Feedstock Supply & Logistics

1.6.1.2

Feedstock Supply Chain Analysis

May 21, 2013
Feedstock Supply & Logistics

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Idaho National Laboratory

Goal Statement

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The primary purpose of this project is to provide technical analysis support to the Bioenergy Technology Office (BETO) by advancing the designing advanced feedstock logistic supply systems, identifying barriers and directing research, monitoring and assessing impacts of technology improvements, supporting sustainable biofuel, and biopower development.

Quad Chart Overview

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Timeline
Project Start Date: Oct. 1, 2005
Project End Date: Sept. 30, 2022

Barriers
Ft-M Overall Integration
Ft-M Overall Quality Monitoring

Budget
Funding for FY13: $450K
Funding for FY12: $466K
Funding for FY11: $475K

Partners
National Renewable Energy Lab
Oak Ridge National Lab
Pacific Northwest National Lab
Argonne National Lab
US Forest Service
USDA-ARS
Iowa State University
Vermeer Manufacturing

INL

Project Overview

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Focus: This project provides the interface between the Bioenergy Technology Office, INL engineering tasks, other national labs, and industry.

- Tracks annual progress toward EERE 2022 goals for biofuel production.
- Identify barriers to achieving targets
- Design and analyze advanced supply systems that reduce barriers
- Disseminate Information

In summary, this project tracks historical progress, designs the future and directs research for all logistic engineering projects at the INL.

INL

Approach

- Collaborate closely with the engineering and science tasks at INL, universities, industry, and other national laboratories
- Develop methodology to support the analyses necessary to develop annual SOT's, MYPP goals, and identify barriers

- Collaborate closely with other platforms within the DOE BETO to assure the sharing of data between platforms, and that each platform is using the best available
- Interface with other DOE BETO programs and projects requiring feedstock logistic analyses
- Meeting DOE goals requires the integration of design improvements, achieved over years of integrated research and analysis

Approach (Cont)

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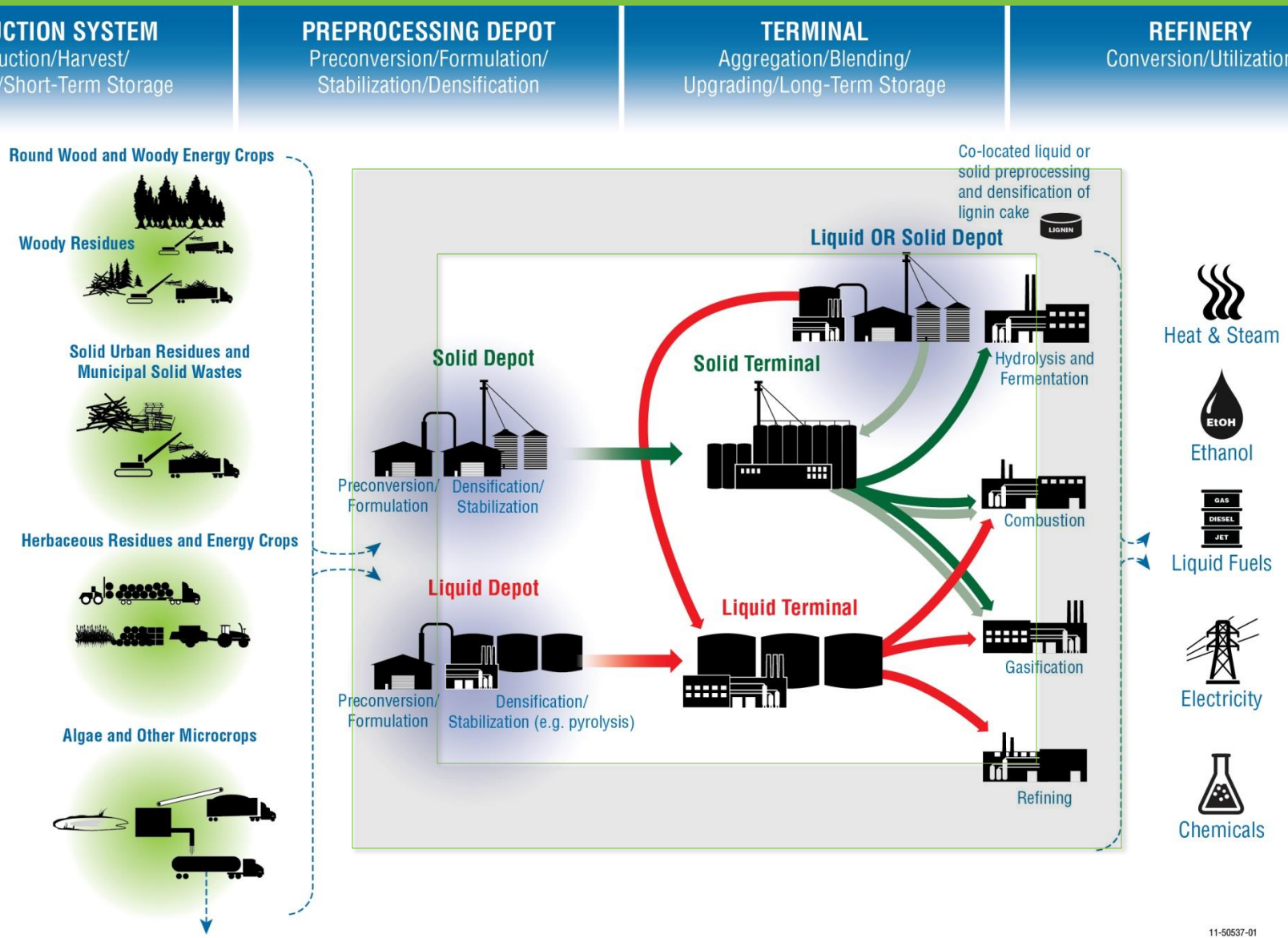
DOE Biofuel Research Pathways



