Project Title: Torrefaction and Densification of Biomass Fuels for Generating Electricity

Contract Number: RD3-4      Milestone Number: 08      Report Date: Wednesday, October 27, 2010

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Congressional District: 5th Congressional District

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

MILESTONE 8 REPORT

Executive Summary:
This project will research torrefaction and densification of biomass feedstocks to develop an efficient and economical biomass supply chain. The approach is to develop and optimize a torrefaction and densification regime that will improve storage capabilities, handling methods and biomass feedstock uniformity for the production of renewable baseload electricity, heat, or syngas. The project is designed to support the following goals:

- Goal 1: Generate electricity, heat or syngas from renewable biomass energy sources that are readily available in Minnesota and approaching economic feasibility
- Goal 2: Strengthen the economy of rural Minnesota through value-added processes that capture renewable biomass energy production capability
- Goal 3: Increase accessibility to information that facilitates the adoption of biomass technologies to generate electricity and reduce fossil fuel use

The main work activity conducted for Milestone 8 consisted of independent co-firing test burns at 10% and 30% co-firing ratios and collecting emission profiles at industrial scale while demonstrating the test burns to RDF administration. Additionally, Milestone 8 consisted of conducting a series of tests to simulate extreme weathering that the product might be subjected to during bulk storage and transportation sequences. Milestone 8 addresses the project goals in the following ways:

- Proving and demonstrating the biocoal product can be used for the production of heat in existing industrial scale stoker grate boilers without modification while co-firing to at 30% on a btu basis.
- Proving and demonstrating that the resultant co-firing emission profiles during the testing have statistically relevant reductions in both NOx and SO2 pollutants.
- Demonstrating that the biocoal product have a statistically relevant reduction in mercury as compared to the representative coal used in the industrial scale co-firing trials.
- Demonstrating that the biocoal product can withstand cyclic extreme weathering exposure and still maintain its mechanical (crush strength) and chemical characteristics (proximate & ultimate).
The project continued with work on Milestone 8 and 9 during the months of March thru October 2010. The team successfully completed the baseline and industrial scale 10% stoker grate co-firing trial at District Energy in April 2010. The team then completed the 30% co-firing trial in late July 2010 at District Energy.

Independent emission profiles were collected by Interpoll Laboratories, Inc. during all three tests (baseline, 10% and 30% co-fire ratios). As a part of these efforts, the team obtained the final emissions test reports for the Milestone 8 Report corresponding with the baseline, 10% and 30% co-firing trials. Additionally, the team developed and conducted extreme weathering tests on the biocoal product to determine its ability to maintain its mechanical and chemical characteristics. Finally, the team continued to coordinate a gasification trial as a part of the Milestone 9 Report.

**Technical Progress: Transportation & Storage Testing – Extreme Weathering Test**

**Extreme Weathering Test: Discussion & Experimental Set-Up**

The ability of the biocoal product to leverage existing international bulk commodity transportation infrastructure is a primary driver for rapid adoption of the biomass torrefaction and densification process technology. A leading indicator of a product’s ability to leverage existing bulk commodity infrastructure is the products “durability.” As we found and reported in our Milestone 4 Report, the durability of the resultant biocoal product performs similar to existing coals used in North America.

With this fact established, and in an effort to expand our understanding of how the biocoal product may perform in transit from one region of the world to another, we developed and performed a cyclic extreme weathering test on our biocoal. The test was designed to determine how well our biocoals primary mechanical and chemical characteristics could withstand simulated bulk transportation and storage weather.

In designing the test, we hypothesized that the biocoal, in one situation, could be produced in the fall in Minnesota and stored outdoors for a period prior to being shipped to a warm and highly humid environment for subsequent use. Under this hypothetical circumstance, it is probable that the material would be subjected to a period of standing water and cyclic freeze and thaw cycles that could include high humidity. A visual flow of the test regime is provided in Figure 1 below.

