



**FOUNTAINHEAD  
ENGINEERING**  
LIMITED

**CASE STUDY**

**Pulp and Paper Mill Residual Value as a Densified Fuel**

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Fountainhead Engineering Ltd. (FHE) completed feasibility evaluations on the use of “Very High Moisture”, short fiber residuals generated by pulp and paper mill facilities in the United States during the period 2007-2009. The primary objective of these assessments or “fuel trials” was to compare the relative “value added” that could be added to these “Very High Moisture” secondary fibers (> 50% moisture content) IF they could be converted to low moisture densified renewable fuel for combustion in onsite industrial boilers versus landfilling of these wastes. Converting these Very High Moisture residuals into Renewable Densified Fuel would not only divert wastes from landfills, it would in some applications increase combustion efficiency of a boiler system when co-fired with high moisture (>25% moisture content) biomass such as green wood chips or green hog fuel. In addition, this type of conversion-beneficial use program would also divert “entrained liquids” or bound moisture found in pulp and paper mill residuals considering that these residuals are comprised of more than 50% moisture and in some instances greater than 60% moisture. The remaining residuals could be used as feedstock in the Renewable Densified Fuel process. The conversion to an industrial renewable boiler fuel eliminates this “liquid waste stream” from ultimately ending up in the mills waste water treatment plant. By eliminating the entrained liquid and not allowing this liquid to become “leachate” in the landfill this reduces both short and long term landfill costs. These combined multiple system objectives are achieved through the conversion of mill residuals from a “waste” to “renewable energy”.

The unique proprietary beneficial use program using the patent pending Renewable Densified Fuels technology develops onsite renewable energy and promotes sustainability. When assessing a mill’s “system contributors” from a cost perspective it is reasonable to compare total system costs associated with managing these wastes against the cost to convert these potential feedstocks into a densified renewable fuel. The *total system cost allocation* method usually supports renewable fuel development. The results from several programs have indicated that value added is achieved by correctly accounting for all related system costs through a comparative analysis when developing a *comprehensive beneficial use program*. Too often the total system costs are under reported in evaluations and these evaluations tend to focus on the short term

(capital) costs associated with changes to developing a new (management) system that create value (i.e. renewable fuel) versus continuing the status quo and the long term loss opportunity costs associated with establishing zero waste initiatives and creating energy independence from fossil fuels while increasing overall environmental performance. The issues will be different at each location however the commitment to change, for continual improvement is a crucial first step and with any new program once adopted the success is measured through avoided cost savings as well as operating costs of all systems using life cycle cost analysis.

When assessing this waste to renewable energy approach the mill is essentially comparing the total costs of managing residual moisture versus creating a renewable energy. This approach also needs to evaluate existing sources of waste energy that are available for removing this moisture as well. In addition, the continual reoccurring long term waste management expenses associated with closure and post closure care as well as the cost of construction of new (disposal) cells for the mills wastes would be reduced significantly as the renewable fuel system was “integrated” into a comprehensive beneficial use program. These avoided costs are real dollars in the short term associated with landfill engineering, permitting, construction, operations, interim closure and then final closure which includes establishing a long term financial commitment (after closure) usually required by state regulatory agencies. The accumulated or entrained moisture in the landfill - leachate is required to be removed and treated for many years therefore removing this moisture during renewable fuel production should be a significant cost savings while also eliminating a majority of the secondary fiber or pulp mill residuals diverting this tonnage to a value added beneficial use and into positive renewable Btu’s. This conversion and beneficial use program improves the entire mills environmental performance while moving towards a “zero waste” system. The entire “mill system” benefits by significantly reducing the long term need for landfill disposal and all of the associated costs primarily associated with managing “water” or landfill leachate (for onsite landfills). If the landfill is offsite this makes even more economic sense especially when calculating increased fuel prices that have been at historic levels so it is important to assess actual savings in transportation, equipment maintenance or the Capital Expenses (CapEx) associated with purchasing of new trucks and equipment as well as the dedicated labor to operate these vehicles within the system. If the true “hidden system costs” were identified and included in the cost to operate the solid waste management system the case for managing the water (or entrained moisture) found in these mill residuals *before* it enters the solid waste management system versus after “in the landfill” should become apparent.