Putting it all together

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Engineering Projects

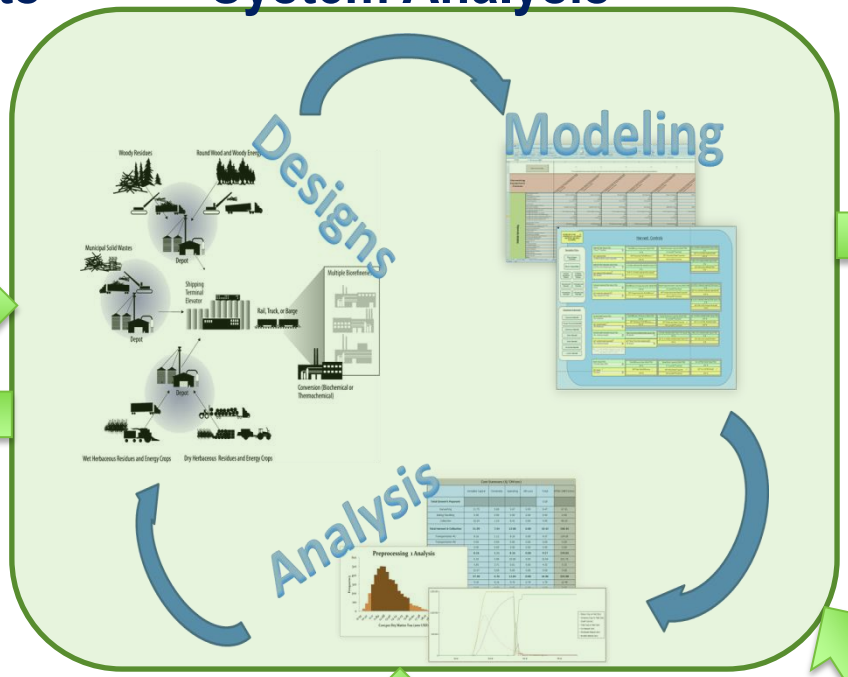
Harvesting

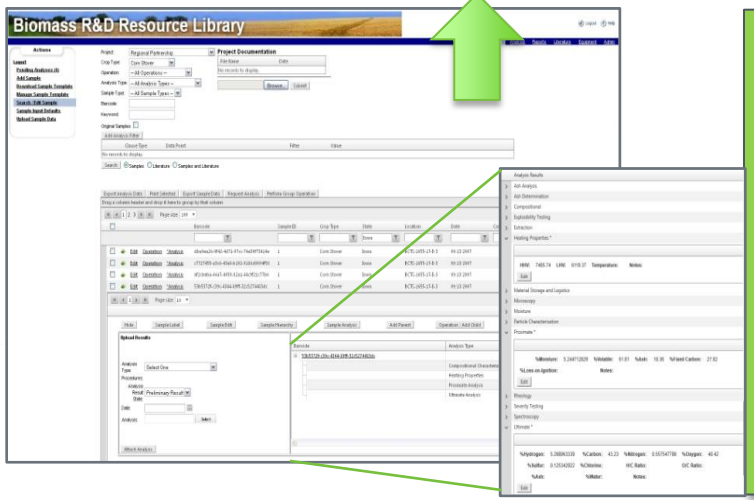
Storage

Transportation

Grinding

System Analysis





Reporting

Processing Area Costs Contributions & Key Technical Parameters	Metric	Woody					
Process Concept: Feedstock Collection, Processing and Delivery to Conversion Reactor Inlet		2009	2010	2011	2012	2012	Total Feedstock Cost
Year $ basis		2007	2007	2007	2007	2007	
Grower Payment	$/dry ton	$15.70	$15.70	$15.70	$15.70	$15.70	
Total Cost of Feedstock Logistics to Plant Gate	$/dry ton	$47.90	$47.90	$42.10	$39.10	$35.00	
Total Cost to Plant Gate	$/dry ton	$63.60	$63.60	$57.80	$54.80	$50.70	
Feed Handling and Drying Costs	$/dry ton	$22.65	$20.00	$14.30	$7.27	$11.37	
tal Cost of Feedstock Logistics to Reactor Throat	$/dry ton	$70.55	$67.90	$56.40	$46.37	$46.37	
rvest and Collection							Feedstock Logistics Cost to Plant Gate
Total Cost Contribution	$/dry ton	22.3	22.3	19.4	18.75	18.75	
Capital Cost Contribution	$/dry ton	6.4	6.4	5.65	6.1	6.1	
Operating Cost Contribution	$/dry ton	14.4	14.4	12.25	11.15	11.15	
Storage and Queuing							
Total Cost Contribution *(assume hot logging)*	$/dry ton	0	0	0	0	0	
Capital Cost Contribution	$/dry ton	0	0	0	0	0	
Operating Cost Contribution	$/dry ton	0	0	0	0	0	
Preprocessing							
Total Cost Contribution	$/dry ton	13.6	13.6	12.2	11.4	8.15	
Capital Cost Contribution	$/dry ton	3.5	3.5	4.2	4.2	2.4	
Operating Cost Contribution	$/dry ton	9.1	9.1	7	6.4	4.75	
