



FutureMetrics LLC

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An Integrated System for Producing Advanced Wood Pellets and Biochemicals

A summary of why Arbaflame offers a technologically and economically superior solution to the shortcomings of white pellets.

FutureMetrics has completed a comprehensive independent study of the Arbaflame steam exploded (SE) pellet technology and biochemical reclaim process. In addition to producing a technologically superior fuel, Arbaflame's latest design enhances their SE pellet plant with an integrated biochemical recovery process. The recovered high-value biochemicals significantly improves the economics of SE pellet production.

Steam Exploded (SE) Pellets

SE pellets primary technical advantages over white pellets are:

- The ability to be stored outdoors without degradation of their functionality. The SE pellet's moisture resistance allows power stations to avoid the cost of building dry storage solutions (domes or silos). This also allows ship loading and unloading during rain and/or snow events, as well as uncovered truck and rail transport. This lowers the probability of demurrage costs and the cost of overland transport.
- They have a higher volumetric and gravimetric energy density than white pellets. The significantly higher energy per cubic meter on board ships, railcars, and storage areas results in lower transportation and storage costs per gigajoule (GJ) of energy.
- They are harder and more durable than white pellets. They produce significantly fewer fines during handling, shipping and storage, which lowers the probability of dust explosions. Fewer fines also lowers mass losses so that more tonnage is retained in the product as it passes through the supply chain.
- The properties of SE pellets permit a wider range of co-firing ratios than white pellets without major modification to a coal power station's pulverizing system, and, depending on the type of coal and the design of the power plant, without burner and fuel piping systems modifications.

Biochemical Production

Arbaflame has significantly improved the economics of SE pellet production by developing a process to extract high quality biochemicals from the condensed reaction gasses produced during the SE process. For a 200,000 tonne per year SE pellet plant, the output of market grade biochemicals consists of furfural (270 kg/hour), methanol (90 kg/hour), and a few other less valuable chemicals. The actual outputs will vary slightly depending on the species of woods used as feedstock.

The characteristics of the steam treatment can be adjusted to raise the yield of furfural and lower the quantity of solid material that is densified into pellets. Additional value can be generated by converting the furfural into furfuryl alcohol. Furfural and furfuryl alcohol are high value products that sell in the range of \$1,500 – \$2,200 per tonne in a global marketplace.



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The furfural market is expected to reach nearly \$1.1 billion by 2021 from \$625.5 million in 2016, increasing at a compound annual growth rate of 12.31% from 2017 to 2021¹. Growing global demand for environmentally sustainable biomass-based chemicals and the growing application of furfural and its derivatives in the pharmaceutical industry is fueling the overall growth of the furfural market.

The process technology for stripping the chemicals from an aqueous phase (the condensate from the steam explosion reaction) is widely deployed in the chemical and refining Industry.

Is the Arbaflame Integrated Pellet/Biochem Factory Cost Competitive?

The reclamation of green biochemicals is a new and differentiating component of the integrated Arbaflame design. The mass loss due to steam treatment and the additional energy cost to run the reactor is more than offset by the added value of the biochemical compounds. The net of the chemical stripping costs versus the revenue from biochemical sales adds significant positive cash flow to the business model.

Furthermore, the highly integrated process is optimally efficient in conserving energy. For example, under typical operating conditions, all of the necessary pre-dryer energy is derived from recycled heat from the process.

FutureMetrics believes that the Arbaflame SE pellet/biochem technology has overcome the shortcomings that have prevented the production of cost competitive SE pellets in the past.

Summary

The ability to deliver hard, energy dense, and waterproof pellets at a price per gigajoule that is cost competitive with white pellets has been a goal of SE and torrefied pellet developers for many years. Until now, neither SE or torrefaction, and the many various designs for implementing those thermal treatment processes, were able to achieve cost competitiveness.

The Arbaflame design changes that.

On the SE pellet production side, Arbaflame's evolution of design in the control, capture, and recycling of energy within the integrated process has optimized the energy needed to produce SE pellets.

The reaction gasses produced from the thermal treatment of the woody feedstock, once a costly waste problem, are now converted into a significant revenue stream.

