2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

1.6.1.9 Feedstock Supply System Integration

May 23, 2013
Sustainability and Analysis Platform

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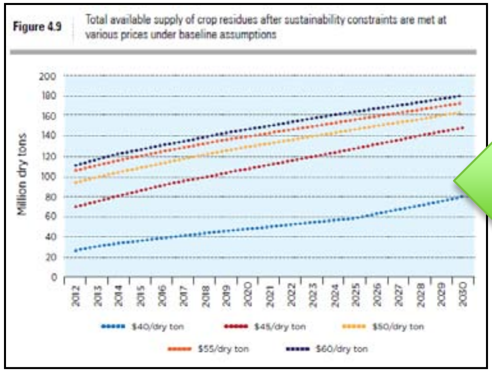
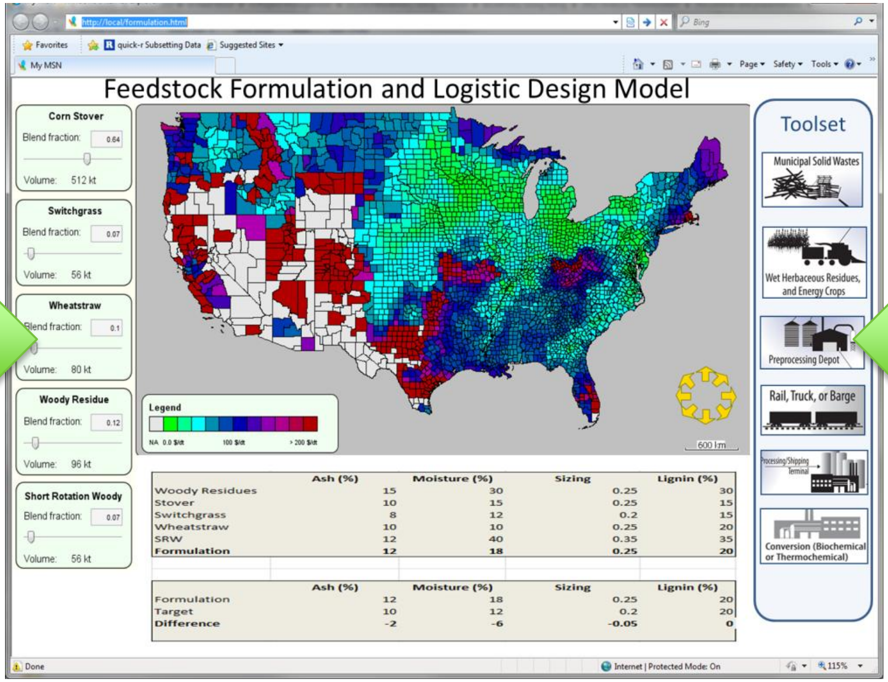
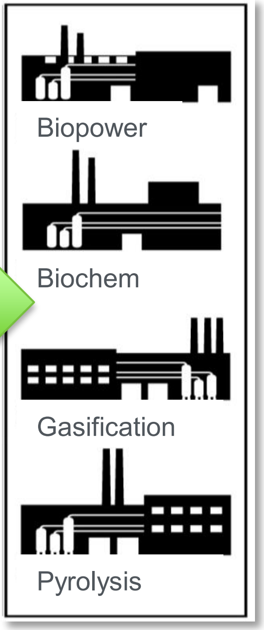
Idaho National Laboratory

Goal Statement

- Develop and deliver the analytic capability required to:
  - Sustainably maximize the biomass resources entering the supply chain
  - Decrease delivered feedstock cost
  - Achieve biomass feedstock performance requirements







Project Quad Chart Overview

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Timeline

- Project start date: 10/01/2009
- Project end date: 09/30/2017
- Percent complete: 50%

Barriers

- Ft-A. Feedstock Availability and Cost
- Ft-M. Overall Integration
- St-F. Systems Approach

Budget

- Total Funding = $1,600,000
  - DOE share – 100%
  - Contractor share – 0%
- Funding in FY11 = $450,000
- Funding in FY12 = $400,000
- Funding in FY13 = $750,000

Partners

- DOE Regional Feedstock Partnership
- Oak Ridge National Laboratory
- National Renewable Energy Laboratory
- Pacific Northwest National Laboratory
- Iowa State University

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Project Overview

Historically supply chain analysis has focused on the cost of operating the minimum set of equipment to get material into a biorefinery reactor.

But several challenges have emerged

- Feedstock variability
- Supply chain business models
- Active controls for key specs
- Sustainability metrics

So this project was developed to:

- Integrate the biomass library
- Couple to the resource
- Build capability for advanced preprocessing analyses
- Integrate sustainability assessment capability

1 - Approach

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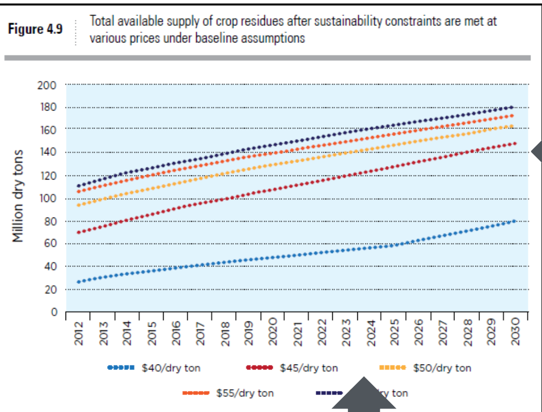
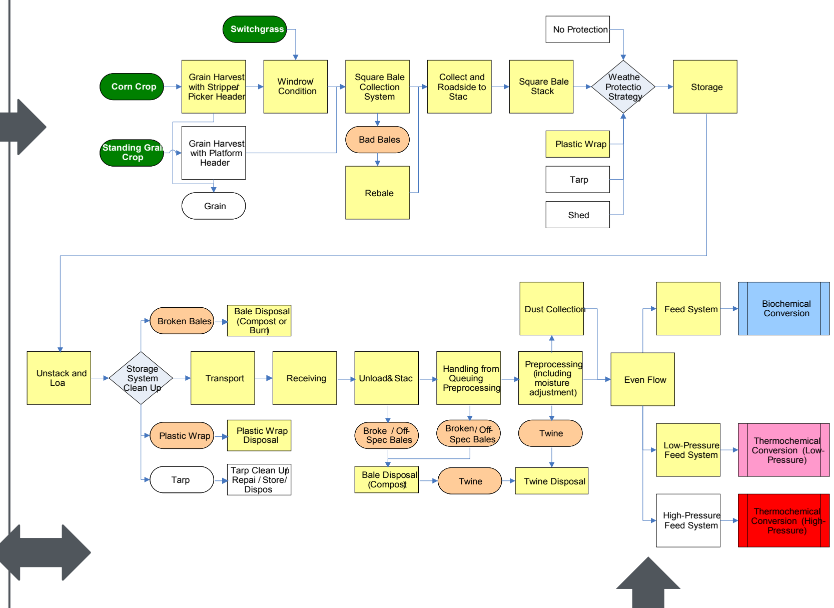
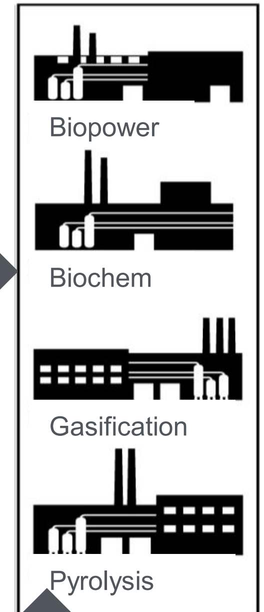
Supply Curves

