NARA Strategic Analysis

2nd Cumulative Report

April 2013 - March 2014

STRATEGIC ANALYSIS

Background

In attaining the USDA NIFA aspiration goal for the Sustainable Bioenergy AFRI CAPs to *"facilitate the establishment of regional systems for the sustainable production of bioenergy and biobased products,*[1]*"* NARA is envisioning an aviation biofuels industry based upon residual materials from the existing softwood supply chain in the Northwestern US. In years 1 and 2 of our project, we focused on refining management systems and team coordination while establishing the individual technical and logistical components. Two major components that were added to aid us in evaluating progress during these early stages of the project were a Techno-Economic Analysis (TEA) on our conversion pathway and a project-wide Phase and Gate Process to guide our transition from Feasibility Assessment through to Commercialization. We have used the results of the analysis to guide the strategic direction of our project towards a continued effort to realizing a *"regional system for sustainable production of bioenergy and biobased products"*. The first two years brought us to a refined vision of how this industry might successfully develop.

One pathway is that of an integrated biorefinery with a single pretreatment process at its core. Through the first three years we have considered multiple thermochemical pretreatments that included mild bisulfite, wet oxidation, and dilute acid. Regardless of the pretreatment process, the functions and assets of such a facility could closely resemble integrated pulping facilities like those that existed in Bellingham, WA. The core of NARA's conversion research is striving to improve efficiencies, yields, and the economics of feedstock sourcing for such an approach.

Initially, economics of this model will necessitate retrofit of existing facilities in the region, ideally those with few existing product opportunities. Our supply chain analysis has demonstrated that a large-scale integrated facility located in the part of our region with lower biomass productivity (e.g. the NARA region east of the Cascade Range) would greatly benefit from rail-located biomass depots, to economically build the quantities of biomass needed for achieving economies of scale at the conversion site.

Our research has also indicated that a **second pathway for potential success may employ a distributed supply chain approach**. This distributed production model relies upon pretreatment and potentially saccharification processes moving upstream in the supply chains to depots. This pathway potentially benefits from additional opportunities to retrofit existing infrastructure including primary wood processing facilities and pulp mills (partial retrofit) for solid or liquid depots, ethanol plants for isobutanol production, and petroleum refining for alcohol-to-jet conversion.

The focus of our Year 3 efforts address the necessary technical research, integration, and scale-up to study feasibility of both pathways. In addition, the NARA Advisory Board specifically directed that the NARA leadership team *"should decide on a single pretreatment process to carry forward"* and *"use the Phase & Gate Analysis process to facilitate this action"*. We have followed these recommendations while continuing to develop impactful research to address our pathways as articulated above.

Approach

In response to this recommendation, the NARA Executive Team directed establishment of a coordinated evaluation of the mild bisulfite and wet oxidation pretreatment methods for a variety of technical metrics, co-products, and commercialization potentials. The process was led by NARA Process Development Analyst, Linda Beltz, and contributed to by all of the NARA Pretreatment, Co-Products, Conversion, and Sustainability Teams.

In addition, the techno-economic analysis (TEA) developed in Year 2 (see Task SM-TEA-1: Techno-Economics Analysis of the 2013 NARA Cumulative Report) was used to assess the specific role of multiple revenue streams from likely co-products developed in the process. To supplement the TEA effort, improvements were continually sought in reducing feedstock costs (Task FL-1: Feedstock Sourcing) and delineating supply chain assets (E-3: Regional Integrated Design Experience – IDX) within our NARA region. At this point, our team is focusing on a supply region spanning the Washington-Oregon border on the west-side of the Cascade Mountains (MC2P – Mid Cascade to Pacific Region). Stakeholder development was targeted by the Outreach Team to engage our new region and develop relationships focused in the states of Washington and Oregon. These groups were specifically developed to assist in supply chain development in the new MC2P region.

[1] USDA NIFA Agriculture and Food Research Initiative Competitive Grants Program.
Sustainable Bioenergy – 2010 Request for Application_http://www.grants.gov/search/synopsis.do;jsessionid=RvWPRSFJ2C2gNjyTL2K0G519XXJLCBcTTHyXT4pVH67H74WDGsYh!1654183736

Summary of Findings

TECHNO-ECONOMIC ANALYSIS

We found in Year 2, assuming a (1) complete greenfield construction of an integrated biorefinery and (2) a 20% internal rate of return, the current cost estimate for producing biojet (IPK) from forest residuals will be 2 to 3 times the current cost of petroleum jet fuel if the biorefinery is designed to produce only aviation biofuel products. With optimistic estimates for improved yields throughout the process, this value might be lowered to 1.45 times the cost of the petroleum equivalent.

