Gaps in Research

Based on the current literature, there are a number of research gaps filled by the biomass feedstock supply chain research for the Forestry Biofuel Statewide Collaboration Center (FBSCC) project. The literature from existing cellulosic ethanol supply chains served as a basis for the development of supply chain management decision support tools. A unique supply chain model was tailored for FBSCC. The unique supply chain model focused on key activities and characteristics of supply chains. Information from previously developed biomass supply chains and mathematical models formed the foundation for the development of a unique biomass feedstock supply chain model.

National Biofuels Plan

The National Biofuels Plan developed by the Biomass R&D Board (2008) includes sustainability as an action area for successful development of the supply chain. This is similar to the FBSCC facilities because sustainability issues are one of the key drivers behind why the facility will be built. The Biomass R&D Board (2008) includes environment, health, and safety into an action area of its biofuels plan. The addition of these elements ensures that the supply chain can operate in a manner that is safe and compliant with energy policies, procedures, laws, and regulations. The FBSCC facilities relates to this part of the plan from an environmental and sustainability policy prospective.

The Biomass R&D Board (2008) also focuses on feedstock logistics because of its affect on the finished cost of cellulosic ethanol. These same feedstock logistics costs will be considered when developing the supply chain for the FBSCC facilities. The areas of focus for feedstock logistics in the biofuels plan that relate to the FBSCC project are harvesting process, storage facilities, and transportation of the feedstock.

The supply chain model for the FBSCC facilities differs from the National Biofuels Plan in that it uses woody biomass (including logs, forest residues or chips) for its feedstock. National Biofuel Plan considered agricultural residues and energy crops as the feedstock. Also, the FBSCC facilities supply chain will be tailored to meet the local criteria and demands of operating in Michigan, as opposed to a nationwide scale supply chain like the National Biofuels Plan. The Biomass R&D Board (2008) also focuses on conversion science and technology, distribution technology for the ethanol, and blending of the ethanol, which are all out of the scope of the project for the supply chain team.

Idaho National Laboratory

Idaho National Laboratory (INL) also developed a biomass supply chain for ethanol. Hess et al. (2007) proposed a uniform-format feedstock supply chain that can be implemented at a nationwide level. This is different from the scope of the supply chain team for the FBSCC facilities. The main goal of the FBSCC supply chain system is to develop a supply chain specific for the FBSCC facilities. Also, unlike the supply chain model that uses woody biomass (including logs, forest residues or chips), the Idaho National Laboratory mainly uses wheat straw and agricultural residues as primary feedstocks. One of the variables identified by Hess et al. (2007) is the different demands for different products that compete for biomass for energy production. This is similar to the FBSCC facilities. Some of the forest products will also be used by mills in the pulp and paper industry. Another recent source of demand for wood resources are the increasing number of combined heat and power (CHP) operations using co-firing of coal and woody biomass or completely operating with woody biomass. There will be a limited amount available for conversion to ethanol. Preprocessing of the biomass is moved prior to the transportation and handling in the INL report. This is so the transportation and handling procedures can be uniform no matter what type of feedstock is used. This is different from the FBSCC facilities supply chain since all of the preprocessing and chipping will occur at the mill. Because of this unique feature, it will be not included in the supply chain model for FBSCC. Hess et al. (2007) also highlight that transportation and handling costs account for nearly 30% of the annual cost for feedstock. The supply chain team will work to minimize transportation costs to the FBSCC facilities to ensure the system is cost effective.

INL (2009) study included some critical success factors for a supply chain feedstock model using wheat and barley straw. One of the critical success factors for the feedstock models includes the ability to contract straw from a specified distance. Even though the feedstock type is different from that of the FBSCC facilities, the issue outlined is very relevant. Woody biomass need to be harvested from specific harvest areas within a 100-mile radius of the facility. INL (2009) highlighted areas of concern for the feedstock supply chain system. The areas that relate to the FBSCC facilities include: (1) the cost of feedstock will vary with demand; (2) the logistics of moving the feedstock are complicated; (3) storage of feedstock may be subject to fire codes; (4) unloading the feedstock after transportation will vary with each case; and (5) the amount of field energy used while handling and transporting the feedstock.

