Forestry Biofuel Statewide Collaboration Center

Supply Chain Model:
Simulation Model – Cost, Energy, Emissions

Thursday, August 25th, 2011

Presenter: Fengli Zhang, Ph.D. Student
Collaborators: Dana M. Johnson, Ph.D., Mark A. Johnson, Ph.D.

Overview

- Project Requirements
- Review of Existing Models
- Model Structure
- Potential Biofuel Facility Selection
- Model Assumptions
- Results
- Next Steps
- Acknowledgement

FBSCC – Task B4: Supply Chain Model

The supply chain models were designed as a pilot for a more comprehensive statewide model to encompass all forest regions in Michigan. The pilot focus area was the upper portion of the lower peninsula of the State of Michigan. There were two types of models developed: (1) optimization model with a one-year timeframe, and (2) simulation model with a twenty year time frame. The models evaluated nine potential locations that were pre-selected based on geographic information system (GIS) criteria. The models sought to minimize transportation cost, emissions, and energy consumption to identify the optimal location for a biorefinery. The purpose was to provide user friendly plug and play models that could be accessed through the website at:

http://michiganforestbiofuels.org/research-project/feedstock-supply-chain-landing-biorefinery

Comparative Models

Comparative Models

Model Structure

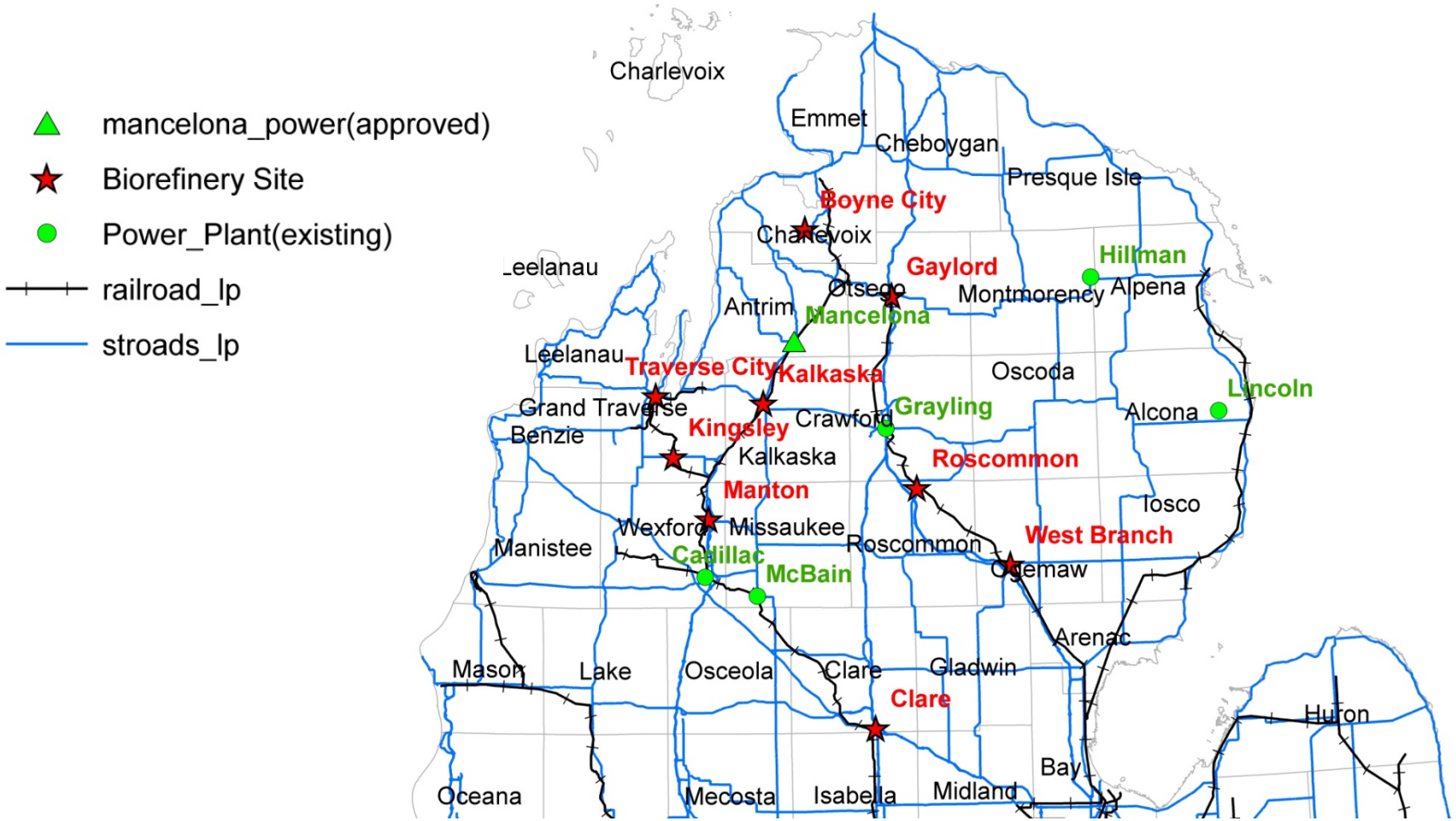
- Simulation model
  - Harvesting/forwarding
  - Transportation
  - Storage
  - Facility size