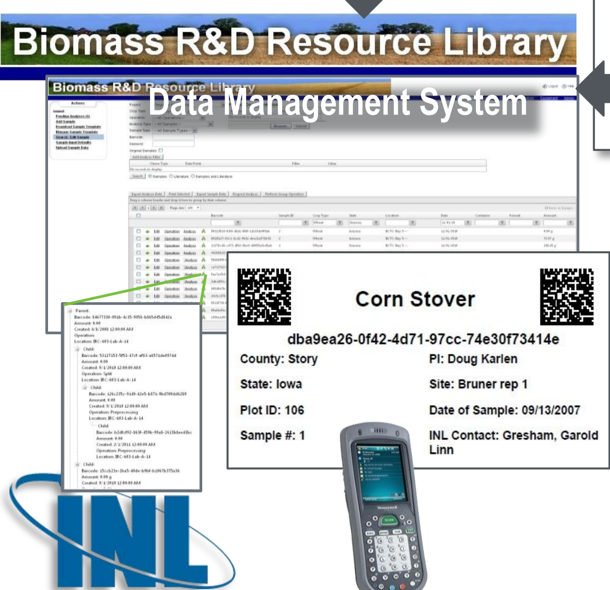


Supply System Engineering



Conversion Interface





Model Integration Interface

- Powersim
- Extend
- Excel
- SAS
- Aspen
- ChemCAD
- ESRI

2 – Technical Progress: Biomass Library

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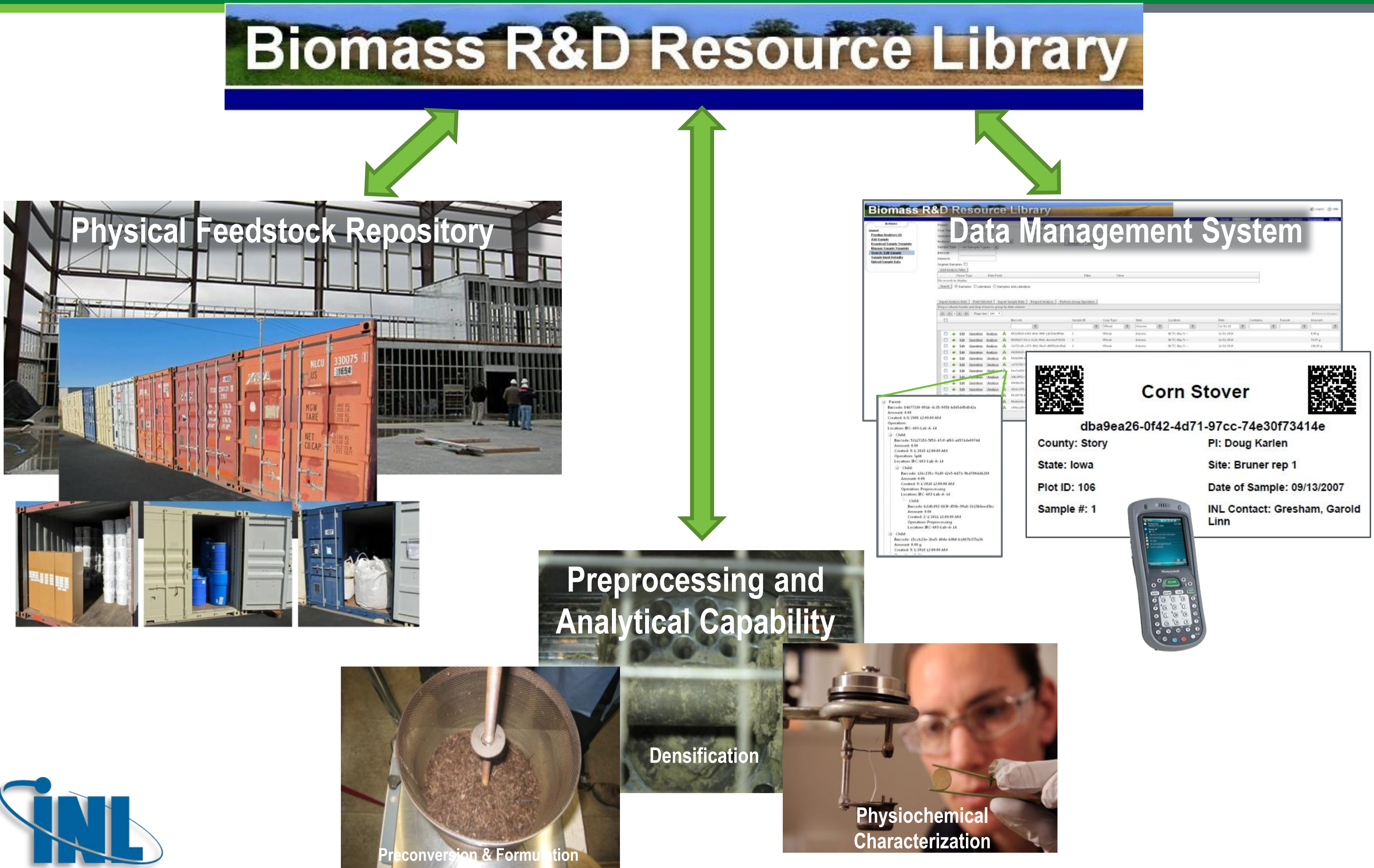

2 – Technical Progress: Biomass Library

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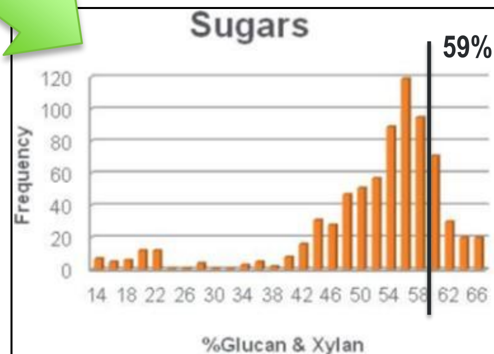
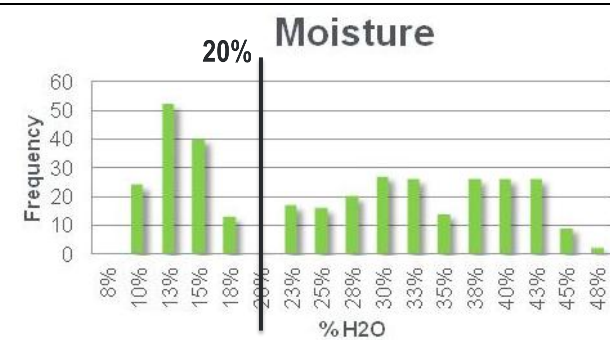
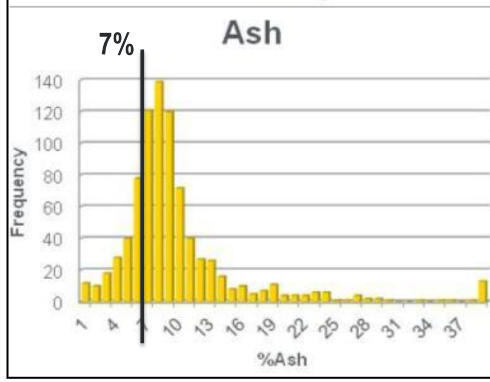
- Over 60,000 Samples
- Computational Infrastructure
- Field-to-Fuel







Particle Size & Distribution
- NREL: ¾” minus
- AFEX: ¼” minus, narrow PSD

2 – Technical Progress: Biomass Library

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Summary – Corn Stover
Sample Count: 7337
Characterized: 2576

Glucan (n=572)
Mean: 33.95%
Stdev: 3.49%

Xylan (n=611)
Mean: 18.74%
Stdev: 2.77%

Ash (n=690)
Mean: 9.552%
Stdev: 7.79%

Moisture (n=507)
Mean: 17.01%
Stdev: 13.07%

HHV (n=136)
Mean: 7318 Btu/lb
Stdev: 466 Btu/lb

LHV (n=133)
Mean: 5911 Btu/lb
Stdev: 544 Btu/lb

Summary
Year: 2007
Sample Count: 178

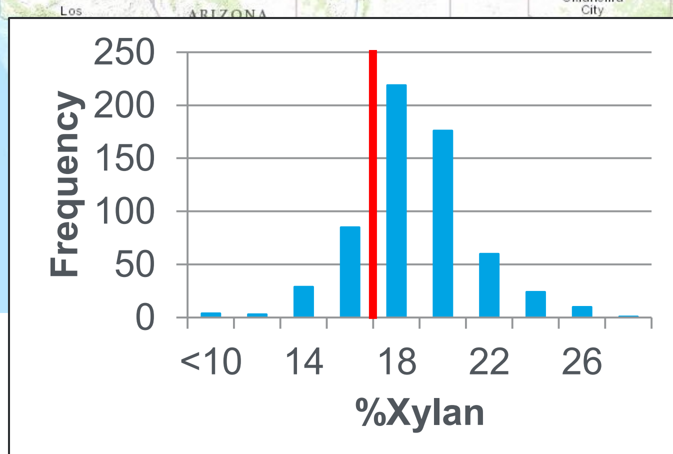
Glucan (n=135)
Mean: 31.98% Stdev: 3.43%