Sandia National Laboratory

Sandia National Laboratories (SNL) performed a study assessing the feasibility of achieving national goals of producing 90 billion gallons of biofuels by 2030 (SNL, 2009; West et al., 2008). The study considered corn-based ethanol, and cellulosic ethanol from energy crops and agricultural and forest residues, to support the national goal. This is different from the FBSCC facilities since the supply chain will only incorporate woody biomass supplied from the forest. Corn-based or agricultural residues-based ethanol will not be in the scope of the supply system. SNL developed a model with inputs such as conversion yield, capital investment/annual capacity per cellulosic plant, energy prices, and feedstock yield improvements. This is very different from the supply chain model developed for FBSCC which includes supply chain inputs such as feedstock inventory and availability, harvesting/processing, storage at landings, transportation, and policy.

Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL) investigated the feasibility of expanding the ethanol industry. Reynolds, R.E. (2002) studied two different cases for this expansion scenario. Costs associated with additional infrastructure being built were estimated. This is similar to the FBSCC supply chain system. FBSCC will consider building infrastructure to meet the demand and the associated cost. The ORNL also calculated transportation costs. The transportation costs are also important to the supply chain team for the FBSCC facilities. However, these costs will be different from what is observed by the supply system for FBSCC. This is because FBSCC facilities only include woody biomass primarily in Michigan within a 100 mile radius of an ethanol plant. The supply chain team will fill the research gap of producing a woody biomass supply system for ethanol plants in Michigan.

Mathematical Models

The issue of chipping is very relevant to the FBSCC facilities' supply chain since it is assumed that chipping will occur at the plant. Gronalt and Rauch (2007) investigated the issue of centralized and decentralized chipping when designing a forest fuel network. Availability issues affect the design of a supply network since not every tree in a forest can be reached to harvest. This is very similar to the FBSCC facilities since a large portion of the eastern Upper Peninsula is wetlands, which poses availability issues with harvesting the forests. The work described by Gronalt and Rauch (2007) solved the supply system problem for several plants at once using numerous storage facilities and terminals to meet the varying demands of each plant. This is similar with the work will be done with the FBSCC facilities. The FBSCC facilities will attempt to supply ethanol plants from a number of terminals, or storage areas on-site and throughout the forest. The similarity involves materials coming from multiple locations.

Gunnarsson et al. (2004) proposed a solution to the supply chain problem involved with a forest fuel network structure through a large mixed integer linear programming (MLP) model. The main product used is forest fuel, which are mainly forest residues in harvest areas or from byproducts from sawmills. The destination for the forest fuel is a heat plant. This is different from the FBSCC facilities because the demand of the heat plant will rise based on the weather and particular season. The study also raised the issues of forests that are owned by the heat plant as opposed to contracted forests. Feedstock coming from forests owned by the plant would not have to be purchased while contracted forests would have to be purchased. This differs from the FBSCC facilities since all the woody biomass feedstock will have to be purchased.

De Mol et al. (1997) created both simulation and optimization models for the logistics of biomass fuel collection. The network structure associated with the models includes nodes that correspond to source locations, collection sites, transshipment sites, pre-treatment sites, and the energy plant itself. Arcs connect the nodes that represent road, water, or rail transportation. This network structure is similar to the FBSCC facilities structure; but water transportation is not included in the FBSCC study. The simulation model created by De Mol et al. (1997) is similar to the simulation model being developed for the FBSCC facilities. Both simulation models include the same network structure. The model for the FBSCC facilities has to investigate a variety of different facility locations for ethanol plants, which is the same as the De Mol et al.'s (1997) simulation model. The optimization model created by De Mol et al. (1997) combines different types of biomass, different nodes, and pre-treatments situations to develop the optimal network structure. The fact that the optimization model includes different pre-treatment situations differentiates it from the FBSCC optimization model. The overall goal of supplying an ethanol plant with biomass is the same for both.

Another gap to be filled includes all of the policy related constraints that affect the FBSCC supply chain. All of the literature reviewed will provide guidance for the team to perform new research and develop an efficient and cost effective log supply chain system.

Summary and Conclusion

The supply chain developed for the FBSCC facilities when compared to the other existing feedstock supply chains has similarities and differences. Some of the similarities with existing supply chains include the output of the supply chain (cellulosic ethanol), the method of transportation (truck and rail), land ownership issues, and facilities involved along the supply chain. The differences in existing feedstock supply chains that the FBSCC facilities supply chain address includes using only woody biomass as the type of feedstock. The chipping of the logs will be performed at the facility, which is different than other supply chains. The combination of these differences from existing supply chains creates a unique opportunity to develop a new supply chain using woody biomass as the primary feedstock to support the FBSCC facilities.

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