NARA Integrated Biorefinery Report

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Introduction

The Aspen team has gathered information from various contributing teams (Feedstock, WY, Gevo, Coproducts) in order to assemble this information into a cohesive process model describing the NARA biorefinery.

- Process information (chemical input, reactions) developed using laboratory data
- Aspen Plus used to create a process model to calculate mass and energy balance, and predict operating costs.
- Aspen Economic Analyzer used to estimate capital cost
- Data from our effort is summarized in an electronic file on Google Drive.

Prior work by our team involved creating department based models for each of the major operations in the NARA biorefinery (i.e. pretreatment, enzymatic hydrolysis). Over the course of the past year, this information has been assembled into an integrated model combining Aspen Plus v8.6 data with literature information as well as information from the Gevo team, as seen in the central figure to the right.

Methods

Assumptions: The development of an Aspen model requires accurate physico-chemical parameters for the chemicals and materials used. In several cases, the Aspen database did not contain chemical properties for the operations that we wished to model. In these cases, the NREL model was used as a base point for comparison. The NREL model gave specific chemical property parameters which were used in this model. In addition, some assumptions that were used in the NREL model were also incorporated into this model. For example:

- Vanillin was assumed to have similar chemical properties as lignin
- Xylan, arabinose, and galactose were assumed to have similar structures and properties, and were all modeled after xylan

Modeling: The process model was built using an iterative process, where Aspen output was checked after each rendition of the model for its closeness to predicted data.

Additionally, as more information became available from the pretreatment teams and co-products teams, the new data was added to the model, which allowed us to look at process benefits from changed parameters.

Models Developed From Literature

Several of the departments were not able to be modelled effectively in Aspen Plus. This included:

- Distribution
- Utilities
- Parts of the Boiler

For these operations, literature information was used to size and cost the equipment and estimate operating cost. Many of the utilities operations, including wastewater treatment, security and fencing, and process water were scaled up or down from the 2013 NREL biorefinery report.

The boiler operation was partially modelled in Aspen, with items such as the baghouse and vent scrubbers estimated outside of Aspen.

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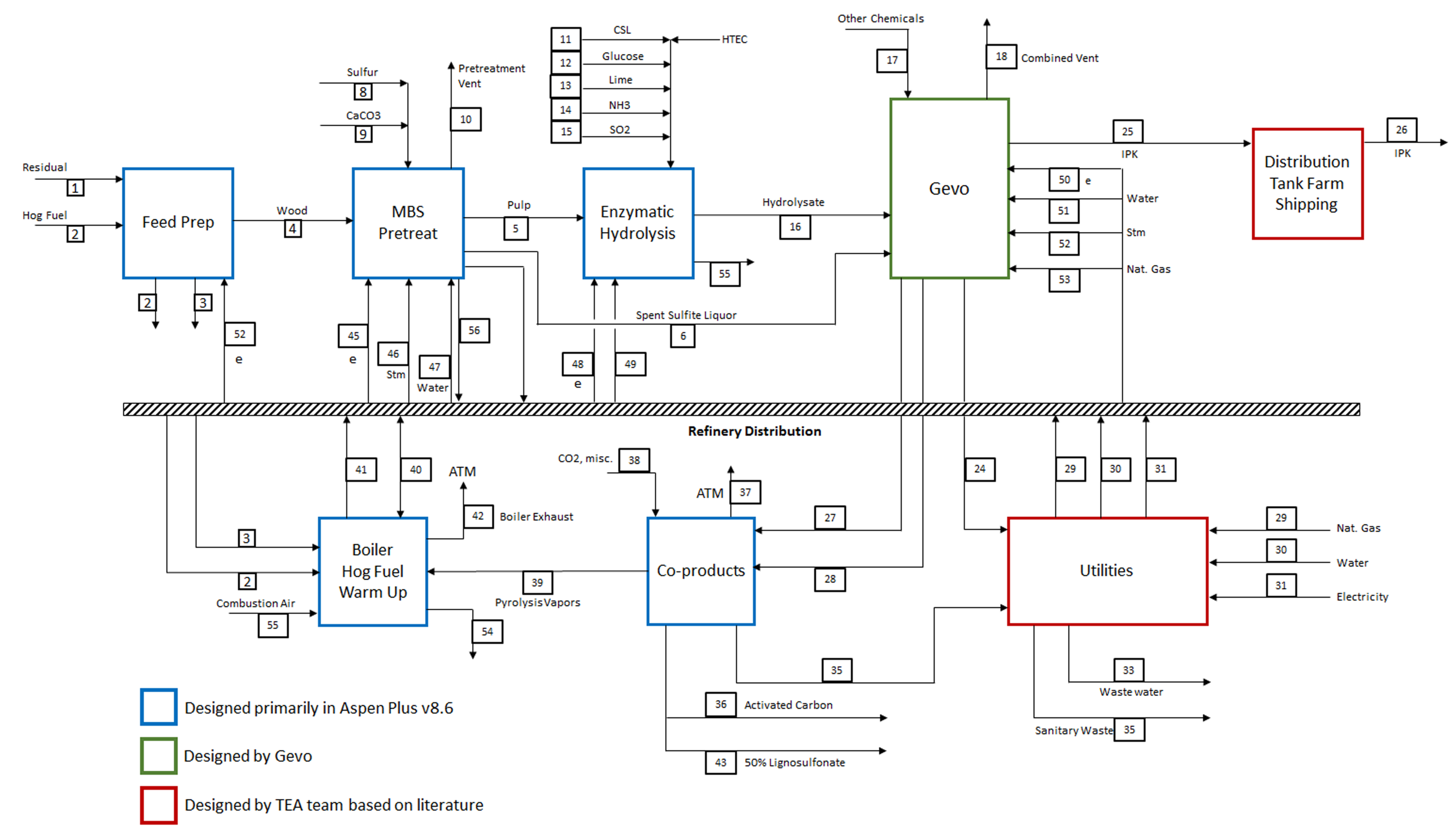