Using the typical price per GJ for white pellets as the price per GJ for SE pellets, the Arbaflame integrated pellet/biochem plant can produce a return on investment that should be attractive to most project developers.

The following pages contain photos of Arbaflame SE pellets and some charts and schematics showing some of the characteristics of the process.

¹ Global Furfural Market 2017-2021, full report at https://www.researchandmarkets.com/research/sj2sml/global_furfural?w=5



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FutureMetrics can apply detailed modeling and analysis to any project-specific set of input variables, including desired output capacity, ambient temperature profiles, feedstock moisture content, transportation and labor costs, and expected revenue per tonne to provide custom analysis for project developers considering the Arbaflame SE pellet/biochemical technology.

Arbaflame pellets after a winter outside in Ontario Canada

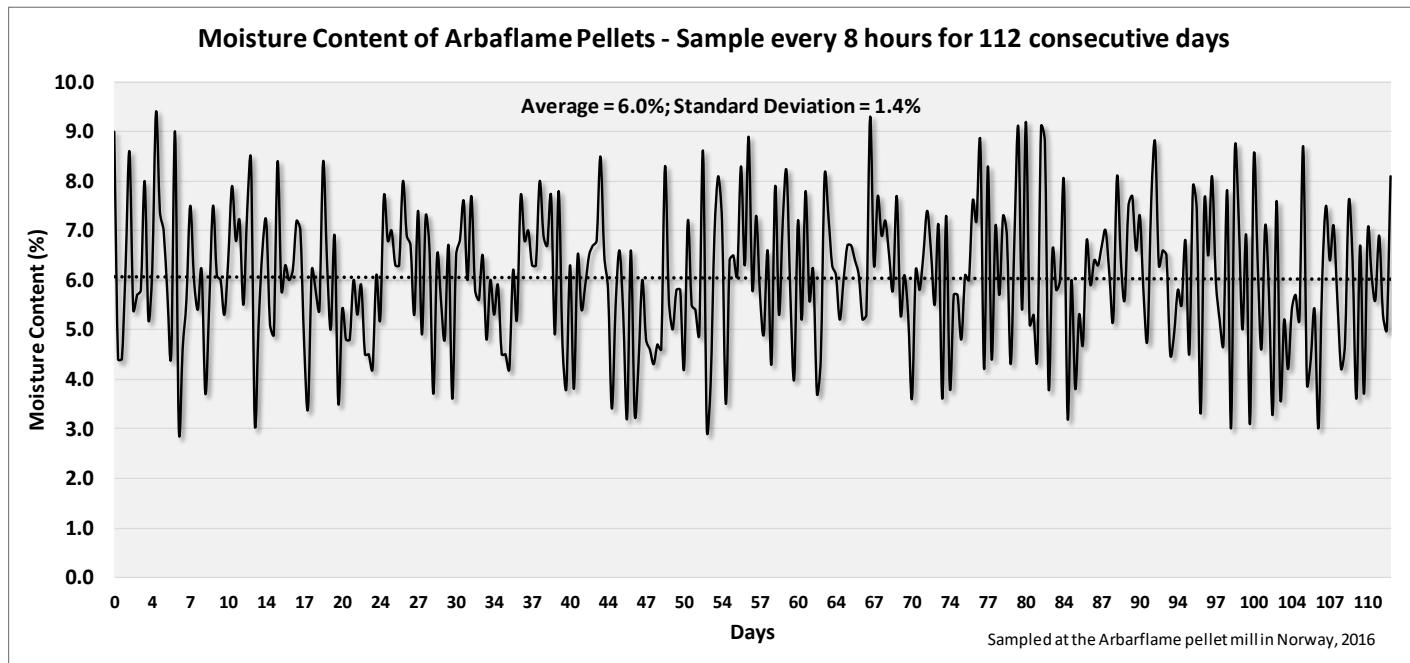




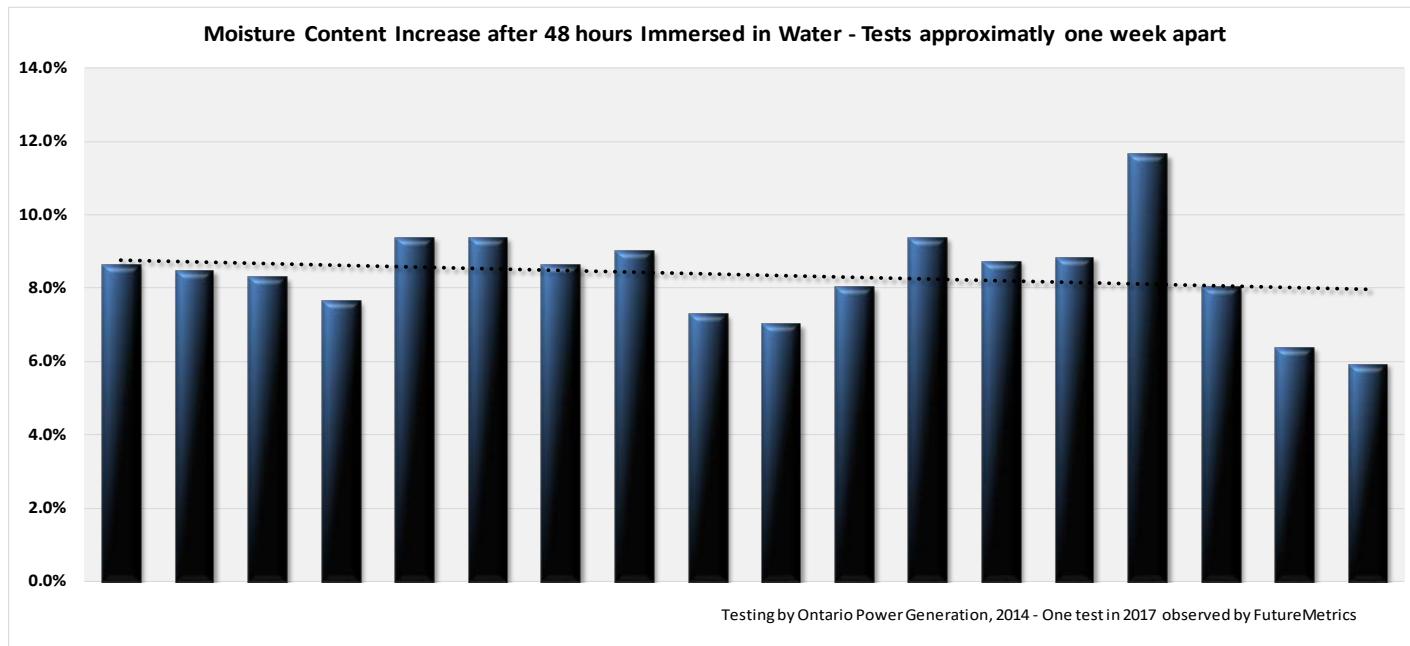
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Moisture content of Arbaflame pellets as produced.



After 48 hours of immersion the water uptake is ~8%, and the change in durability is -0.7%, from an average of 98.9% to an average of 98.2%. If the pellets are then left in the open air, they return to their original MC and durability.