In Year 3, we focused the TEA on discerning the impact of potential co-products on the revenue stream for a biorefinery. In this process we considered two commercially viable co-products: (1) lignosulfonates used for concrete additives, and (2) activated carbon to be used for mercury adsorption in coal fired power plants. Other revenues included the sale of alternative jet fuel at cost parity with petroleum, the RIN value of this fuel, and the sale of isooctane, which is a byproduct of producing biojet. After adjusting the expected capital and operating expenditures for the added co-product production, an internal rate of return (IRR) of 12.5% (Figure SA-1) is realized. This profit margin is still unlikely to be sufficient for investments of the magnitude required to build an integrated biorefinery through greenfield development. Our efforts in Year 4 will focus on assessing the value that retrofit of existing pulp mill facilities might bring to the computed IRR for a pulp-mill based, integrated biorefinery.

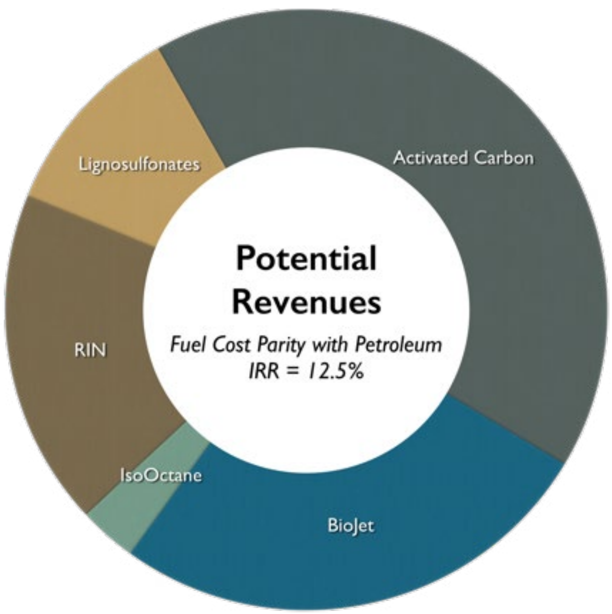

Figure SA-1. Summary of the current status of the techno-economic analysis for an integrated biorefinery producing biojet (IPK) and lignin co-products using forest residuals as a feedstock assuming a complete greenfield construction. Relative contributions of individual revenues are provided for analysis.

FEEDSTOCK COSTS

Feedstock remains the single largest cost item within the integrated biorefinery TEA. In an effort to improve our processing efficiency, NARA undertook an extensive study of feedstock preparation. In this effort, slash piles were deconstructed, the materials were categorized, moisture levels were controlled, and all the materials were processed at a controlled site with actual harvesting equipment. Processing energy was monitored carefully to assess fuel usage. By controlling biomass size, bit type, and moisture content, this effort has demonstrated pathways that will result in ca. $30/bone dry ton (BDT) savings to the feedstock production (Figure SA-2).

DISTRIBUTED SUGAR PRODUCTION

The core of a distributed production model is the ability to pretreat on a small scale in facilities where residues are readily available, e.g. sawmills. NARA has been investigating a pretreatment method that would be based solely on mechanical milling technologies (Figure SA-3). These efforts have been supported by work to design supply chain technologies and systems around this distributed production. For more information, see tasks C-P-5 (Clean Sugar and Lignin Pretreatment Technology, p-59) and E-8 (Distributed Sugar Depot, p-244) in this report.

The targeted energy consumption by the pulverized wood operations has been used for a techno-economics analysis (TEA) for clean sugar and lignin production from forest residual chips. Based on this TEA, if the targeted energy consumption of wood milling is met or achieved within the range of 0.56-0.84 kilowatt-hour/oven dried kg wood at a sugar conversion yield of about 58-65%, the economics by milling as a pretreatment technology looks plausible for clean sugar and lignin fuel pellet production. Examination of the milled wood sugar by Gevo is ongoing, but preliminary assessments indicate that organism growth and isobutanol production are excellent. Overall, the distributed production scenario demonstrates continued benefits for consideration.

OUTREACH AND EDUCATION TEAM SUPPORT

The assessment of existing regional assets to be applied to the emerging biofuels industry in regional supply chains is a key component of our Goal 3: Supply Chain Coalitions, and is carried out by our Outreach and Education Teams. This effort not only produces supply chain analysis resulting in site ranking and design, but critically links stakeholders to this effort to engage them in these efforts and involve them in the development of a future biofuels industry.

Efforts of the Outreach Team were successful at aligning State of Washington economic development programs with our fuels vision. A state grant was provided by the Washington Department of Commerce to assist a NARA member, Cosmo Specialty Fibers, in evaluating the potential to expand their operation to include biochemical and sugar products. NARA education teams worked with Cosmo and other regional stakeholders in western Washington and Oregon to envision supply chain nodes in the Mid-Cascade to Pacific (MC2P) region that spanned the Washington-Oregon border. These efforts resulted in site designs for facilities that included both solid and liquid depots for the distributed manufacturing model as well as integrated biorefinery designs. As a result of these combined Education and Outreach efforts, Cosmo announced at our 2013 stakeholder meeting in Seattle that they were pursuing a biorefinery business model.

