,000 lb/hr. The test burns were conducted at 160,000 lb/hr, the maximum steam flow that WMS could handle with Turbine #5 down for maintenance. The second modification to the test plan was due to the limitations of the limestone feeder used to supply the 60 percent biomass fuel by heat input at the feed rate required; it was decided to perform the third test at 15 percent biomass fuel by heat input. In addition to the limestone feeder limitations, increased temperature in the feed pipe was observed by the WMS staff and safety became the sounding factor of the decision to limit the biomass feed rate to 15 percent by heat input.

Emissions testing for this program was conducted using the continuing emissions monitoring system (CEMS) for CO, CO_2, NO_x, SO_2 and continuous opacity monitoring system for opacity, which are located upstream of the stack.

3.2 Facility and Boiler

The testing was completed on the WMS Unit #8 boiler which is a 25 MW circulating fluidized-bed boiler permitted to fire coal, untreated virgin wood, and TDF. This boiler is currently fired with a 60:40 blend PRB Coal and TDF. The exhaust gas from Unit #8 is directed to a baghouse which collects flyash. Bottom ash and fly ash generated by the boilers is removed and disposed of in a local landfill.

The CEMS monitors flue gas CO, CO_2, NO_x, SO_2 and Opacity concentrations. Table 3 summarizes the Unit #8 CEMS specifications.

Table 3 Unit #8 CEMS

Parameter	Instrument Make/Model	Instrument Range	Measured Units	Reporting Units
CO	CAI Model 300A	5000 PPB	PPM	LB/MMBTU
CO_2	CAI Model 100	1500 PPM	Percent	LB/MMBTU
NO_x	API Model 200 A	3000 PPB	LB/MMBTU	LB/MMBTU
Opacity	Teledyne RM4100	0-31.5	Percent	Percent
SO_2	API Model 200 A	3500 PPM low 25,000 PPM high	LB/MMBTU	LB/MMBTU

The facility has a fully-equipped control room that continuously monitors boiler operations. The system's distributed control system (DCS) includes a PI Historian software package that allows the facility to customize data acquisition, storage, and reporting activities. WMS also collected DCS screen shots to document the boiler efficiency during testing. Operation parameters that were recorded during this test program include the following:

1) Intake air temperature, ^oF
2) Flue gas temperature at air heater inlet and outlet, ^oF
3) Fuel temperature, ^oF
4) Fuel consumption, lb/hr
5) Combustion air temperature, ^oF
6) Steam flow, lb/h
7) Steam pressure, psig

8) Steam temperature, °F
9) Supply water pressure, psig
10) Supply water temperature, °F
11) Power generation, kW
12) Excess O_2
13) Moisture in ambient air, lb/lb dry air

These data were recorded using the PI Historian software package and the DCS system during each test period. Readings were recorded every five minutes during each test period using an assigned start and end tag, and then averaged over the test period to document boiler operations during co-firing rates, and boiler efficiency. Key parameters such as heat input and steam flow are summarized in the results section of this report.

3.3 Fuel Handling Field Test

The biomass fuel cubes were delivered via a walking-bed truck and dumped onto the Unit#8 reclaim. The cubes were then conveyed via the existing conveying system to the Unit #8 limestone silo. The limestone silo housed the biomass fuel for the duration of the test burns. This was done to alleviate costs associated with adding new storage. Another option was to build a dividing wall in the existing Unit#8 coal bunker separating the two pant legs which feed into coal feeders A and B. The addition of the dividing wall would have created an additional cost of approximately $100,000. Therefore, it was decided to empty the limestone silo, mix the limestone manually with the bed gravel, and utilize the limestone silo to house the biomass. The biomass was fed into the boiler via the limestone feed pipe which is located at the centerline of the boiler wall and approximately five feet above the boiler -bed elevation.

The renewaFUEL, LLC facility in Battle Creek, Michigan, shipped the 100 percent biomass wood fuel cubes to the WMS yard via 25 ton walking-bed trucks. The cubes were densified wood product approximately two inches in size. No glue or binding agents were used during the densification of the cubes. A sample of the fuel cubes collected from the transfer house belt is shown in Figure 2.

Figure 2 renewaFUEL Cube 100 Percent Wood Product off Transfer House Belt

Figure 3 shows the cubes after they have been conveyed through the existing system into the limestone silo and are being fed into the limestone feed pipe to the boiler bed via the limestone feeder.

Figure 3 renewaFUEL Cube 100 Percent Wood Product from Limestone Feeder

Proximate and ultimate analysis of the cubed wood product used for this testing is as follows in Table 4.

Table 4 Proximate and Ultimate Analysis

Analysis	Percent by Weight as Received	
	30 Percent Test	15 Percent Test
Proximate		
Moisture	7.89	8.30
Ash	0.70	1.04
Volatile Matter	76.77	73.33
Fixed Carbon	14.64	17.33
Ultimate		
Carbon	43.98	45.57
Hydrogen	5.45	5.58
Nitrogen	0.11	0.29
Oxygen	41.83	39.18
Sulfur	0.04	0.04

The average heating value was 7,645 British thermal units per pound (Btu/lb) of the biomass cubed wood product.

Two-hundred and fifty tons (T) of renewaFUEL 100 percent wood product was delivered to the WMS site. The biomass fuel was fed into the limestone silo and the PRB Coal/TDF 60:40 fuel blend was fed into the Coal Bunker #8. The fuels were not blended prior to entering the boiler. Therefore, the boiler bed received coal as it typically does during operation with the biomass fuel inserted approximately five feet above the bed through the limestone feed pipe.

3.3.2 Field Testing Matrix

A baseline test was performed on May 14th while firing a 60:40 fuel blend of PRB Coal and TDF at 180,000 lb/hr. On June 9th, a second set of tests began while co-firing wood renewaFUEL product at 160,000 lb/hr with WMS PRB Coal/TDF fuel blend in various mixture ratios. The duration of the tests run are shown in Table 5 – WMS Biomass Co-firing Program Test Matrix. Other than changes in fuel composition, all other boiler operations were replicated as closely as possible during test sets except for the steam flow rate that was adjusted due to the Turbine #5 trip. Test and sampling procedures were also consistent between sets of tests. For further information and details of the test burn see Appendix Q.

