

Feedstock Supply & Logistics

Feedstock Supply System Integration

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Project 1.6.1.9

Technology Area Review

May 21, 2013

Robert Jeffers, PI
Idaho National Laboratory

Determine the regional performance of biomass feedstock logistic supply chains driven by conversion facility in-feed specifications, by...

Improving the capability of research toolsets to:

- Collect and relay relevant biomass characteristics at multiple points in the supply chain
- Translate these characteristics into measures of value and performance
- Determine how logistics pathways change these characteristics
- Suggest the most promising supply chain configurations
- Couple best-available predictive models spatially and temporally
- Facilitate research integration

1.6.1.9 Quad Chart Overview

Timeline

Project Start Date: Oct. 1, 2009

Project End Date: Sept. 30, 2022

Barriers

Ft-M: Overall Integration

St-F: Systems Approach

Budget

Average funding per year: \$380k

Years funded to date: 5 years

Funding for FY13: \$750k

Funding for FY12: \$250k

Funding for FY11: \$285k

Partners

National Renewable Energy Lab

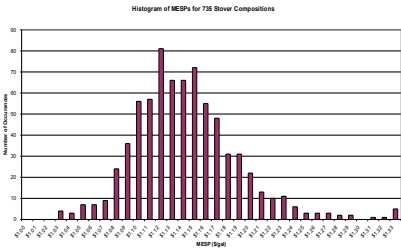
Oak Ridge National Laboratory

Biomass R&D Library Consortium

Iowa State University



1.6.1.9 Project Overview



Biomass characteristics library

1. Develops and manages the Biomass Resource Library as a centralized collection of characteristic information
2. Incorporates the Billion Ton Update cost vs. volume data to inform least-cost formulations by county
3. Integrates modularized Biomass Logistic Model components to assess feedstock logistics pathways
4. Spatially and temporally couples biomass resources through pathways with conversion facilities
5. Creates a usable interface to these integrated models, providing analytical capability to multiple researchers

INL Least Cost Formulation Spatial Tool

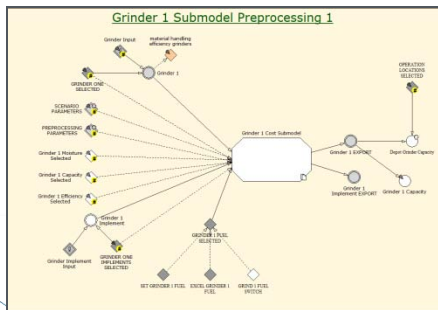
Year: 2017 Selected Area: Clay County, Missouri

Fayette County, Illinois

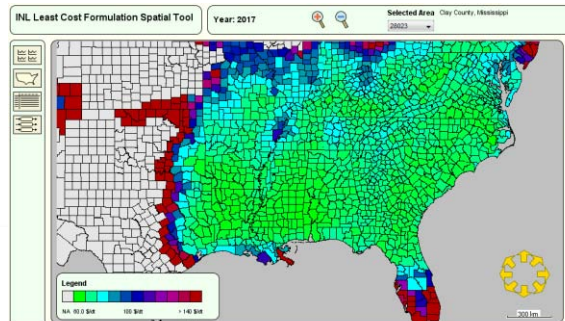
Population: 22140 Area: 728.238 mi² Current Cost: \$-899/ton Current Volume: 0 ton

| | Volumes (dry ton), versus costs (\$/ton) | | | | | | | | | |
|---------------|--|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
| Wheat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wheat straw | 0 | 2000 | 4000 | 6000 | 8000 | 10000 | 12000 | 14000 | 16000 | 18000 |
| Sorghum grain | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sorghum straw | 0 | 1704.42 | 3408.84 | 5113.26 | 6817.68 | 8522.10 | 10226.52 | 11930.94 | 13635.36 | 15339.78 |
| Cellulose | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cellulose | 0 | 2422.22 | 4844.44 | 7266.67 | 9688.89 | 12111.11 | 14533.33 | 16955.56 | 19377.78 | 21800 |
| Aspen | 0 | 1973.33 | 3946.67 | 5920 | 7893.33 | 9866.67 | 11840 | 13813.33 | 15786.67 | 17760 |
| LSGP | 0 | 4100 | 8200 | 12300 | 16400 | 20500 | 24600 | 28700 | 32800 | 36900 |
| LSGP | 0 | 147.0 | 294.0 | 441.0 | 588.0 | 735.0 | 882.0 | 1029.0 | 1176.0 | 1323.0 |
| LSGP | 0 | 790.07 | 1580.13 | 2370.20 | 3160.27 | 3950.33 | 4740.40 | 5530.47 | 6320.53 | 7110.60 |
| LSGP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LSGP | 0 | 1300 | 2600 | 3900 | 5200 | 6500 | 7800 | 9100 | 10400 | 11700 |
| LSGP | 0 | 400 | 800 | 1200 | 1600 | 2000 | 2400 | 2800 | 3200 | 3600 |
| MSW | 200.00 | 7074.24 | 14148.48 | 21222.72 | 28296.96 | 35371.20 | 42445.44 | 49519.68 | 56593.92 | 63668.16 |
| Total | 200.00 | 14048.48 | 28096.96 | 42145.44 | 56193.92 | 70242.40 | 84290.88 | 98339.36 | 112387.84 | 126436.32 |