The test consisted of pulling 60 random briquettes from the 25 ton demonstration run conducted in February 2010. From there, 10 briquettes were pulled as the “baseline,” and 10 were immediately subjected to a standing water / extreme rain test. The remaining 40 briquettes were subjected to cyclic freezing and high humidity extremes, and at the end of each cycle 10 briquettes were removed and allowed to equilibrate prior to being placed in sealed bags for subsequent mechanical (crush strength) and finally chemical (proximate and ultimate) testing.

In Figure 1, a “Hot & Humid Cycle” consisted of placing the biocoal briquettes into a sealed oven at near 100% humidity with a temperature of 120 °F for two days (48 hours). A “Freezing Cycle” consisted of placing the biocoal briquettes in a standard freezer for one day (24 hours) immediately after the HH cycle. The standing water / extreme rain cycle consisted of placing the 10 biocoal briquettes in room temperature (Approximately 72 °F) distilled water for two (2) hours after which the water was drained off and the biocoal allowed to equilibrate for two (2) days.
Extreme Weathering Test: Results – Mechanical

The following table gives the force necessary to crush the sample briquette under the different weathering conditions tested. Unless otherwise noted, the values given in the table are in lbf. The press used to perform the test had a maximum rated capacity of 150 lbf, therefore if a sample was not crushed after 150 lbf was applied to it, it received a 150+ rating.
Table 1. Crush test data acquired for weathered biocoal samples. The control sample received no weathering. Standing water samples are represented by the Water column, HH and F stand for Hot and Humid cycles and Freezing cycles endured by each sample respectively.

<table>
<thead>
<tr>
<th>Briquette</th>
<th>Control</th>
<th>Water</th>
<th>1HH/0F</th>
<th>1HH/1F</th>
<th>2HH/1F</th>
<th>2HH/2F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>145</td>
<td>85</td>
<td>150+</td>
<td>125</td>
<td>150+</td>
<td>150+</td>
</tr>
<tr>
<td>2</td>
<td>150+</td>
<td>150+</td>
<td>105</td>
<td>125</td>
<td>125</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>105</td>
<td>150+</td>
<td>125</td>
<td>150+</td>
<td>150+</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
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<td>7</td>
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<tr>
<td>9</td>
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<td>150+</td>
<td>120</td>
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<td>10</td>
<td>150+</td>
<td>150+</td>
<td>150+</td>
<td>150+</td>
<td>90</td>
<td>150+</td>
</tr>
</tbody>
</table>

| Crushed Average | | | | | | |
| % Not Crushed   | 50% | 70% | 40% | 50% | 40% | 50% |

The crushed average row of the table is the average crush strength of the briquettes that were successfully crushed. Since the 150+ briquettes did not break, their true value is not known. Therefore, the average crush strength was deemed a more useful figure. To represent the uncrushed briquettes (150+) not represented in the crushed average, the percent not crushed row was added.

Test results showed that the different weathering conditions do not appear to significantly impact the physical strength of the briquettes during the crush testing performed (StDev 5.1%). Variation between samples was small and was attributed to random variability in the briquettes. Larger sample sizes and longer testing may be necessary for these preliminary results to be conclusive. However, preliminary results are promising.
Extreme Weathering Test: Results – Chemical

After crushing the six samples, the broken biocoal briquettes were then sent to SGS for proximate and ultimate analysis to determine how or if their calorific value or other chemical aspects changed during the extreme weathering test. As the graph below shows, the calorific value was not materially impacted by the extreme weathering test regime. With a standard deviation of 155 btu/lb seen during the 25 ton production run the variation seen in the calorific value from the results of this test could be entirely attributed to the variation in the biocoal product itself.
However, one aspect of the test that showed up in the proximate results, while interesting, is not too surprising. The percentage of ash in the finished biocoal product appeared to be statistically lower in the biocoal product that was subjected to the standing water test. At first glance this might sound surprising. However, given the fact that biomass ash is predominately made up of alkaline earth and alkali metals – it stands to reason that some of these could have dissolved into the standing water thereby reducing the percentage of ash within this sample.