Table 5 WMS Biomass Co-firing Program Test Matrix

Test	Fuel Blend	Test Day	Test Durations and Sampling Frequency
Baseline	100 percent PRB Coal/TDF fuel blend (sample coal and flyash prior to biomass fuel test)	Prior to Outage	• 1 test, 8 hours in duration
Test #1 –	30 percent renewaFUEL wood biomass fuel and 70 percent PRB Coal/TDF fuel blend	Test Day #1 June 8th	• 1 test, 20 hours operation at steady state conditions (steam flow and fuel mixture) at 30 percent biomass by heat input, then collect test samples for a period of 8 hours • Test duration 28 hrs
Test #2 –	15 percent renewaFUEL wood biomass fuel and 85 percent PRB Coal/TDF fuel blend	Test Day #2 June 10th	• 1 test, immediately ramp down to 15 percent biomass by heat input after Test #1 • 20 hours operation at steady state conditions (steam flow and fuel mixture) at 15 percent biomass, then collect test samples for a period of 8 hours • Test duration 28 hrs

Note: 1. Baseline fuel test was run at a boiler output of 180,000 lb/hr. All biomass fuel tests were run at a boiler output goal of 160,000 lb/hr due to Turbine #5 being out of service.

The goal was to perform all testing during stable boiler operations defined as boiler steam flows varying by less than five percent over a five minute period. This goal was accomplished for the entire test duration during the 30 percent biomass test. There were approximately six instances, over 96 measurements or six percent, during the 15 percent biomass test a difference in steam flow greater than five percent was recorded. The data collected for each biomass was considered to meet the requirements of the test protocol. Barr coordinated testing activities with boiler operators to verify that testing was conducted at the desired boiler operating set points and the boiler operation data needed to calculate efficiency was properly logged and stored.

3.4 Boiler Performance Test Procedures

Conventional field testing protocols and reference methods were used to determine boiler efficiency, emissions, and fly ash properties. A brief description of the methods and procedures is provided below.

3.4.1 Boiler Efficiency

Boiler efficiency was determined following the Btu method in the Babcock and Wilcox (B&W) Steam Manual[3]. The efficiency determinations were also used to estimate boiler heat input during each test period. The facility logs all of the data required for determination of boiler efficiency on a regular basis. Certain parameters, such as ambient conditions and moisture in air, were independently measured using National Oceanic and Atmospheric Administration (NOAA) as referenced in Appendix H. A summary of the boiler operation parameters logged during testing are shown in Table 6. For further information regarding test procedures, sample frequency, or sampling program see Appendix Q and Appendix BB.

Table 6 Summary of Boiler Efficiency Parameters

Operation Parameter	Source of Data	Logging Frequency
Moisture in ambient air, lb/lb dry air	NOAA[4]	1 hour intervals
Fuel temperature, °F	Assumed Ambient	
Intake air temperature, °F Flue gas temperature at air heater inlet and outlet, °F Combustion air temperature, °F Fuel consumption, tons/hr Steam pressure, psig Steam temperature, °F Supply water temperature, °F Supply water pressure, psig Steam flow, lb/h Excess O_2 Power generation, kW	PI Historian Software	5 minute intervals
Unburned carbon loss, % Coal heating value, Btu/lb TDF heating value, Btu/lb	Analytical Laboratory	Samples taken every 30 minutes – One composite sample (total of 1)
Biomass heating value, Btu/lb	Analytical Laboratory	Samples taken every 30 minutes – One composite sample for each test (total of 3)

[3] "Steam/Its Generation and Use;" Babcock & Wilcox; 1978; Chapter 6 Principles of Combustion; page 6-18; Table 12.

[4] National Weather Service Forecast Office; National Oceanic and Atmospheric Administration; http://www.weather.gov/climate/index.php?wfo=dtx.

Operation Parameter	Source of Data	Logging Frequency
Moisture in ambient air, lb/lb dry air	NOAA[4]	1 hour intervals
Fuel temperature, °F	Assumed Ambient	
Fuel ultimate analysis, PRB Coal and TDF	Analytical Laboratory	Samples taken every 30 minutes – One composite sample for coal, TDF, and fly ash (total of 1 for each)
Fuel ultimate analysis, PRB Coal and TDF	Analytical Laboratory	Samples taken every 30 minutes – One composite sample for coal, TDF, and fly ash (total of 3 for each)

Note: All data was required using the PI Historian software excluding the moisture in air, which was recorded via the National Oceanic Atmospheric Administration (NOAA).

3.4.2 Fuel Sampling and Analyses

Fuel samples of PRB Coal/TDF were taken every 30 minutes from each of feeders A and B. Over an eight hour period, sixteen samples were taken from each belt for a total of 32 samples. This was done for each of the tests – Baseline, 30 percent Test Burn, and 15 percent Test Burn – for a total of 96 samples.

Fuel samples of biomass were taken every 30 minutes from the feeder during this test. Grab samples were manually taken from the feeder belts for both the PRB coal/TDF and biomass. Samples were collected in one-gallon containers, sealed and marked with fuel type, feeder name, date and time. Over an eight hour period, a total of 16 samples were taken from the belt. This was done for each of the biomass tests – 30 percent Test Burn and 15 percent Test Burn – for a total of 32 samples.

Ash samples were taken every 30 minutes from the baghouse hoppers #1 and #2. These hoppers were selected because of the proximity to the inlet flow as can be seen in Appendix S. Samples were collected every 30 minutes. However, the baghouse has an automatic cleaning cycle, and if hoppers #1 or #2 had recently been cleaned automatically, an ash sample was not available for collection.

Cliffs Natural Resources (CNR) completed the initial analyzing of the samples. The PRB Coal/TDF samples were separated manually and a mass balance was completed for PRB Coal and TDF. The fuel samples were then sent to an outside laboratory, SGS Analytical Laboratories, where the proximate and ultimate analyses were completed.