Source: www.bioenergy.ornl.gov

Criteria for Selecting Potential Biofuel Facility Locations

- Within one mile of a major state road / railway
- Within a community size of at least 1,000
- Within ¼ mile of a water body (rivers, lakes, etc.)
- > 1.4 million green tons of biomass within a 100-mile radius
- Excludes locations having a co-fired power plant

Nine Potential Biofuel Facility Sites



Model Assumptions

- Harvesting areas
  - < 100 miles radius
  - County-basis
  - Starting from the centroid of a county
  - No feedstock from the U.P., MI

Model Assumptions

- Biorefinery
  - 30, 40, and 50 million gallons per year (MGY)
  - Operates 20 years continuously
  - Operates 350 days (50 weeks) per year with 2 weeks for maintenance
  - Operates on 24/7 schedule
  - ~1,250,000 green tons/year (a conversion factor of 40 gallons biofuel per green ton of biomass)
  - ~3,572 green tons/day

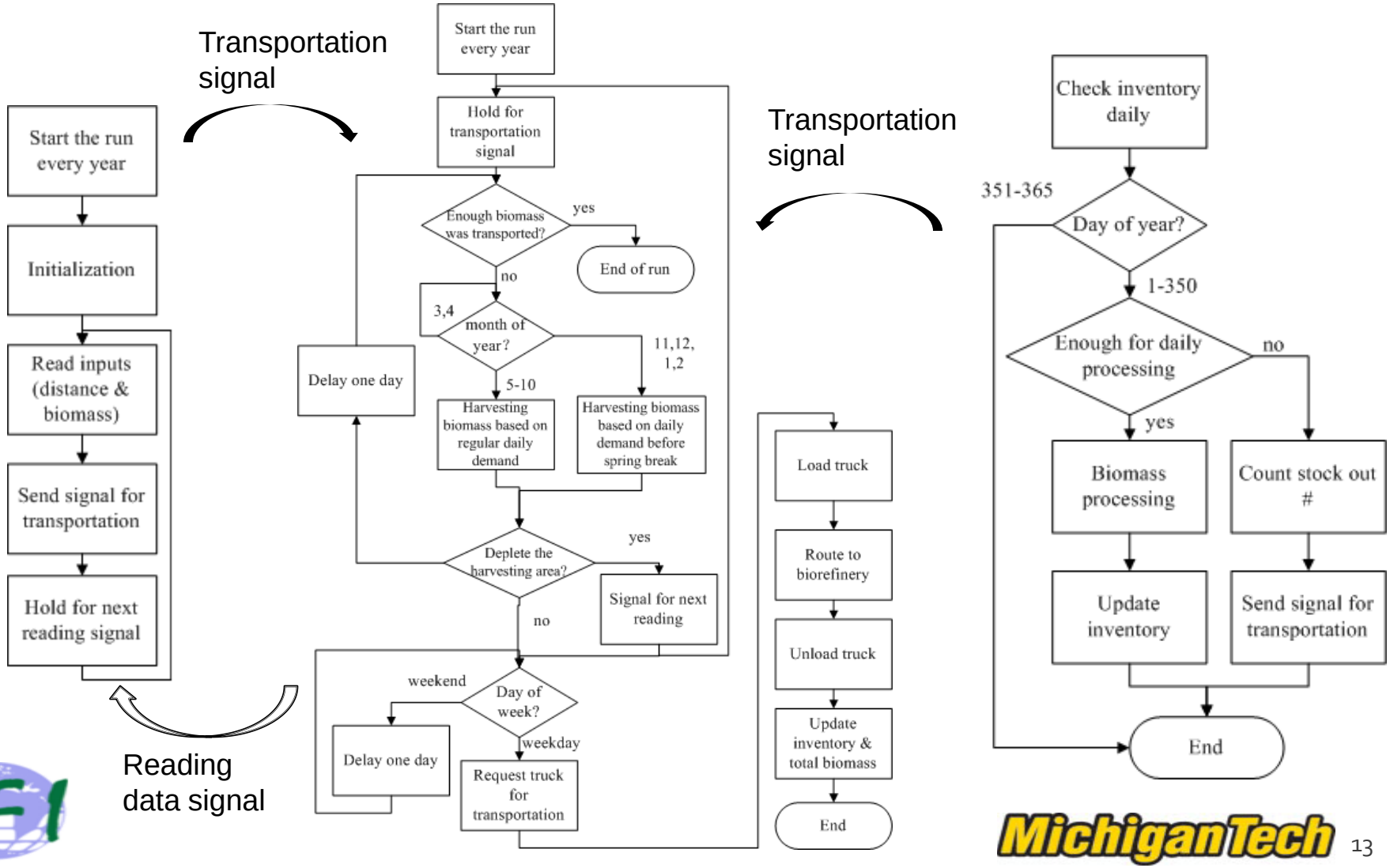
Model Assumptions

- Truck transportation
  - 50 tons, full loaded
  - Operates on 5-day schedule
  - 8 hours driving + 2 hours of loading/unloading per day
  - Return empty