Transportation and Handling							
Total Cost Contribution	$/dry ton	12	12	10.5	8.95	8.1	
Capital Cost Contribution	$/dry ton	4.1	4.1	3.55	2.35	2.3	
Operating Cost Contribution	$/dry ton	7.9	7.9	6.95	6.6	5.6	
Feed Handling And Drying							
Total Cost Contribution	$/dry ton	22.65	20	14.3	7.27	11.37	Feedstock H&D Cost
Capital Cost Contribution	$/dry ton	5.45	4.5	4.25	2.25	11.37	
Operating Cost Contribution	$/dry ton	17.2	15.5	14.3	4.82		

Spatial/Temporal Data System

Spatial Data	Production Data	Management Data
State County Region (Fields) Area	Yield Harvest Days Harvest Weeks Feedstock Harvested Acres Planted	Crop(s) Rotations Tillage Fertilizer Operations Removal Rate

Climate Data	
Daily Temperature Precipitation Wind Heat Units	Locally Managed USDA NASS Database

Accomplishments

- 2012 Design Case
- Multi-Year Program Plan Updated Targets
- 2012 Herbaceous Design Case
- 2012 Woody Design Case
- 2012 Energy Design Case
- Annual State-of-Technology Reports
- Draft of Feedstock Logistics Design Report Update
- Biochemical Sizing/Siting Peer Review Publication – March 2013
- Dynamics Analysis of Policy Drivers for Bioenergy Commodity Markets – January 2013, Energy Policy
- Thermochemical Sizing/Siting Peer Review Publication – In Draft
- Modeling & Analysis Peer Review Paper – In Review Biomass & Bioenergy

Completed the 2012 Design Case

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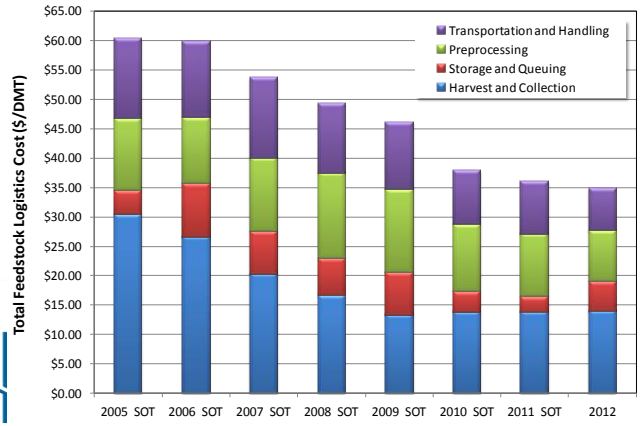
2012 Design Case – Demonstrate an over all cost of <$35/ton with actual field data.