The establishment of a comprehensive beneficial use system that results in the production of sustainable renewable fuel should be offset by the life cycle cost of operating the entire solid waste management system with a value placed on eliminating long term risk as well. The energy recovered from implementing this type of beneficial use program displaces fossil fuels and in hog fuel boiler systems would improve boiler efficiency in some instances. When a percentage of “lower value biomass” or wood residuals (generated through round wood processing) such as small limb debris, bark, screened or reclaimed fines, etc. are combined into a densified fuel “Mix Design” with

other Very High Moisture “process” residuals/secondary fibers fuel converts these multiple residuals into a high value fuel using the Renewable Densified Fuel system and diverting these otherwise low value residuals from a boiler system improves performance especially in stoker grate boiler systems. Removal of these biomass fines from a boiler system also can reduce fine particulate matter (i.e. PM 10 or PM 2.5) emissions which is an additional advantage of implementing this comprehensive beneficial use approach. The incorporation of biomass fines or other similar residuals along with the use of Very High Moisture residuals converted simply into a renewable densified fuel allows for capturing more potential energy, more efficiently and at a lower cost and in many instances should improve environmental performance of a mill from air quality to stormwater management. The ability to have a flexible renewable fuel production system is a key aspect in modifying a mill’s existing management system. However, adopting this beneficial use approach should, from a life cycle perspective reduce total (system) operating costs associated with implementing renewable energy and beneficial use programs while potentially increasing boiler efficiency, reducing carbon and potentially improving the overall environmental performance of the mill (or plant location). This approach is also consistent with ISO 14001 programs. Each opportunity will need to be assessed and the fuel trial is only the start of the process. Once a viable Mix Design is developed the process continues. Each opportunity to reduce costs and improve efficiencies should be fully vetted based on mills “total system costs” as described previously and it is primarily associated with managing water and diverting and converting wastes to renewable energy – long term. This comparison is represented in Table 1 and demonstrates the *net effective energy value* of the combustion of Very High Moisture (“VHM”) residuals/secondary fiber **without** converting these residuals to Renewable Densified Fuel.

**Table 1: Net Effective Energy Value of Residual Sludge’s and Secondary Fibers**

<b>Residual Feedstock</b>	<b>Moisture Content (MC)</b>	<b>Energy Value As Received Btu/lb.</b>	<b>Btu’s required to dry to 5% MC<sup>1</sup></b>	<b>Net Effective Btu/lb<sup>2</sup></b>
Recycled Newsprint Sludge	62.83%	1,609	1,156.6	452.4
Recycled Tissue Mill Sludge	64.42%	1,432	1,188.4	243.6
Sulfite Pulp Mill Screenings	68.57%	2,545	1,271.4	1,273.6
Green Bay Packaging Secondary (Recycled) Cardboard Fiber	53.97%	3,438	979.4	2,458.6
“BWC” Secondary Cardboard (Recycled) Fiber	51.62%	3,426	932.4	2,493.6

<sup>1</sup> This assumes that approximately 2,000 Btu’s are required to remove 1 lb. of H<sub>2</sub>O in a standard drying system (i.e. rotary drum dryer) boiler operations and efficiencies will produce various results .

<sup>2</sup> Calculated as Energy Value As Received Btu/lb less Btu’s required to dry to 5% MC for combustion in a boiler.

Through nearly 50 fuel trials using the Renewable Densified Fuels, LLC technology a wide range of residuals have been proven to be a viable feedstock to create a renewable fuel and would be relatively easily converted into a boiler fuel that would combust effectively and provide sustainable renewable energy. Other paper mills such as International Paper's Ticonderoga mill have tried to address their ongoing waste disposal issues associated with VHM residuals (i.e. sludges) by attempting to create an alternative fuel to reduce fossil fuel usage without densification. The reduction in the amount of landfill space and capital cost required to continue disposing of these residuals versus recapturing the potential energy promoting sustainability is the "delta" both from a management and cost perspective. The value added approach however still lies in applying the correct drying technology of "sludges" or secondary fibers along with the ability to create a suitable renewable fuel that can also be stored for long periods of time (like coal) and co-fired with coal which reduces carbon and diverts waste. The higher the moisture the less desirable the fuel and this lowers the *net effective energy value* within the boiler. Trying to combust wet secondary fiber or paper sludge is not an efficient "energy" solution.