![Extreme Weathering: Impact on Ash](image)

**Technical Progress: Biocoal vs. Coal Comparison**

Prior to the actual industrial scale co-firing trials the team wanted to also understand the differences between the two products (biocoal and coal) in regards to mineral ash analysis, chlorine and mercury content.

The mineral ash analysis, which determines the molecular make-up of the ash within a specimen, can help determine the relative fouling and slagging propensity of the fuel ahead of time, whereas the chlorine content can help determine the longer term corrosion potential of the fuel. Typically, fuels higher in chlorine are more corrosive than fuels with lower levels of chlorine. Finally, the team wanted to understand the relative levels of mercury in the biocoal fuel as compared to the coal that was going to be used. Since mercury testing at the stack emission level is time consuming and costly to perform, the team decided to instead test the relative levels of mercury in the biocoal fuel vs. that of the coal product to determine the theoretical reduction in mercury that could be achieved for different co-firing ratios.

The first comparison was that of the mineral ash analysis between the coal and the biocoal that was used for the industrial scale co-firing trials. As is seen in the graph below and discussed earlier in the extreme weathering tests, the biocoal ash is predominately different from coal in its composition from both alkaline earth and alkali metals (potassium, magnesium, calcium, etc.). As compared to the coal which is
Predominately iron, silicon and aluminum oxides, the biocoal ash has a lower ash fusion temperature – or will become molten / soft at lower temperatures. This chemical variation means that, all things equal, the biocoal ash will have a higher propensity for slagging or fouling as compared to the coal ash in this situation.

A visual representation of the differences between this particular set of coal and biocoal mineral ash analysis is provided below. It should be noted that as the raw biomass feedstock for biocoal production varies so too will the mineral ash analysis. This is also true of coal – different types (anthracite, sub-bituminous, etc.) and even different seams within the same mine will produce different mineral ash analysis signatures.

The second comparison examined was the difference between the relative percentage of chlorine within the two fuels (coal and biocoal) that were used for the industrial scale co-firing trial. The coal sample from District Energy (eastern low volatile sub-bituminous coal) had, on average, 0.15% chlorine on a dry mass basis within the fuel as compared to our biocoal fuel which had, on average, 0.19% chlorine on a dry mass basis.
At a 10% co-firing ratio (mass basis), we could expect a 3.3% increase in the relative level of chlorine within the boiler. Correspondingly, at a 30% co-firing ratio (mass basis), we could expect a 10% increase in the relative level of chlorine within the boiler. As discussed above, chlorine can impact the long term corrosion of the boiler and its steam tubes – adversely impacting heat exchange rates and increasing maintenance costs for the operating facility. However, the exact impact to a particular boiler would need to be studied prior to concluding if the relative increase would have a material negative long-term impact on the operating facility.

The third comparison examined was the difference between the relative percentage of mercury within the two fuels (coal and biocoal) that were used for the industrial scale co-firing trial. The coal sample from District Energy (eastern low volatile sub-bituminous coal) had, on average, 0.12 μg/g of mercury on a dry mass basis within the fuel as compared to our biocoal fuel which had, on average, 0.03 μg/g of mercury on a dry mass basis.

At a 10% co-firing ratio (mass basis) we could expect a 7.6% decrease in the relative level of mercury exiting the boiler as emissions. Correspondingly, at a 30% co-firing ratio (mass basis) we could expect a 22.8% decrease in the relative level of mercury exiting the boiler as emissions. Mercury emissions are regulated air pollutants and are increasingly becoming more regulated. For power producers or utilities that are close to meeting their mercury reduction mandates, co-firing with biocoal may be able to help reduce the capital investment costs of meeting emission targets.
Technical Progress: Industrial Scale Co-Firing Trials – Pre-Test Preparation

Prior to the start of the industrial scale co-firing trial at District Energy, it was necessary to determine the type and relative characteristics of the coal with which the biocoal was going to be co-fired, particularly since we wanted to co-fire on a btu basis and not a mass basis, and District Energy uses a high quality (high btu content) low-sulfur low-volatile sub-bituminous coal from the east coast for its stoker grates.

