NARA

Production of 1,000 Gallons of BioJet

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Northwest Advanced Renewables Alliance

USDA

1,000 Gallons of BioJet Fuel – Task Objective

Produce 1,000 gallons of jet fuel using the cellulosic sugars produced from softwood forest residues as identified and researched in the USDA funded NARA project.

1,000 Gallons of BioJet Fuel – Task Objective – Cont.

1. A quantity of 1,000 was chosen to enable a blended jet fuel trial by a commercial airline plus useful performance, quality and composition tests.

2. Key aspects taken from the NARA project to be utilized in the production are:
    1. Feedstock: Softwood forest residues, primarily Douglas-fir and hemlock
    2. Pretreatment: A mild bisulfite variant of the SPORL process as developed by USDA/FPL and Catchlight Energy
    3. Enzymatic Saccharification: Utilizing commercial enzymes from Novozymes and as utilized by USDA/FPL and Gevo on this pretreated material
    4. Isobutanol Production: Via fermentation using Gevo patented organisms and fermentation protocols
    5. Jet Fuel Conversion: Via Gevo process

1,000 Gallons of BioJet Fuel – Task Objective – Cont.

3. Efforts will be made to accommodate the production of representative co-products

4. Cost and availability of suitable demonstration scale equipment will dominate

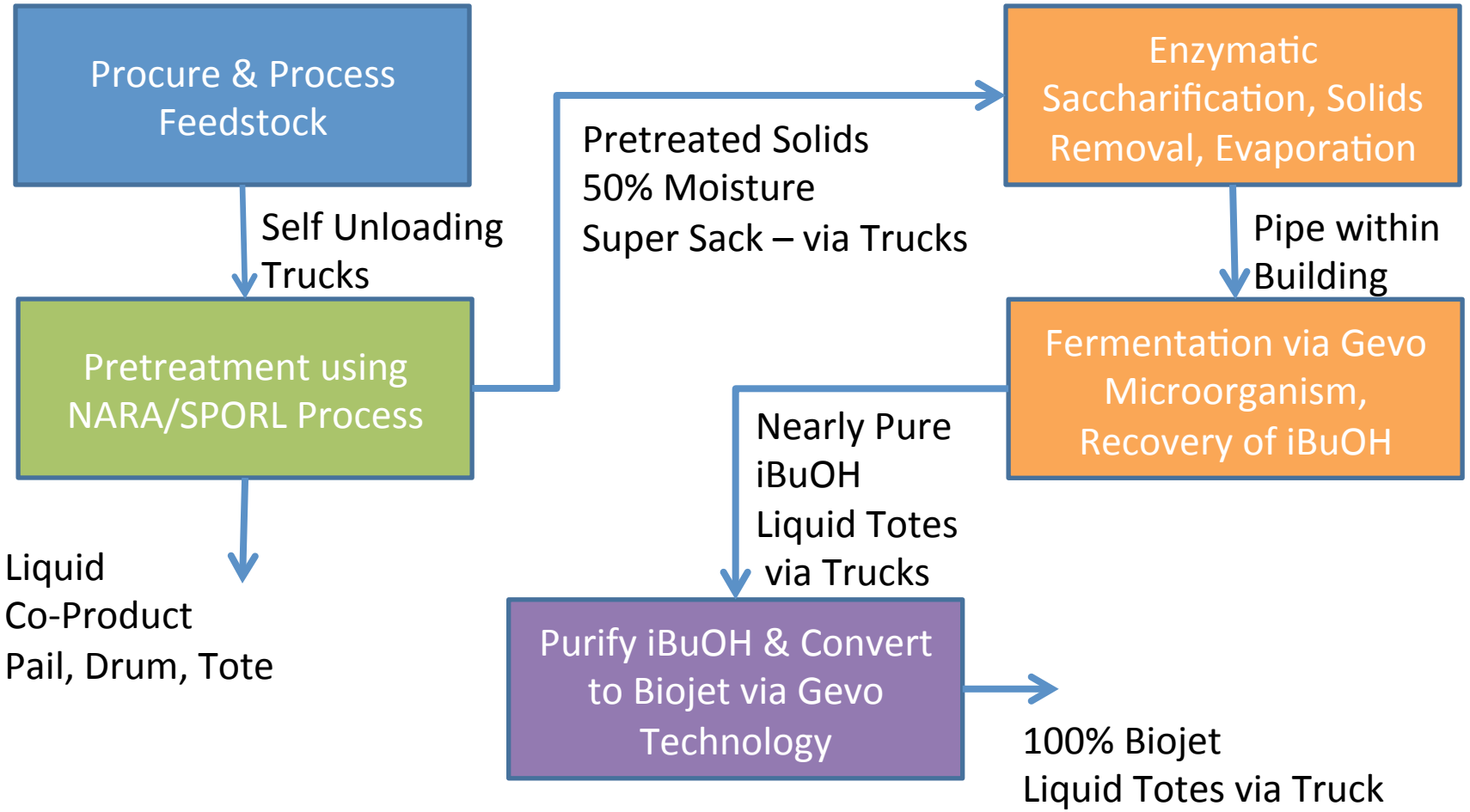
5. Efforts will be made to determine representative or scalable yields as opportunities present themselves (for pretreatment generally)