Renewable Densified Fuels, LLC (RDF) developed a patent pending technology (patented in Canada) that produces a biomass fuel that approaches or exceeds 10,000 Btu/lb., is very low moisture and very low ash focusing primarily on biomass residuals as a primary feedstock. The Renewable Densified Fuel (RDF) can be customized using a variety of biomass, agricultural and mill byproducts to create a biomass fuel with specific characteristics for boiler systems currently burning coal or high moisture biomass (i.e. over 25% moisture biomass). This renewable biomass fuel was developed in consultation with boiler and grate manufacturers and has primarily been targeted for use in industrial, large commercial, institutional or utility boiler systems that combust fuel at very high temperatures and in most cases ***without changes to existing infeed, storage or solid fuel handling systems.*** Added to the biomass feedstocks is a small amount of a Reconstituted Carbon Binder or "RCB" that is sourced as either recycled HDPE (No.2) or LDPE (No.4) in the form of films as well as retail bags. These recycled RCB feedstocks mainly retail bags, are used for their very high carbon and hydrogen composition and relatively low melting points when producing this fuel. The result, when used in this proprietary system, is a very durable renewable fuel which provides a water resistant protective surface while binding different biomass feedstocks together which is superior to other biomass fuels not using this technology with RCB. The strategic use of the RCB allows for short fiber residuals such as biomass fines and secondary fibers such as recycled newsprint, tissue, cardboard or similar residuals to produce a durable and robust boiler fuel from unconventional yet potentially viable feedstocks. This approach allows for the densified fuel to be shipped via a variety of transport systems as well as being able to be delivered into boiler systems without any special handling requirements and with very minimal fugitive dust during delivery and transport. This feature also allows for outside storage of this fuel for extended periods of time without any significant (Btu value) or physical degradation.

## Recycled Newsprint Sludge – Renegy Snow Flake, Arizona

FHE conducted a preliminary densified fuel evaluation on recycled newsprint sludge and biomass residuals (fines) feedstocks provided by Renegy, a 25MW biomass renewable energy system co-located at Catalyst Paper in Snowflake, Arizona. The preliminary mix design for this limited sample was a 50% mixture of Catalyst recycled newsprint (mill residual “sludge”) and 50% biomass fines supplied by the renewable energy facility. After receipt of the biomass fines and newsprint sludge these prospective feedstocks were sampled to obtain base line (incoming or “as received”) feedstock characteristics such as moisture content, density per cubic foot, incoming Btu value, ash content and other basic chemistry used in most combustion (fuel) applications as well as in FHE evaluations.

The incoming biomass or “Renegy Fines” retrieved from onsite stockpiles had a moisture content of 14.95% with ash content of 41.59% on an “as received” basis. There were significant inorganics in these fines. Chlorine content was 1,173 ug/g and the Btu value was 4,339 Btu/lb. Sulfur content of the sample was 0.007%.

The incoming Catalyst sludge had a moisture content of 62.83% as received with an ash content of 19.22%. Chlorine content was 189 ug/g and a reported as received Btu value of 1,609 Btu/LB. Sulfur content of this sample was 0.024%.

After receipt of this preliminary data and due to the high percentage of inorganic material in the fines, FHE screened the Renegy Fines to remove composted or other inorganic materials thereby making this potential biomass feedstock more viable as fuel. After screening this material was also sent to an independent lab for additional testing. The results of the “Screened Renegy Biomass Fines” reported a moisture content of 20.13% with ash content of 13.84% reported on an as received basis (a reduction of 33%). Chlorine content was 435 ug/g. The reported as received Btu value **increased** over 26% to 5,905 Btu/lb. or an additional 1,566 Btu/lb. without drying even though total moisture content increased by just over 5%. Sulfur content of this sample was 0.008%. This simple step of screening the inorganics that add no value in a combustion process from the remaining usable biomass in these stockpiles potentially allowed for up to 45,000 tons of stockpiled “fines” to now be considered available for densified fuel production (along with the recycled paper mill sludge) for an approximate cost of \$2.50/ton. These fines had been “inventoried” or stored for a long period of time due to a lack of an end use and the cost of offsite disposal. After screening the residual composted material was removed from these stockpiles and was deemed suitable as a potting soil ingredient and the sale of the potting soil ingredient essentially would pay for the cost of screening if not create net income. This value added approach “found” 265,725,000 Btu’s stored in waste piles at the site. If this approach was adopted previously and incorporated into a renewable “fuel supply” beneficial use approach the “fines” stockpiles could have been significantly reduced. This new system would have been self-supporting and consumed up to 90,000 TPY of recycled newsprint residuals.

