1.6.1.9 Goals: Supply System Integration

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
## Timeline

<table>
<thead>
<tr>
<th>Project Start Date</th>
<th>Oct. 1, 2009</th>
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<tr>
<td>Project End Date</td>
<td>Sept. 30, 2022</td>
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## Barriers

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<th>Barrier</th>
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<tr>
<td>Ft-M: Overall Integration</td>
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<tr>
<td>St-F: Systems Approach</td>
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## Budget

<table>
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<tr>
<th>Year</th>
<th>Funding</th>
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<tr>
<td>FY11</td>
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<td>FY12</td>
<td>$250k</td>
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<td>FY13</td>
<td>$750k</td>
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<td>Average funding per year</td>
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<td>Years funded to date</td>
<td>5 years</td>
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## Partners

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<th>Partner</th>
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<tbody>
<tr>
<td>National Renewable Energy Lab</td>
</tr>
<tr>
<td>Oak Ridge National Laboratory</td>
</tr>
<tr>
<td>Biomass R&amp;D Library Consortium</td>
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<tr>
<td>Iowa State University</td>
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1.6.1.9 Project Overview

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

**Image Descriptions:**

- **Biomass characteristics library**
- **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

\[ y = 321.69x^{1.097} \]
\[ R^2 = 0.9995 \]
Overview: Biomass Logistics Model Framework

Inputs:
- Volume
- Characteristics
- Desired output specs

Outputs:
- Volume
- Characteristics
- Cost

Modular logistics components

- System Dynamics Analytic Engine
- Location Sub-model
- Unit Operation Sub-model
- Equipment Sub-model
- Cost Sub-model
- Spatial Data: Crop Yields, Climate, Road Networks, Local Regulations, etc.
- Equipment Performance Data: Capital Costs, Fuel Usage, Capacities, Efficiencies, etc.
- Labor Data: Spatially Explicit Agribusiness, Transportation, Equipment Operator, etc. Labor Statistics
Overview: System-level Simulation Engine

Resource cost vs. volume

Upgrade cost vs. moisture change

Value to refinery vs. moisture

Resource 1 (LOGP)

F_{1-1}

F_{1-2}

Pathway 1 (storage only)

Biorefinery 1 (thermochem a)

Resource 2 (LOGT)

F_{2-1}

F_{2-2}

Pathway 2 (grind + dry)

Biorefinery 2 (thermochem b)
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.

**System-level simulation engine**

- **Resource 1** (stover) → **Pathway 1** (storage only) → **Biorefinery 1** (biochem a)
- **Resource 2** (wheat straw) → **Pathway 2** (grind + dry) → **Biorefinery 2** (biochem b)

**Biomass characteristics library**

**County-level volume vs. cost**

**Modular logistics components**

**Intuitive user interface**

**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
Results: Least-cost formulation

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

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

Legend
- HA <40 HA
- 40-100 HA
- > 100 HA

INL Least Cost Formulation Spatial Tool

1. Select feedstock(s):
   - Woody
   - LOGI
   - LOGP
   - LOGR
   - LOGT
   - LOGTOP
   - NRESUU

2. Set Target Density and Radius:
   - draw radius: immediate county
   - target density (ton per m^2):
     - 1
     - 100
     - 1,000

3. Get Cost ($/ton) By County:
   - Scenario: ELY-EC1_BLT
   - Year: 2017
   - Production unit: d1

Run Calculations
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

<table>
<thead>
<tr>
<th>Resource</th>
<th>BTU code(s)</th>
<th>Supply (Mton/yr) No Blending</th>
<th>Supply (Mton/yr) Intra feedstock blending</th>
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</thead>
<tbody>
<tr>
<td>Agricultural Residues</td>
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<tr>
<td>Corn Stover</td>
<td>Corn-strv</td>
<td>13.87</td>
<td>22.74</td>
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<tr>
<td>Cereal Straw</td>
<td>Wheat-strw, Oats-strw</td>
<td>3.21</td>
<td>5.27</td>
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<td>Energy Crops</td>
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<td></td>
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<tr>
<td>Herbaceous energy crops</td>
<td>Penngrass, Annlengycrp</td>
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<td>7.56</td>
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<tr>
<td>Woody energy crops</td>
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<td>Forest Resources</td>
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<tr>
<td>Pulpwood</td>
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<td>0.06</td>
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<td>Logging residues and fuel treatments</td>
<td>LOGR</td>
<td>101.17</td>
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<tr>
<td>Other forestland removals</td>
<td>LOGT, LOGTOF</td>
<td>36.95</td>
<td>60.22</td>
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<td>Urban and mill wood wastes</td>
<td>MRESUU</td>
<td>4.56</td>
<td>7.79</td>
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<tr>
<td>Potential feedstock supply (Totals)</td>
<td></td>
<td>164.4</td>
<td>267.67</td>
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</table>
Results: Library informs pathways

**Variability over time**

- 2009 Harvest
- 2010 Harvest

**Distributed blending to spec**

- TC: 1%
- BC: 7%

ASH

*N=840*
Relevance

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
Success Factors

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
Future Work

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?
Summary

• 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.