County-level volume vs. cost



Modular logistics components



Spatial and temporal analysis engine



Intuitive user interface



Overview: Biomass Library

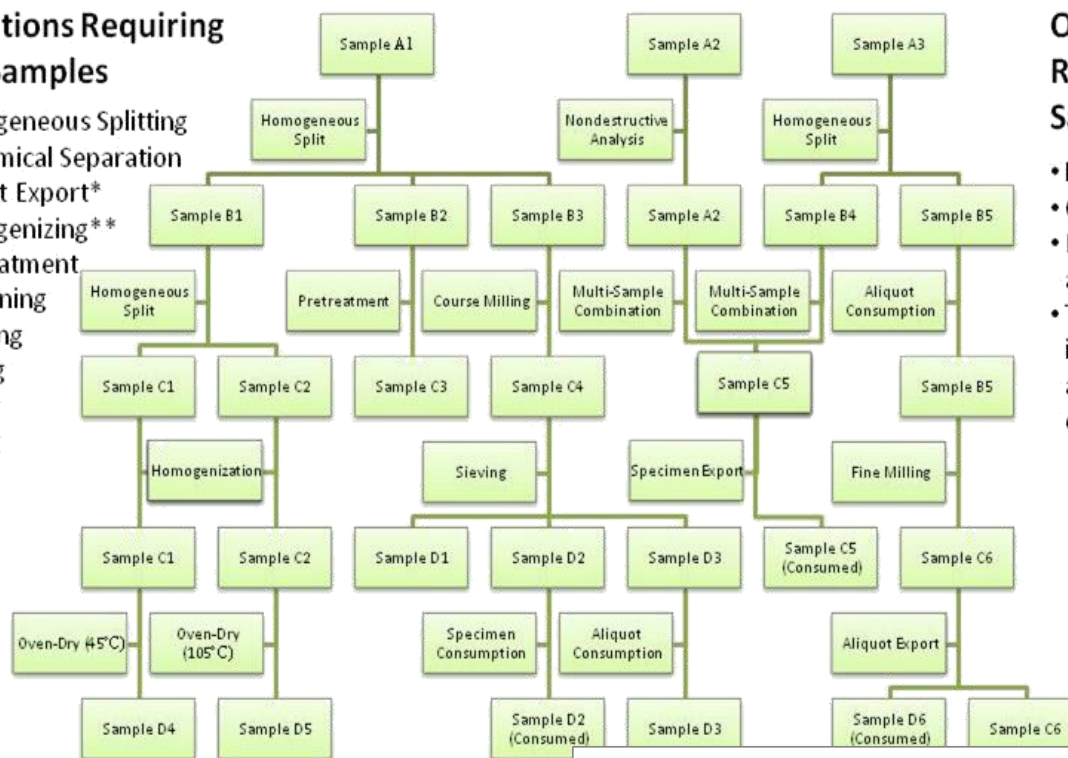
Biomass Library:

- Biomass Type
- Location
- Date of Harvest
- Moisture
- Sugars
- Lignin...

This information will be used to formulate a feedstock based on a conversion facility specification.

Operations Requiring New Samples

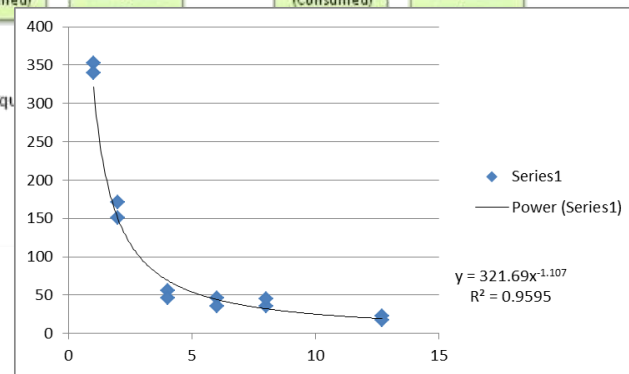
- Homogeneous Splitting
- Anatomical Separation
- Aliquot Export*
- Homogenizing**
- Pretreatment
- Combining
- Grinding
- Sieving
- Drying
- Milling



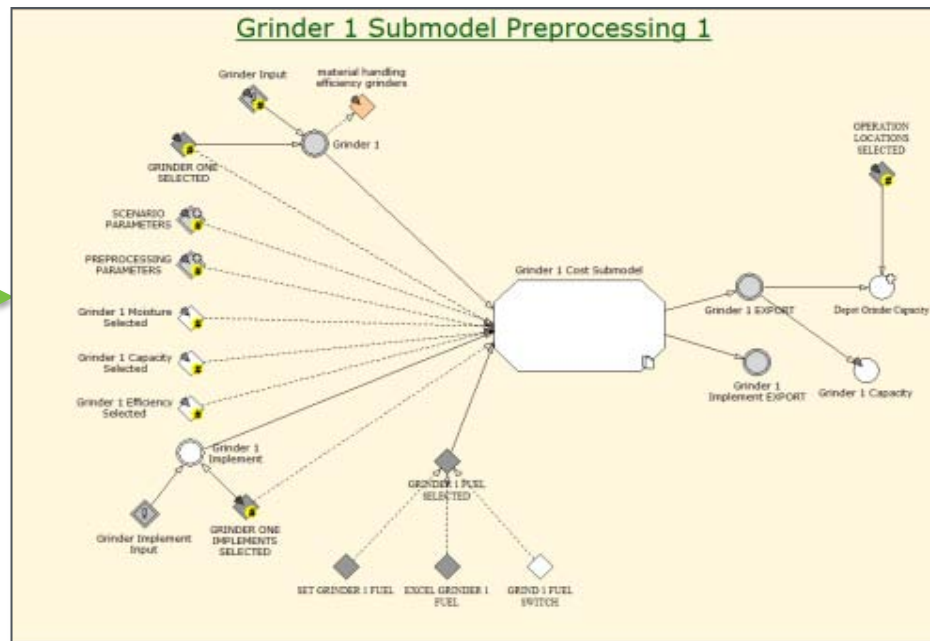
Operations NOT Requiring New Samples

- Homogenizing***
- Consumption
- Removal of an aliquot for analysis
- Typical child sample is direct result of analysis and is consumed

* Aliquot Export results in the creation of only one child sample with a unique ID
 ** Homogenizing through centrifugal milling
 *** Homogenizing by mixing a single sample



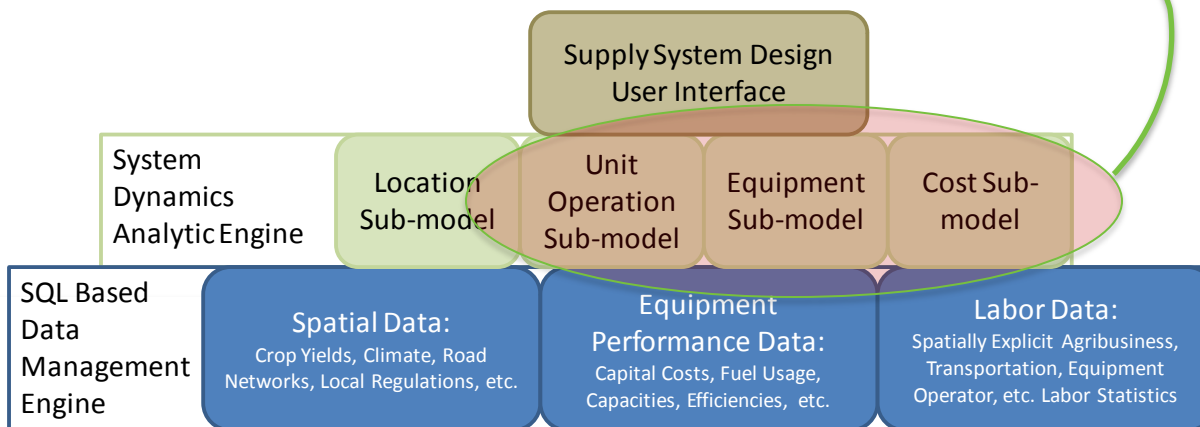
Overview: Biomass Logistics Model Framework