The Mix Design developed for this assessment using these feedstocks created a much more valuable renewable (boiler) fuel for combustion in the Renegy boiler while keeping a significant volume of newsprint sludge out of the Catalyst Paper onsite landfill. To explore the range of the patented Thermal Mixer and assess the proposed system parameters FHE conducted a variety of tests at different (incoming) feedstock moisture levels so that the patented Thermal Mixer performance could be evaluated over a range of moisture levels.

The Catalyst recycled newsprint sludge was partially dried using a proprietary approach to reduce the moisture content to just below 45% for this fuel trial. The objective with this feedstock during the initial trials was to slightly extend the residence time in the Thermal Mixer during fuel production to further dry the sludge during fuel production knowing that the sludge could be dried to at least the target 15% moisture content (MC) in the proprietary drying system before fuel production. This was a client request to evaluate the potential of using higher moisture residuals in this proprietary system.

The limited drying resulted in an incoming “Processed Catalyst Sludge” moisture content of 44.12% with ash content of 26.67 both on an as received basis. Chlorine content was 333 ug/g and with a reported as received value of 2,508 Btu/LB resulting in an increase of 36% by removing just under 20% of the moisture found in the sludge. Sulfur Content was 0.033% of the sample.

The initial mix design was a mixture of 50% screened biomass fines with a Moisture Content (MC) of 20.13 and the partially dried “Processed Catalyst Sludge” with a MC of 44.12% all much higher than our typical Mix Designs for this type of feedstock. This preliminary “small batch” was mixed with 12% Reconstituted Carbon Binder – RCB which was recycled HDPE fines with No. 4 film shred both un-marketable residuals from other industrial processes. The incoming processed sludge (at just over 44% MC) had a density of 31.7 lbs./ft<sup>3</sup>. The incoming screened fines had a density of 11.0 lbs./ft<sup>3</sup>. The incoming 50/50 mix design including 12% RCB and resulted in a density of 20.1 lbs./ft<sup>3</sup> (before fuel production).

The results during the fuel trials using this recycled newsprint sludge with residual recycled RCB illustrated that a “formed” extremely moisture resistant densified “biomass fuel” using mill residuals and stored biomass fines could increase the efficiency of the 25MW biomass boiler system versus combusting +60% moisture newsprint sludge with other high moisture hog fuel and wood chips. This fuel also had significant hardness allowing for outside storage and was able to use existing infeed systems (PDI of 99%). The as received Btu value was significantly increased and the fuel produced much less ash. This beneficial use and conversion created a renewable fuel that was made from 100% recycled feedstocks making this fuel highly sustainable while potentially diverting nearly 100,000 tons/year of recycled newsprint residuals and unusable biomass fines.

The Renewable Densified Fuel 50/50 mix achieved 7,597 Btu/lb. which was **5,988 Btu/LB higher** than the incoming sludge and **3,258 Btu/LB higher** than the incoming fines even though the moisture content of this fuel was 9.63% - very high for typical mix designs. This Renewable Densified Fuel was planned to be added to other

high moisture feedstocks (wood chips and hog fuel) in the boiler. This new renewable fuel would drastically reduce the total moisture content of the combined boiler fuel thereby increasing boiler efficiency and increasing power production.

The Sulfur content was reported at 0.031% and the Chlorine content was 357ug/g all under permit conditions. This initial fuel trial indicated a very good potential for utilization of the Catalyst newsprint sludge as a viable fuel using the RDF process based on this preliminary mix design. Based on preliminary mass and energy balances the RDF technology significantly enhanced the Btu value of all residuals available for fuel production as well as other “characteristics” of these residuals providing significantly enhanced energy content versus these residuals acting as a substantial heat sink (in the combustion process). The unprocessed newsprint sludge and biomass fines were being consumed by the boiler as well as other outside or purchased biomass and were a low value boiler fuel, however implementing this value added beneficial use strategy would create a superior fuel while diverting nearly 90,000 (wet) tons of recycled paper mill sludge from the mills on-site landfill making this approach much more sustainable.