To be able to accurately predict the blending ratios, we wanted to know, for example, what the calorific value and incoming moisture of the fuel was such that more specific co-firing calculations could be made. Therefore, the team took several samples of coal that was representative of the type to be used for the co-firing trial and subsequent proximate and ultimate analysis tests were conducted. The average results of these tests are summarized on the next page.
Based on the above results, the team turned its attention towards allocating the available biocoal material to conduct the three tests. The three tests were set up to determine the relative emission profile performance of 100% coal vs that of a 10% biocoal and 30% biocoal blend on a btu basis. To collect the emissions, the team contracted with Interpoll Laboratories, an independent air emission engineering testing company. Additionally, since District Energy has a common stack for multiple power units, the team worked with District Energy to ensure that no other systems were operational during these tests to avoid any interaction effects on the results. This essential timing and coordination to schedule the test burns was a gating item.

**District Energy: Stoker Grate Co-Firing Trial Calculations**

**District Energy, St. Paul Minnesota**

**Test Combustion Solid Fuel Variables**

<table>
<thead>
<tr>
<th>Biocoal - Torrefied Corn Stover</th>
<th>Coal - Low Volatile Sub-Bituminous (Eastern)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific Value (As Received)</td>
<td>Calorific Value (As Received)</td>
</tr>
<tr>
<td>8,568</td>
<td>13,034</td>
</tr>
<tr>
<td>2.8% Moisture Content (%)</td>
<td>3.9% Moisture Content (%)</td>
</tr>
<tr>
<td>7.4% Ash Content (%)</td>
<td>8.0% Ash Content (%)</td>
</tr>
<tr>
<td>9,540 DAF (Calculated)</td>
<td>14,783 DAF (Calculated)</td>
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</table>

**10% Co-Firing Calculations**

<table>
<thead>
<tr>
<th>Boiler Capacity: 139,216,000 btu/hour</th>
<th>Test Run Duration: 8 hours</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Biocoal btu's (10%)</th>
<th>Coal btu's (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,921,600 btu/hour</td>
<td>125,294,400 btu/hour</td>
</tr>
<tr>
<td>8,568 btu/lb (as received)</td>
<td>13,034 btu/lb (as received)</td>
</tr>
<tr>
<td>1,625 lbs/hour required</td>
<td>9,613 lbs/hour required</td>
</tr>
<tr>
<td>14.5% Mass Mixture Ratio</td>
<td>85.5% Mass Mixture Ratio</td>
</tr>
<tr>
<td>12,999 Total Mass Required (lbs.)</td>
<td>76,901 Total Mass Required (lbs.)</td>
</tr>
<tr>
<td>6.5 Total Tons Required</td>
<td>38.5 Total Tons Required</td>
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</tbody>
</table>
30% Co-Firing Calculations

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Boiler Capacity: 139,216,000 btu/hour</th>
<th>Test Run Duration: 8 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocoal btu's (30%)</td>
<td>Coal btu's (70%)</td>
<td></td>
</tr>
<tr>
<td>41,764,800 btu/hour</td>
<td>97,451,200 btu/hour</td>
<td></td>
</tr>
<tr>
<td>8,568 btu/lb (as received)</td>
<td>13,034 btu/lb (as received)</td>
<td></td>
</tr>
<tr>
<td>4,875 lbs/hour required</td>
<td>7,477 lbs/hour required</td>
<td></td>
</tr>
<tr>
<td>39.5% Mass Mixture Ratio</td>
<td>60.5% Mass Mixture Ratio</td>
<td></td>
</tr>
<tr>
<td>38,998 Total Mass Required (lbs.)</td>
<td>59,812 Total Mass Required (lbs.)</td>
<td></td>
</tr>
<tr>
<td>19.5 Total Tons Required</td>
<td>29.9 Total Tons Required</td>
<td></td>
</tr>
</tbody>
</table>