- Fuel analyses, both wood and coal mixture
    - Proximate
    - Ultimate
    - Resource Conservation and Recovery Act (RCRA) – Michigan '12' Metals
        - Arsenic, As
        - Barium, Ba
        - Cadmium, Ca
        - Chromium, Cr
        - Copper, Cu
        - Lead, Pb
        - Manganese, Mn
        - Mercury, Hg
        - Nickel, Ni
        - Selenium, Se
        - Silver, Ag
        - Zinc, Zn
    - Toxicity Characteristic Leaching Procedure (TCLP) Metals
    - Minerals
    - Chlorine
    - Mercury
    - Fusion – 8 Point, Reducing and Oxidizing on same sample
- Fuel heating value, Btu/lb
- Unburned carbon loss, %

3.4.3 Boiler Emissions

The following CEMS measurements were collected during the testing:

- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Nitrogen oxides (NO_x)
- Sulfur dioxide (SO_2)
- Opacity

3.4.4 Fly Ash Characteristics

Fly ash samples were collected during each of the three tests – Baseline, 30 percent Test, and 15 percent Test. The samples were used to evaluate the impact of biomass co-firing on ash composition. Fly ash samples were collected from the baghouse collection hoppers during each test. The hoppers were cleaned out before each test. Collected samples were delivered to CNR for testing. CNR took a composite of the samples and sent them to SGS Analytical Laboratories for determination of the parameters listed below.

- Michigan '12' Metals
- TCLP Metals
- Minerals
- Chlorine
- Mercury
- Fusion – 8 Point, Reducing and Oxidizing on same sample

3.5 Sustainability

This project evaluated certain sustainability issues in relation to this test. The following sustainability-related issues were evaluated:

- Fly ash composition, use and waste disposal including delivery and distance
- Estimated daily and annual woody biomass consumption at 30 percent and 15 percent co-firing rates
- GHG emission comparison

Biomass availability is a key factor in the decisions to proceed further. Biomass consumption rates were measured during each test. This data was used to estimate the daily and annual biomass consumption rates (100 tons/day, 39,055 tons/yr) that would be required in the future. These figures were used to aid in determining whether the use of biomass fuel is sustainable for WMS.

While evaluating the average biomass fuel consumption rate during the testing, upstream CO_2 emissions associated with the biomass supply were estimated. Emission factors were calculated based on World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) GHG Protocol for Stationary Combustion emissions factors.

To determine if co-firing had a measurable impact on the carbon content of the ash, the baseline coal fly ash analysis was compared to the two co-fired test burn fly ash analyses. To evaluate the impact on the metals content, the Resource Conservation and Recovery Act (RCRA) and Toxicity Characteristic Leaching Procedure (TCLP) results were compared for the baseline fly ash versus the two co-fired test burn fly ash.

4 Test Burn Results

The results of the biomass fuel co-firing on WMS Unit #8 are summarized in the following paragraphs.

Field and analytical data collected during the verification process are compiled in Appendix O. Overall, the WMS Unit #8 boiler was able to handle and burn the biomass fuel with nominal changes in operation. As stated in section 2, the only variation in fuel handling applied was storage of the biomass fuel in the limestone silo in lieu of the Unit #8 coal bunker. This was done to prevent the biomass fuel from absorbing moisture from the inherently moist PRB Coal and to reduce unnecessary costs associated with testing. Other than this modification, the WMS facility was capable of accommodating the biomass in their boiler.

The third test was originally set to run at a 60 percent biomass fuel by heat input to determine the capability of the boiler. However, due to the limitations of the limestone feeder used to supply the 60 percent biomass fuel by heat input at the feed rate required, it was decided to perform the third test at 15 percent biomass fuel by heat input. In addition to the limestone feeder limitations, increased temperature in the feed pipe was observed by the WMS staff and safety became the sounding factor of the decision to limit the biomass feed rate to 15 percent by heat input.

When evaluating whether biomass co-firing resulted in identifiable changes in boiler performance, standard deviation in results were addressed using statistical analysis. This method aided in determining the statistical significance of the observed changes in boiler efficiency or emissions.

4.1 Boiler Efficiency

The major fuel characteristics for the PRB Coal/TDF fuel and the biomass fuel are summarized in Table 7 Fuel Characteristics (as received).

Table 7 Fuel Characteristics As Received

Test	Fuel	Moisture (%)	Carbon (%)	Sulfur (%)	Ash (%)	Heating Value (Btu/lb)
Baseline	PRB Coal	23.57	54.44	0.39	5.72	9487
	Tire Derived Fuel (TDF)	8.37	67.82	1.26	14.04	12799
	Blended Fuel	16.58	60.59	0.79	9.55	11011
15 percent Biomass Fuel (by heat input)	Biomass	8.30	45.57	0.04	1.04	7634
	PRB Coal	21.96	55.60	1.14	6.60	9751
	Tire Derived	8.37	67.82	1.26	14.04	12799
	Blended Fuel	14.00	57.62	0.93	7.96	10413
30 percent Biomass Fuel (by heat input)	Biomass	7.89	43.98	0.04	0.70	7665
	PRB Coal	21.95	55.22	0.35	5.85	9642
	Tire Derived Fuel (TDF)	8.37	67.82	1.26	14.04	12799
	Blended Fuel	12.97	55.05	0.61	6.25	9996

WMS normally operates using 60 percent PRB coal combined with 40 percent TDF. The biomass testing was completed using this typical 60/40 blend ratio and then adding the biomass at 30 percent and 15 percent rates by heat input. The biomass was inserted into the boiler via the limestone feeder. Samples were taken every 30 minutes of the testing for the PRB coal/TDF blend and also the biomass. All samples were sent to Cliffs Natural Resources for analysis. The PRB coal/TDF blend was manually separated. Mass balances were performed on each sample. Table 8 shows the PRB coal/TDF blend ratios that were determined from the samples taken during each test.