### **Recycled Tissue Mill Sludge – Southeastern U.S. Mill**

Densified fuel trials were conducted by FHE in August and September 2009 for a large southeastern (United States) recycled tissue mill. The feasibility assessment was to document the initial characteristics of the mills candidate feedstocks in order to create a preliminary mix design that could be co-fired in the mills coal boilers in order to achieve “zero waste”. The primary feedstock and process residual for these trials were combined waste water treatment sludges generated by the mill. The mill shipped processed wet sludge to Sturgeon Bay, Wisconsin where FHE used Heat Treat Furnaces, Inc (HTF) proprietary drying system to dry the sludge. After the material was dried by FHE staff to the target moisture content it was shipped to the Johnson Timber/Renewable Densified Fuel facility in Park Falls, WI for fuel production. FHE also evaluated the use of recovered co-mingled plastics or “tailings” generated by the mill for use as the RCB component in this fuel. The recycled tissue mill sludge on an as received basis had a moisture content of 64.42%, with ash content of 17.08% and a gross heating value of 1,432 Btu/lb. After the sludge was dried to a moisture content of 9.72% ash content increased to 34.16% and the as received heating value increased to 3,654 Btu/lb. This demonstrates the ash handling issues created simply by drying the recycled tissue sludge to lower moisture content for combustion rather than going a step further and producing a densified fuel product.

After consultation with both mill and corporate engineering and environmental staff it was agreed that the Mix Design required the addition of biomass residuals that were indicative or available in the region. The starting (average) density of the processed (dried) sludge was 14.48 lbs/ft<sup>3</sup>. After manufacturing Renewable Densified Fuel the average density increased to 31.75 lbs/ft<sup>3</sup>.

There were several mix designs produced and tested and the laboratory results illustrate that the optimal mix design for the “recycled tissue sludge fuel” would require 50% Sludge and 35% biomass fines with 15% Reconstituted Carbon Binder (RCB). The results using this mix design created a fuel of 9,006 Btu/lb. with a moisture content of only 2.41% and ash content of only 6.52%.

As mentioned previously the biomass fines were added due to the short fiber content of the sludge insuring that the patent pending process could infuse the RCB into both the biomass fines as well as the sludge residuals. As with plant locations, densified fuel mix designs present unique challenges and part of the objective of fuel trials is to also define how the potential new management system would change existing systems and evaluate and compare these systems to ascertain and document the most appropriate (new) system for the mill. By assessing the characteristics of feedstocks FHE was able to develop a Mix Design that added value to the fiber sludge by creating a densified fuel (after drying) of 9,006 Btu/lb. from 3,654 Btu/lb. sludge (incoming energy value of the “very wet” sludge was 1,423 Btu/lb.) or an increase in energy value of 40%. The addition of biomass fines allowed for the fuel to achieve a very solid “structure” necessary for storage in feed systems and reduced ash content - nearly 75% less ash than the current fossil fuels used in the boiler system. The result validated that the mill could use their Very High Moisture (“VHM”) process (sludge) residuals that are currently landfilled and convert this waste to energy.

### **Sulfite Pulp Mill Screenings – Flambeau River Papers, LLC Park Falls, Wisconsin**

In August 2007 a large scale boiler test was performed (following USEPA protocols) at Flambeau River Papers, LLC No. 6 Boiler in Park Falls, Wisconsin. This boiler system produces up to 165,000 lbs/hour of high temperature, high pressure steam and generates 5 MW of electricity for use by the paper mill. The strategy at the paper mill was to replace “supplemental” coal being co-fired with high moisture hog fuel (biomass). In December 2008 the Wisconsin Department of Natural Resources (WDNR) approved Renewable Densified Fuel for use in FRP’s No. 6 Boiler.