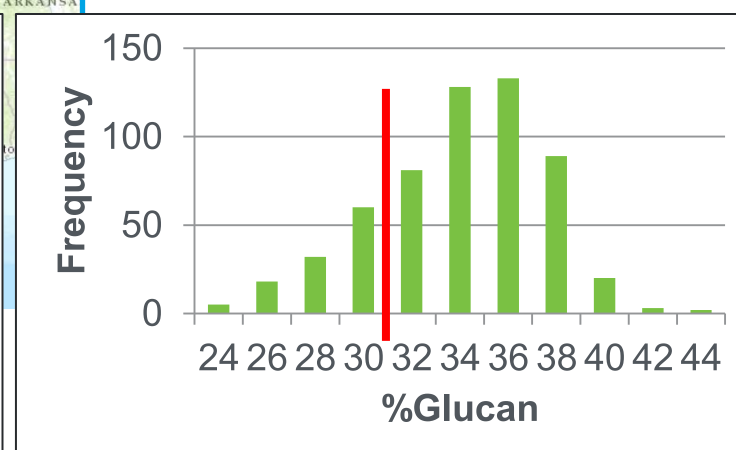
Xylan (n=147)
Mean: 17.16% Stdev: 2.23%

Ash (n=166)
Mean: 7.54% Stdev: 1.77%

Moisture (n=0)
Mean: N/A Stdev: N/A

HHV (n=68)
Mean: 7273 Btu/lb Stdev: 167 Btu/lb





2 – Technical Progress: Biomass Library

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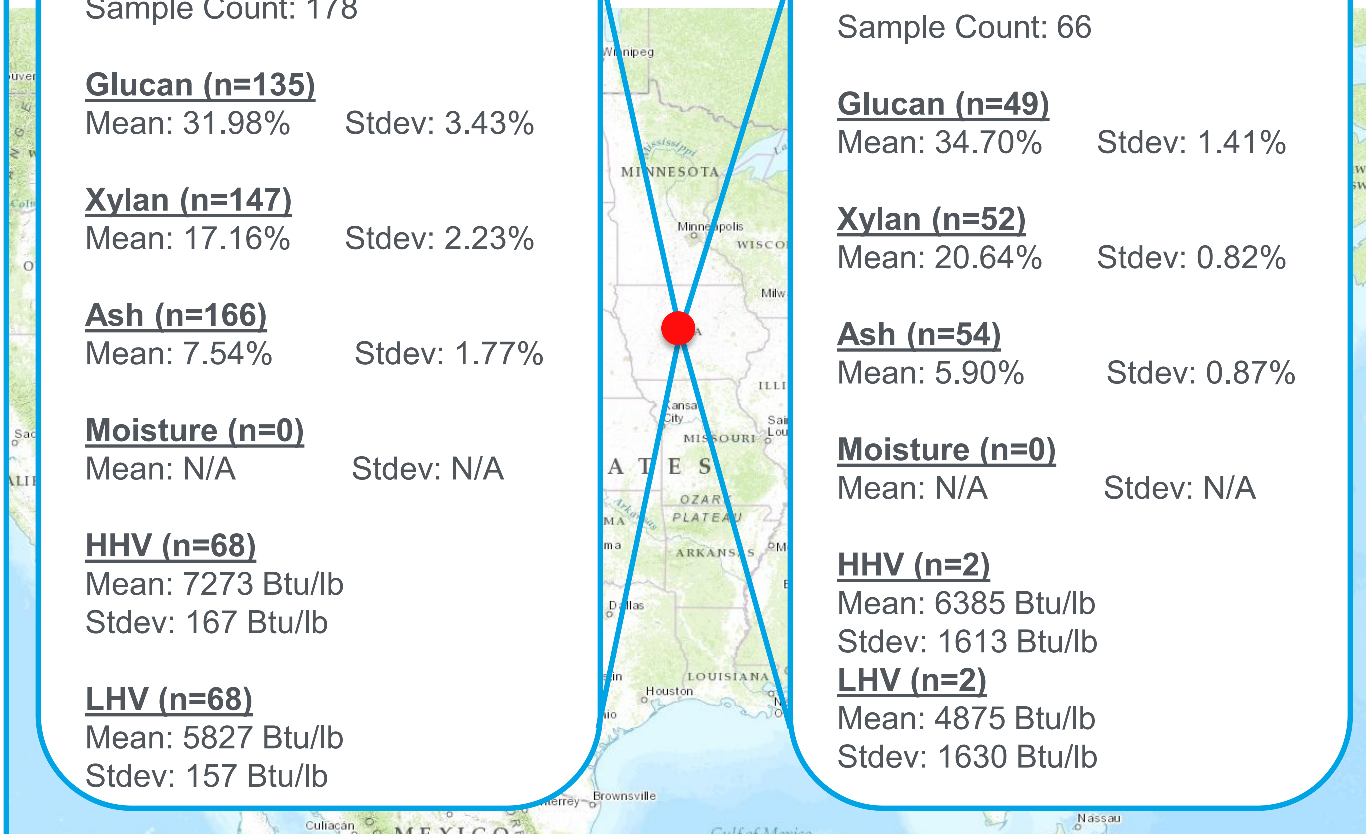

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HHV (n=68)
Mean: 7273 Btu/lb
Stdev: 167 Btu/lb

LHV (n=68)
Mean: 5827 Btu/lb
Stdev: 157 Btu/lb

Summary
Year: 2009
Sample Count: 66

Glucan (n=49)
Mean: 34.70% Stdev: 1.41%

Xylan (n=52)
Mean: 20.64% Stdev: 0.82%

Ash (n=54)
Mean: 5.90% Stdev: 0.87%

Moisture (n=0)
Mean: N/A Stdev: N/A

HHV (n=2)
Mean: 6385 Btu/lb
Stdev: 1613 Btu/lb

LHV (n=2)
Mean: 4875 Btu/lb
Stdev: 1630 Btu/lb

2 – Technical Progress: Resource Coupling

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Figure 4.11 Supply curves of potential corn stover production for various years under baseline assumptions