6. An overall optimized yield from wood to jet fuel is not expected

Determine Scale-up Requirements

- Review Information from potential tolling partners
- Determine additional testing needed by FPL and Gevo to scale to a continuous system that may require different process conditions than previously studied
  - Will depend on recommendations from or observations about specific toller
- Discuss potential need for pre-trials with specific tolling equipment
  - Feedstock preparation needs
  - Multiple hours on demo pretreatment equipment (at expected toller)
  - Scaling requirement of saccharification & fermentation
- Requirements and procedures for shipping of intermediate materials – Will depend on toller capabilities and locations
  - Low pH of hydrolyzates
  - Moisture content of solids
  - Bio-stability of sugar containing materials

Overall Process Flow



Feedstock

Feedstock Collection

- Weyerhaeuser Siuslaw 900 Site, WA
- CSTK Lands near Enumclaw, WA
- Muddleshoot lands near Flathead Lake, MT

Feedstock Processing

- Lane Forest Products, Junction City, OR
- Forest Concepts, Auburn, WA

List of Possible Process Tolling Partners

- Pretreatment
  - Andritz Pilot Facility, Springfield, OH
  - American Process (API) Pilot Plant, Thomason, GA
  - Zeachem Development Plant, Boardman, OR
  - Cosmo Speciality Fiber, Cosmopolis, WA
  - Forest Products Lab (FPL), Madison, WI
  - ICM Corn & Cellulose Pilot Plant, St. Joseph, MO
  - NREL Biomass Pilot Plant, Golden, CO
  - University of Florida Pilot Plant, Perry, FL

- Fermentation
  - ICM, St. Joseph, MO
  - NREL Biomass Pilot Plant, Golden, CO

- iBuOH Purification & Conversion to Jet
  - South Hampton Resources, Silsbee, TX

Pretreatment Toller

- Zeachem – Boardman OR
  - Good Experience with pretreatment of wood for fuels and chemicals
  - Nominal 10 BDT/day
  - No SO_2 Handling Experience – Designs & Procedural Modifications
  - Cost Negotiation Difficult – Special Thanks to Eric Rogers (WSU Purchasing)
  - Andritz Designed and Supplied Equipment
    - Trial at Andritz Pilot (Springfield, OH)
    - Budget Quote for Andritz Commercial Plant for NARA
  - Refiner and High Pressure Blow will insure small particle size
  - Filter Press can produce 50% Solids, quite suitable for non-Hazmat Shipping
  - Highly motivated team at Zeachem

Zeachem Pretreatment Plant, Boardman, OR

2015 Annual

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Hydrolysis

ZeaChem

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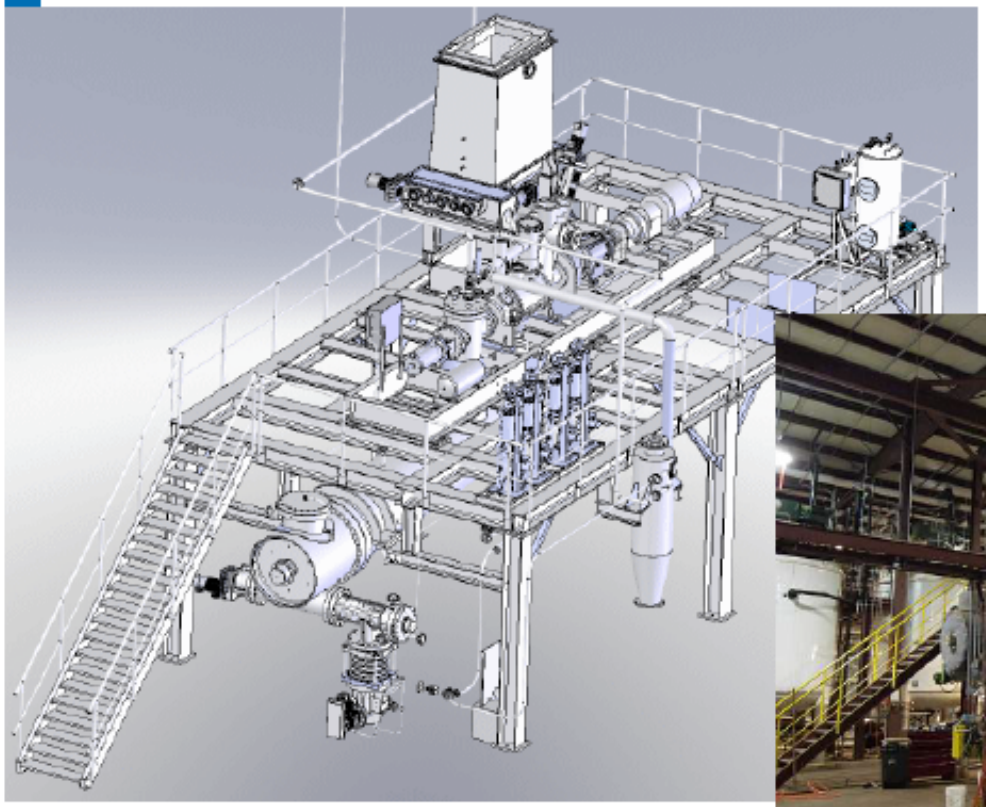
Andritz Pilot Plant, Springfield, OH