Modular logistics components

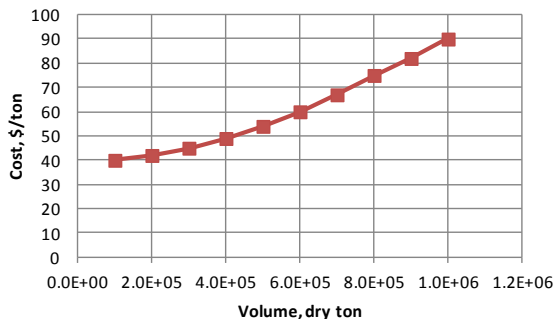
Inputs:
Volume
Characteristics
Desired output specs

Outputs:
Volume
Characteristics
Cost

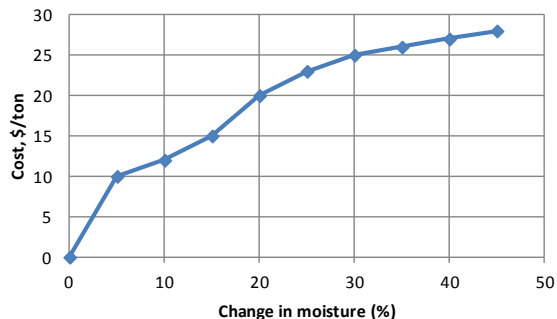


Overview: System-level Simulation Engine

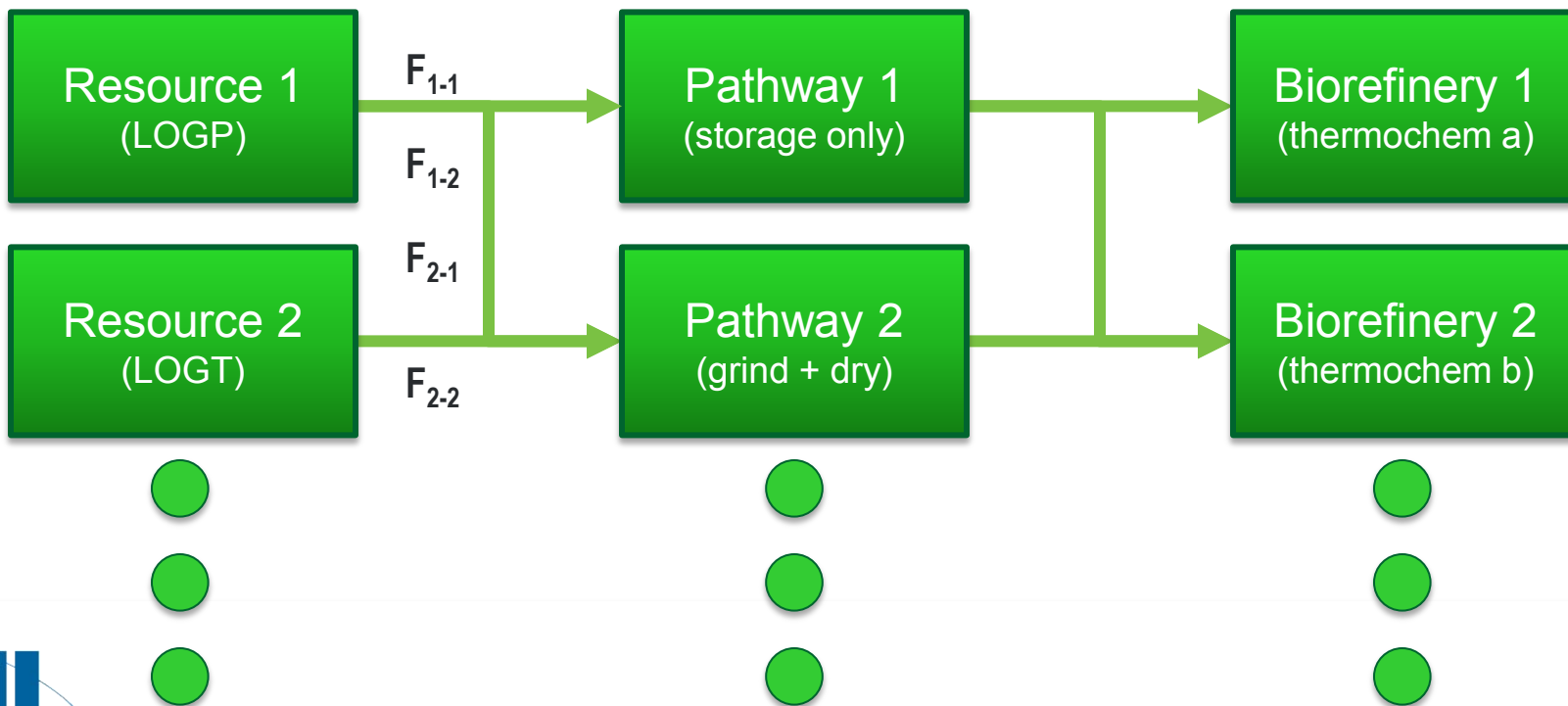
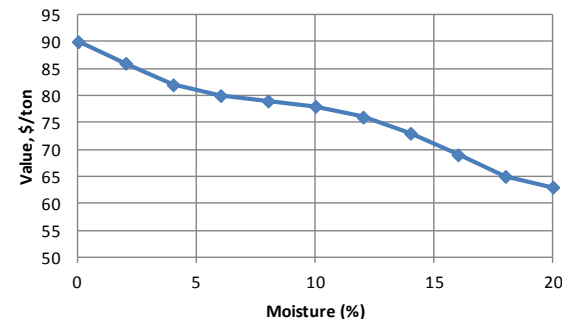
Resource cost vs. volume



