Energy 85 (2015) 353–365

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Potential savings and cost allocations for forest fuel transportation in Sweden: A country-wide study

Patrik Flisberg [a], Mikael Frisk [a], Mikael Rönnqvist [b], Mario Guajardo [c, *]

[a] The Forestry Research Institute of Sweden, Uppsala, Sweden
[b] Département de génie mécanique, Université Laval, Canada
[c] Department of Business and Management Science, NHH Norwegian School of Economics, Helleveien 30, N-5045 Bergen, Norway

ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form
17 March 2015
Accepted 20 March 2015
Available online 22 April 2015

Keywords:
Forest biomass
Transportation
Collaboration
Cost allocation
Cooperative game theory
Sweden

ABSTRACT

Bioenergy is becoming a more important energy source. An important bioenergy assortment in Sweden is given by primary forest fuels. These account for about 14% of the biofuels or about 4% of Sweden's total energy. There are large volumes of forest fuel available. However, it is a low-value commodity and it is very sensitive to logistic cost to make it profitable. In this article, we analyse alternatives to lower the logistic costs. This includes the scheduling of the harvest and chipping operations in relation to transportation, delivered mix of assortments to customers and collaboration. We study these alternatives in a case that accounts for all operations in Sweden, involving 200,000 registered transports of about 6.1 million tons of forest biomass, equivalent to 17.4 TWh of energy consumption. We define a number of instances for these alternatives and formulate an optimization model based on linear programming. The solution is obtained by using a decision support system. We identify savings potential of about 22% from changing the operations. These savings can have a large impact on the industry and, more importantly, increase the use of bioenergy. We also test cost allocation methods to spread the savings based on cooperative game theory concepts.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

All around the world there are goals on how much to increase the proportion of bioenergy or renewable energy before certain target years. One example is the "20–20–20 targets" for the EU, which includes raising the share of EU energy consumption produced from renewable resources to 20% by 2020. Recently, in October 2014, another goal was set, "40–27–27", where the second number is to increase the proportion of renewable energy to 27% by 2030. These types of goals are important for many reasons, including reducing CO_2 emissions and removing dependency on non-renewable energy resources such as oil, gas and coal. In Sweden, the use of renewable energy resources such as water, wood fuel, wind and sun, contributed to more than 47% of the total energy use already in 2009 [30]. Bioenergy is a renewable energy made available from materials derived from biological sources. In Sweden the total energy usage during 2013 was 404 TWh, and as much as 130.8 TWh, i.e. 32.4%, came from bioenergy. Forest fuel is an important part of bioenergy and in 2013, 6.2 million tons of forest biomass (equivalent of 17.6 TWh) were transported from forest sites to receiving industries such as district heating plants. A general and complete description of forest biomass can be found in Ref. [2].

The main players in the Swedish wood fuel market are forest companies, forest owners' associations, and a number of small or medium-sized sales organizations. Today there are about twenty companies specialized in the wood fuel business, which account for about 90% of the total volume. Among the actors who buy forest fuels, the energy sector and the forest industry are the big players, but there is also the pellet industry and a number of small-scale users. During 2012 there were 647 receiving points (heating plants and terminals) in Sweden which were the main forest fuel customers. The supply was transported from over 58,000 harvest areas using 200,000 registered transports. The receiving points were spread all around Sweden, including large communities or cities. The market is diversified and there were 63 companies registered as suppliers. Among these, 28 had transports of more than 10,000 tons during 2012. The total demand for forest fuel was 17.4 TWh which corresponds to a weight of about 6.1 million tons. Hence, the needs for transportation involve very large volumes.

* Corresponding author. Tel.: +47 55959834; fax: +47 55959650.
E-mail address: mario.guajardo@nhh.no (M. Guajardo).

http://dx.doi.org/10.1016/j.energy.2015.03.105
0360-5442/© 2015 Elsevier Ltd. All rights reserved.