Table 8 Percent of Fuel by Weight

Test	PRB Coal	TDF	Biomass
Baseline	54%	46.0%	NA
30 Percent Biomass (by heat input)	35.1%	29.9%	35.0%
15 Percent Biomass (by heat input)	41.6%	35.4%	23.0%

Table 9 summarizes boiler efficiency during the test periods.

Table 9 Boiler Efficiency

Test	Fuel	Heat Input (MMBtu/hr)	Heat Output (MMBtu/hr)	Efficiency (%)
Baseline	PRB Coal/TDF(54 percent wood, 46 percent coal/TDF by weight)	195.7	147.1	85.18
30 percent Biomass Fuel (by heat input)	Blended Fuel (35 percent wood, 65 percent coal/TDF by weight)	183.4	138.7	82.36
15 percent Biomass Fuel (by heat input)	Blended Fuel (23 percent wood, 77 percent coal/TDF by weight)	180.1	136.9	83.59

The boiler efficiency did not change significantly over the three tests. The efficiency does trend down slightly when burning biomass. The heating value of the mixed fuel was approximately five to ten percent lower than the baseline test. The difference in boiler efficiencies may be due to the difference in heating value and that the boiler efficiency calculations are based from data averaged over time; given a margin of error for the calculation. Co-firing densified wood cubes does not appear to affect the performance or efficiency of the boiler at the 15 percent or the 30 percent biomass blend by heat input. Boiler efficiency calculations for each test can be found in Appendices W, X and Y.

4.1.1 Boiler Operation and Fuels

Boiler operations can be controlled using three methods including manually controlling fuel feed rate, controlling fuel feed using a steam header pressure set point, or controlling fuel feed using a steam mass flow control point. For this testing, boiler operations were controlled using steam flow. During baseline testing, the steam flow was set at nominal 180,000 lb/hr. During co-firing, fuel inputs were controlled to a maximum of 160,000 lb/hr due to Turbine #5 being out of service. The steam flows are presented in the Figure 4 below.

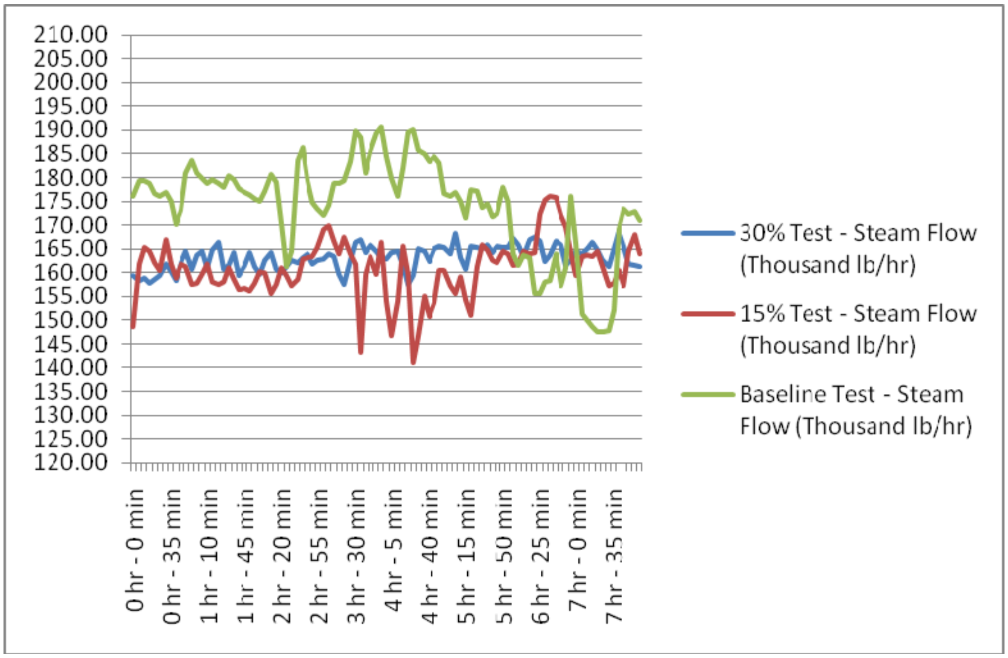

Figure 4 WMS Unit #8 Steam Flow

The plant employs gravimetric feeders to measure the consumption of both types of fuels. The biomass passed thru the limestone silo onto a low pressure gravimetric feeder with electronic weighing, and the PRB Coal/TDF blend passed thru Bunker #8 onto gravimetric feeders A and B. These feeders were used to measure fuel consumption and co-firing rates during all test periods, and to calculate boiler heat input with the fuel heat content analysis. The fuels were not premixed and are fed into the boiler separately, the PRB Coal/TDF mixture was fed thru the coal pipes from feeders A and B and the biomass was fed through the limestone feed pipe approximately five feet above the bed along the midsection of the boiler.

4.2 Boiler Emissions

The renewaFUEL biomass fuel that was used for this test burn is a 100 percent wood composite cube. The cubes can be produced in various sizes, but typically are cubed and approximately 2x2x3 inches and have a density of 30 lb/ft3. Moisture content of the fuels is approximately eight percent and the fuels have a higher heating value of 7,645 Btu/lb. Feedstock woods for renewaFUEL's products come from industrial and agricultural entities. Table 4 summarized typical fuel characteristics for this site.

The WMS facility performed a baseline test where the boiler is operating on PRB Coal/TDF fuel only. During the baseline testing, heat input was maintained at a level that produces the nominal 180,000 lb/hr steam typically produced by the boiler.

Michigan '12' Metals Emissions analysis was completed for the testing. The fuel samples were collected at 30 minute intervals during the 8 hour test recording period. The PRB Coal/TDF samples were manually divided and a single composite sample of the coal was compiled for each of the three tests. A single composite sample was created from all three tests for the TDF analysis. A composite sample of the 30 percent and the 15 percent test was compiled for the biomass fuel product. The results for this testing are shown in Table 10.