Upgrade cost vs. moisture change



Value to refinery vs. moisture

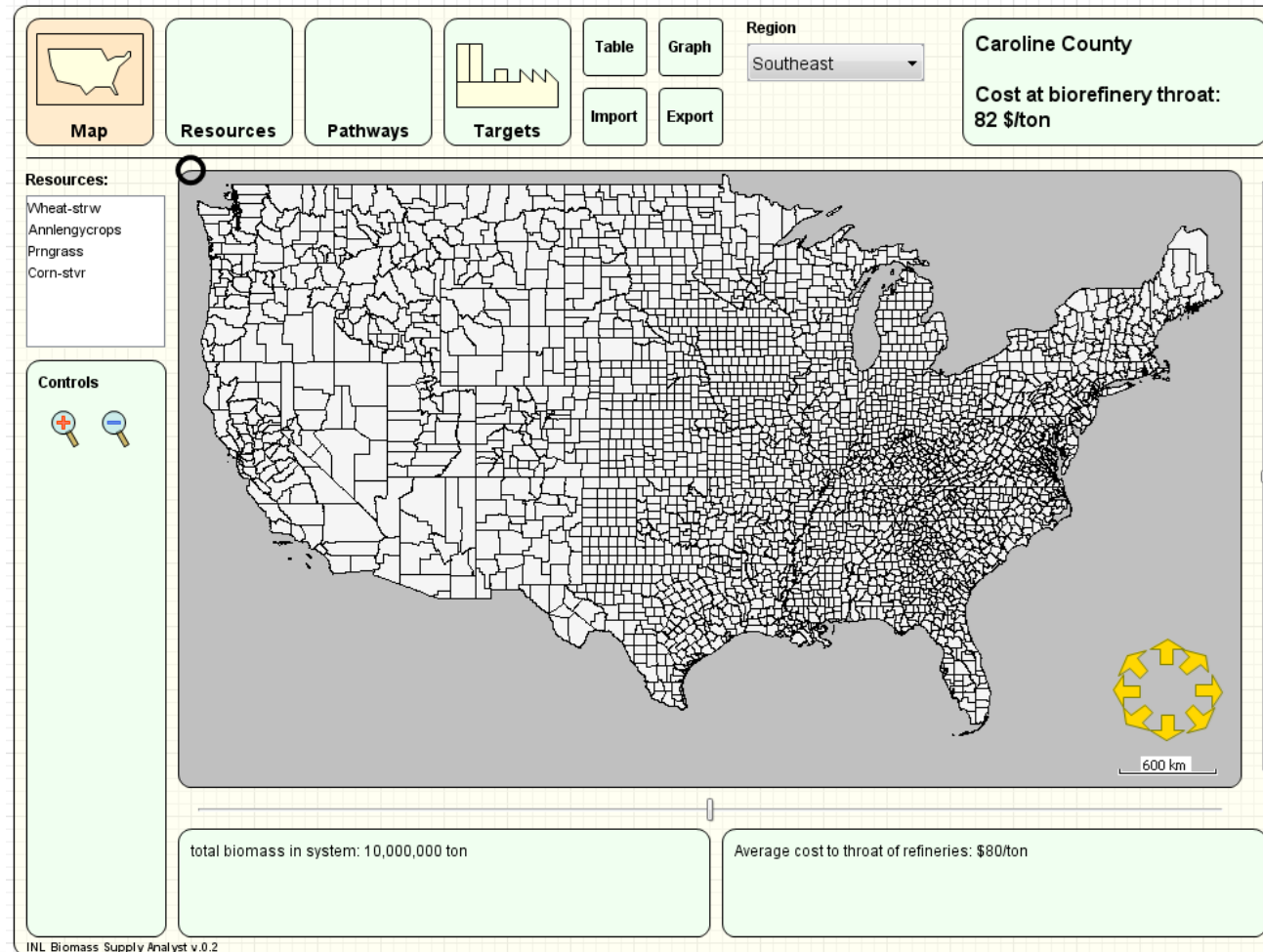


Overview: Visualization and Interface

User access to:

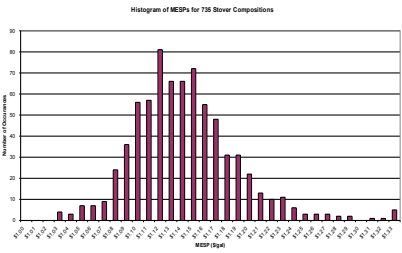
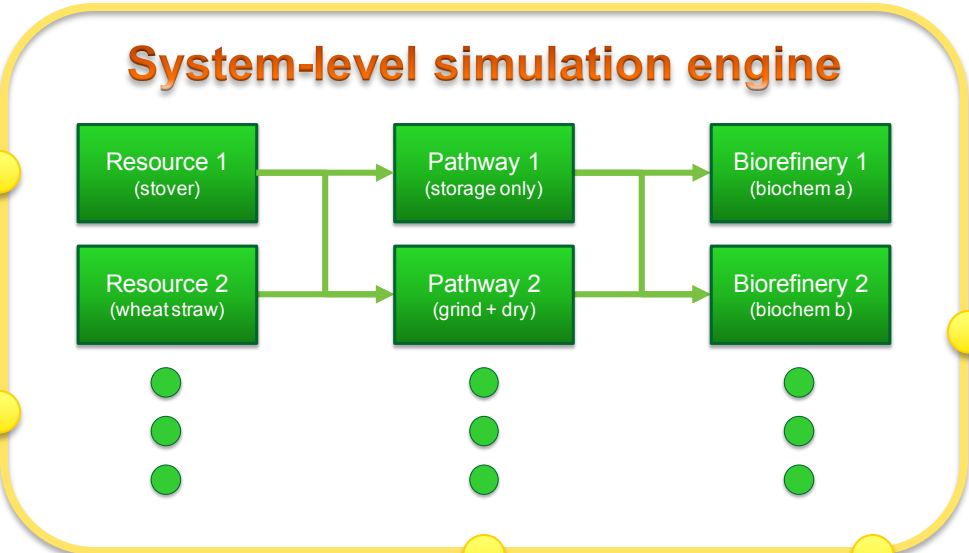
- BTU data
- Characteristics
- Logistics designs
- Biomass blends
- Regional info

Visual web-based
interface for testing
pathway performance
over space and time



1.6.1.9 Approach

Develop integrative tools and methodologies that support large-scale technical, economic, and policy decisions regarding the feedstock supply system



