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ANALYZING MACHINE CONCEPTS AND DELIVERY STRATEGIES TO CUT DELIVERY COSTS FOR FOREST FUELS USING A DISCRETE-EVENT SIMULATION MODEL

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ABSTRACT

Stumps are a possible source of biomass for energy production, but stump extraction is still only a small scale operation and no standardized supply chain has evolved. In order to evaluate possible supply chains, we have developed a discrete-event simulation model for cost-efficient analysis of delivery costs and machine utilization in different scenarios and system configurations. In this new and undeveloped business, simulation results can be used as decision support in planning stump fuel supply. The simulation model is currently being extended to include weather-driven modules for fuel quality changes during storage and the daily fuel demand of heat and power plants.

1 INTRODUCTION

Today, 130 TWh (33.6%) of the energy used in Sweden is produced using biofuels, most derived from forests. These includes residue from forest industries and sawmills, recycled wood and biomass harvested for energy production. Branches and tops from conventional timber harvesting are an important biomass assortment used for heat and power production in Sweden. A fairly standardized supply chain has evolved, with the material transported to roadside storage during the snow-free season and left there until demand arises at the heating plant in colder periods of the year. When demand arises, the biomass is chipped at the roadside and transported by truck to the plant. Thus, storage of the biomass is needed to balance production and consumption. Fuel quality is altered during storage; appropriate storage with natural drying increases the fuel value, but storage can also lead to material degradation.

A large, currently unutilized, source of biomass is tree stumps, which are usually left in the forest. Stump extraction on an experimental scale results in stumps contaminated with sand and stones, so they cannot be chipped using a chipper. Instead, a grinder is needed to produce the chips demanded by the heating industry. As most grinders are large machines, there are advantages of scale if this work is done at terminals or the heating plant. However, the bulkiness of whole stumps makes transport costly, as trucks cannot reach maximum load weight. Skogforsk has carried out field trials of the processes within the supply chain for stump fuel, including extraction, forwarding, storage, road transportation, and grinding. A new concept with grinding at roadside landings and sieving integrated into the crushing process before transportation has been proposed. This system would, in theory, improve transport efficiency and produce a higher quality fuel. However, the long-term performance of the system has not been tested, as large-scale field trials of procurement system performance are extremely costly.

Therefore in order to analyze potential supply chains for stump fuel as regards supply cost and product quality for the fuel delivered, we developed a discrete-event simulation model. The aim of the simulations was to describe which systems providing the best economic return depending on transport distance.

2 METHODOLOGY

The discrete-event simulation model, which includes all activities in the supply chain linked to transport and comminution, was developed in ExtendSim® (Eriksson et al. 2014). A random set of landing objects with geographical location, amount biomass, and fuel quality values stored in attributes was created at the start. Quality parameters affected how the material was handled and also determined the final monetary value of the fuel delivered. After each activity or machine handling, new values were set for the quality parameters based on distributions from Skogforsk's field studies.

Three crusher concepts at forest landings were modelled, two of which included sieving of the material. Each crusher concept was connected to two different truck transport options, one using self-loading chip trucks and the other using trucks with interchangeable containers. A reference system transporting bulky uncomminuted stumps was also tested. These seven systems were simulated in parallel for one year of operation, handling an equal set of objects, and results for each machine were sent to a machine costing template.

3 RESULTS

The results revealed that the costs for the reference system increased faster with transport distance than for the other systems. In areas where average transport distance exceeds 50 km, the reference system should be avoided. However, since it is a non-complex cold system, performance and delivery costs are predictable. If stumps are crushed at the landing before road transport, a system where crushing and truck loading can be done with small machine interactions, i.e. using self-loading chip trucks, is preferable. A hot system, with direct loading from the crusher into truck containers, makes it difficult to maintain high machine utilization for crusher and trucks. This results in increased supply costs, since the crusher is the most expensive machine in the system. In addition to increasing fuel value, sieving the material before road transport lowers the cost of ash handling. Sieving is not an profitable option unless it transforms a unacceptable material into an acceptable fuel.

4 ONGOING DEVELOPMENT

As storage is a central component of supply systems for forest biomass and has a large effect on fuel quality and value, quality changes during storage must be included in forest fuel supply models. Fuel quality is affected by storage time, weather and storage conditions. The fuel demand of a combined heat and power (CHP) plant is also dependent on prevailing weather conditions, mainly outdoor temperature. This makes the use of dynamic weather-driven simulation models a logical option when evaluating supply and storage strategies. We have extended the model described above by using weather data to simulate demand variations and fuel quality changes on a daily basis (Figure 1). This will enable evaluation of different supply strategies, potentially resulting in supply strategies that will provide CHP plants with a fuel closer to requested quality and quantity at any time, and improve annual machine utilization for contractors working in the supply chain. Results from these simulations will be presented during 2016.

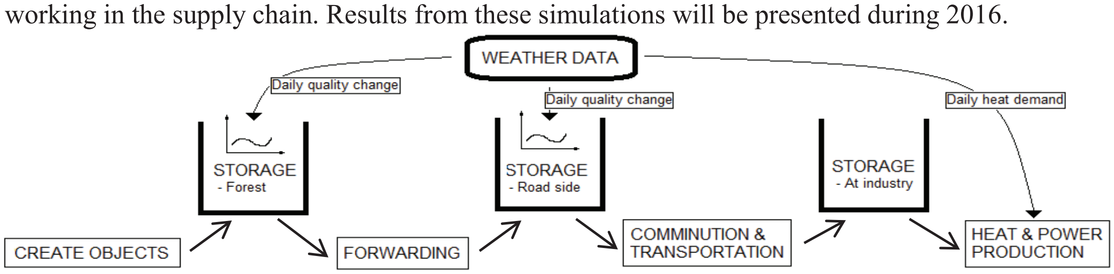

Figure 1: Main structure of the weather-driven forest fuel supply chain model.

REFERENCES

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