Table 10 Michigan '12' Metals Emissions (mg/kg)

Test	Fuel	As	Ba	Cd	Cr	Cu	Pb	Mn	Hg	Se	Ag	Zn	Ni
Baseline	PRB Coal	ND	450	ND	3.5	14	ND	49	*30.1	10	ND	50	5
	Tire Derived Fuel	30	770	ND	1.3	57	ND	370	*13.9	20	ND	590	8.6
Biomass Test 30% (by heat input)	PRB Coal	ND	470	ND	2.7	13	ND	410	*28.2	ND	ND	380	5.3
	Tire Derived Fuel	30	770	ND	1.3	57	ND	370	*13.9	20	ND	590	8.6
	renewaFUEL Biomass Cubes	ND	45	0.72	2.3	37	3.8	75	*3.8	4	ND	22	2.1
Biomass Test 15% (by heat input)	PRB Coal	ND	460	ND	5.2	35	ND	130	*32.5	20	ND	230	6.9
	Tire Derived Fuel	30	770	ND	1.3	57	ND	370	*13.9	20	ND	590	8.6
	renewaFUEL Biomass Cubes	ND	27	4.3	5.0	58	5.1	130	*2.62	4	ND	22	3.3
MQL (PRB Coal)		60	1	1	1.5	3	15	0.1	*9.8	30	2.5	20	1.5
MQL (TDF)		60	1	1	1.5	3	15	0.1	*3.95	30	2.5	20	1.5
MQL (Biomass)		12	0.3	0.2	0.3	0.6	3	0.4	*2.44	6	0.5	1	0.3

Note:
* = Mercury metal emissions are reported in ng/g dry
ND = Not Detected
MQL = Method Quantitation Limit

Table 10 CEMS Emissions

Test	Fuel	Opacity (%)	CO (%)	CO_2 (PPM)	NO_x (lb/MMBtu)	SO_2 (lb/MMBtu)	Limestone Feed Rate (lb/hr)
Baseline	PRB Coal/TDF	0.8636	0.2871	11.859	0.2376	0.1991	906
30 percent Biomass Fuel (by heat input)	Blended Fuel (35 percent wood, 65 percent coal/TDF by weight)	0.0873	0.1459	10.968	0.2091	0.1599	591
15 percent Biomass Fuel (by heat input)	Blended Fuel (23 percent wood, 77 percent coal/TDF by weight)	0.1231	0.1662	10.966	0.2127	0.3695	591
Limit per WMS permit		Act 348, Section 15	0.2400		0.4000	0.4960	As needed

Note: Baseline was run at 180,000 lb/hr, Test burns were run at 160,000 lb/hr due to Turbine #5 being out of commission.

CEMS emissions show a trend downward, however as noted previously the baseline conditions were run at 180,000 lb/hr of steam flow while the test burns were run at 160,000 lb/hr due to the Turbine #5 being out of commission for repairs.

Test results appear to have the trends stated below with the current test results. More testing and analysis will be required to completely understand the impact of co-firing densified wood biomass cubes.

1. Opacity appears to be reduced during testing.
2. The results for CO show a downward trend with regard to the amount of biomass used. As previously stated, the steam flow rates differ between the baseline and the test burns due to Turbine #5 being out of service. The downward trend could correlate to the lower moisture content of the renewaFUEL product and WMS's high moisture content in the coal/TDF.

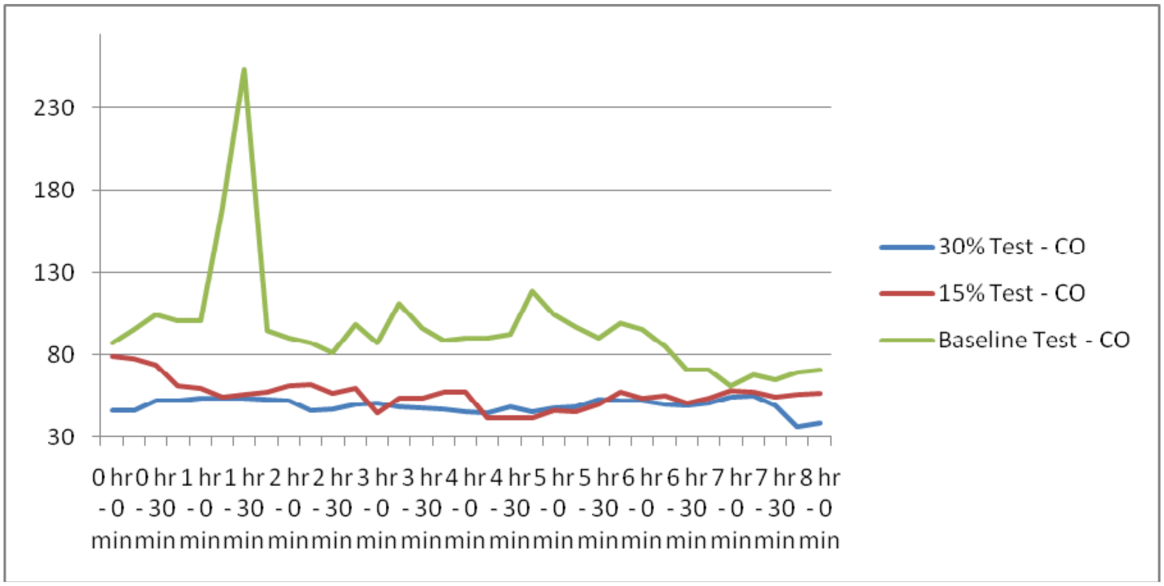

Figure 5 WMS Unit #8 Carbon Monoxide

3. CO_2 emissions appear to trend downward slightly.
4. NO_x emissions appear to trend downward slightly.
5. The SO_2 levels were within permit compliance throughout the duration of the biomass testing. The average SO_2 emissions trend downward for the 30 percent test and trend upward for the 15 percent test. Figure 6 shows that there was considerable variation throughout the course of the test in SO_2 emissions, which could be due to the amount and timing of the limestone injections.