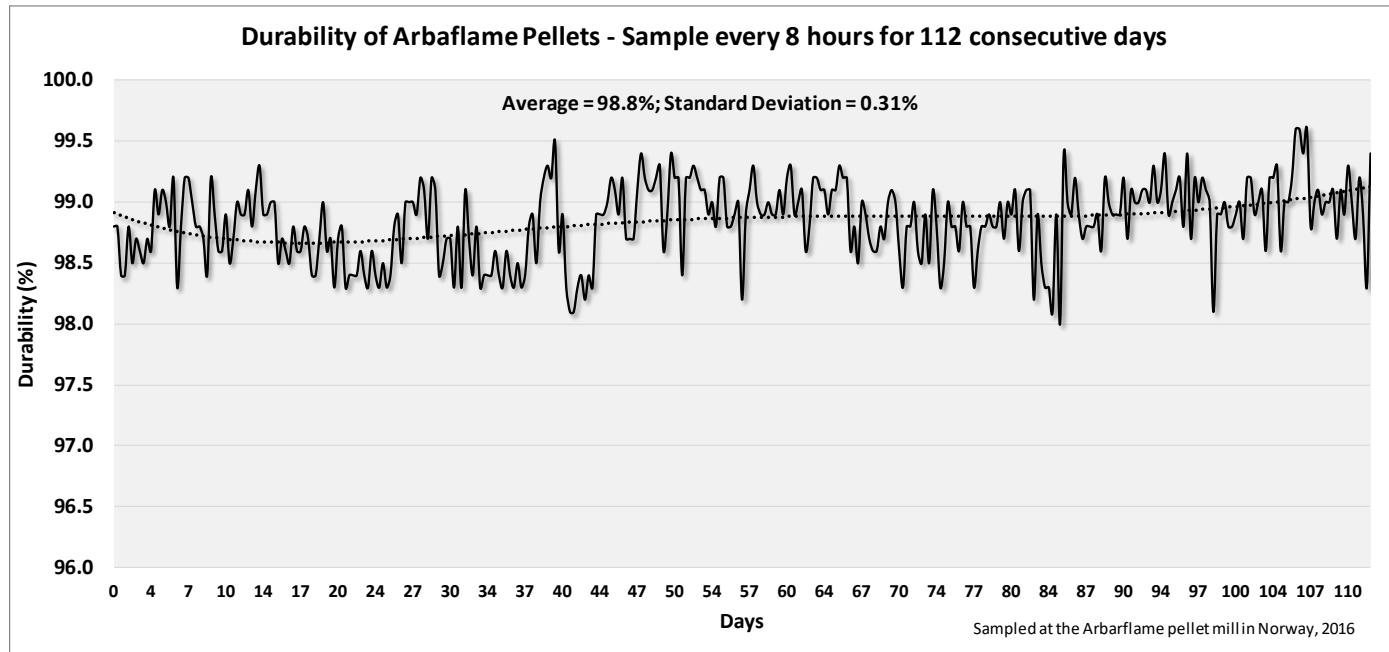


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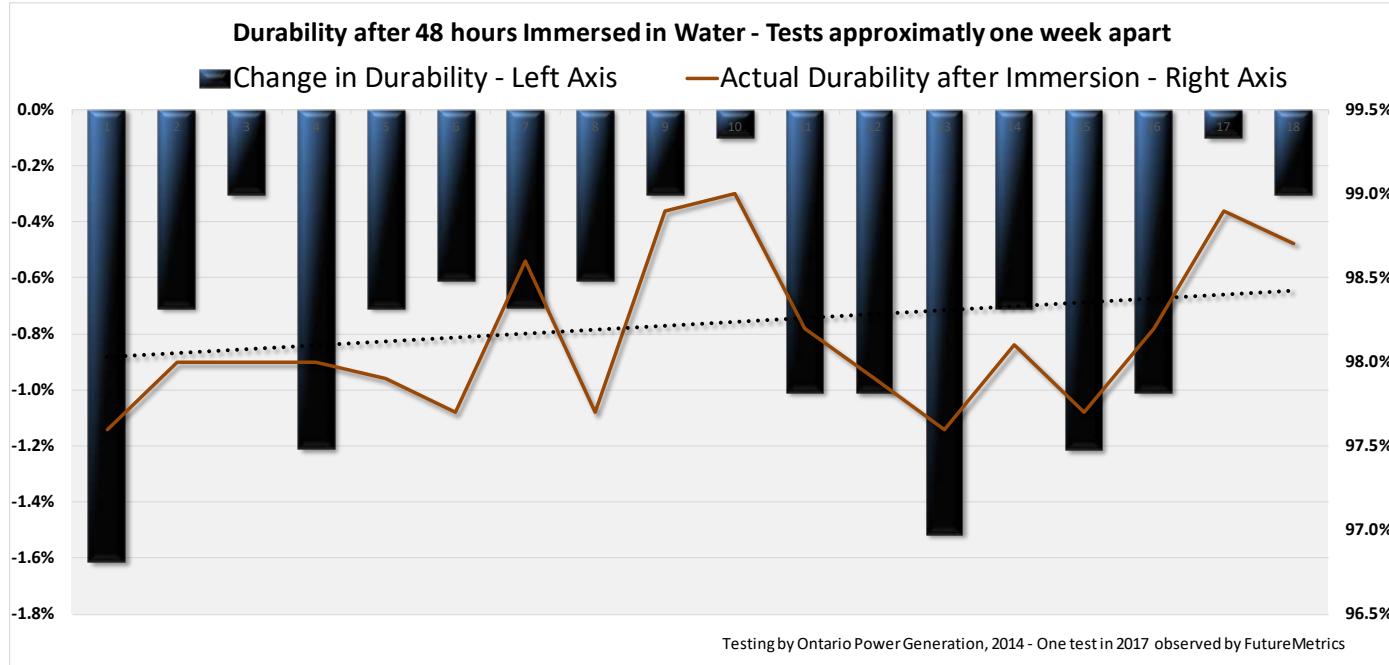
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The SE pellets do not lose their mechanical characteristics after the uptake of water.