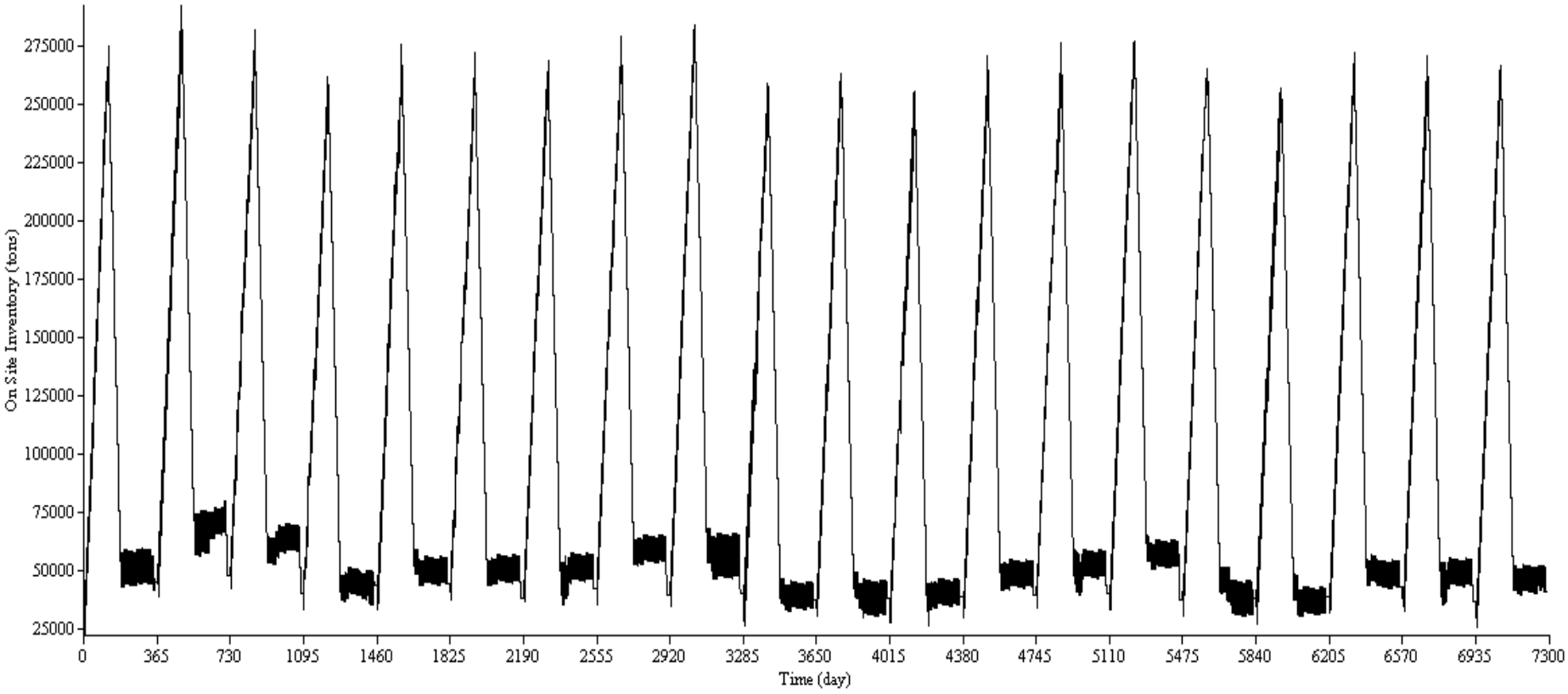
Model Assumptions

- Spring breakup
  - March 1st ~ April 30th (61 days of duration)
    - Based on MDOT approximation for lower peninsula
  - November 1st ~ the end of February, build inventory
  - Pull biomass feedstock from inventory only
- Others
  - No dry matter loss considered (i.e., weight loss during storage due to insect infestation)
  - There will be a starting inventory quantity of equal to 7 days of inventory