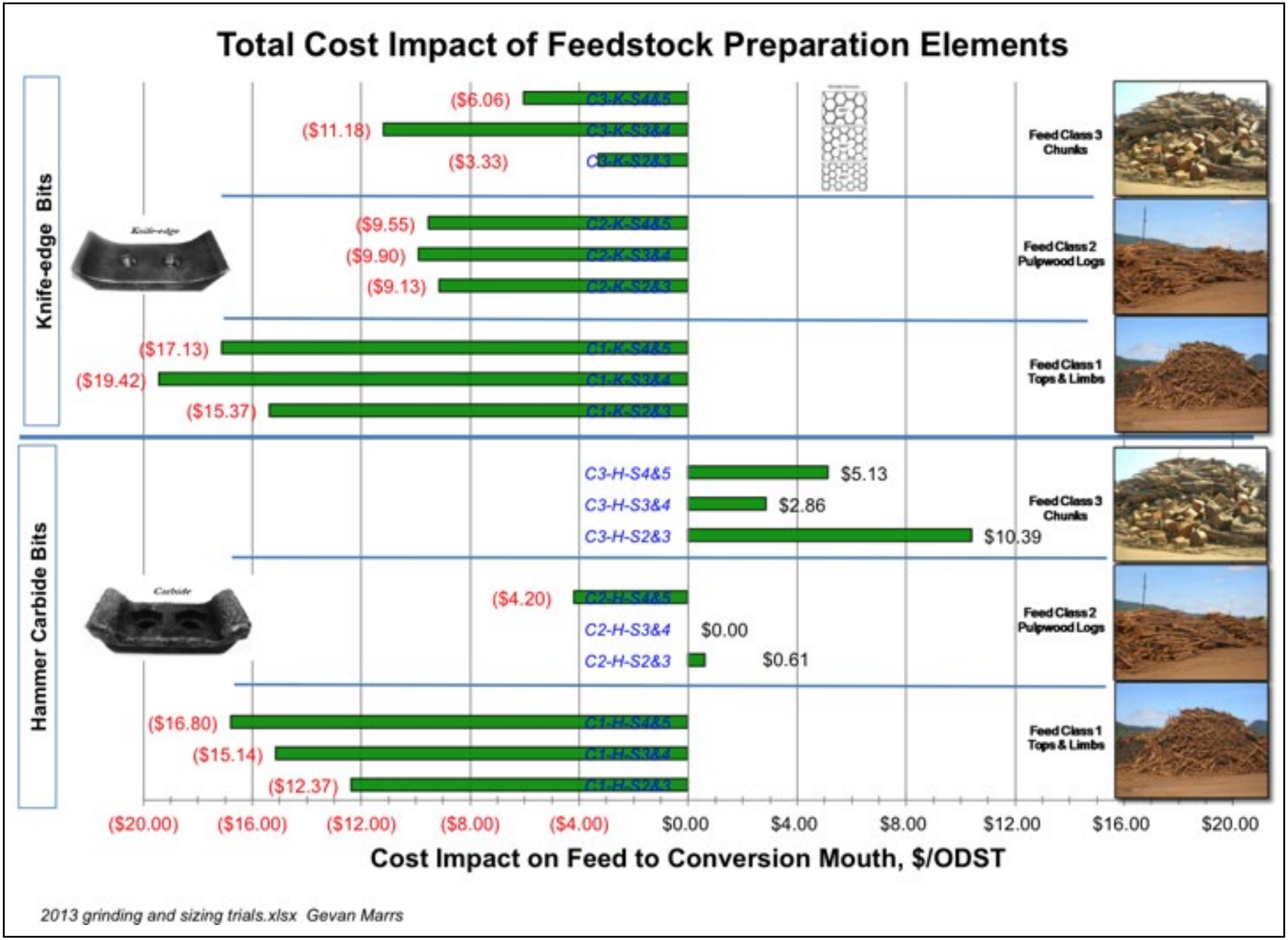

Figure SA-2. Summary of the cost impact on feedstock conversion costs for a variety of biomass and processing bit types

Figure SA-3. Milled wood powders of FS-10 chips, under various milling time, 30, 60, 80, and 100 minutes. Varying color of milled wood samples corresponds to milling temperatures. All materials were directly hydrolysable after milling with no chemical treatment.

Future Directions

Given the need to increase production efficiency by decreasing feedstock costs and reducing capital costs, we recommend the following:

- Continue seeking regional assets that might be retrofit for an emerging biofuels industry. These facilities include primary wood processing plants for depots, pulp plants for pretreatment and hydrolysis, and ethanol plants for fermentation. We will perform an analysis of the four-state NARA region.
- Specifically evaluate the potential of a retrofitted facility by providing a modified TEA around the strategy of converting a bisulfite pulp mill into biofuels, biochemical, sugar, and lignin products.
- Further assess the role of feedstock densification prior to shipping in decreasing feedstock costs.
- Produce a full simulation and TEA of a sugar depot to further evaluate the role of distributed manufacturing.
- Seek commercial partners for our carbon co-products development.
- Develop a firm commercialization strategy that will culminate in 1,000 gallons of biojet fuel produced as an initial demonstration effort.