Durability of Arbaflame pallets as produced.



Durability after immersion in water.

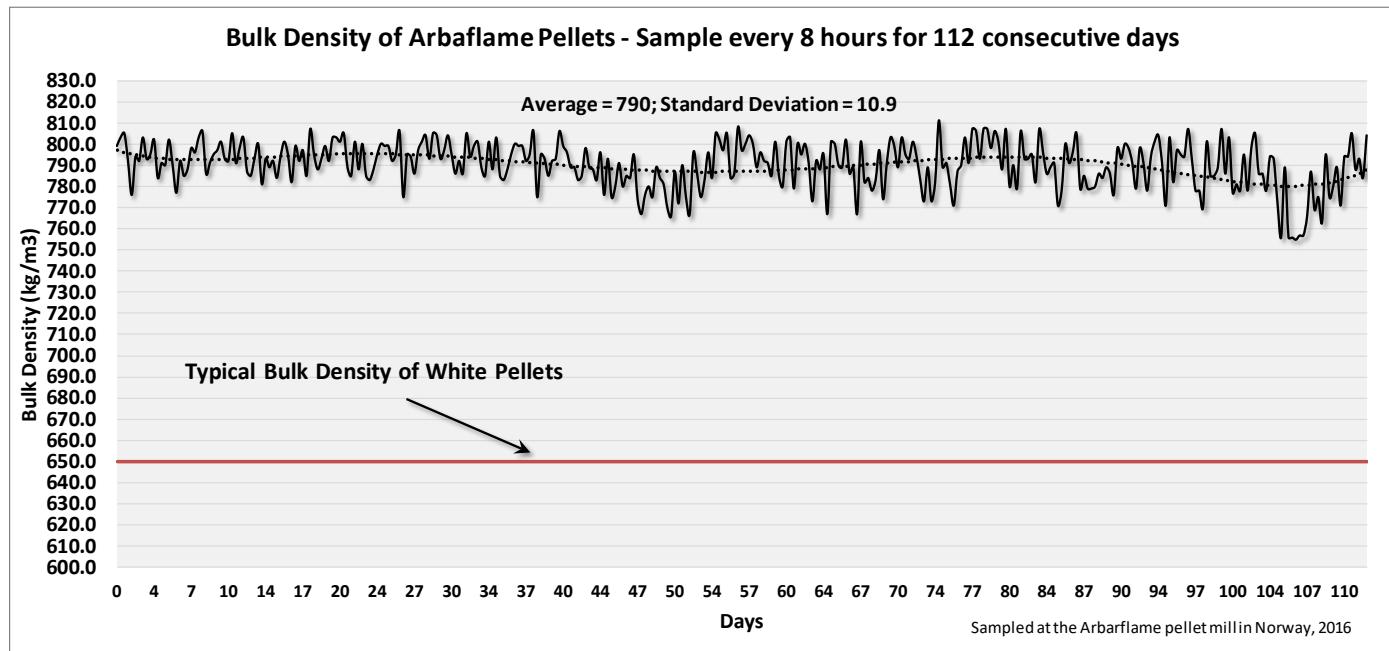




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Bulk density is significantly higher than white pellets



The higher energy content per tonne (about 19.5 - 20.0 GJ) and the higher bulk density results in about 41% more energy per cubic meter versus white pellets.