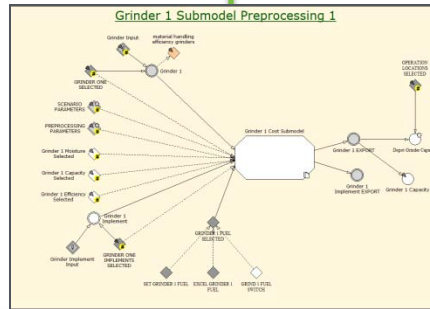
Biomass characteristics library



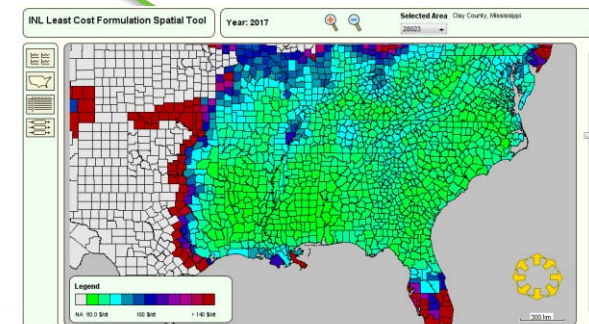
Intuitive user interface

| INL Least Cost Formulation Spatial Tool | | | | | | | | | | | |
|---|-------------------------|------------------|-----------------------------------|-----------------------------|----------|----------|----------|-----------|-----------|-----------|----------|
| Fayette County Illinois | | Year: 2017 | Selected Area: 25 mi ² | Draw Inputs: Populate Table | | | | | | | |
| Population: | 22140 | Current Cost: | 4-899 \$/ton | Current Volume: | 0 ton | | | | | | |
| Area: | 728,228 mi ² | Current Density: | 0 ton/mi ² | | | | | | | | |
| Commodity | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Wheat straw | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stover | 0 | 2000 | 2200 | 700 | 1500 | 1790.27 | 12370.91 | 10229.91 | 20500 | 32000 | 32000.00 |
| Propane | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cellulose | 0 | 1784.42 | 3562.23 | 5095.00 | 719.46 | 6622.28 | 10727.28 | 36993.81 | 30200 | 10200.00 | |
| Cellulose | 0 | 2422.22 | 4844.44 | 7266.67 | 9688.89 | 37150 | 80077.53 | 171402.28 | 285750 | 350807.42 | |
| Aspen | 0 | 1272.39 | 2749.67 | 4725 | 5893.29 | 6988.97 | 8246 | 9612.59 | 8220 | 12800 | |
| LWD | 0 | 1400 | 2260 | 3200 | 3300 | 3400 | 3500 | 3600 | 3700 | 3800 | |
| LWD | 0 | 147.0 | 275 | 382.5 | 489 | 595.5 | 702 | 808.5 | 915 | 1020 | |
| LWD | 0 | 706.67 | 1413.33 | 2120 | 2826.67 | 3533.33 | 4240 | 4946.67 | 5653.33 | 6360 | |
| LWD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| LWD | 0 | 1500 | 3000 | 4500 | 6000 | 7500 | 9000 | 10500 | 12000 | 13500 | |
| MCE | 0 | 400 | 1200 | 2000 | 2800 | 3600 | 4400 | 5200 | 6000 | 6800 | |
| MSW | 200.00 | 7074.24 | 14148.48 | 21222.72 | 28297.96 | 35373.20 | 42448.44 | 49523.68 | 56598.92 | 63674.16 | |
| Total | 2500.00 | 14898.58 | 29797.16 | 44695.74 | 59594.42 | 74493.10 | 89391.78 | 104290.46 | 119189.14 | 134087.82 | |

County-level volume vs. cost



Modular logistics components



Spatial and temporal analysis engine



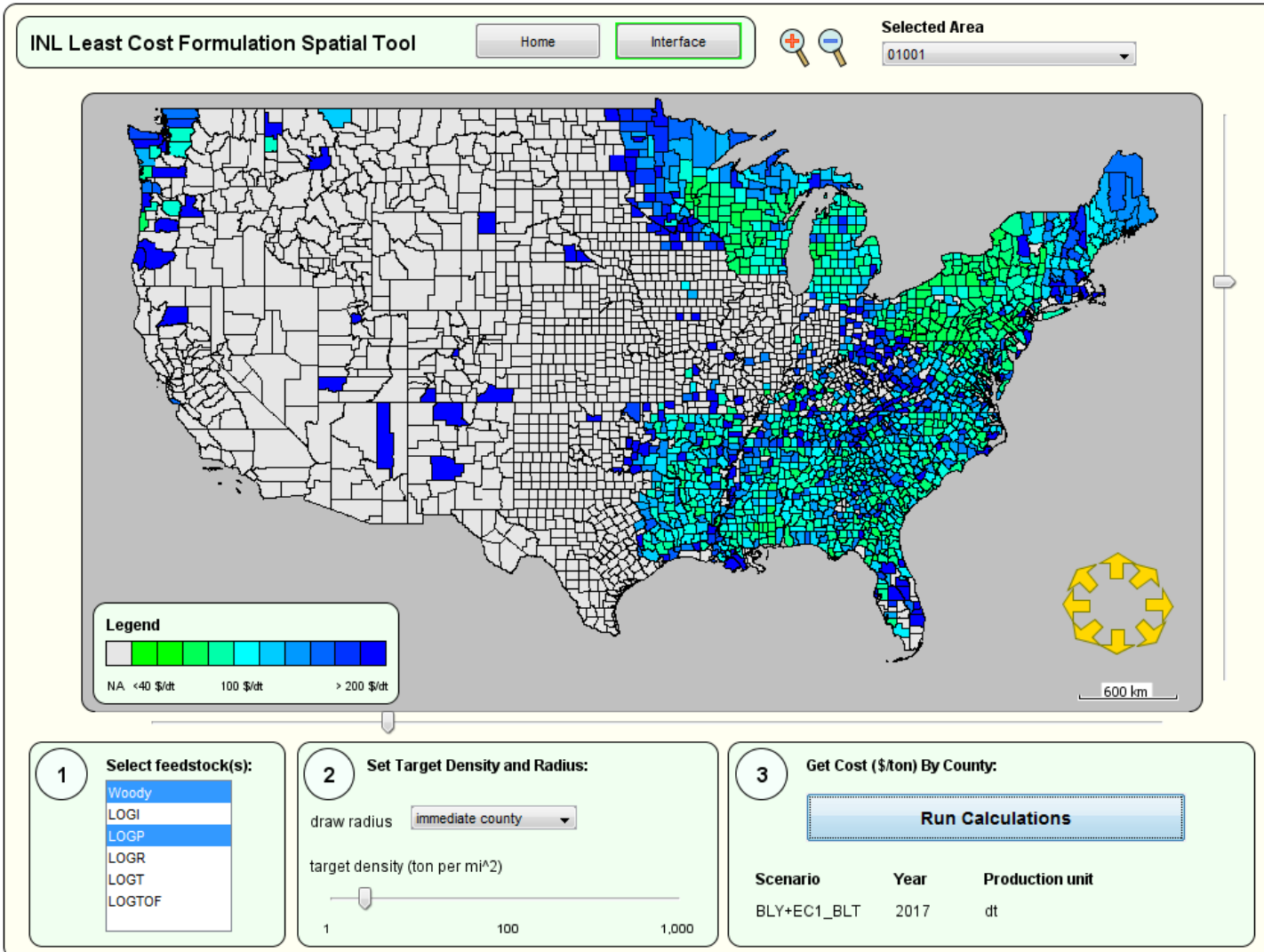
Supported the Joule Milestone of achieving an \$80/dt target delivered feedstock

