STUDY PLAN: DESIGN OF SYSTEMS ANALYSIS OF FOREST BIOMASS SUPPLY CHAIN COST AND ENERGY EFFICIENCY FOR BIOREFINERIES IN THE BA REGION

The objective of this info-sheet is to outline the design of a systems analysis to be performed within the Forest Refine project. The systems analysis will define and design some few specific case scenarios of supply chains of forest biomass to biorefinery industries in the BA region. The result from the system analysis will give the cost- and energy demands of the different systems for delivering the right qualities and quantities of raw materials at right time to current and possibly future biorefinery industries in the BA region. The objective of the system analysis is to compare supply chain improvement options to conventional supply chain practices. Important factors in the supply chain are, for example, forest stand composition and geographic location, harvest strategy, terrain transport and storage at landing, terminal handling and fractioning, characterization of different fractions, and the specific requirements on the feedstock properties set by the receiving industry. Project partners and other stakeholders are invited to partake in the design of the systems analysis.

OBJECTIVES

The systems analysis provides a means to compare tentative, improved, supply chains to a reference case representing present supply chains. The systems analysis will include design, cost analysis and energy balance calculation for the supply chains of forest biomass to biorefineries in Finland and Sweden, in reference to their requirements of biomass qualities and quantities and geographical location to biomass resources and infrastructure.

DESIGN PARAMTERS

A key step in the design of a systems analysis is to define the purpose and the scope of the study. A multitude of parameters could influence the studied system, and it is important to design a study such that the chosen parameters can be studied (main effects), while the parameters left out do not affect the conclusions (noise). Initially, a number of observations on the purpose and scope of the study has been compiled within the project group. The observations are:

- The study should be able to quantify the costs and energy use of a suggested supply chain compared to a reference chain.
- The systems analysis should be based on well-defined cases: A few specific types of industries at specific locations with specific requirements on the raw material should be studied.
- The case studies should be geographically and temporally explicit.
- The GIS tools and data available to the project make it possible to be specific on the location of the industry and considered supply areas. It also allows us to study explicit points in time (or time spans). I.e. an industry located at coordinates [x; y] is supplied from forest within region A and the

- potential supply is calculated from 2015 to 2035. This could distinguish our study from many others, which use a very "general" approach when calculating feedstock volumes and costs. We will still use some generalized assumptions and models within the very specific case studies.
- Forestry and forest industry are already multi-product systems, and thus:
  - The total market situation is very complex (i.e. prices of several products on different markets are interdependent)
  - A complete analysis of the market would require e.g. market equilibrium modelling
- Scale issues are of importance: Processing industry has relatively large scale advantages, however, biomass supply has relatively large scale *disadvantages.*
- In Sweden, there is an inland-coastland "conflict", which is interesting to take into consideration in the systems analysis.
- Any feedstock preparation within the biorefinery industry gate needs to be included, in order to provide a fair comparison between different feedstock assortments.

A number of factors which may influence the supply chain costs and energy requirements have been collected in Table 1, along with possible alternatives to be considered for each parameter.

Table 1. Possible design parameters

Parameters											
Central bio-refinery process	Size of bio-refinery	Location of biorefinery	Location of terminal	Type of terminal	Raw material quality	Feed-stock type	Feedstock competition from other industries	Forest biomass yield	Supply chain technology	Supply chain logistics	Harvesting restrictions
Potential parameter alternatives											
Biocehmical, Hydrolysis of polysacharids	Small	Coast	Close to industry	Large (multi-purpose-complex)	Low	Current	Current	Current	Current	Current	Current
Chemical, lignin depolymerisation (pulping)	Medium	Inland	Close to forest	Small (storage)	Medium	Future	Low	Increased	Effective-new	Optimized	Lower
Thermo-chemical, gasification	Big	Industrial site			High		High				Higher
Chemical / physical Extraction of natural substances		Greenfield									

Preliminary study design

The supply of forest biomass feedstock to potential biorefinery industries at specific geographic locations in northern Sweden and Finland is assessed with respect to supply chain costs and energy use. To identity optimal locations is not a central question to the analysis. Rather, locations are selected based on a qualitative discussion, to reflect different conditions regarding infrastructure, closeness to forested areas, integration possibilities with existing industries and access to a district heating network. A preliminary selection would be: 1) Storuman – surrounded by forested area, existing terminal, 2) Umeå – large district heating network and possible integration with CHP, 3) Örnsköldsvik – possible integration with existing pulp-mill based biorefinery and other industries, 4) Finnish BA-region: Ongoing development of terminal handling of forest biomass in relation to large forest industries.

The analysis takes into account the existing forest resources and the forecasted development of the resources over the coming decades. For each location, the supply chain and energy use is calculated for a range of scales of the receiving industry, ranging from 10 MW to 500 MW. The results are calculated as average energy use and cost per delivered unit of feedstock, and as the marginal energy use and cost (i.e. the energy use and cost associated with the delivery of one additional unit of feedstock). Results are calculated for a reference case, applying current harvest levels and supply systems, and for a number of cases applying increased levels of biomass recovery and new supply systems.