The above pre-test co-firing trial calculations were developed based on the proximate analysis results from the coal and biocoal, the available biocoal from the 25 ton production run, the duration required to conduct the emission profiles (minimum 4 hours of steady state run time) and the boiler operating parameters. This grid helped the team determine how much coal might be needed, its potential volume and approximate run time available for the particular fuel mixture and its associated volume.

Technical Progress: Industrial Scale Co-Firing Trials – Baseline & 10% Co-Firing Trial

Wednesday, April 7, 2010

We started the industrial scale co-firing trial activities on Wednesday, April 7, 2010. Interpoll labs set up the stack emissions monitoring equipment as planned. District Energy started up Boiler #2 on 100% coal and allowed the boiler to stabilize. Throughout the day, four (4) emission profile tests were completed to obtain the relative baseline for the subsequent 10% and 30% co-firing trials. The first emission profile test was discarded as trace levels of wood chips blended with the coal were still in the system.

During “normal” operation, District Energy blends in wood chips with its coal in an effort to produce more “green” energy. However, these wood chips tend to stick and/or take awhile to be fully purged from the stoker grate feed handling system. Therefore, while the system was being fed with 100% coal, there were still a few wood chips being fed into Boiler #2 during the early morning hours of the emissions monitoring tests. To offset this potential confounding factor in the emission results, Interpoll labs agreed to extend the number of tests to four, thereby eliminating the first emission trial from the results due to the inclusion of wood chips.

As the emissions monitoring tests proceeded the 10% biocoal shipment lot arrived. Beaver Creek Transport delivered the required supersacks of biocoal to the District Energy fuel yard around 12:00 noon. The supersacks delivered were from our February 2010 25 ton demonstration run (Reference: Milestone 7 Report). Two loads of coal were also delivered with the first load weighing 25.21 tons and the second 13.9 tons for a total of 39.11 tons of coal for the 10% co-firing trial planned to commence the next day (April 8, 2010). A copy of the coal receipts are attached to this report as an Appendix A.
The coal and biocoal was pre-blended at the targeted ratios by btu content. However, due to physical space constraints, the custom blending operations took place in two distinct phases. The first phase of blending took place by unloading the first load of coal (25.21 tons) on grade followed with layering biocoal on top as close as possible to the target blend condition (10% co-firing ratio) as possible. The supersacks were lifted in the air by a forklift and then suspended over the bucket of a front-end loader while the underside of the supersack was untied to allow the contents to flow out into the bucket. With the bucket full of biocoal, the driver proceeded to sprinkle the contents evenly over the sitting bed of coal on grade. Once all of the biocoal was unloaded on the pile of coal, the driver thoroughly mixed the pile prior to pushing it into a surge hopper for temporary storage.

The first load of coal was unloaded on grade to allow the biocoal to be spread on top of it to help the overall blending. Since 25.21 tons of coal represented 64.46% of the total coal to be used, the appropriate biocoal supersacks were selected to be blended with this coal. These selected supersacks totaled 7,891 lbs. or 3.95 tons of biocoal or 57.25% of the total biocoal to be used. Once blended this pile was pushed into the surge hopper where it was stored until Boiler #2 at District Energy burned out of its existing 100% coal source.