Economic Analysis

FY12 Cost Summary ($/DM ton)					
	Installed Capital	Ownership	Operating	DM Loss	Total
Harvesting	19.00	1.08	2.20	0.00	3.28
Baling	33.51	2.73	4.20	0.00	6.93
Roadsiding	19.12	2.39	1.41	0.00	3.80
Total Harvest & Collection	**71.62**	**6.20**	**7.81**	**0.00**	**14.01**
Transportation #1	4.06	0.78	6.44	0.00	7.22
Total Transportation	**4.06**	**0.78**	**6.44**	**0.00**	**7.22**
Preprocessing #1	13.87	2.93	5.68	0.00	8.61
Total Preprocessing	**13.87**	**2.93**	**5.68**	**0.00**	**8.61**
Storage	6.88	2.56	0.00	1.38	3.94
Plant Handling & Queuing	0.95	0.19	0.89	0.00	1.08
Total Storage & Queuing	**7.83**	**2.75**	**0.89**	**1.38**	**5.02**
Total	**97.38**	**12.66**	**20.82**	**1.38**	**34.86**

Environmental Analysis

	Energy Use (kJ kg^{-1})	Kg CO_2-Eq
Harvesting	144	7.52
Baling	71	8.45
Roadsiding	36	1.19
Total Harvest & Collection	**251**	**17.16**
Transportation #1	98	4.07
Total Transportation	**98**	**4.07**
Preprocessing #1	196	150.01
Total Preprocessing	**196**	**150.01**
Storage	13	2.52
Plant Handling & Queuing	18	3.38
Total Storage & Queuing	**31**	**5.90**
Total	**576**	**177.14**



Bailing Cost			
Peak Capacity			
Machinery Eff.			
Tractor & Baler Ownership			

Windrowing Cost			
Peak Capacity			
Machinery Eff.			
Tractor & Windrowing Ownership Cost*			

Collection Cost			$/ton
Peak Capacity	ton/hr	31	
Machine Eff.	%	85%	
Tractor & Wagon Ownership Cost*	$/ton	$2	$2.15
Labor*	$/hr	$14.20	$0.60
Fuel Rate	gal/hr	10.51	$0.78
Fuel Cost*	$/gal	$2.50	
Lube Rate	%	15%	
Equipment Life	years	6	
Interest Rate	%	4%	
Working Days	day/yr	30	
Shift Time	hr/day	16	
Maintenance	%	10%	$0.03
T/I/H	%	2%	$0.24
Overhead	%	0%	$0.00
Total			$3.80

*Uses 2007 Values

Transportation Cost			$/ton
Truck Peak Capacity	bales/load	37	
Truck Eff.	%	100%	
Truck & Trailer Ownership Cost	$/ton		$0.25
Truck Labor	$/hr	$17.48	$2.34
Trucking Equipment Life	Miles	1,000,000	
Truck & Trailer Maintenance	$/ton		$0.12
Loader Peak Capacity	ton/hr	42	
Loader Eff.	%	100%	
Loader Ownership Cost	$/ton		$0.14
Loader Labor	$/hr	$14.20	$0.63
Loader Equipment Life	Hrs	10,000	
Loader Maintenance	$/ton		$0.05
Unloader Peak Capacity	ton/hr	42	
Unloader Eff.	%	100%	
Unloader Ownership Cost	$/ton		$0.14
Unloader Labor	$/hr	$14.20	$0.63
Unloader Equipment Life	Hrs	10,000	
Unloader Maintenance	$/ton		$0.05
Transport Distance	Miles	35.1	
Fuel Cost	$/gal	$2.96	$2.62
Lube Rate	%	10%	
Interest Rate	4%		
Working Days	day/yr	300	
Shift Time	hr/day	14	
T/I/H			$0.25
Overhead	%	0%	$0.00
Total			$7.22