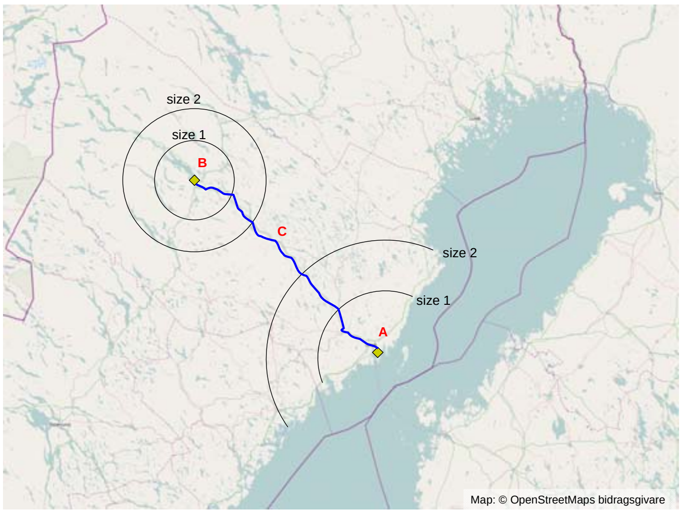

Figure 1. Example of biorefinery locations and supply areas. A: Biorefiney on the coast with local supply, B: Inland biorefinery with local supply, C: Biorefinery on the coast with supply from an inland terminal. Supply area sizes are indicated for two different levels of feedstock requirements.

Three potential, future biorefinery industries are defined. Each of the three biorefineries has their specific requirements and preferences regarding the feedstock properties. Based on the feedstock quality requirements of the biorefineries, and the properties of the considered feedstock, we suggest supply chain designs for each biorefinery type, and estimate the costs and energy use of the suggested supply chain compared to a reference supply chain, which apply conventional methods. A preliminary selection of biorefinery types, based on their key process, is: 1) biochemical hydrolysis and ethanol production integrated with CHP plant, 2) multiproduct pulp-mill with black liquor gasification, 3) biomass gasification with catalytic conversion into liquid fuels.

Finally, we consider the option to perform feedstock preparation operations, such as sorting, comminution, fractioning etc. at a terminal close to the harvesting site. The costs and energy use associated with delivery of refined fuels from the terminal to the biorefinery are calculated and compared to costs and energy use for supply chains where feedstock preparation is performed at the industry and not at a terminal.

Three combinations of biorefinery locations and supply area locations are illustrated in Figure 1: A) Biorefinery located on the coast, with proximity to, for example, larger population centres, existing industries and harbour facilities. Feedstock supply from the surrounding area. B) Biorefinery located in forest-rich, inland area, possibly with proximity to smaller population centres and existing small-scale industries. Feedstock supply from the surrounding area. C) Biorefinery located on the coast (same as A) with feedstock supply from a terminal located inland, and with some feedstock preparation performed at the terminal. The size of the supply area, illustrated by concentric circles in Figure 1, depends on a number of factors, for example: amount of feedstock required by the biorefinery, share of forest land, productivity and existing stock of forest land, parts of the tree which can be used (stemwood, bark, tops, branches, stumps, needles), the share of these tree parts which can be extracted, competition from other industries. In our study, a theoretical, minimum supply area is calculated, assuming that most of the tree parts can be extracted and used, and that there is no competition from other industries. Next, a more realistic supply area size is calculated, taking the aforementioned constraints into account. The supply area size influences the transportation distance and, hence, transportation costs and energy use.

GIS software is used to calculate geographically explicit supply potentials and transport distances (hence, the shapes of the supply areas may not be circular, but depend on forest resource locations and road network). Modeling of forest growth and management is used to forecast supply potentials, and the supply chains results are calculated in 5-year intervals between 2015 and 2060.

A sensitivity analyses will be performed to indicate the influence of changes in key parameters and uncertain set values on the results.

Calculation methodology

The investment, operational and maintenance cost of the supply chain, from harvesting site to processing at industry (comminution at industry is included) are calculated at fixed annual utilization use and are based on functions in literature of production rates for conventional forestry operations. LCA data is used to calculate primary energy use of unit operations and the full supply chains. The energy return over energy invested for the different systems will also be included. A schematic representation of three different supply chains is displayed in Figure 2.

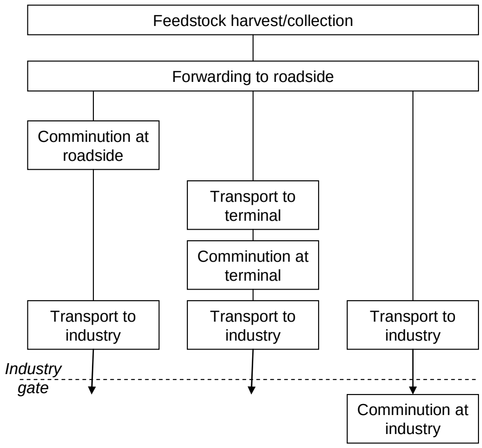

Figure 2. Three general types of forest fuel supply chains.

Time plan

The work on designing the systems analyses will proceed until summer 2013 and modeling and analyses will subsequently be performed in autumn. Results will be presented early 2014.

Design process and interaction

The design phase constitutes a large part of the systems analysis and is crucial for the outcome of the analysis. During this phase it is important to carefully consider all aspects that may be relevant for the systems analysis. As a means to identify these aspects, Forest Refine project partners and other stakeholders are invited to contribute with ideas and suggestions. For contact information of the authors, see bottom of this page.

Keywords

Biorefinery, forest biomass, operational efficiency, logistics, supply chain, systems analysis

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