Figure: Nara integrated biorefinery model. Streams represent mass and energy balances calculated with Aspen and from literature analysis.

Department	Installed Capital Cost ($MM)
Feedstock Handling	47.7
Pretreatment	206.2
Enzymatic Hydrolysis	76.8
Gevo Fermentation, Separation, and ATJ	188.9
Coproducts	123.9
Distribution	10
Boiler	43.2
Utilities	134.7
Total	**831.4**

Department	Operating Cost ($MM/ yr.)
Feedstock Handling	67.09
Pretreatment	10.1
Enzymatic Hydrolysis	27.9
Gevo Fermentation, Separation, and ATJ	36.4
Coproducts	0.1
Distribution	4.4
Boiler	35.8
Utilities	17.4
Total	**199.19**

Tables above: NARA biorefinery installed capital cost and operating costs

Department	Net Steam Requirement (klbs/ hr)
Pretreatment	116.0
Enzymatic Hydrolysis	1.0
Gevo Fermentation & Upgrading	270.0
Coproducts	34.2
Total	421.2

- In addition to the primary hog fuel boiler, which combusts fines and hog fuel, there are two other boilers which provide steam to the plant: the mixed fuel boiler used for the pyrolysis vapors from the activated carbon process, and the sulfur boiler in the pretreatment department.
- The sulfur boiler combusts elemental sulfur at high temperature to produce SO_2 for generation of calcium bisulfite used in pretreatment.

Plant Steam Requirement

- Steam for the NARA biorefinery is provided by a set of boilers. These boilers do not produce electricity, which is purchased from the municipal grid.
- The boiler department consists of the hog fuel boiler and also includes assessment for the mixed fuel boiler for pyrolysis vapors in the co-products process.
- There are two sources of fuel for the hog fuel boiler: fines and directly purchased hog fuel. Hog fuel is described as a wet mix of coarse chips of bark and wood. The fines are forest residual chips that pass through the lower screen in the feedstock handling department, and are too small to be used for pretreatment.
- The boiler needs to produce ~421,000 lbs/hr of steam to meet the refinery steam needs.

https://drive.google.com/a/nararenewables.org/folderview?id=0B5GOdPhOdioecUoxUHBRWFAwdnc&usp=sharing

Detailed Breakdown

Each department was broken down into five detailed documents, consisting of a description and diagram, input and output diagram, capital expenditure, operating expenditure, and atmospheric discharge.

1. Description & Diagram: Contains a prose description of what the process entails, and the process model diagram created in Aspen Plus of the department.
2. Input and Output: A spreadsheet containing Aspen data for mass and energy balance. This spreadsheet shows steam and water flows as well as the individual component masses that were modeled.
3. Capital expenditure: Installed equipment cost for the department.
4. Operating expenditure: Cost of chemicals and energy for the department.
5. Atmospheric discharge: An estimate of compounds discharged to water or air that are not explicitly contained in the model.