Blend **Phase 1** Effective Co-Firing Ratio: **9.82%**

Biocoal: $(8,700 \text{ btu/lb}) \times (7,891 \text{ lbs.}) = 68,651,700 \text{ btu}$

Coal: $(12,500 \text{ btu/lb}) \times (50,420 \text{ lbs.}) = 630,250,000 \text{ btu}$

Total: $68,651,700 + 630,250,000 = 698,901,700 \text{ btu}$

Co-Firing Ratio: $68,651,700 / 698,901,700 = 0.09822797$

Total Mass % of Day 2: $58,311 / 91,204 = 63.93%$

The second load of coal was unloaded on grade to allow the biocoal to be spread on top of it to help the overall blending. Since 13.9 tons of coal represented 35.54% of the total coal to be used, the appropriate biocoal supersacks were selected to be blended with this coal. These selected supersacks totaled 5,893 lbs. or 2.95 tons of biocoal or 42.75% of the total biocoal to be used. Once blended, this pile was pushed into the surge hopper where it was stored on top of the Phase 1 blend until Boiler #2 burned out of its existing 100% coal source.

Blend **Phase 2** Effective Co-Firing Ratio: **13.19%**

Biocoal: $(8,700 \text{ btu/lb}) \times (5,893 \text{ lbs.}) = 51,269,100 \text{ btu}$

Coal: $(12,500 \text{ btu/lb}) \times (27,000 \text{ lbs.}) = 337,500,000 \text{ btu}$

Total: $51,269,100 + 337,500,000 = 388,769,100 \text{ btu}$

Co-Firing Ratio: $51,269,100 / 388,769,100 = 0.13187544$

Total Mass % of Day 2: $32,893 / 91,204 = 36.07%$

Photos of the general coal and biocoal blending process that took place on April 7, 2010 for the 10% co-firing trial are provided on the next page for reference.
After the 100% coal trial was completed, the operators at District Energy allowed all of the coal within the feed handling system to completely burn out. Once the feed handling system was empty, the system was re-filled with the 10% co-firing mixture that had been blended earlier in the day. As the mixture moved through the extensive feed handling system at District Energy, significant opportunities exist for subsequent and further mixing of the two materials. With the system re-filled, District Energy waited until the early morning of the following day (April 8, 2010) to commence the 10% co-firing trial activities.

**Thursday, April 8, 2010**

At approximately 6:00 a.m. on Thursday, April 8, 2010 Boiler #2 was re-started and began to burn the 10% biocoal / coal blend. For the first hour of operation, the operators tweaked the various boiler operational parameters in an effort to obtain a steady state combustion profile. With the system stabilized, Interpoll Laboratories started the first of the three required emission profile trials for the 10% co-firing trial.
The following is an excerpt from the Interpoll Laboratories completed test report and represents the emission profile test protocol used for all three tests (100% baseline, and the 10% and 30% co-firing trials):

“Oxygen, carbon dioxide, sulfur dioxide, carbon monoxide and oxides of nitrogen concentrations were determined in accordance with EPA Methods 3A, 6C, 10 and 7E. A slipstream of sample gas was withdrawn from the exhaust gas stream using a heated stainless steel probe equipped with a filter to remove interfering particulate material. The particulate-free gas was transported to the analyzers by means of a heat-traced probe and filter assembly. After passing through the filter, the gas passed through a chilled condenser-type moisture removal system. The particulate-free dry gas was then transported to the analyzers with the excess exhausted to the atmosphere through a calibrated orifice, which was used to ensure that the flow from the stack exceeds the requirements of the analyzers.

The analog response of each analyzer was recorded with a computer datalogger. The analyzers were calibrated with Airgas EPA Protocol 1 standard gases. The instruments were calibrated before and after each run as per EPA Method 3A, 6C, 10 and 7E.

Testing on the No.2 Boiler Stack was conducted from four test ports oriented at 90 degrees on the common Stack. These ports are located 8.7 diameters downstream and 1.99 diameters upstream of the nearest flow disturbances.”

Throughout the morning the Interpoll lab team successfully conducted the required three (3) one-hour emission profile tests during the 10% co-firing trial.