- Helped to develop supply chains that can deliver high quality, low cost biomass to the biofuel conversion reactor throat.
- Suggested biomass supply chain pathways by region that utilize blending to achieve the \$80/DMT target.

Internally demonstrated that these tools can be published via the web.

- A web-based logistics analysis tool will be deployed in June through the KDF

Clean Wood Chip Cost and Quantity: Landing Price



Primary Resources

- Conventional Wood
- Pulp Wood
- Short Rotation Woody

Results: Least-cost formulation

Formulated Woody Feedstock Cost and Quantity: Landing Price

INL Least Cost Formulation Spatial Tool

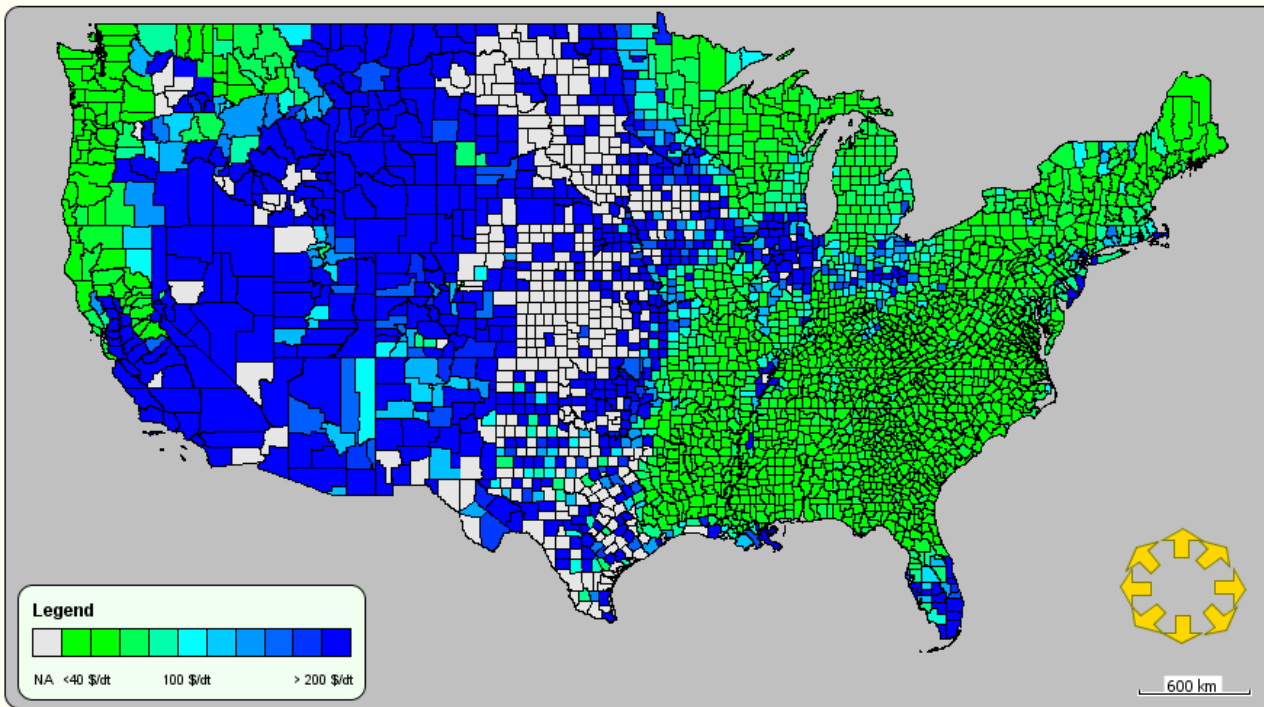
Home

Interface

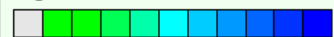


Selected Area

01001



Legend



NA <40 \$/dt 100 \$/dt > 200 \$/dt

600 km

1

Select feedstock(s):

Woody
LOGI
LOGP
LOGR
LOGT
LOGTOF
MRESUU

2

Set Target Density and Radius:

draw radius immediate county

target density (ton per mi²)

1 100 1,000

3

Get Cost (\$/ton) By County:

Run Calculations

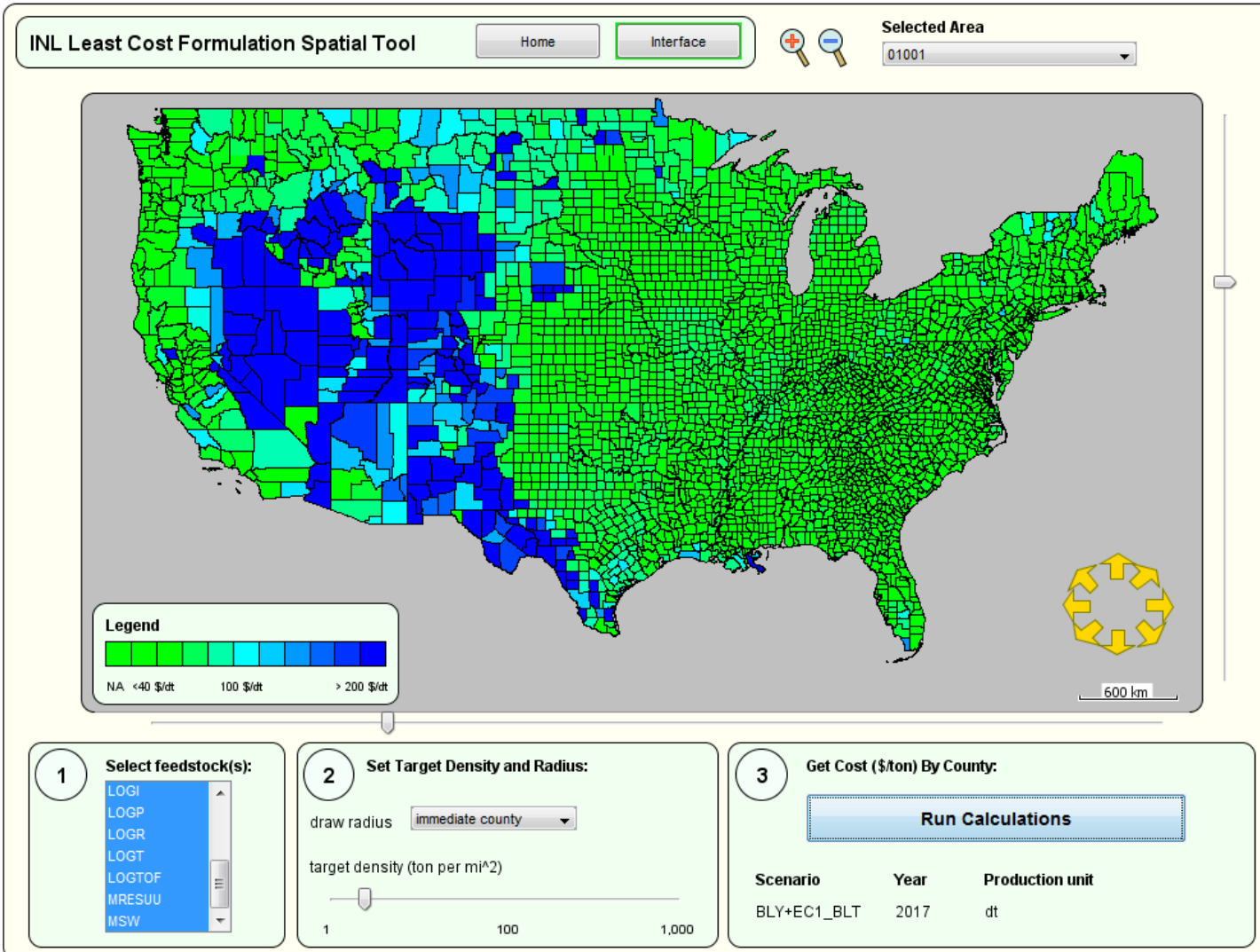
| Scenario | Year | Production unit |
|-------------|------|-----------------|
| BLY+EC1_BLT | 2017 | dt |

Primary Resources

- Conventional Wood
- Pulp Wood
- Short Rotation Woody
- Thinnings
- Logging Residues
- Unused Mill Residues

Results: Least-cost formulation

Formulated Woody/Herbaceous/MSW Blend Feedstock Cost and Quantity: Landing/Farmgate Price



Primary Resources

- Conventional Wood
- Pulp Wood
- Short Rotation Woody
- Thinnings
- Logging Residues
- Unused Mill Residues
- Ag Residues
- Perennial Grasses
- Energy Sorghum
- Potentially Usable Fraction of MSW

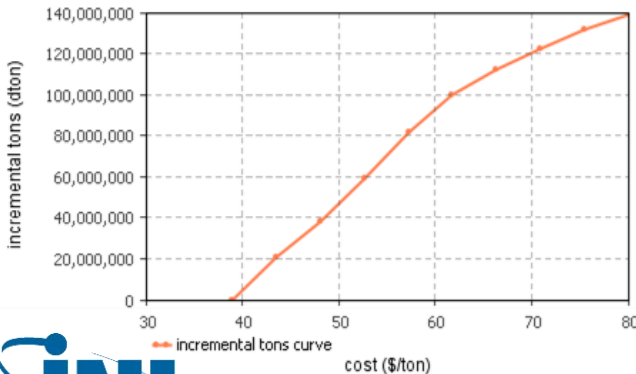
Two types of blending:

Selection of multiple resources with complementary characteristics

Selection of one resource type over multiple periods or locations

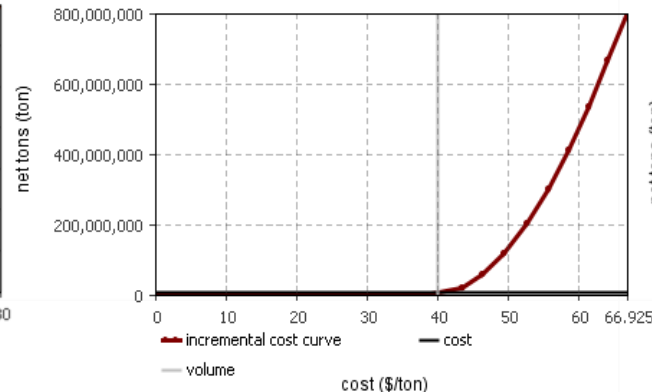
| National feedstock supply for 2017 at \$40/ton | | | Supply (Mton/yr) | Supply (Mton/yr) |
|--|--------------------------------------|------------------------|------------------|--------------------------|
| Resource | | BTU code(s) | No Blending | Intra feedstock blending |
| Agricultural Residues | Corn Stover | Corn-strv | 13.87 | 22.74 |
| | Cereal Straw | Wheat-strw, Oats-strw | 3.21 | 5.27 |
| Energy Crops | Herbaceous energy crops | Perngrass, Annlengycrp | 4.61 | 7.56 |
| | Woody energy crops | Woody | 0.01 | 0.01 |
| Forest Resources | Pulpwood | LOGP | 0.02 | 0.06 |
| | Logging residues and fuel treatments | LOGR | 101.17 | 164.02 |
| | Other forestland removals | LOGT, LOGTOF | 36.95 | 60.22 |
| | Urban and mill wood wastes | MRESUU | 4.56 | 7.79 |
| Potential feedstock supply (Totals) | | | 164.4 | 267.67 |