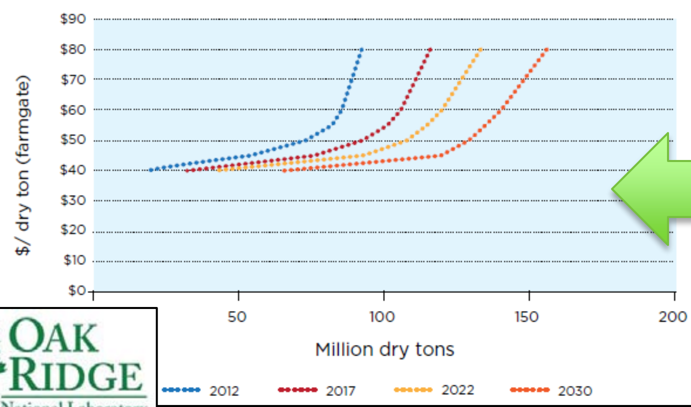
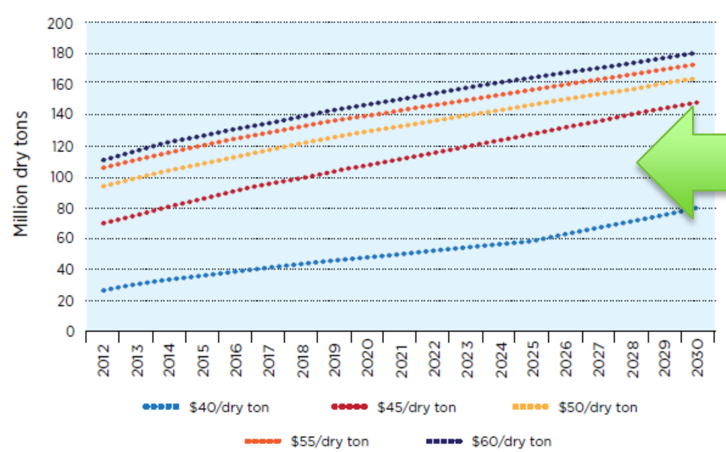
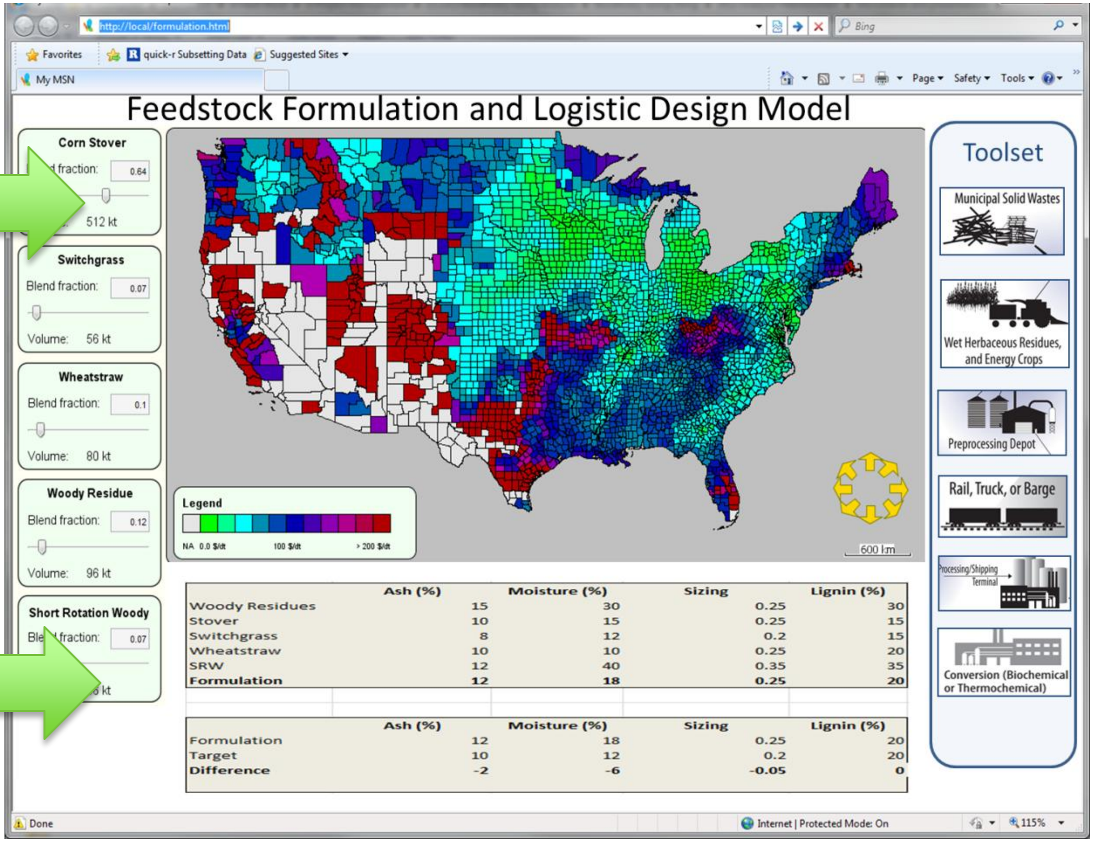


Figure 4.9 Total available supply of crop residues after sustainability constraints are met at various prices under baseline assumptions





	Ash (%)	Moisture (%)	Sizing	Lignin (%)
Woody Residues	15	30	0.25	30
Stover	10	15	0.25	15
Switchgrass	8	12	0.2	15
Wheatstraw	10	10	0.25	20
SRW	12	40	0.35	35
Formulation	12	18	0.25	20

	Ash (%)	Moisture (%)	Sizing	Lignin (%)
Formulation	12	18	0.25	20
Target	10	12	0.2	20
Difference	-2	-6	-0.05	0

OAK RIDGE National Laboratory

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2 – Technical Progress: Resource Coupling

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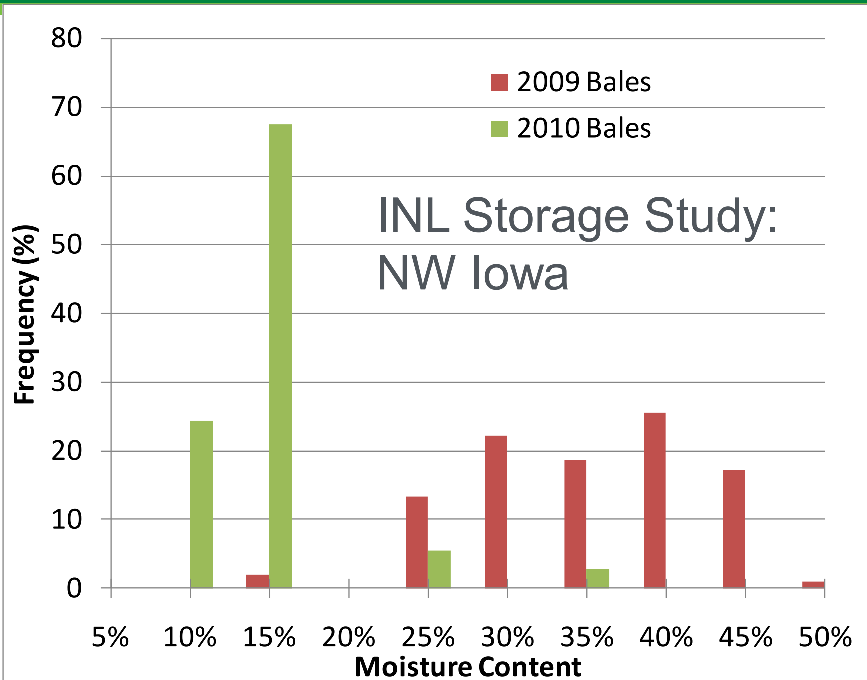
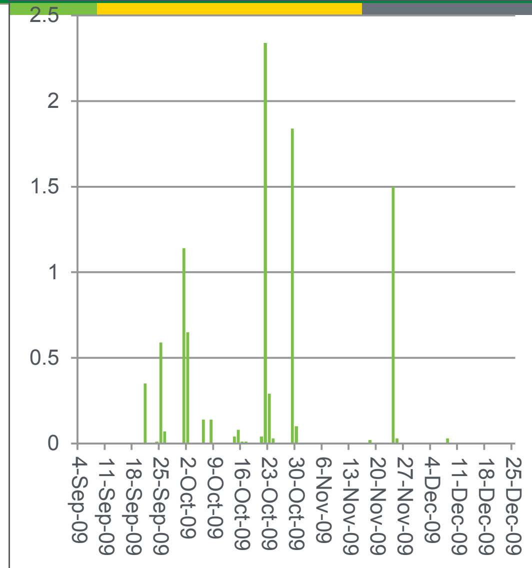
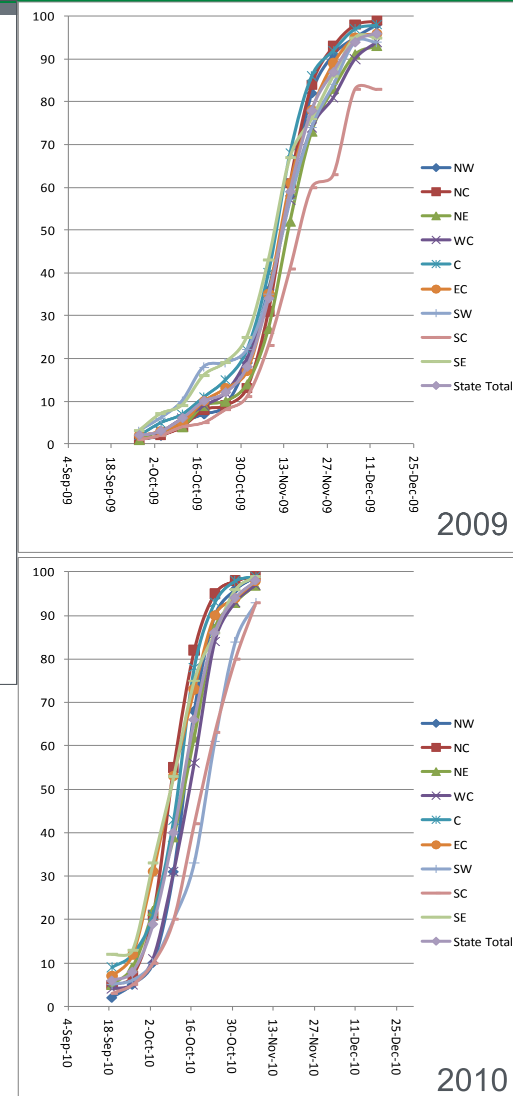




2009 Daily Precipitation (in)
Boone County, IA



Harvest progress (corn grain) by week in Iowa: 2009, 2010 by Crop Reporting District

- Coupling supply systems explicitly to the resources facilitates an understanding of the specifications of material entering the system
- Conventional bale-based systems
  - < 15% moisture
- Places significant requirements on data management and modeling approaches

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Least Cost Formulation

What is it?