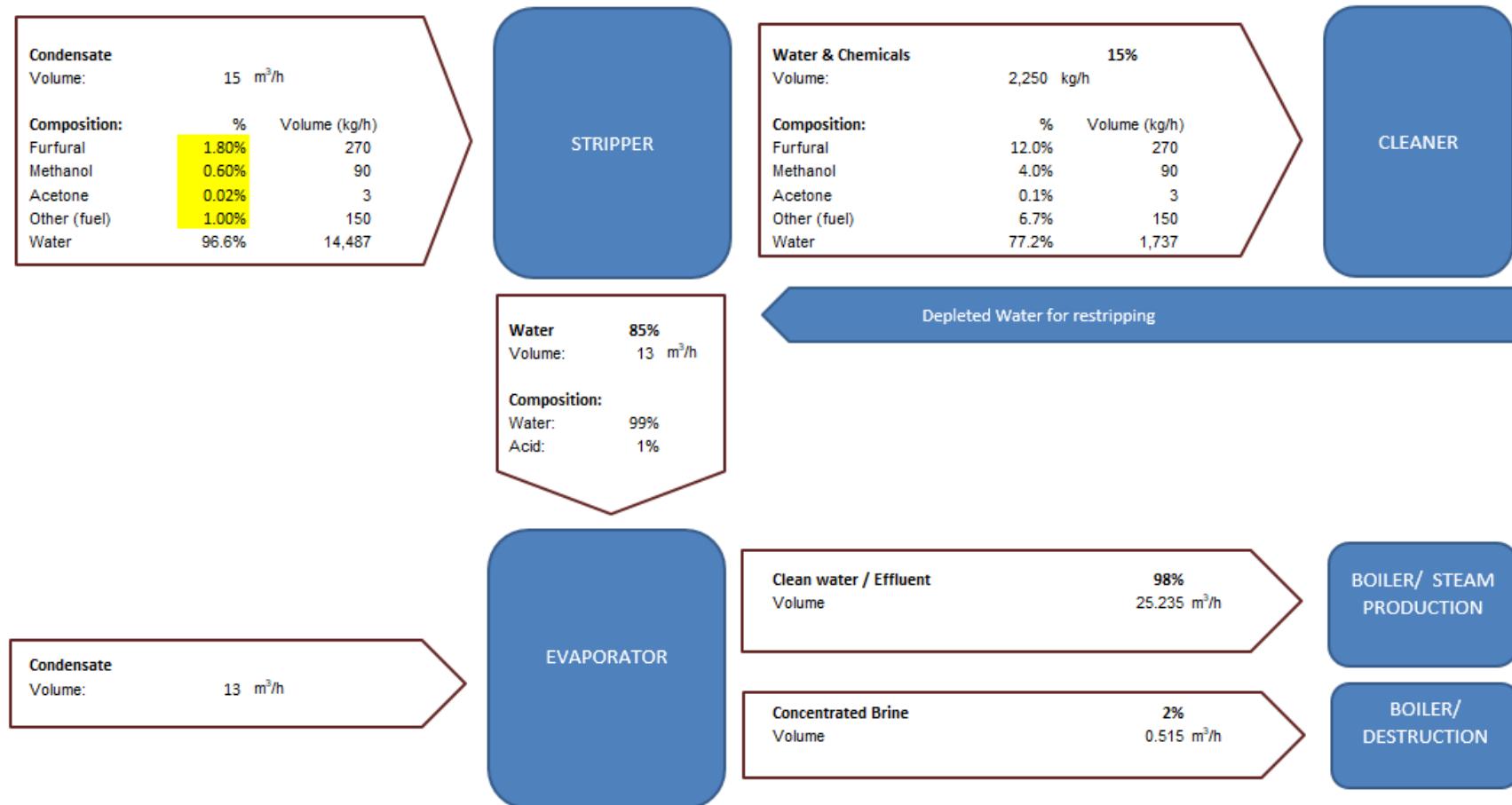
	Vessel volume (m^3)	Tonnes on board	GJ on board
White	60,000	39,000	682,500
Steam Exploded	60,000	47,400	924,300



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Biochemical reclaim schematic





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Integrated Process Flow Schematic (details greyed out)

Project: FutureMetrics Analysis
Annual pellet production: 200,000 ton/y
Ambient air temperature: 15 °C
Relative Humidity ambient air: 75 %
Feedstock MC in: 50 %
MC at pre-dryer outlet: 32.1 %

