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NVREC subtask 1.1: Pre-treatment of lignocellulosic biomass

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Overview & Objectives

There is considerable interest in utilizing lignocellulosic biomass as feedstocks for combustion or thermochemical conversion to fuels. Two majors problems limiting current use:

1) considerable non-homogeneity of feedstocks in terms of sizes, shapes, and handling properties
2) low energy density

The main objectives of this project are to develop and utilize pre-treatment processes that will address these problems, thereby improving the practicality of utilizing biomass for energy and fuels. The pre-treatment method we are exploring is called **hydrothermal carbonization (HTC).**

In this project, DRI will design and fabricate a laboratory-scale, continuous HTC process unit to treat Nevada relevant biomass feedstocks. Gaseous, aqueous-phase, and solid products will be collected and characterized. Complete mass and energy balances will be conducted, and optimized pre-treatment conditions will be defined.

Hydrothermal Carbonization (HTC)

HTC involves treating raw biomass with hot, pressurized water.

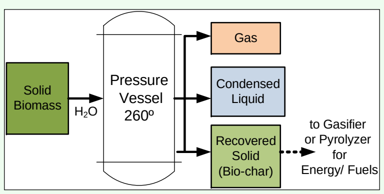

Figure 1: HTC pretreatment process produces gaseous, liquid and solid products. The solid products can be used in energy processes. We are also investigating the utility of the gases and liquids.

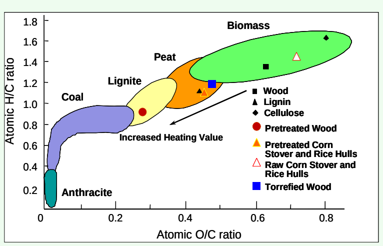

Figure 2: This Van Krevelen diagram illustrates that by decreasing oxygen content and increasing the carbon density, the HTC pretreatment of biomass produces a solid product that is more similar to coal.

Under these conditions, the hemi-cellulose components of biomass are extracted, while the cellulose and lignin components are concentrated in the solid product. The resulting "bio-char" is a black-colored, friable solid.

The benefits of the process are:
- Lower O content
- Higher C content
- Faster than conventional torrefaction.
- Increased energy density

Results from Related Work

To better define optimum pre-treatment operating conditions for the HTC process unit, we are conducting a series of small-scale experiments using a 2-Liter, stirred Parr pressurized reactor. Mixtures of wood chips in water (mass ratio of 1/8) have been treated over a range of temperatures from 215°C to 295°C. The following analyses were performed on each of the products:

Solids: Mass, Moisture, Energy Content, C,H,N,S,O, and Lignocellulosic Fractions
Liquids: Total Mass, Non-volatile Mass, NPOC, Sugars and Organic Acids
Gases: Total Volume, CO_2, CO, CH_4, and H_2

Figure 3: Liquids collected after pre-treatment and the raw feedstock compared to the pre-treated solid.

The calorific energy content of the resulting bio-char was measured on samples recovered under each condition (Table 1). The energy content of the bio-char increased with increasing HTC reactor temperature, although the mass recovery decreased (data not shown. An optimum temperature for the process (in terms of energy densification) is in the range of 255-275°C.

Table 1: Mass Recovery and Energy Content of products from HTC process from 215-295ºC.

Reactor Temperature	Recovered Biochar	Gases Evolved	Non-Volatiles In Liquid	Excess Water	Total Mass Recovery	% Mass Recovery	Btu/lb
Feedstock	-	-	-		85.3 *		9738
215 C	58.9	N/A	8.5	13.9	81.4	95.4%	9708
235 C	54.3	6.7	7.5	13.7	82.2	96.4%	10436
255 C	43.3	7.2	8.9	21.9	81.2	95.2%	12067
275 C	43.4	9.1	7.1	25.9	85.6	100.4%	12475
295 C	42.8	10.1	6.4	24.8	84.1	98.5%	12690

*bone dry starting feedstock weight

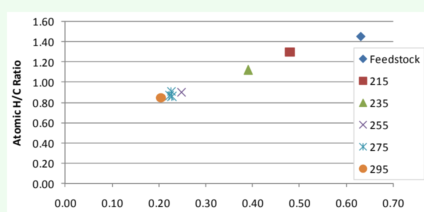

Figure 4: Van Krevelen diagram for Temperature tests (215-295ºC) of Tahoe Wood Chips (White Fir/Jeffrey Pine Mix)

Continuous Pre-Treatment Reactor

A preliminary design of the continuous HTC unit is shown in Figure 5. This unit contains specially designed augers to:

1) introduce raw biomass feedstock into the reactor unit
2) convey the biomass through the reaction zone and deliver the produced bio-char to a product container.

The continuous reactor also allows for sampling of gaseous and liquid products throughout the reaction process.

The two augers have been installed within a transparent, plastic, non-pressurized model of the HTC unit. We will use this model to investigate the behavior of different biomass types, and learn to operate the augers for optimum conveyance of the biomass into and through the reactor system.

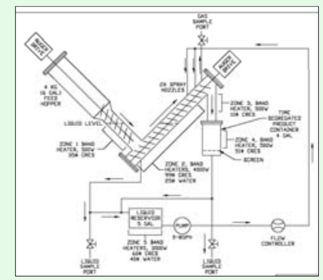

FIGURE 5: Preliminary design of the continuous HTC system. It will be designed for a 2 hour run time with a 1-20 minute residence time for maximum temperatures and pressures of 300ºC and 1300 psi.

Figure 6: A clear plastic assembly for the auger drive and reactor is used to show where feed issues may occur with various feedstock types and sizes.

Project Schedule

Our progress to-date on each task is slightly less than anticipated at this stage of the project. The chart below reflects the revised schedule.

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13
Task 1: Modify facilities and develop safety plan													
Task 2: Design pre-treatment reactor system													
Task 3: Build and operate pre-treatment reactor													
Task 4: Project management and reporting													
Deliverables*			Q			Q			Q			D	F

*Deliverables: Q = Quarterly report; D = Draft Report; F = Final Report