- Standard practice in the animal feed industry
- Identify the least cost resources necessary to achieve a performance target

Our Challenges

- No commodity markets setting price points and making material available
- Characterization requirements
- Predicting performance
- Fast and low cost screening

Feed Reference No. QuickFinder

110

Feed No	Ingredient Name	As-Fed Diet Composition	$/Cwt As-Fed
145	COTTONSEED HULLS	15	
405	Corn Grain Cracked		
404	Corn Hominy	53	
510	Distillers Gr. Dehy - Inter.	30	
812	Limestone	2	
	As-Fed Total	100	
	Dry Matter Total	90.5	

Predicted DMI: lbs/hd/d, %BW	14.44	2.35	
Estimated DMI: lbs/hd/d, %BW	14.44	2.35	
DMI Adjuster	100	% Predicted DMI	

NUTRIENT PROFILE

	DIET DM COMP*	DIET PROVIDED	ANIMAL REQ.		Percent Requirement
Dry Matter %	90.5		--------		
NDF %	39.1		--------		
eNDF (%DM)	6.7				
TDN %	82.0				
ME (Mcal/lb)	1.35				
NEm (Mcal/lb)	0.91	5.34	5.34	Mcal	100%
NEg (Mcal/lb)	0.61	5.55	4.92	Mcal	113%
CP %	15.9	2.29	2.07	lbs	111%
DIP (%CP)	40.4	0.926	1.027	lbs	90%
Fat %	7.3				
Ca %	0.88	0.127	0.083	lbs/d	154%
P %	0.56	0.082	0.044	lbs/d	186%
Mg %	0.28	0.041	0.014	lbs/d	282%
K %	0.67	0.097	0.087	lbs/d	112%
Na %	0.14	0.020	0.012	lbs/d	174%
S %	0.15	0.022	0.022	lbs/d	100%
Co ppm	0.09	0.57	0.656	mg/d	86%
Cu ppm	11.16	73.20	65.615	mg/d	112%
I ppm	0.03	0.17	3.281	mg/d	5%
Fe ppm	228	1492.78	328.074	mg/d	455%
Mn ppm	16.81	110.31	131.229	mg/d	84%
Se ppm	0.12	0.79	0.656	mg/d	121%
Zn ppm	20.45	134.20	196.844	mg/d	68%

***Values are not valid if numbers are missing from an ingredient's profile in the feed list**

PERFORMANCE INDICATORS

Calf Weight (lbs)	615
Desired Rate of Gain (lbs/d)	3.00
Energy Predicted Rate of Gain (lbs/d)	3.49
As-Fed Feed Cost per lb gain	0.000
Dry Matter Feed Conversion (Feed:Gain)	4.1

BALANCE ISSUES

MAKE SURE ENOUGH FIBER IS IN THE DIET FOR RUMEN HEALTH

Current Ca:P 1.56 :1

HIGH FAT WARNING, LOWER HIGH FAT INGREDIENT

2 – Technical Progress Advanced Preprocessing

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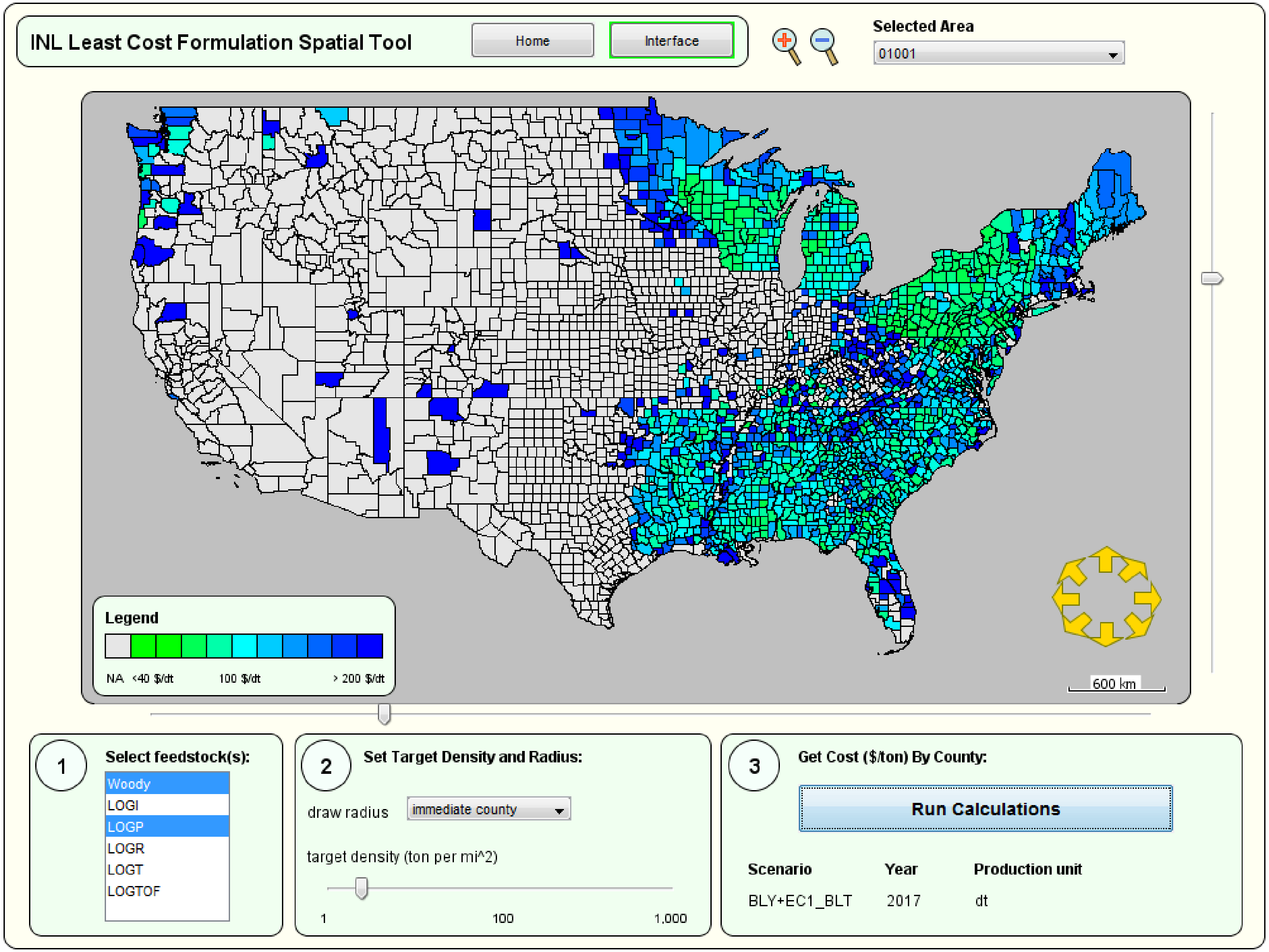
Clean Wood Chip Cost and Quantity: Landing Price