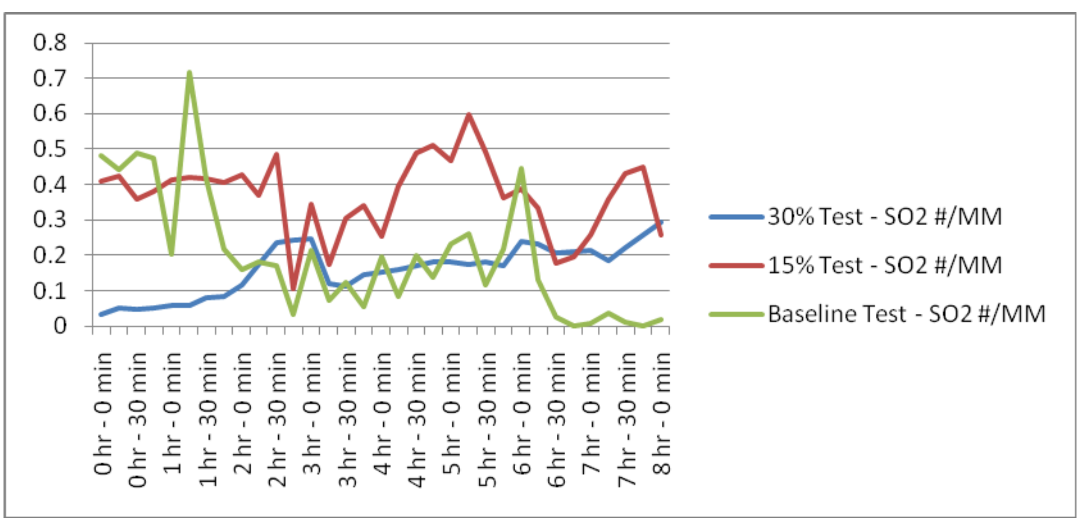

Figure 6 WMS Unit #8 SO2 Emissions During Testing

The 15 percent test shows a SO_2 trend upward, less limestone was used to remain below compliance levels than during the baseline test. Less coal and TDF were burned during the biomass tests which would result in a lower SO_2. Further testing would be required in order to form solid conclusions in regards to SO_2 due to difference in limestone consumption. The biomass product was stored in the limestone feeder, therefore, requiring the limestone to be manually added with the gravel feed. As shown in Figure 7, the total pounds of limestone consumed during both of the biomass test burns was approximately half that used in the baseline testing. Less coal and TDF, the main suppliers of sulfur, were burned during the biomass tests which would result in a lower SO_2 and require less limestone to be added.

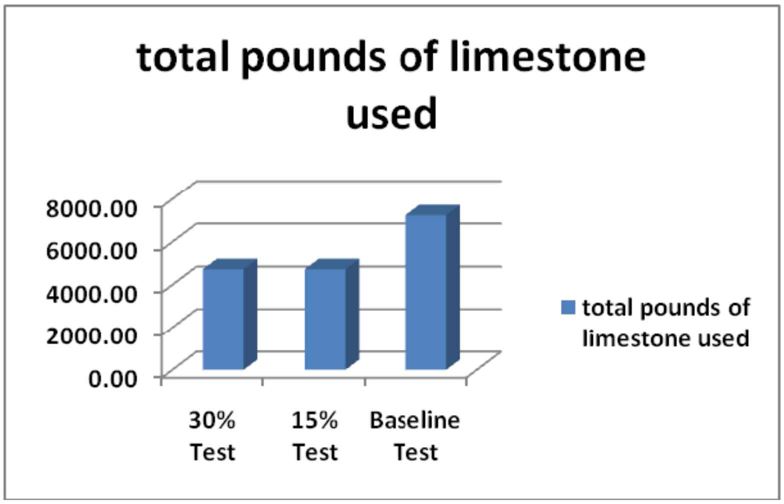

Figure 7 WMS Unit #8 Limestone Consumed

4.3 Fly Ash Characteristics

Results of the fly ash analysis are included in Tables 12 and 13 below. The data indicates that changes in the ash characteristics were generally small. This is favorable for ash handling systems since the data suggests that the ash handling system would not be expected to be impacted by co-firing biomass as tested.

Table 12 Ash Characteristics

Test	Fuel	Carbon, wt %	Silicon Dioxide, % as SiO2	Aluminum Oxide, % as Al2O3	Iron Oxide, % as Fe2O3	Reducing Atmosphere: Initial Deformation °F	Oxidizing Atmosphere: Initial Deformation °F
Baseline	54% PRB Coal, 46%TDF	3.93	17.43	5.32	27.58	2210	2270
Biomass Test 30% (by heat input)	Blended Fuel (35% biomass, 65% PRB coal/TDF by weight)	22.75	20.63	7.87	24.6	2200	2250
Biomass Test 15% (by heat input)	Blended Fuel (23 percent wood, 77 percent coal/TDF by weight)	17.32	19.32	6.75	28.91	2210	2260

Table 13 Ash TCLP '12' Metals (mg/l)

Test	Fuel	As	Ba	Cd	Cr	Cu	Pb	Mn	Hg	Se	Ag	Zn	Ni
Baseline	54% PRB Coal, 46%TDF	1.4	0.39	ND	ND	ND	ND	ND	*171	ND	ND	6.5	ND
30 percent Biomass Fuel (by heat input)	Blended Fuel (35% biomass, 65% PRB coal/TDF by weight)	ND	0.98	0.0029	0.07	0.013	0.072	ND	*201	0.016	ND	4.33	ND
15 percent Biomass Fuel (by heat input)	Blended Fuel (23 percent wood, 77 percent coal/TDF by weight)	ND	0.96	0.0023	0.06	0.011	0.073	ND	*278	0.01	ND	4.94	ND

* Note: Mercury metal emissions are reported in ng/g dry

4.4 Sustainability Issues

There are three main areas for sustainability issue consideration. They are use or disposal of fly ash, woody biomass consumption rates, and greenhouse gas emissions.

4.4.1 Fly Ash Composition

Biomass co-firing did not impact the use or disposal of fly ash with regard to fly ash TCLP metals and Class F requirements.