This boiler historically used up to 45 tons per day (TPD) of coal (winter months) co-fired with 400-500 tons per day of biomass, with the biomass having a moisture content ranging between 25%-43%. The objective in this application at the paper mill was to illustrate the use of the Renewable Densified Fuel process to replace the fossil fuel co-fired with biomass in the No.6 Boiler. The fossil fuel was essentially used to drive off moisture from the hog fuel. Testing indicated that sulfur emissions were drastically reduced and other regulated emissions also improved.

The use of the densified biomass fuel would displace an estimated 15,000– 20,000 tons per year (TPY) of carbon previously attributed to coal (fossil fuel) use. The carbon footprint of the mill has been reduced significantly while beneficially reusing onsite biomass fines and process residuals generated from the pulp mill. The change over from coal to Renewable Densified Fuel also improved ash quality making the ash produced by No. 6 Boiler available for evaluations in other beneficial use applications. A portion of the densified fuel used for the 2007 boiler tests used pulp mill rejects or

"knots" to illustrate beneficial reuse of pulp mill residuals (at 30% of the total mix design for the mills' densified fuel) with up to 12% RCB. Subsequently FHE developed several specific mix designs depending on available feedstocks. The mix design for the FRP No. 6 Boiler will continue to use reclaimed fines from the mills biomass grinding/hogging operations and knots generated by the pulp mill. A fines recovery system was installed as part of this project to provide biomass residuals to the onsite densified fuel plant and also assists with reduction of potential fugitive emissions from the boilers biomass handling systems.

The state of Wisconsin in 2009 passed Senate Bill 406 that qualified this new type of densified fuel (pellets) made from certain (processed) wastes and having certain properties as renewable fuel source under the state's Renewable Portfolio Standard – RPS along with other sources used to create renewable energy such as solar, wind, geothermal, biomass, synthetic gas etc.

The American Forest & Paper Association (AF&PA) recognized Flambeau River Papers (FRP) for outstanding industry performance in its 35th Annual Environmental & Energy Achievement Awards. This award recognizes AF&PA member companies that have significantly contributed to advances in the practical application of new and improved environmental and energy technology. This approach in 2008 was awarded to the mill and AF&PA stated that: *“Flambeau River’s innovative project cut the mill’s reliance on fossil fuels by increasing the mill’s use of carbon-neutral biomass. This new technology reduced Flambeau River’s carbon dioxide emissions by 7,000 tons, and now this technology can be utilized in other applications across the forest products industry”*.

The sulfite pulp mill screenings (“Knots”) sampled from the stockpile had a moisture content of 68.57%, ash content of 0.57% and gross heating value of 2,545 Btu/lb. After processing (drying) this candidate feedstock at HTF using the proprietary drying system located in Sturgeon Bay, Wisconsin the as received moisture content of the pulp mill screenings was reduced to 5.19 %, with an ash content of 1.01% and a gross heating value of 7,512 Btu/lb. The pulp mill screenings were then combined (maximum of 30% by weight) with woody biomass residuals, bark and dust collection fines and 12% RCB to produce a Renewable Densified Fuel that resulted in a moisture content of 2.28%, ash content of 0.67% and a heating value of 10,103 Btu/lb.

### **Cardboard Fiber Rejects – Green Bay Packaging Green Bay, Wisconsin**

Green Bay Packaging Inc. is a privately owned, diversified manufacturer of paperboard packaging. The Green Bay, Wisconsin Mill is a fully-integrated pulp and paper mill that manufactures 100% recycled containerboard. Built in the 1940s, as a 100% virgin corrugating medium mill, this mill utilized the newly developed NSSC pulping process. It also started a philosophy of research and development as well as a quest for never-ending improvement according to the company. As early as 1957 the first recycled fiber was incorporated into the raw material mix. This increased to 50% recycled content in the late 1980s. Between 1989 and 1991, the facility was completely redesigned, rebuilt and converted from a manufacturer of 50% corrugating medium to a state-of-the-art 100% recycled linerboard mill. Today, the Green Bay Mill Division manufactures 100%

recycled linerboard and Eco-Stack™ High Performance Containerboard. Eco-Stack™, introduced in June 1991, was the industry's first 100% recycled linerboard. Current capacity of the Green Bay Mill is according to the company 220,000 tons per year.