Primary Resources

- Conventional Wood
- Pulp Wood
- Short Rotation Woody

2 – Technical Progress
Advanced Preprocessing

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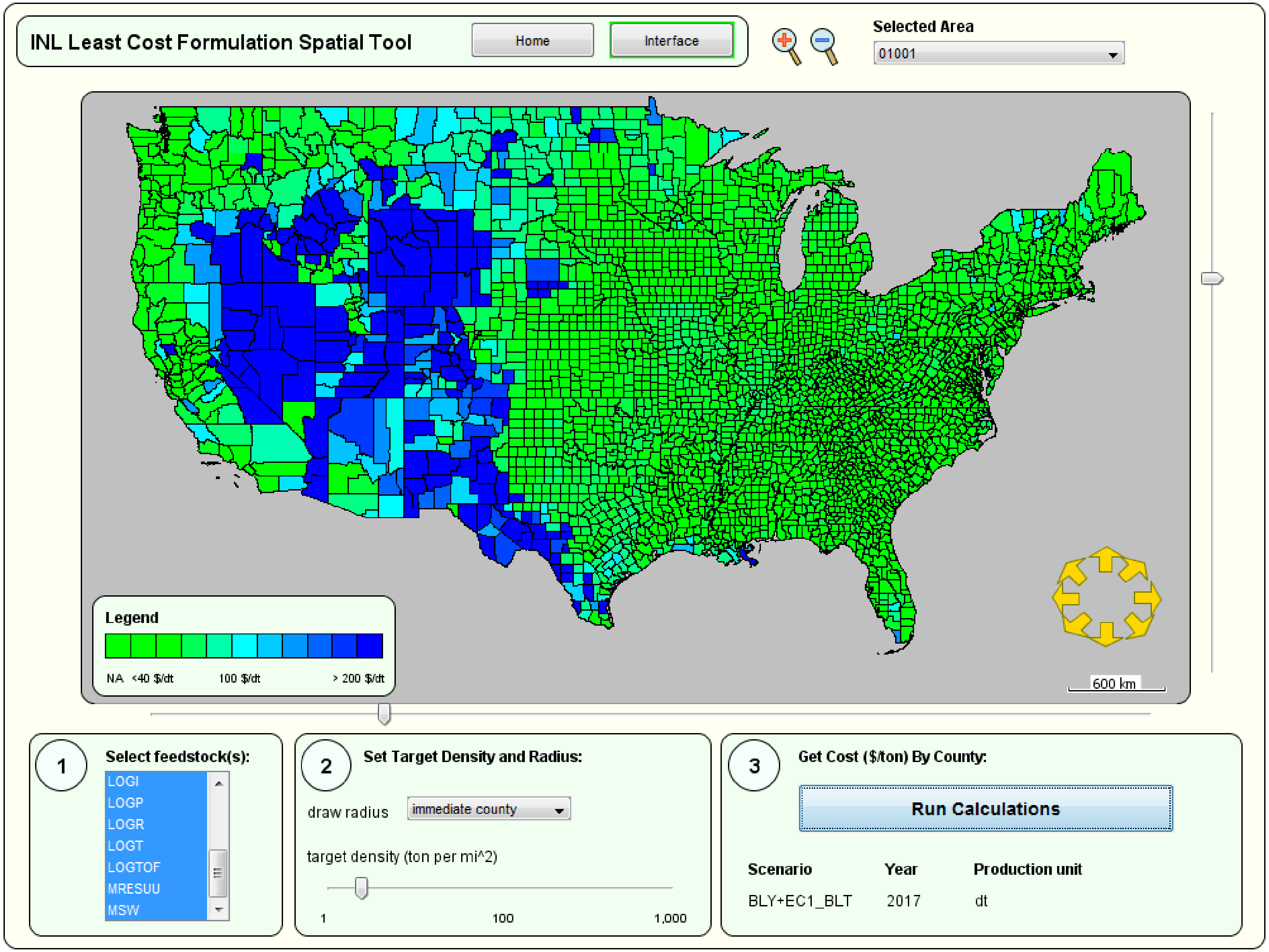
Formulated Woody/Herbaceous/MSW Blend Feedstock Cost and Quantity: Landing/Farmgate Price



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

2 – Technical Progress Advanced Preprocessing

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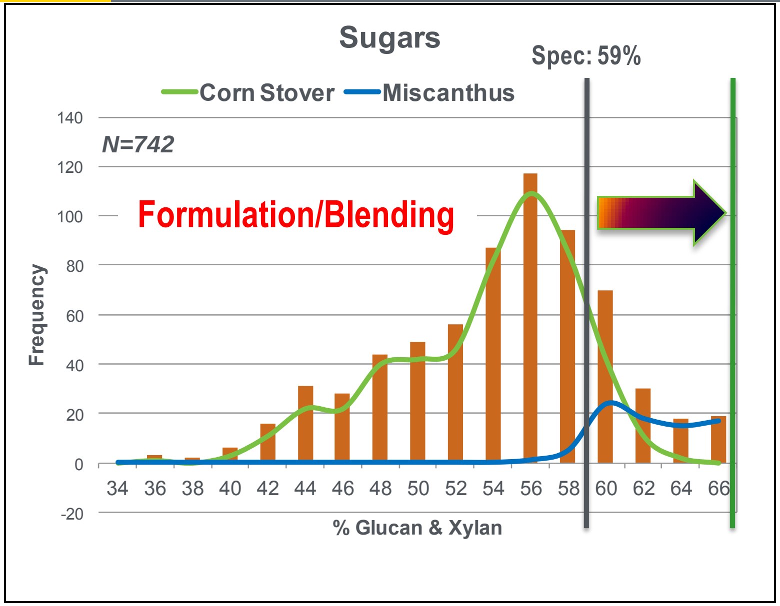
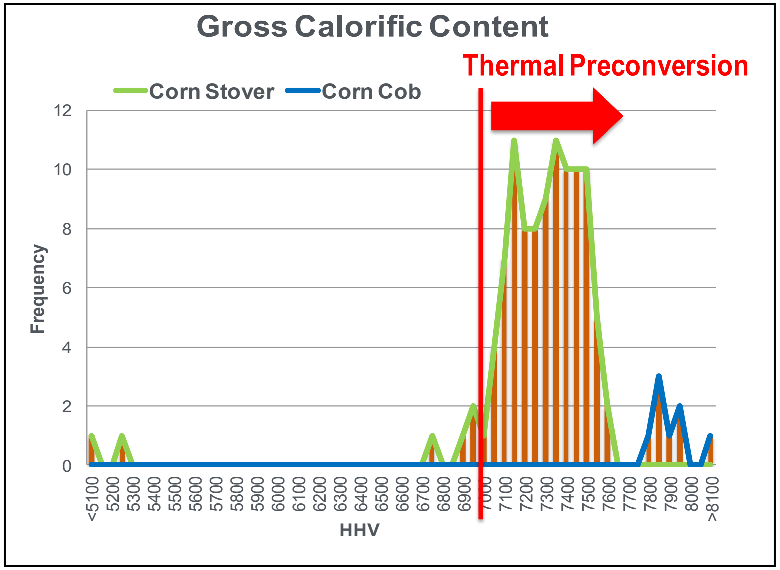
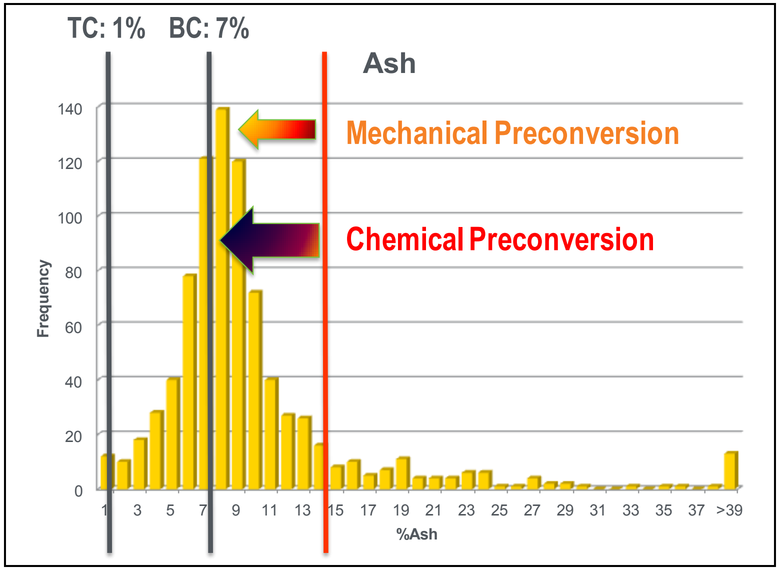
- Formulation of raw biomass can reduce variability
- Lowest cost resources are typically low quality
- Least cost formulation provides an opportunity to implement active quality controls within cost constraints