*Uses 2007 Values

Develop Targets for the Multi-Year Program Plan

	2009 SOT	2010 SOT	2011 SOT	2012 SOT
Total Feedstock Logistics, $/DT	$46.15	$37.80	$36.10	$35.00
Harvest and Collection	$13.30	$13.80	$13.80	$13.15
Storage and Queuing	$7.25	$3.50	$2.65	$2.45
Preprocessing	$14.15	$11.45	$10.65	$11.50
Transportation and Handling	$11.45	$9.05	$9.00	$7.90
Total Feedstock Logistics, $/gal Ethanol	$0.63	$0.50	$0.46	$0.44
Harvest and Collection	$0.18	$0.18	$0.18	$0.17
Storage and Queuing	$0.10	$0.05	$0.03	$0.03
Preprocessing	$0.19	$0.15	$0.14	$0.14
Transportation and Handling	$0.16	$0.12	$0.11	$0.10
Gallons Ethanol/DT	73	75	78	79

Tracking our progress

Looking to the Future

Table B-3: Technical Projections for Dry Woody Feedstocks Collection, Preprocessing, and Delivery to Pyrolysis Conversion Reactor Inlet*

Pyrolysis		Woody Biomass: Purpose Grown 6-8" Trees					
Process Concept: Feedstock Harvest through plant gate and insertion to Conversion Reactor Inlet	Metric	2009 SOT	2010 SOT	2011 SOT	2012 Projection	2013 Projection	2017 Projection
	Year $ basis	2011	2011	2011	2011	2011	2011
Pyrolysis							
Total Feedstock Logistics (Harvest through insertion to conversion reactor inlet)	*$/DM ton*	***$90.90***	***$86.94***	***$74.55***	***$63.69***	***$61.85***	***$54.50***
	$/gal (biofuel)	***$1.25***	***$1.19***	***$1.02***	***$0.87***	***$0.74***	***$0.51***
Total cost of feedstock logistics to plant gate	**$/DM ton**	**$54.02**	**$52.34**	**$47.90**	**$44.69**	**$43.27**	**$37.62**
Capital Cost Contribution	$/DM ton	$15.62	$15.12	$15.19	$14.51	$13.17	$11.37
Operating Cost Contribution	$/DM ton	$38.39	$37.22	$32.71	$30.18	$30.10	$26.25
Total cost of feedstock handling after plant gate	**$/DM ton**	**$36.88**	**$34.60**	**$26.65**	**$19.00**	**$18.58**	**$16.88**
Capital Cost Contribution	$/DM ton	$6.81	$6.25	$5.66	$2.96	$3.41	$3.10
Operating Cost Contribution	$/DM ton	$30.08	$28.35	$20.99	$16.04	$15.17	$13.78
Total cost of grower payment (see TB-1)	**$/DM ton**	**$16.02**	**$16.02**	**$16.02**	**$16.02**	**$26.25**	**$26.25**
Total Feedstock Cost Through Process Feed	**$/DM ton**	**$106.92**	**$102.96**	**$90.57**	**$79.71**	**$88.10**	**$80.75**
	$/gal (biofuel)	**$1.46**	**$1.41**	**$1.24**	**$1.09**	**$1.05**	**$0.76**
Harvest and Collection							
Total Cost Contribution	$/DM ton	$24.89	$23.77	$23.15	$22.24	$20.70	$19.53
Capital Cost Contribution	$/DM ton	$7.14	$6.70	$6.74	$6.64	$5.99	$5.66
Operating Cost Contribution	$/DM ton	$17.74	$17.08	$16.41	$15.60	$14.70	$13.87
Harvest Efficiency	%	65%	65%	80%	80%	81%	82%
Collection Efficiency	%	65%	75%	75%	75%	75%	75%
DM Density	lbs/ft3	10.0	10.0	10.0	10.0	10.0	10.0
Moisture Content	% (wet basis)	50%	50%	40%	40%	35%	30%
Storage and Queuing							
Total Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Capital Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Operating Cost Contribution	$/DM ton	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Landing Preprocessing							
Total Cost Contribution	$/DM ton	$15.18	$15.18	$13.60	$12.17	$13.08	$11.73