Incremental volume vs. cost



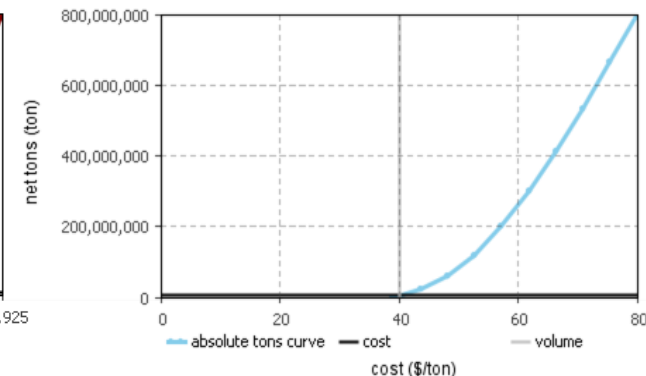
Interpolated Volume = 7,564,127.2 tons

Net volume vs. average cost paid

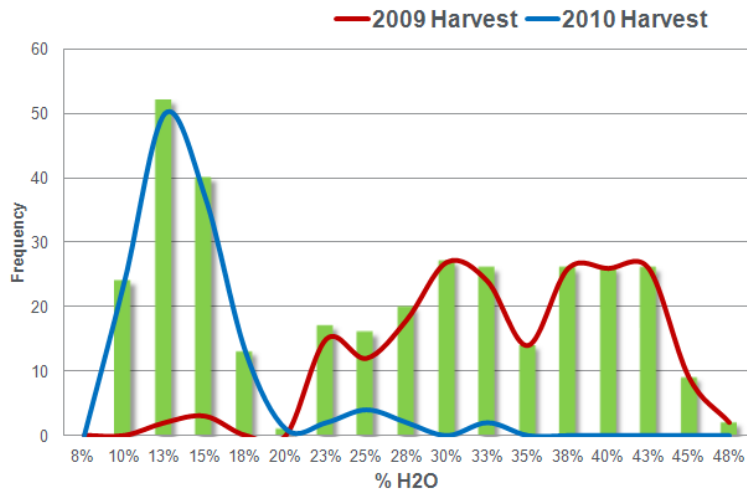


Interpolated Value = 4,612,272.683 tons

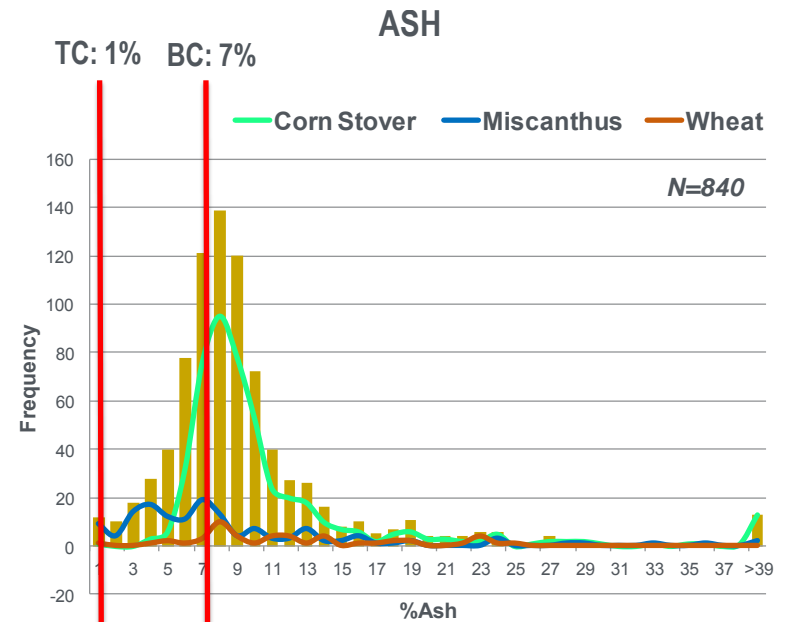
Net volume vs. last cost paid



Variability over time



Distributed blending to spec



Relevant to industry

- Can show return on investment in logistics systems
- Shows the most promising logistics designs by location and year

Relevant to BETO

- Publishing online gives a clear indication of “vision”
- Informs the most promising areas of technical research

Relevant to researchers

- Easy and fast access to spatial and temporal cost and characteristic information
- Feedback & discussion: quickly implement design ideas

Library:

- Encourage collaborators to further populate the Biomass Library
- Increase the pedigree of the data in the library
- Minimize data “gaps” – defined by areas of analytic difficulty

Logistics model:

- Modularize the Logistic Submodels to allow dynamic coupling
- Develop a web-based logistics analysis tool – deploy in KDF
- Incorporate predictive algorithms based on Library data

Overall toolset:

- Integrate with and inform industry partners
- Show return on investment in depot systems
- Become predictive about the most promising feedstock pathways

Data:

Updated BTU database

example: questionable information from “woody, perngrass”

Continuously evolving Biomass Resource Library

work “BRL data upload” into projects’ milestones

Biorefinery behavior vs. feedstock characteristics

example: how much does it cost to accept biomass above ash targets?

Below? What determines the value of the feedstock?

Analytics:

Determine preprocessing/logistics cost dynamics

example: in anomaly years, how do depots buffer characteristics, lowering the overall long-term cost of operation?

Publish tools online and get feedback from researchers and BTOE

Continue to discuss ideal “blends” for different regions

Publishing:

Extend beyond our “normal” publishing avenues

examples: Biomass & Bioenergy (elsevier), Energy & Fuels (ACS), System Dynamics Society, others?



- **Approach...**

From biomass to feedstock: Biomass with variable characteristics over time and space, to commoditized bioenergy feedstocks with reliable characteristics.

From descriptive to predictive: Developing tools that inform feedstock supply chain pathways instead of simply analyzing them.

Full integration:

- **Outcomes...**

To date: Over 50,000 data points in the Biomass Library, modularization of grinding and drying unit operations for the Biomass Logistics Model, incorporation of Billion Ton Update data in the Least Cost Formulation Model

To come: Automated analysis of multiple feedstock pathways by incorporating cost-predictive models based on biomass characteristics at multiple points in the supply chain.



Questions



Least Cost Formulation of Biomass to Reduce the Cost of Renewable Hydrocarbon Fuels, Dave Muth, Robert Jeffers, Jake Jacobson, Kara Cafferty, Kenneth Bryden, Accepted to 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit and 11th International Energy Conversion Engineering Conference. July, 2013.

Robert F. Jeffers, Jacob J. Jacobson, Erin M. Searcy. (INL) *Dynamic Analysis of Policy Drivers for Bioenergy Commodity Markets*, Energy Policy (January 2013). The publication is a summation of the results of a dynamic analysis of the competition for biomass for three competing entities, biofuel, biopower and international exports.

Link: <http://www.sciencedirect.com/science/article/pii/S0301421512007549>