4.4.2 Woody Biomass Consumption

Table 14 Daily and Annual Woody Biomass Consumption Rates

Percentage of Biomass by Heat Input	Daily Consumption (tons/day)	Annual Consumption (tons/yr)
30 Percent Biomass	107	39,055
20 Percent Biomass	71	25,915
15 Percent Biomass	53	19,345

4.4.3 Biogenic Carbon Lifecyle

The carbon within renewaFUEL wood-based fuel is carbon derived from biogenic (plant or animal) sources that was recently contained in living matter. According to the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) GHG Protocol for Stationary Combustion, wood wastes are considered a solid biomass (an organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation). The WRI/WBCSD also consider wood to be a renewable energy source[5]. The carbon within a fossil fuel like bituminous coal has been trapped in geologic formations for millennia and is a non-renewable fuel.

Due to the differences in the life cycle of carbon in biogenic versus fossil fuels, the current GHG reporting protocols require GHG emissions from the combustion of biogenic fuels and fossil fuels to be treated differently. Emission inventory protocols for biogenic emissions are still being refined; however, the Climate Registry's General Reporting Protocol[6] (GRP) requires that CO_2 emissions from the combustion of biomass (such as wood, landfill gas, ethanol, etc.) to be reported separately from other direct GHG emissions. Methane and nitrous oxide emissions from biomass combustion should be reported with other direct GHG emissions. The U.S. EPA's Mandatory Reporting of Greenhouse Gases Rule (40 CFR Part 98) concurs. Pursuant to Subpart C, CO_2 emissions from biomass stationary combustion sources must be reported separately from CO_2 emissions from fossil fuel sources.

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[5] WRI/WBCSD Calculation Tool for Direct Emissions from Stationary Combustion, Version 3.0, July 2005 (http://www.ghgprotocol.org/calculation-tools/all-tools)

[6] The Climate Registry General Reporting Protocol, May 2008, http://www.theclimateregistry.org/downloads/GRP.pdf

4.4.4 GHG Emission Calculations

Direct (Scope 1) carbon dioxide equivalent (CO_2e) emissions have been calculated for the baseline test (the combustion of a 100 percent fuel blend (60 percent bituminous coal and 40 percent tire-derived fuel)). According to the GRP, if an emission unit's CO_2 emissions can be determined through direct measurement or continuous emissions monitoring (CEMS), then this highest-quality data tier (Tier A1) shall be used. Stack tests were not conducted during the baseline test, and complete CEMS data is not available. As a result, GRP emission factors for the combustion of bituminous coal and TDF have been used to calculate CO_2 (GRP, Table 12.1, Tier C Method). GRP emission factors for the stationary combustion of bituminous coal in a fluidized bed combustor were used to calculate methane (CH_4) and nitrous oxide (N_2O) emissions from the baseline test (GRP, Table 12.5, Tier B method). Methane (CH_4) has a Global Warming Potential (GWP) of 21 and nitrous oxide (N_2O) has a GWP of 310; therefore, actual CH_4 and N_2O emissions were multiplied by 21 and 310 respectively, to calculate emissions in terms of CO_2 equivalent. GHG emission calculations and emission factor references for the baseline test are included in Appendix G and summarized in Table 15.

Direct (Scope 1) carbon dioxide equivalent (CO_2e) emissions have also been calculated for the 30% biomass test burn and 15% biomass test burn. Stack tests were not conducted during the 30% and 15% biomass test burns, and complete CEMS data is not available. As a result, GRP emission factors for the combustion of wood waste, bituminous coal and TDF have been used to calculate CO_2 (GRP, Tables 12.1 and 12.2, Tier C Method). As noted previously, the CO_2 emissions from the biomass component of this fuel has been reported separately from the fossil fuel component. Standard GRP emission factors for wood waste were used to calculate CH_4 and N_2O (GRP Table 12.5, Tier B method). Once again, the GWP of CH_4 and N_2O were factored in so that emissions are reported in terms of CO_2 equivalent. GHG emission calculations and emission factor references for the 30% and 15% biomass test burns are included in Appendix G and summarized in Table 15 below.

Table 15 Direct (Scope 1) CO_2 Equivalent Emissions from Combustion

Fuel Type	Fuel Mixture	Biogenic CO_2 emissions (lbs/ton combusted)	Fossil Fuel CO_2 emission (lbs/ton combusted)	CH_4 emission converted to CO_{2e} (lbs/ton combusted)	N_2O emission converted to CO_{2e} (lbs/ton combusted)	Total Emission CO_{2e} (lbs/ton combusted)	CO_{2e} Ratio (lbs emitted/lbs combusted)
Powder River Basin Coal (Baseline)	60%Coal/ 40% TDF	N/A	51,456	11	9,634	61,101	2.7
renewaFUEL Wood-Based Fuel (30% Biomass Test)	30% Biomass	14,879	N/A	31	290	15,200	1.7
	70%Coal/ TDF (60/40 Fuel Blend)	N/A	37,540	8	7,024	44,572	2.7
renewaFUEL Wood-Based Fuel (15% Biomass Test)	15% Biomass	9,913	N/A	21	193	10,127	1.7
	85%Coal/ TDF (60/40 Fuel Blend)	N/A	45,555	10	8,531	54,096	2.7

Note: The baseline test resulted in 180,000 lb/hr steam flow. The 30% biomass test and 15% biomass test each resulted in 160,000 lb/hr steam flow. As a result, the total CO_2e emissions for the baseline and biomass tests are not directly comparable. The total CO_2e calculations demonstrate that in the 30% biomass and 15% biomass tests, a significant proportion of the total CO_2e emissions are from a biogenic fuel source.

5 Project Evaluation

5.1 Biomass Combustion Options

The initial test plan included evaluating different biomass feedstock to compare the differences in energy output, stack emissions, and handling efficiency based on the type of feedstock, particle size (chipped, shredded, tub ground), and moisture content. During the biomass fuel supplier study, it was determined that renewaFUEL was the only supplier within 120 miles that could supply densified wood cubes. Unit #8 is a circulating fluidized bed boiler which requires a fuel to be sized two inches and larger for optimal operation. The renewaFUEL product is the only product that met this size requirement.