2 – Technical Progress Advanced Preprocessing

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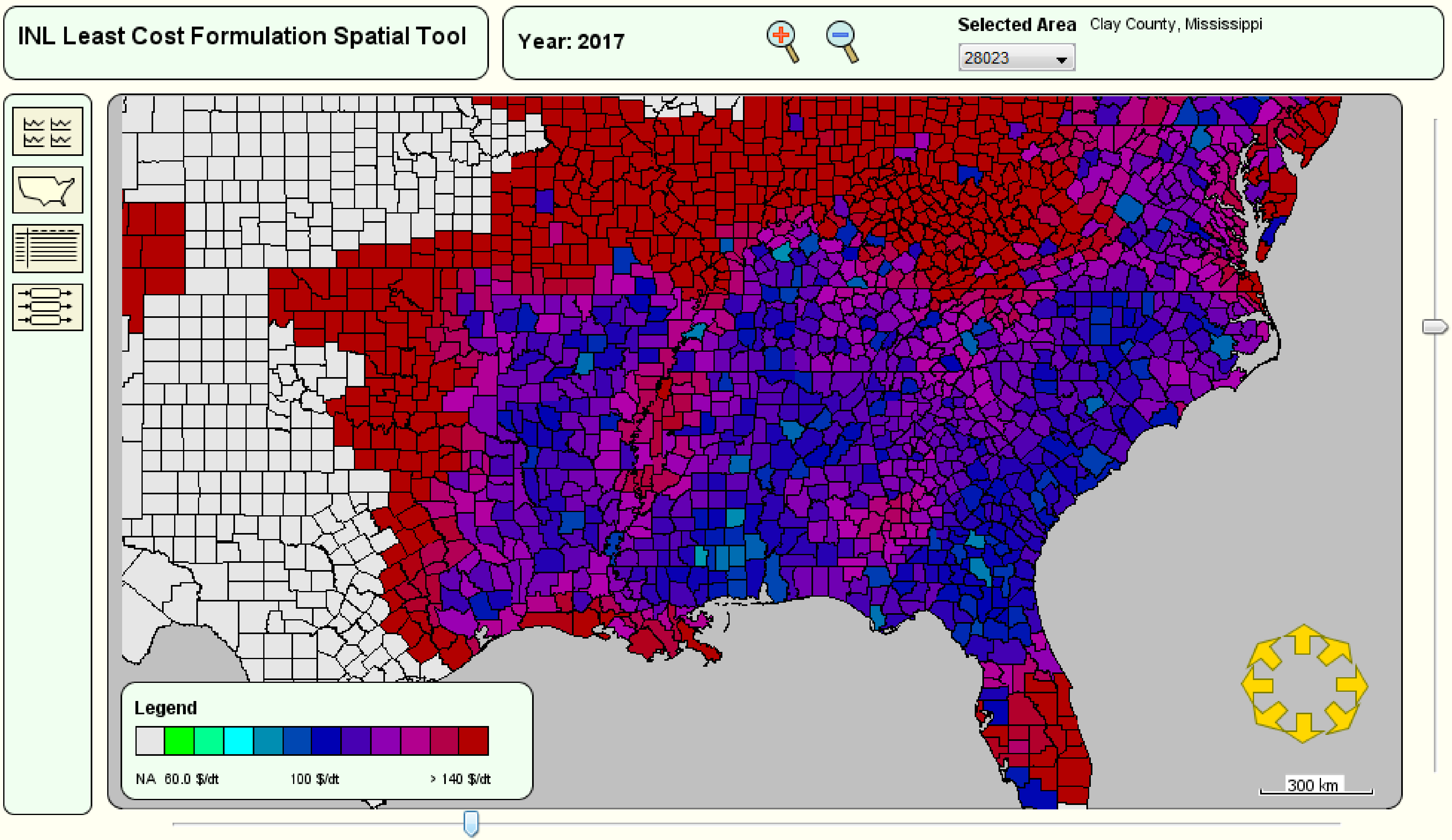
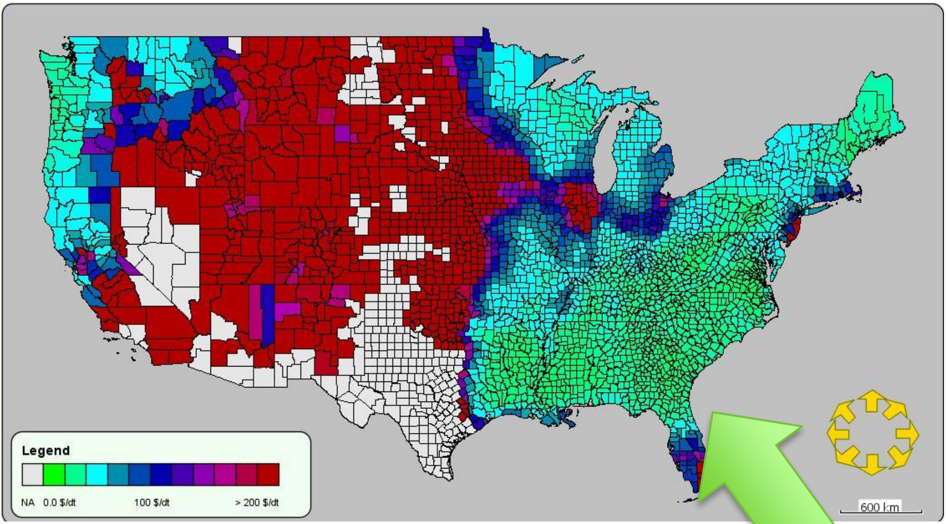


2012 Design case applied spatially using BTU supply curve projections (*assumes waste heat dry)

2 – Technical Progress Advanced Preprocessing

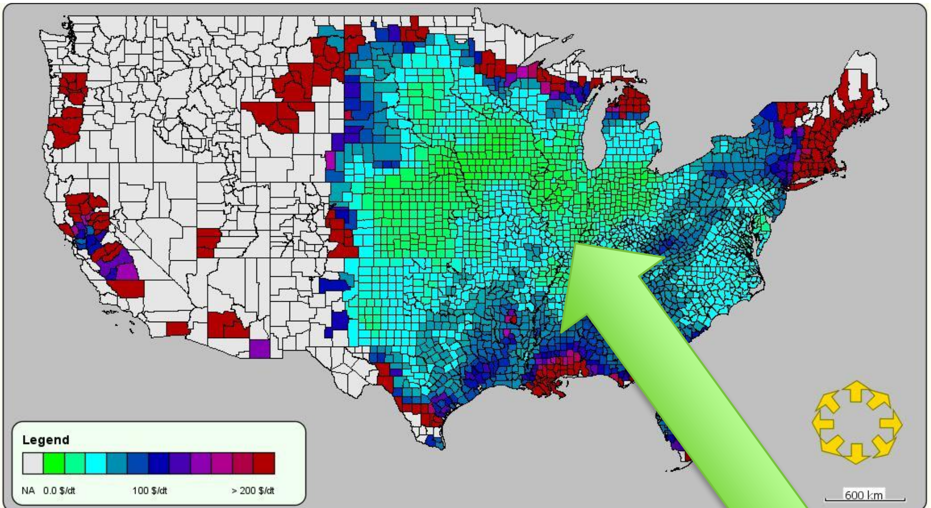


Initial 2017 Design Case: Bio-oil and Syngas Conversion Pathways:

- Formulation achieves specs
- Formulation achieves costs
- Increases the resource base

Feedstock	Reactor Throat Feedstock Cost ($/ton)	Formulation Fraction (%)	Reactor Throat Ash (%)	Reactor Throat Moisture (%)
Forest Thinnings	76.40	40	2.25	10.0
Logging Residues	74.13	40	2.25	10.0
6"-8" Purpose Grown Pine	98.52	20	0.5	10.0
Delivered Formulation Totals	**79.92**	**100**	**1.9**	**10.0**

2 – Technical Progress Advanced Preprocessing



Initial 2017 Design Case: Cellulosic Sugars Conversion Pathways:

- Formulation achieves specs
- Formulation achieves costs
- Dedicated energy crops enter the supply chain
- Significant sustainability impacts