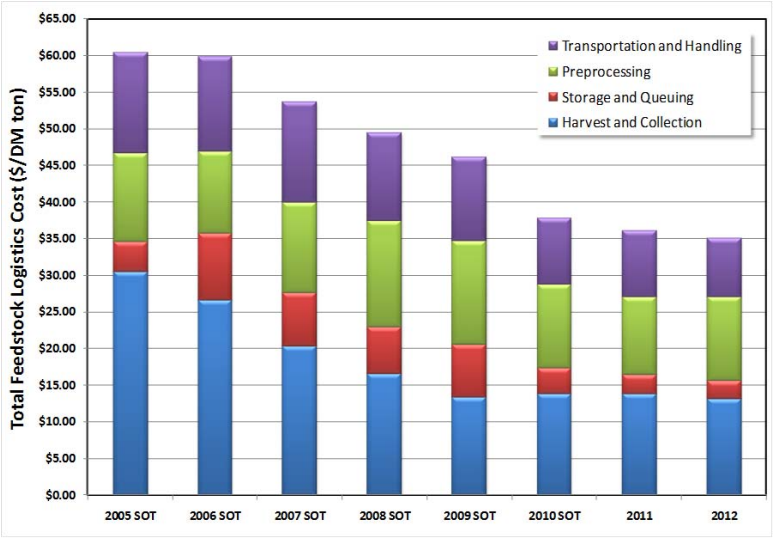
Annual State of Technology Report

Developed the annual State of Technology supply system designs and cost estimates for Herbaceous and Woody biomass supply systems for 2010 and 2011

Conventional Bale Feedstock Supply System Cost Summary Table

FY10 Cost Summary ($/DM ton)					
	Installed Capital	Ownership	Operating	DM Loss	Total
Harvesting	60.97	0.61	1.23	0.00	1.84
Baling	24.59	3.47	6.35	0.20	10.02
Roadsiding	7.69	1.09	0.84	0.00	1.93
Total Harvest & Collection	**93.25**	**5.17**	**8.42**	**0.20**	**13.79**
Transportation #1	4.59	1.49	7.53	0.00	9.02
Transportation #2	—	—	—	—	—
Total Transportation	**4.59**	**1.49**	**7.53**	**0.00**	**9.02**
Preprocessing #1	11.44	1.97	9.50	0.00	11.47
Preprocessing #2	—	—	—	—	—
Total Preprocessing	**11.44**	**1.97**	**9.50**	**0.00**	**11.47**
Storage	6.01	1.70	0.08	1.35	3.13
Plant Handling & Queuing	1.62	0.17	0.22	0.00	0.39
Total Storage & Queuing	**7.63**	**1.87**	**0.30**	**1.35**	**3.52**
Total	**116.91**	**10.50**	**25.75**	**1.55**	**37.80**

Breakdown of historical cost by logistics process



Developed Design Cases

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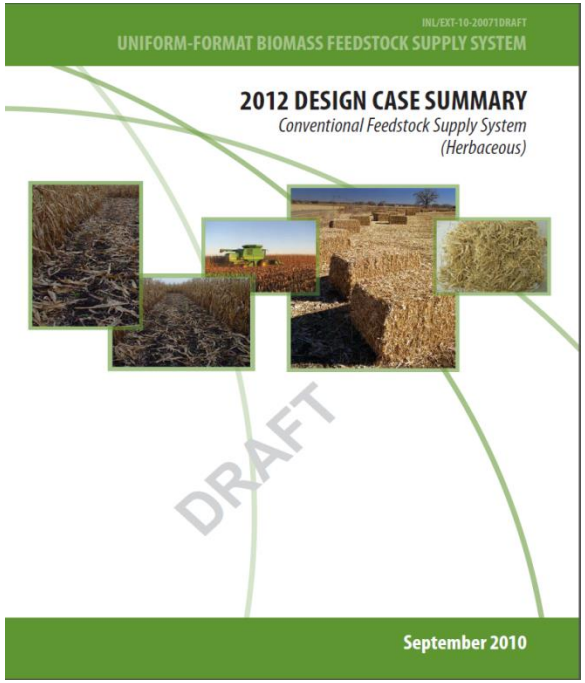