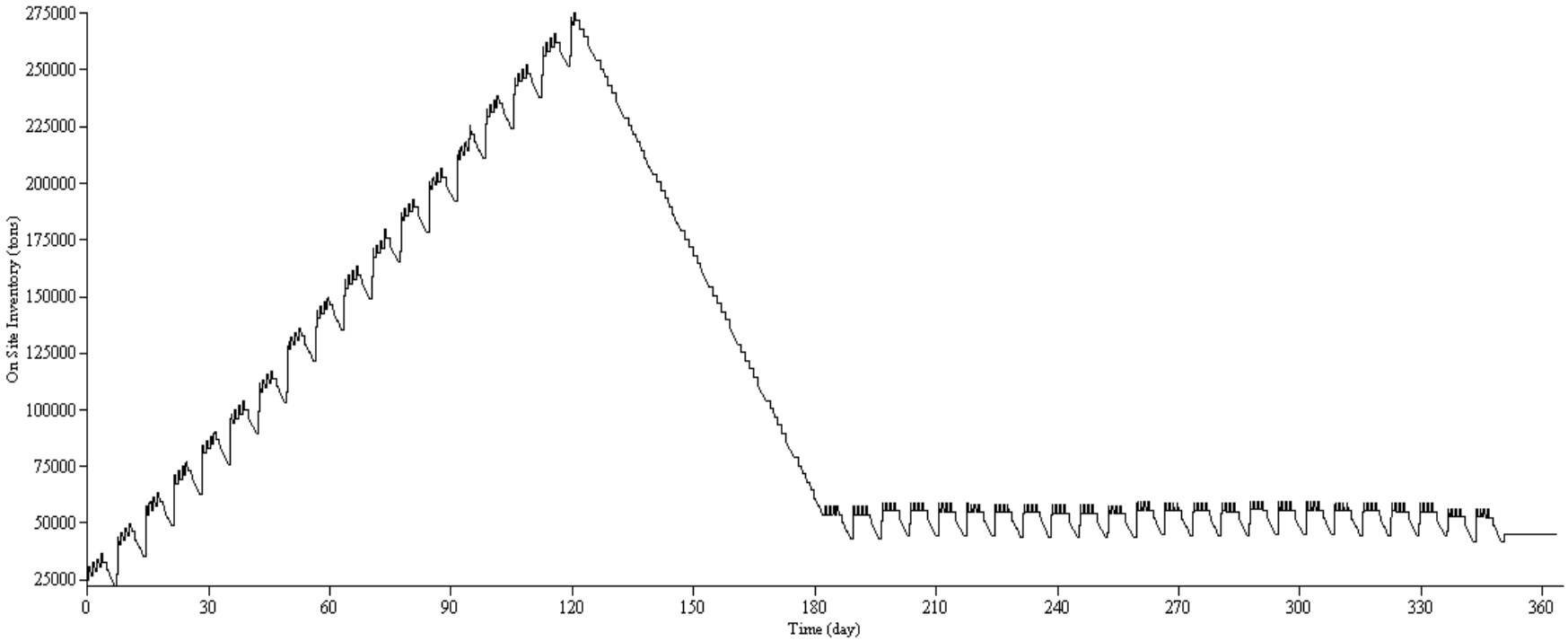
Model Logics



Inventory level for a facility size of 50 MGY in Gaylord operating 20 years



A Better Look for One Year Operation



Eight Most Preferable Harvesting Areas for Supplying Gaylord Plant

Order	Harvesting Area	Rectlinear Distance (mile)	Biomass (green tons)
1	Otsego	4.023	274,920
2	Antrim	24.754	134,827
3	Crawford	27.196	120,789
4	Montmorency	27.607	200,041
5	Cheboygan	37.356	225,280
6	Charlevoix	40.748	96,751
7	Kalkaska	43.740	171,816
8	Emmet	44.968	28,450

System Performance Indicators

Indicators	Total		
	50 MGY	40 MGY	30 MGY
Cost (1000 $)	9810.66	7239.59	4882.3
Energy use (Mill Btu)	110824	75546	44884
GHG emissions (ton)	13118.7	8942.7	5313.1

Indicator	Average		
	50 MGY	40 MGY	30 MGY
Cost ($/ton)	7.8485	7.2396	6.5097
Energy use (Btu/ton)	88659	75546	59845
GHG emissions (lb/ton)	20.9900	17.8854	14.1683

Next Steps

- Refine the model
- Simulate scenarios
- Integrate uncertainty (i.e., spring break)
- Integrate inventory holding cost

Researcher Acknowledgement

- We would like to acknowledge several researchers for their support in our project work:
  - Tim Jenkins, ME-EM provided some of the initial GIS selection criteria
  - Dr. Robert Froese, SFRES, for feedstock data and availability information from FIA EVALidator
  - Dr. Robert Handler, SFI, for information related to emissions and energy consumption
  - Dr. Pasi Lautala, CEE, and graduate student Justin Hicks, CEE, for their transportation cost estimates
  - Donna LaCourt, MEDC, Project Sponsor, for her insights and preliminary feedback on model development

References

- Arena simulation software, Available at: http://www.arenasimulation.com/.
- Biomass Research and Development Board, National Biofuels Action Plan, Biomass Research & Development Initiative, 2008.
