Mixed-Integer Linear model for multi-product multi-site biomass supply chain

Nasim Zandi Atashbar[1], Nacima Labadie[1], Christian Prins [1]

[1] ICD-LOSI, University of Technology of Troyes (UTT), Cs 42060, 10004, Troyes, France
{nasim.zandi_atashbar,nacima.Labadie,christian.prins}@utt.fr

Keywords: *Biomass supply chain, optimization, Mixed Integer Linear Program*

1 Introduction

Increasing concerns about the effect of greenhouse gas emissions from fossil fuels and ever-growing energy demand have raised a strong interest in sustainable and renewable energies. Biofuels derived from biomass can play a crucial role as one of the main sources of renewable energies. As logistics may represent 50% of the biomass cost, it is necessary to design efficient biomass supply chains to provide bio-refineries with adequate quantities of biomass at reasonable prices and appropriate times. More and more researchers have been involved in modelling and optimizing biomass supply chain [1, 2]. The paper proposes a Mixed Integer Linear Program (MILP) to optimize a multi-period and multi-biomass supply chain for several bio-refineries, at the tactical decision level. The locations of refineries can be fixed by the user or determined by the model. The aim is to minimize the total cost of the supply chain, including biomass production, pretreatments, storage, handling, bio-refineries setup and transportation, while satisfying given refinery demands in each period. To the best of our knowledge, this is the only research that deals with a multi-period biomass supply chain, at tactical levels, considering different biomass types, centralized storages and by locating new bio-refineries or using the existing refineries.

2 Approach

The MILP is designed to handle comprehensive multi-period and multi-biomass supply chain with several node types. Biomass can be harvested in elementary production zones (small administrative areas called "cantons" in French), and then either stored in farm storages or transferred directly to centralized storages. Biomass can also be shipped from farm storages to centralized storages. Finally, it is transported to the refineries. The supply chain can be described by a graph with a node-set composed of biomass production zones, farm storages, centralized storages and bio-refineries input stocks, and an arc-set. Each arc denotes a pre-computed shortest path between any two nodes in the road network, with specified length and a required vehicle.

The model relies on some constraints: (1) a refinery will not shut down once it is operational; (2) each refinery is already placed or must be located, and there is at most one per zone; (3) each refinery defines its needs in dry tonnes per product and per period, (4) biomass are transported only by road.

The mathematical model is “data driven”: all data even the network structure is stored in external files. It is possible to add new products or new facilities. The supply chain ranges from finished products (ready to ship in the farms) to bio-refineries storages

The input data stored in a data base include: (1) cost functions associated with production, farm storage, centralized storage, handling, bio-refineries setup and transportation; (2) the geographic distance between each node in the biomass supply chain processed by MapPoint; (3) the annual yield of each type of biomass and biofuel demand; (4) initial inventory for each node (biomass production zones, farm storages, centralized storages and bio-refineries); (5) Loss coefficient per period for each node; (6) capacities for biomass production zones, farm storages, centralized storages and bio-refineries; (7) harvesting window for each type of biomass.

To minimize the total cost, the following optimal decisions are determined by the model: selection of biomass production zones; inventory level of (harvested biomass, farm storages, production zones, centralized storages and bio-refineries); material flow from (production zones to farm storages, production zones to centralized storages, centralized storages to bio-refineries and farm storages to centralized storages); site selection for locating of bio-refineries; capacity level (size) for selected bio-refineries.

The objective is to minimize the total cost of biomass including biomass production, storage, bio-refineries set-up, handling and transportation costs at the refinery gates. In our model, the constraints are formulated in a generic way to be applied to several types of nodes if possible, although some constraints are specific to the bio-refineries. The storage capacity constraints apply to all production zones, farm storages, centralized storages and bio-refineries. They ensure that each site respects its available capacity. Shared capacity constraints for a group of nodes sharing the same storage capacity for different products, are considered. Also, final inventory in the last period must be respected. Inventory balance constraints control the balances in each node. Also, the maximum throughput constraints are used to limit the total flow leaving a node. The demand satisfaction constraints are considered and they look like the inventory balance equations, but the output flow is replaced by a demand.

3 Results and Conclusion

The model is already tested on an 100-km^2 area around the city of Compiègne (60 km North of Paris), with 29 zones (administrative districts containing several communes each and 1768 farms in total) and 3 rape products (bulk seeds, straw bales and chaff bales), and a 1-year horizon divided into 52 weeks. All data is based on real values. Two refineries may be created in any district. By using Xpress-IVE 7.8 from FICO, on a 2.70 GHz Intel Core i7 portable PC with 32 GB of RAM and Windows 7 Professional, Xpress finds an optimal solution costing 52,057,53 euros in 63s. The cost of biomass represents 51.8%, capital and operating costs of refineries 38.4%, transport 5.1%, handling 2.6%, and storage 2.0%. The model has 99645 variables and 7615 constraints.

This paper proposes a multi-period, MILP model to optimize multi-biomass supply chain for several bio-refineries at the tactical level. The objective is to minimize the total cost of the supply chain, including biomass production, storage, handling, bio-refineries setup and transportation. The amount of biomass produced, shipped and stored during each period as well as the number, size and locations of bio-refineries are determined. The work in progress consists in testing the model on larger cases covering two regions of France (Champagne-Ardenne and Picardie), with 9 biomass types, to see the increase in running time, and to handle multi-modal transportation. Future research will focus on designing different solution approaches such as decomposition techniques, relaxation methods and meta-heuristics.

[1] Ba, B. H., Prins, C., and Prodhon, C. Models for optimization and performance evaluation of biomass supply chains: An Operations Research perspective. *Renewable Energy*, 87, 977-989, 2016.

[2] Gold, S., and Seuring, S. (2011). Supply chain and logistics issues of bio-energy production. *Journal of Cleaner Production*, *19*(1), 32-42, 2011.