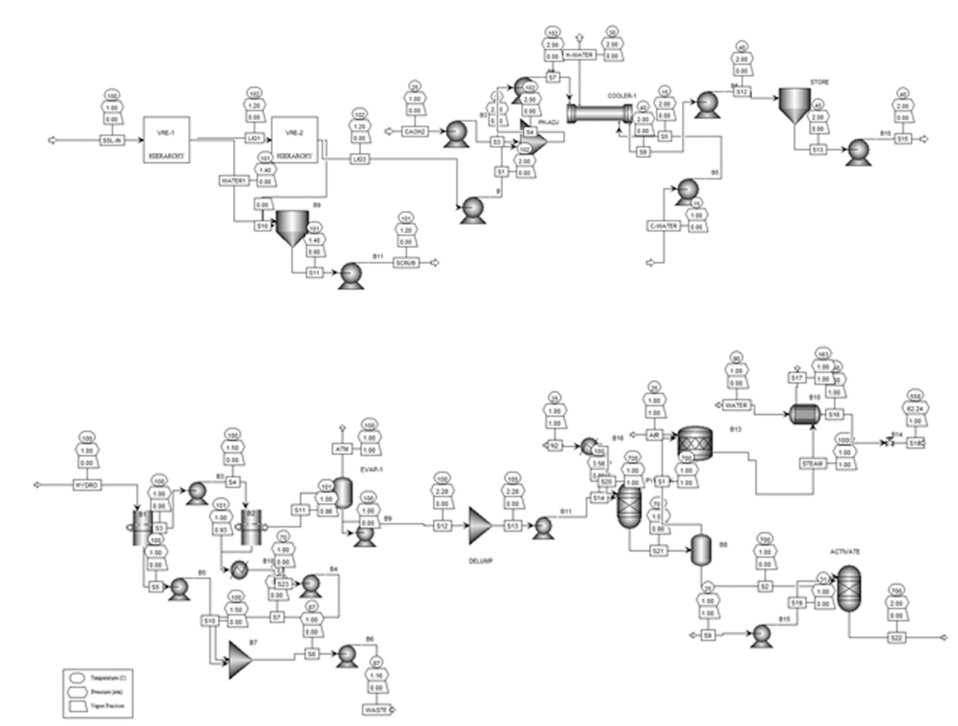

Figure: Diagram of the coproducts department (top: SSL bottom: activated carbon

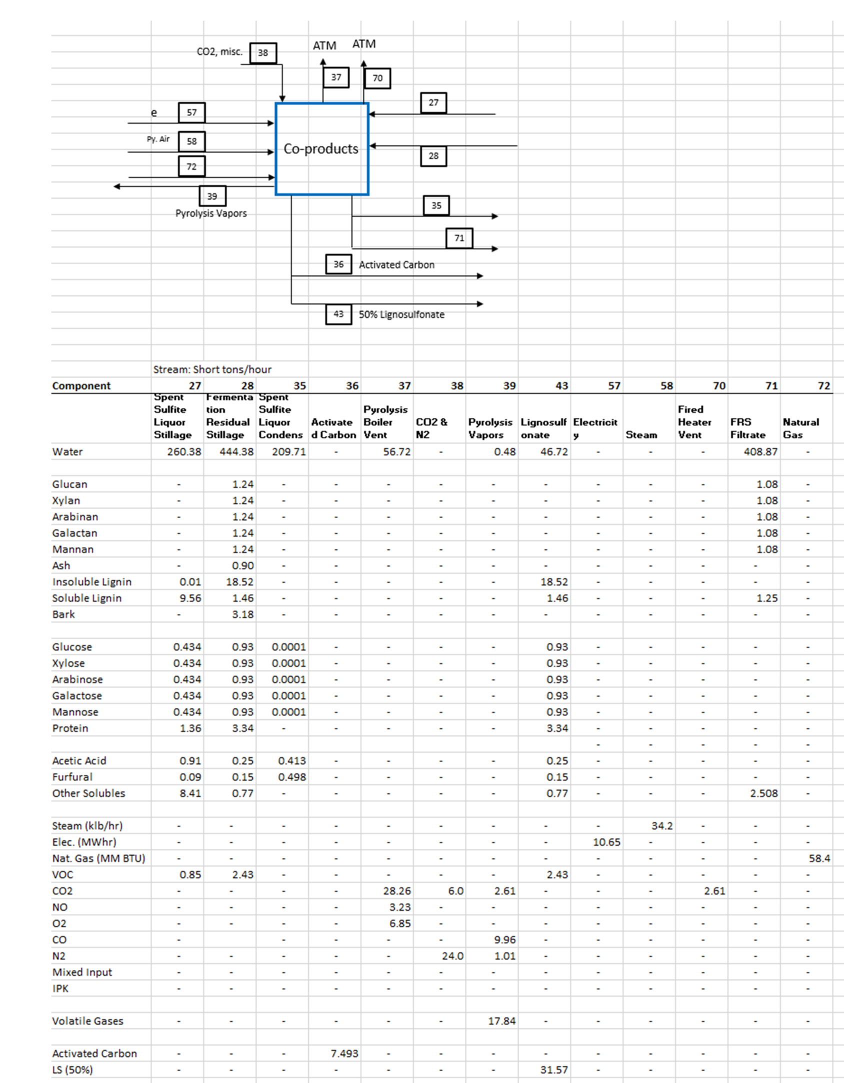

Figure: Input Output diagram of the coproducts department

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NARA

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