Feedstock	Reactor Throat Feedstock Cost ($/ton)	Formulation Fraction (%)	Carbohydrate Content (%)	Reactor Throat Ash (%)	Reactor Throat Moisture (%)
Multi-Pass Corn Stover	78.24	60	58	9.0	20.0
Single-Pass Corn Stover	78.27	33	60	3.5	20.0
Perennial grass	102.48	7	65	4.0	15.0
Delivered Formulation Totals	**79.94**	**100**	**59**	**6.8**	**19.7**

2 – Technical Progress Advanced Preprocessing

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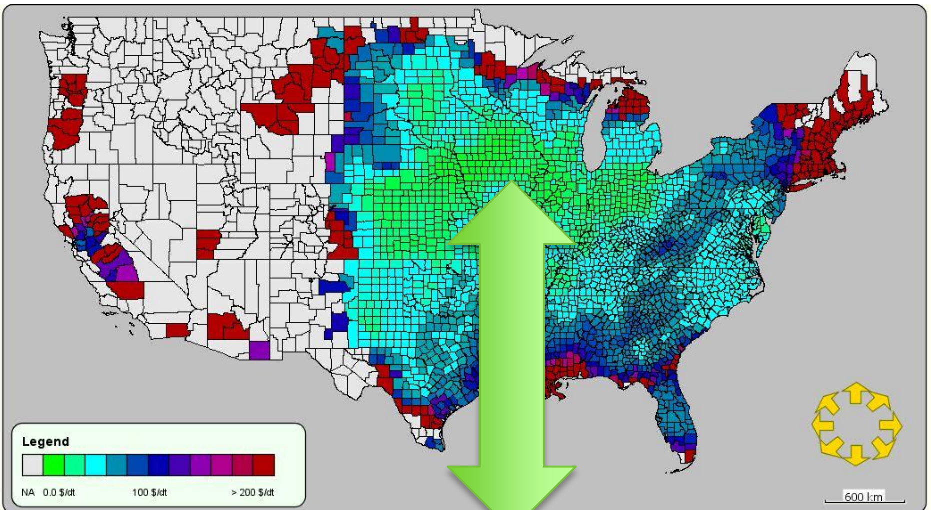
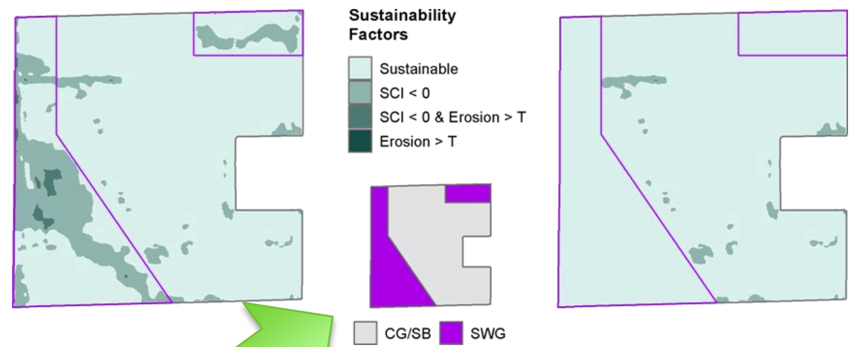
Least Cost Formulation and Sustainability





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3 – Relevance

Relevant to BETO

- Foundational capability for 2017 design case support
- Unified data management methodology for biomass characteristics

Relevant to industry

- Establishing analytical basis for new supply chains
- Delivering DOE (and partner) developed data

Relevant to researchers

- Coupling sustainability and supply chains
- Analytical platform for scenario exploration

4 – Critical Success Factors

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Success Factors

- Engaging library collaboration across the biofuel production chain
- Analytics environment deployment through the KDF

Potential Challenges

- Changing paradigm in supply chain design
- Predictive assessment of conversion process performance for supply chain design valuation
- Computational limitations

Advancing the State of Technology

- Thought leadership in supply chain design and performance evaluation
- Creating analytic tools that can impact industry decisions in the near term
- Building the supply chain design basis for dedicated energy crops to emerge in the production landscape

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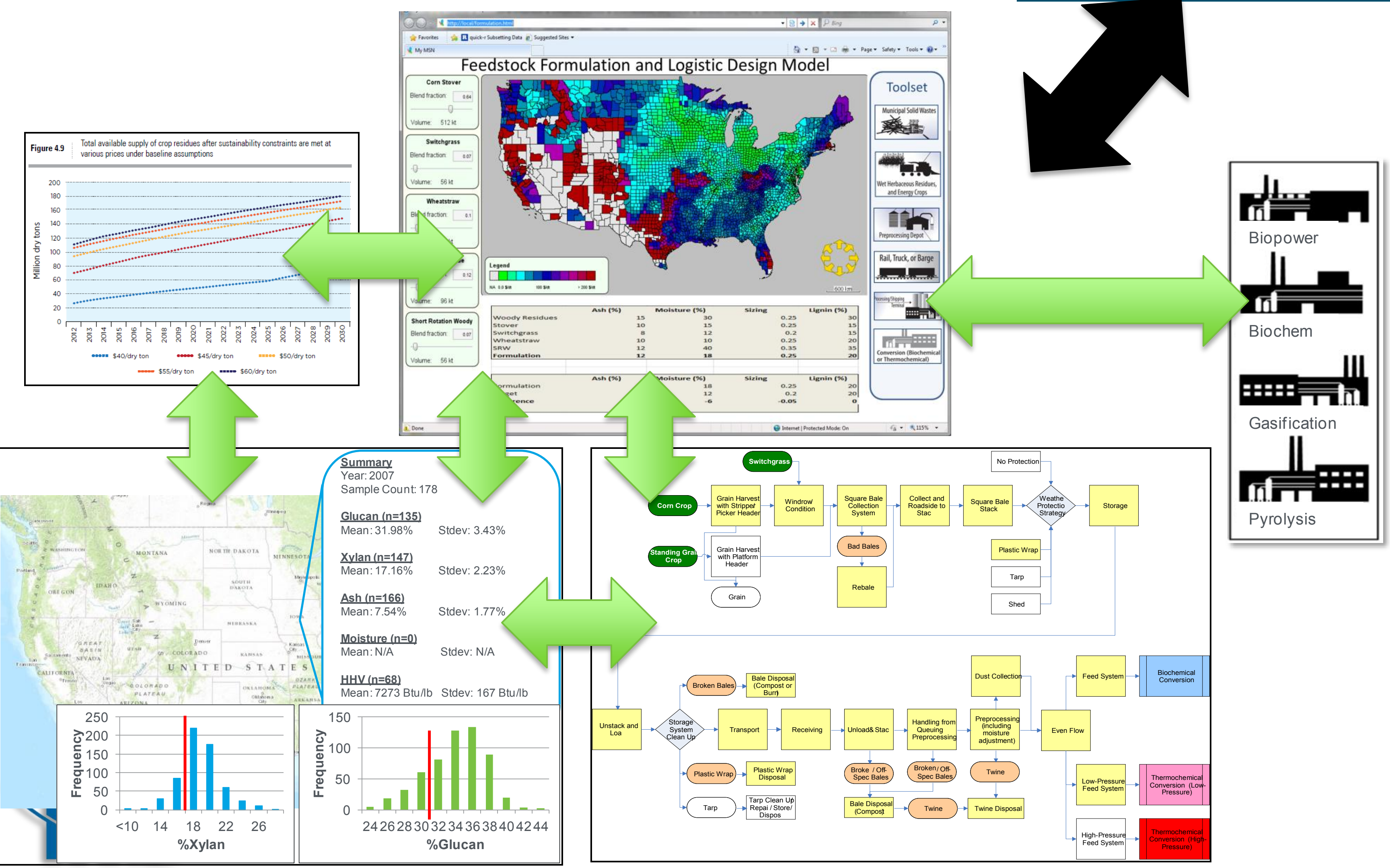
Future Work

Making R&D and Industry decisions simultaneously:

BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK
U.S. DEPARTMENT OF ENERGY



Summary

- **Approach**
  - Analytic framework that overcomes key challenges:
    - Feedstock variability
    - Supply chain business models
    - Active controls for key specs
    - Sustainability metrics

- **Accomplishments**
  - Integrate the biomass library
  - Couple to the resource
  - Build capability for advanced preprocessing analyses
  - Integrate sustainability assessment capability
  - Deliver capability necessary for BETO 2017 goals

Questions

Publications/Presentations

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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