- Hess, J.R., Wright, C.T., and Kenney, K.L., 2007, "Cellulosic biomass feedstocks and logistics for ethanol production," Biofuels, Bioproducts & Biorefining, 181-190.
- Iakovou, E., Karagiannidis, A., Vlachos, D., Toka, A., and Malamakis, A., 2010, "Waste biomass-to-energy supply chain management: A critical synthesis," Waste Management (in press).
- Idaho National Laboratory (INL), 2006, Bioenergy Technology, Available at: http://www.inl.gov/bioenergy/projects/d/1006_ch2m.pdf.
- Michigan State Policy, http://www.michigan.gov/msp/0,1607,7-123-1586_1710-87560--,00.html, accessed on Sep. 26, 2010.
- Reynolds, R.E., 2002, "Infrastructure Requirements for an Expanded Fuel Ethanol Industry," South Bend, IN: Oak Ridge National Laboratory Ethanol Project, http://www.ethanolrfa.org/objects/documents/94/dai.pdf.

References

- Rentizelas, A.A., Tatsiopoulos, I.P., and Tolis, A., 2009, "An optimization model for multi-biomass tri-generation energy supply," Biomass and Bioenergy, 33, 223-233.
- Sandia National Laboratories (SNL), and General Motors' R&D Center, 2009, "90-Billion Gallon Biofuel Deployment Study: Executive Summary," Available at: http://www.greenbiz.com/sites/default/files/document/Exec_Summary02-2009.pdf.
- Slade R., Bauen A., Shah N, 2009, "The greenhouse gas emissions performance of cellulosic ethanol supply chains in Europe," Biotechnology for Biofuels 2:15.
- West, T., Dunphy-Guzman, K., Sun, A., Malczynski, L., Reichmuth, D., Larson, R., Ellison, J., Taylor, R., Tidwell, V., Klebanoff, L., Hough, P., Lutz, A., Shaddix, C., Brinkman, N., Wheeler, C., and O'Toole, D., 2009, "Feasibility, economics, and environmental impact of producing 90 billion gallons of ethanol per year by 2030", Available at: http://www.sandia.gov/news/publications/white-papers/90-Billion-Gallon-BiofuelSAND2009-3076J.pdf.

Acknowledgement

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-EE-0000280.