**Technical Progress: Industrial Scale Co-Firing Trials ~30% Co-Firing Trial**

**Thursday, July 22 – Friday, July 23, 2010**

With the 100% baseline and 10% co-firing trial completed, the team then turned its attention towards the completion of the 30% co-firing trial. On Thursday, July 22, the remaining biocoal produced during the 25 ton production run was delivered in supersacks to District Energy. Additionally, the corresponding coal that was to be co-fired with the biocoal was also delivered to be blended a day prior to the commencement of the 30% co-firing trial. Interpoll Laboratories also came on site late in the day on the 22nd to set up the emission monitoring equipment to be ready for the testing that was conducted on the 23rd.

The supersacks of biocoal were unloaded on-grade to allow the coal to be spread on top of it to help the overall blending. Combined, the supersacks unloaded for the 30% co-firing trial totaled 28,864 lbs. or 14.43 tons of biocoal. Once all of the biocoal was unloaded, the coal was delivered in one load and spread out on top of the biocoal. Images showing this blending operation are provided on the following pages. The coal delivered totaled 46,120 lbs or 23.06 tons of coal. Once blended this pile was pushed into the surge hopper where it was stored until Boiler #2 burned out of its existing 100% coal source.
Effective Co-Firing Ratio: **30.34%**

Biocoal: \((8,700 \text{ btu/lb}) \times (28,864 \text{ lbs.}) = 251,116,800 \text{ btu}\)

Coal: \((12,500 \text{ btu/lb.}) \times (46,120 \text{ lbs.}) = 576,500,000 \text{ btu}\)

Total: \(251,116,800 + 576,500,000 = 827,616,800 \text{ btu}\)

Co-Firing Ratio: \(\frac{251,116,800}{827,616,800} = 0.30342158\)

After Boiler #2 ran out of 100% coal late in the evening of July 22, the team at District Energy then ran the bulk handling feed system to load the pre-blended 30% co-firing material into the Boiler #2 hopper. This material was held until early in the morning on the 23rd of July. As was done in the 10% co-firing trial Boiler #2 was operated / kept hot via a natural gas burner between these two time points. Then, at around 6:00 a.m. on July 23 the 30% co-firing blend was started on Boiler #2. As before, the operators worked quickly to obtain a steady state operating condition such that Interpoll Laboratories could start the three required emission profile tests.

Interpoll Laboratories used the same test procedures as before. Throughout the morning of the 23rd the Interpoll lab team successfully conducted the required three (3) one-hour emission profile tests with the intra-test calibrations during the 30% co-firing trial.
Technical Progress: Industrial Scale Co-Firing Results

One of the primary objectives of the industrial scale co-firing combustion testing was to determine the emissions profile of the various solid-fuel blends as compared to the baseline 100% coal benchmark. The final outcomes from the test in regards to the two primary emissions of SO₂ and NOₓ are presented below. The combustion of biocoal made of corn stover not only allows the production of carbon neutral heating capacity, but also provides an emissions reduction incentive via the reduction of both SO₂ and NOₓ when blended with traditional fossil fuel coal.

<table>
<thead>
<tr>
<th>Emissions Reduction as Compared to Baseline</th>
<th>SO₂ ESP (lb/mmbtu)</th>
<th>NOₓ ESP (lb/mmbtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Stover Biocoal</td>
<td>11.13%</td>
<td>34.15%</td>
</tr>
<tr>
<td>30% Stover Biocoal</td>
<td>23.81%</td>
<td>41.30%</td>
</tr>
</tbody>
</table>

These emission reduction results coupled with the ease of using the product within the existing bulk handling systems proved the feasibility of using a “biocoal” product in existing stoker grates when co-fired with coal at ratios up to 30% blends on a btu basis.

Milestones:
We are currently working on Milestone 9.

Milestone 9 consists of conducting a test gasification with biocoal to collect stack emissions profiles while demonstrating the test gasification to RDF administration. Also, it consists of completing the feasibility and economic analysis.
**Project Status:**

The project has successfully completed the requirements for Milestone 8. The team is in active discussions to execute the gasification trial as a part of our Milestone 9 requirements.

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APPENDIX A: INBOUND COAL RECEIPTS