In early September 2009 FHE conducted fuel trials to assess the feasibility for using 100% cardboard fiber rejects (secondary fiber) generated at the Green Bay, Wisconsin facility to replace a portion of the coal used in the boiler system. Approximately two tons of Renewable Densified Fuel was produced using the cardboard residuals provided by the mill. As with previous fuel trials the HTF facility in Sturgeon Bay, Wisconsin was used and dried the cardboard residuals (candidate feedstocks) and the feedstocks were shipped to the Johnson Timber/Renewable Densified Fuel facility in Park Falls, WI for fuel densified fuel production.

The cardboard fiber rejects had a moisture content of 53.97%, an ash content of 4.26% and gross heating value of 3,438 Btu/lb. After processing (drying) the feedstock using the proprietary HTF drying system the as received moisture content of the cardboard residuals was reduced to 12.08%, with an ash content of 8.46% and a gross heating value of 6,625 Btu/lb. The densified fuel produced using the cardboard fiber rejects with 11% RCB which were plastic “tailings” generated by the mill had an as received moisture content of 1.85%, ash content of 9.00% and gross heating value of 8,566 Btu/lb. The starting density of the processed (dried) Green Bay Packaging Feedstock was 4.35 lbs/ft<sup>3</sup> and the Renewable Densified Fuel produced in Park Falls, Wisconsin had a density of 23.5 lbs/ft<sup>3</sup>. This validated the concept that a 100% densified fuel could be produced using recycled cardboard fiber and reclaimed plastic from the mill to create a low moisture high Btu value densified fuel. In addition, this fuel could replace a significant portion of the coal used in their existing boiler further increasing environmental performance of the mill as well as nearly achieving zero waste status.

### **BWC Companies/Secondary Cardboard Fiber Beneficial Use Fuel Trials**

BWC Companies located in Solon, Iowa was founded in 1989 and comprise a group of companies that include BWC Industrial, BWC Excavating, and Whitters Industrial. In 2009 “BWC” provided corn stover and secondary fiber (cardboard) feedstocks for densified fuel trials. The primary objective was to conduct fuel trials for candidate feedstocks (separately and together) that included corn stover and secondary fiber (cardboard) residuals generated from a containerboard plant in Iowa. BWC shipped the cardboard/secondary fiber materials to HTF in Sturgeon Bay, Wisconsin. The cardboard fiber feedstocks had an incoming moisture content of 51.62%, an ash content of 7.68% and gross heating value of 3,426 Btu/lb. After processing (drying) the feedstock using the proprietary HTF drying system the as received moisture content of the cardboard residual feedstock was reduced to 16.88%, with an ash content of 13.72% and a gross heating value of 5,652 Btu/lb.

The densified fuel specification for these cardboard fiber rejects used 12% RCB sourced as No. 4 recycled LDPE mixed plastic/retail shopping bags. The LDPE bags were processed by Republic Machine, Inc. using their Split-a-Part Single Shaft Shredder. Republic Machine, Inc. is an OEM manufacturer of single shaft shredders located in Louisville, Kentucky (<http://republicmachine.com/index.html>).

The final Renewable Densified (recycled cardboard) Fuel produced reported a moisture content of 0.99%, ash content of 16.38% and gross heating value of 8,179 Btu/lb. The starting density of the processed (dried) BWC supplied feedstock was 7.00lbs./ft<sup>3</sup> and the Renewable Densified Fuel produced in Park Falls, Wisconsin at the JTC Densified Fuel plant had a density of 22.0 lbs/ft<sup>3</sup>.

These fuel trials represent examples of how mills can use a wide range of process residuals to support development of a comprehensive residual management/beneficial use program and provide a renewable fuel for onsite use in industrial boilers. Each mill or renewable energy project had unique feedstocks issues requiring examination of the most appropriate combinations of available feedstocks within certain parameters in order to create a viable boiler fuel from very high moisture process residuals. The value of the proprietary HTF drying system was also validated and it too proved extremely flexible and effective with a wide range of high moisture and very high moisture feedstocks.

Ultimately the implementation of any beneficial use program requires in-depth assessments and evaluations of all systems and the fuel trials were only one component of this evaluation process that documented the “viability” of diverse very high moisture residuals as a potential renewable fuel.

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