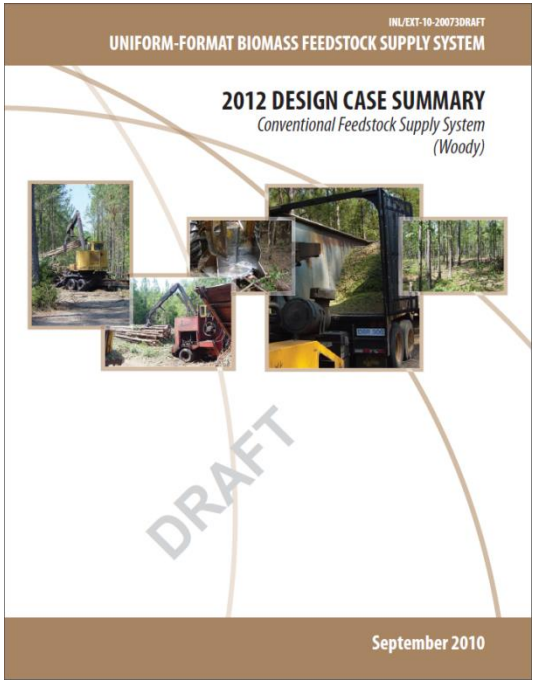

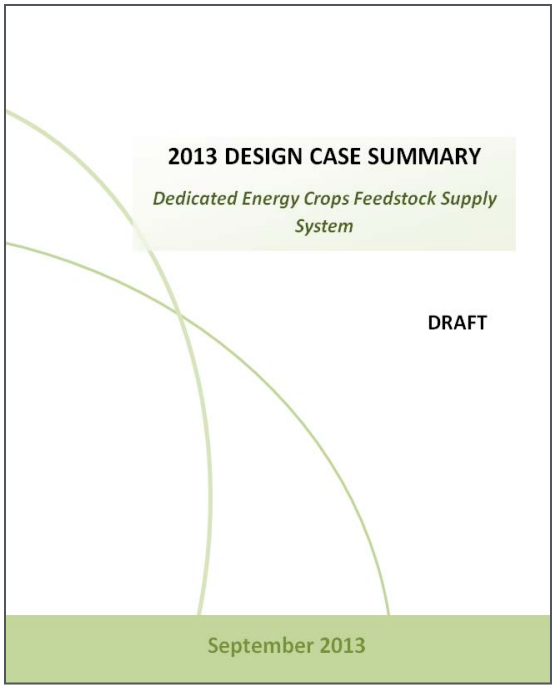

Design Cases are brochure type publications that outline the logistic supply systems specific to certain biomass types and conversion pathways.

Relevance

BETO:

The biomass logistics analysis is a critical part of the overall biofuel production system. The greatest contribution to the program from this task is the thought leadership on to transform from the current thinking towards an agri-business concept.

- **2012 Design Case:** Demonstrated achievement of 2012 cost goal.
- **SOTs:** Annually assess supply system costs associated with using current state of technology (SOT) equipment to collect and deliver biomass feedstocks to the conversion facility.
- **MYPP:** Develop designs and cost targets for the different conversion platforms based on projected advancements from research in feedstock logistic equipment and processes.

Industry, Universities & Other National Labs:

- **Collaborate** with the engineering and science tasks, provide systems analysis that interface between feedstock production and conversion in-feed requirements.
- **Analytical services** on supply system logistics to other national laboratories, universities, and industry partners.

Critical Success Factors

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Success Factors

- Engaging the bioenergy research and commercial communities support with data and models
- Providing analyses that bring value from concept through deployment

Potential Challenges

- Matching feedstocks with downstream requirements
- Advancing the thinking to understand future needs while meeting the goals of the present

Advancing the State of Technology

- Identifying technology gaps that facilitate process discovery
- Provide advanced analysis methodologies that provide for investigating technologies, processes, and design concepts
- Supporting commercial viability by helping understand key risk elements, and potential for reduction