2015

Pilot System – Reference Pictures

Horizontal Reactor



ANDRITZ Pulp & Paper

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Enzymatic Saccharification & Fermentation Toller

- ICM – St. Joseph, MO
  - Considerable experience with:
    - Biomass Saccharification
    - Fermenting to isobutanol
    - Recovery and purification of isobutanol using Gevo Technology
  - Existing, 35,000 gallon enzyme saccharification tanks
  - Filter Press with washing capability to remove solids after Saccharification
  - Evaporation to concentrate sugars to 150 g/l for fermentation
  - Experience making Gevo Seed Yeast in Sterile Fermenters
  - Existing 6,000 gallon sterile fermenters that can be used in parallel
  - Existing pilot unit using the Gevo GIFT technology for high efficiency of isobutanol recovery from Fermentation

ICM - St. Joseph, MO Site

Isobutanol Purification & BioJet Production Toller

- South Hampton Resourses, Silsbee, TX
  - Isobutanol Purification - ICM will produce near fuel grade, but depending on contaminants may need additional purification
    - Small pilot distillation columns available
    - Site Familiar with isobutanol
    - Vast experience in distillation
    - Experience in using these columns for material similar to isobutanol
    - On-site with jet fuel production
  - Biojet Production
    - Only pilot facility already set-up to produce BioJet from isobutanol
    - Facility has been running nearly continuously producing Biojet from isobutanol since late 2011 for Gevo

Gevo's BioJet Facility at South Hampton Resources

Biojet Demonstration Plant
South Hampton Resources
Silsbee, Texas

South Hampton Resources
An Independent, Petrochemical
Manufacturer in Southeast Texas

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Progress to Date

- Process Tollers Selections Completed
- Stage Gate Review Completed
  - First Review - March 17, 2015 Proceed by revisit Costs
  - Final Review – July 30, 2015 Proceed with Task
- Feedstock
  - ~ 180 BDT Procured from:
    - Weyerhaeuser Siuslaw 900, Washinton
    - CSTK lands near Flathead Lake, Montana
    - Muddleshoot lands near Enumclaw, Washington
  - Processed at Lane Forests Products, Junction City, Oregon
    - Grinding, Screening, Microchipping
  - Processed at Forest Concepts, Auburn, Washington
- Delivered to Zeachem
  - ~ 70 BDT
  - Self-Unloading Truck
- Processing underway at Zeachem
  - Began August 17, should be complete this week

Schedule

Sub-Task	Status
Obtain, Process & Deliver Feedstock	Complete
Andritz Pretreatment Trial	Complete
Zeachem Pretreatment Production	Complete by 9/30/15
ICM Saccharification & Fermentation	11/1/15 thru 12/20/15
SHR BioJet Production	1/1/16 thru 2/1/16
Accept Biojet Fuel & Ship to Seattle	2/1/16 thru 2/15/16


NARA Feedstock FS-17
OR Douglas-fir Forest Residuals - As-harvested
1 2 3 4 5 6 7 8 9 10
inches


Lane Forest Concepts
Junction City, OR

Processing at Lane Forest Products

As Received at Lane Forest Products

Material Used at Zeachem

Mountain of Feedstock

Processing at Zeachem

Just Come of the Product from Zeachem

Contributors to This Task

- John Sessions – Oregon State University - Feedstocks
- Gevan Marrs – ex. Weyerhaeuser - Feedstocks
- JY Zhu - Forest Products Lab - Pretreatment
- Rollie Gleisner - Forest Products Lab - Pretreatment
- Bill Gilles - Forest Products Lab - Pretreatment
- Andrew Hawkins – Gevo – Hydrolysis & Fermentation
- Joe Ley – Gevo – Hydrolysis & Fermentation
- Paul Starkey – Gevo – BioJet Production
- Glenn Johnson – Gevo - Overall
- Johnway Gao- Weyerhaeuser – Pretreatment, Enzyme Saccharification
- Tom Spinks – Consultant – Bisulfite Pulp Processing
- Eric Rogers - WSU Procurement Extraordinaire
- Julie Semler - Purchasing & Support
- Janet Duncan – WSU - Scheduling & Support
- Linda Beltz – Gate Reviews
- Mike Wolcott – WSU – Everything Everywhere
- Ralph Cavalieri – WSU – Project Leadership
- Folks at Lane Forest Products, Forest Concepts, Andritz Pilot Plant, Zeachem Pilot Plant, ICM Pilot Plant, SHR Pilot Plant