Wood chips or shredded wood sized larger than two inches may have worked, but it was concluded that the existing material handling system and storage bunkers would not feed this type of product without installation of costly equipment. For this reason the renewaFUEL product was the only biomass fuel tested.

5.2 Storage and Feeding System Requirements

WMS performed the biomass test burn using their existing storage and fuel handling system, no new equipment was added for testing. Biomass was delivered by truck with walking floor trailers which unloaded the biomass directly onto the Unit#8 reclaim. The existing conveying system was used to feed the biomass from the reclaim in the Unit#8 limestone silo. From the silo, the biomass fed onto a gravimetric feeder and ultimately went into the boiler through the limestone feeder pipe. No material handling problems were identified during the test period. The biomass was dustier than coal and increased housekeeping was required to keep dust from building and becoming an explosion hazard.

The renewaFUEL product is a manufactured biomass fuel that will break down when exposed to water or wet conditions. Additional covered storage would be required to be installed to protect the fuel from such conditions. Additional material conveying systems would also be required to get the fuel from this covered storage into the boiler.

An opinion of probable cost was developed for the proposed additional equipment that may be required to burn biomass on a long term basis in Unit#8. The cost estimate is based from engineering experience with the types of equipment listed, RS Mean's data, and historical cost data. The accuracy of the cost estimate is +/-75 percent as is to be used for budgetary purposes. Figure 8 below indicates labor, material and engineering costs required for the installation of the proposed equipment.

Work Area & Description of Work Activity	Quantity	Unit	Material		Equipment/Subcontract				Labor				Total Cost
			Unit Cost	Total Cost	Prod Rate	Hours	Rate	Cost	Prod Rate	Hours	Rate	Cost	
1: New Biomass Handling Mechanical and Equipment													
Contractor Mob/Demob	1	ls	$10,000	$10,000						96.0	$64.03	$6,147	$16,147
Truck Scale	1	ls	$32,000	$32,000						256.0	$64.03	$16,392	$48,392
Conveyor #1	1	ls	$196,500	$196,500						148.0	$64.03	$9,476	$205,976
Storage Bin	1	ls	$147,000	$147,000						475.0	$64.03	$30,414	$177,414
Feeder	1	ls	$65,000.00	$65,000						144.0	$64.03	$9,220	$74,220
Bucket Elevator	1	ls	$200,000.00	$200,000						145.0	$64.03	$9,284	$209,284
Chute-Work	1	lot	$16,350.00	$16,350						136.0	$64.03	$8,708	$25,058
Dust Collection	1	lot	$103,500.00	$103,500	1	1	82000.000	$82,000					$185,500
Explosion Protection	1	lot	$37,200.00	$37,200	1	1	33000.000	$33,000					$70,200
Fire Protection	1	lot	$33,000.00	$33,000	1	1	100000	$100,000					$133,000
HVAC	1	lot			1	1	40000	$40,000					$40,000
Subtotal:								$255,000		1304.00		$83,495	$1,185,192.00
2:New Biomass Handling Civil / Structural													
Site Work and Truck Reciveing Building	1	ls			1	1	810000	$810,000					$810,000.00
Subtotal:													$810,000
3: New Biomass Handling Electrical													
Site Wide Electrical	1	ls			1	1	425000	$425,000					$425,000.00
Subtotal:													$425,000
Total								$1,490,000				$83,495	$1,995,192.00
Small Tools % of Labor												3%	$2,505
Freight													
Material Tax													
Subtotal													$1,997,697
General Contractor Overhead and Profit												10%	$199,770
Subtotal													$2,197,467
Contingency													
Geotechnical Investigation & Report													
Engineering Design Cost												7.0%	$139,839
Total													$2,337,305
Probable Cost Range												-75%	$584,326
												75%	$4,090,284

Since Barr has no control over the cost of labor, materials, equipment, services furnished by others, the contractor(s)' methods of determining prices, or competitive bidding or market conditions, the engineer's opinions of probable total project costs and construction costs provided are made on the basis of our experience and qualifications. These opinions of total project and construction costs represent our best judgment as an experienced and qualified professional engineer, familiar with the construction industry. However, we cannot and do not guarantee that proposals, bids, or actual total project or construction costs will not vary from the opinions of probable cost prepared by Barr.

Figure 8 Opinion of Probable Cost

6 Financials/Budget

See attached DELEG form c-108 and supporting documents

Appendices

A. 2010 Wyandotte – List of Sample Analysis Costs R-1
B. 2010 Wyandotte – Wyandotte Fuel Specifications
C. Biomass, Biofuels, and Bioenergy Feedstock Opportunities in Michigan
D. Clean Energy from Wood Residues in Michigan
E. Measures of Wood Resources in Lower Michigan Paper
F. Measures of Wood Resources in Lower Michigan
G. MI SO2 1866-2009
H. National Oceanic Atmospheric and Administration Weather Data
I. Opportunities in Michigan Wood Energy
J. Potential Availability of Urban Wood Biomass in Michigan
K. Quantifying Urban Saw Timber Abundance and Quality in Southeastern Lower Michigan
L. renewaFuel Wood Dust MSDS
M. RF-Wyandotte Sustainability Details
N. Robert Froese Traverse City Presentation
O. Sawmill Operations Serving Southeastern Michigan
P. Test Burn PI and CEMS Data
Q. Test Burn Procedure
R. Traverse City Report
S. Urban Wood Waste in Michigan
T. WMS Baghouse Screen Shot
U. WMS MDNRE Air Quality Permit
V. WMS Test Burn Boiler Efficiency 15 percent Biomass
W. WMS Test Burn Boiler Efficiency 30 percent Biomass
X. WMS Test Burn Boiler Efficiency Baseline
Y. Wood Fuel Availability Study
Z. Wood Waste Processing and Utilization in Southeastern Michigan
AA. Woody Biomass Retrofit Opportunities in Michigan Boiler
BB. Wyandotte Sample Test Plan
CC. GHG Calculations