Future Work

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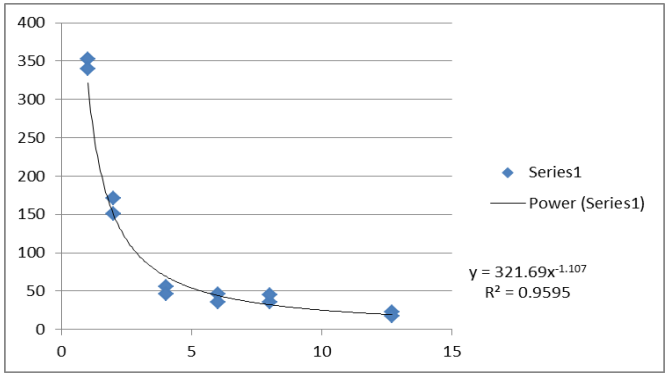
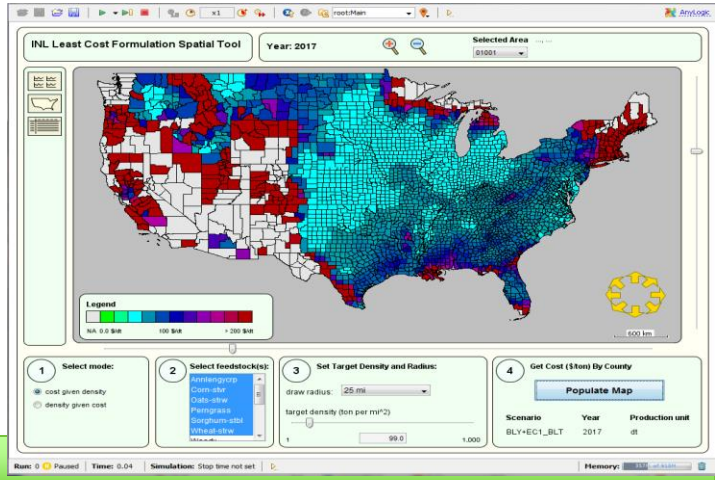
Moving toward the Least Cost Formulation of a feedstock mix to help meet cost and quantity goals will be essential.

The most important task will be to continue to track the progress and identify the barriers as we drive toward the 2017 and 2022 BETO and RFS2 goals.

Development on concept of a total systems agri-business concept moving away from engineering evaluation analysis. Determining the underlying business sustainability barriers and moving the industry forward.





Summary

- This project is where the thought leadership is developed. Understanding what are the limitations, barriers and opportunities.
- This project is the interface between the engineered processes and the decision makers.
- Being responsive to BETO and other labs is a big part of this project.
- Collaboration is key! Not only within the INL but with BETO, the other National Labs, industry and universities.
- Publishing and disseminating the information derived from this project is important.

Questions

Publications/Presentations (Recent)

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- *Model Based Biomass System Design of Feedstock Supply Systems for Bioenergy Production,* Kara Cafferty, Dave Muth, Jake Jacobson (INL), Kenneth M. Bryden (ISU), paper has been accepted to the ASME International Design Engineering Technical Conference (IDETC/CIE 2013), Accepted: August 4-7, Portland Or.

- *Investigation of Biochemical Biorefinery Sizing and Environmental Sustainability Impacts for Conventional Bale System and Advanced Uniform Biomass Logistics Designs*. R. Graham, M. Langholtz, L. Eaton, J. Jacobson, C. Wright, D. Muth, D. Inman, E. Tan, M. Wu, Y.-W. Chiu, S. Jones, L. Snowden-Swan, A. Argo, BioFPR, (April, 2013).

- *Investigation of Thermochemical Biorefinery Sizing and Environmental Sustainability Impacts for Conventional Bale System and Advanced Uniform Biomass Logistics Designs*. A. Schwab, M. Langholtz, L. Eaton, J. Jacobson, C. Wright, D. Muth, A. Dutta, E. Tan, M. Wu, Y.-W. Chiu, A. Argo, BioFPR, (In Review).

- *Herbaceous Design Case (2010), Woody Biomass Design Case (2011), Energy Crop Design Case (2012).*

Publications/Presentations

- *Feedstock Handling and Processing Effects on Biochemical Conversion to Biofuels,* Inman, D. , Nagle, N., Jacobson, J. Searcy E., Ray, A.E., Biofuels, Bioproducts and Biorefining, Volume 4, Issue 5, September 2010
- *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.
- *Programmatic Requirements for Modeling and Analysis of Feedstock Logistics,* Erin Webb, Shahab Sokansanj, Sam Tagore, Jacob J. Jacobson, American Society of Agricultural and Biological Engineers, Summer Meetings, Pittsburg. June 2010.
- *Uniform-Format Feedstock Supply System Design for Woody Biomass,* Jacob J. Jacobson, Erin Searcy, 2010 AICHE Spring Meeting and 6th Global Congress on Process Safety, American Society of Chemical Engineers. March 2010.
- *Comparison of supply system costs of forest residues when comminution is performed a landing vs at biorefinery,* Jacob J. Jacobson, Erin Searcy,, Society of Industrial Microbiology Annual Conference, April 2010.