The forest fuel market is still relatively new and can therefore change rapidly. New biomass-fired CHP (combined heat and power) plants are being built or planned to be built, and must be provided with large amounts of forest fuels. Woodchip-fired heating plants that supply schools, retirement homes, churches, etc., are more prevalent in rural areas and also need fuel. As the demand for wood fuel increases, the number of operators also increases, and there is competition at every level. This applies to both the seller side and the user side. In some regions, this becomes more evident than in others, and there are significant local and regional variations, both in terms of supply and demand. Due to high transport costs for trucks, there is a regionalization of the market. The ability to import alternative fuels affects the market and the pricing considerably. Many thermal plants use import for the equalization of the domestic market, to balance and to keep prices down.

Forest fuels require long-term planning as there is a relatively long lead time from harvesting to use. Moreover, there are several steps involved, such as forwarding, drying, comminution, transport, sorting and inventory handling. Today there is no uniform product standard for forest fuels, which makes it difficult for operators to do transparent business. For example, many different conversion ratios exist between combinations of species, assortment, moisture contents and energy. This makes it difficult to evaluate and find standardized prices. Each business is more or less a separate settlement between the parties.

Since forest fuel is bulky and has a relatively low value compared to roundwood (saw logs and pulpwood) and is replaceable by other energy sources, it is significantly more sensitive to the cost of transport. This is also reflected in the average transport distances: 64 km of forest fuel, and 94 and 102 km for saw timber and pulpwood. Also, seasonality factors due to temperatures imply that demand may be as much as four times larger during cold winters as compared to the summer. In order to best use the chipping and transportation capacity, there is also a need to use terminals for inventory and comminution handling.

Analysis shows that the transport's share of the cost to the industry of primary forest fuels is as high as 15–26%. In comparison, the transport cost for roundwood is about 16%. An increase in the cost of forest fuel at any stage in the supply chain to the thermal plants is not likely to be compensated with a higher price from the customers due to competition from other fuels. Producers of wood fuel currently have small margins. Therefore, there is no space to increase the cost of the primary wood fuel. Having an efficient logistic system in order to make the use competitive is thus critical for profitability.

A critical question is how to make the logistic systems more efficient. There are several approaches that deal with the choice of machine system for comminution, scheduling of teams, location of terminals, use of multi-modal transports, etc. A number of articles have developed these approaches in the context of bioenergy and forest fuel. De Meyer et al. [6] describe the forest biomass supply chain and provide a review of related articles. An extensive review of biomass supply chain operations management models presented in the literature is provided in Ref. [23]. Yue et al. [32] describe the key challenges of biofuel value chains and review the major energy pathways. Sweden has been an active country in the debate concerning forest biomass supply chain and related issues. An early study by Ref. [20] showed this country could increase the use of renewable energy based on its large biomass resources, contributing not only with energy-efficiency improvements but also with considerable reductions in CO_2 emissions. Another early study by Ref. [3] analysed the geographical distribution of biomass potential and local demand for fuels in Sweden, concluding that the extensive utilization of this biomass would lead to short transportation distances and low transportations costs. Miranda and Hale [24] perform a full social cost analysis in Sweden, concluding that forest residues are an attractive source of energy in terms of reducing emissions and may reasonably help to replace energy produced from other sources in such as nuclear power, coal and oil. In their analysis, however, they assert forest residues are not a full solution for the country and suggest their attractiveness can improve by shortening the transport distances between forest residue supplies and energy plants. Joelsson and Gustavsson [19] evaluate different strategies of using Swedish biomass to reduce CO_2 emission and oil use, identifying important niches in which biomass has a comparative advantage over other energy sources. Converting biomass into energy involves planning a number of logistic activities. Some articles dealing with this are [15] that study a Swedish forest fuel company and formulate a mixed integer optimization model for the logistic planning of the company, and [8] which describes a DSS (decision support system) for forest fuel logistics that has been used for case studies in Sweden. Related forest biomass problems are also relevant in other countries. For example [14], present a geographic information system for the optimal planning of forest biomass use for energy production in Italy. Devlin et al. [7] study the performance of biomass based haulage in Ireland according to different criteria, such as distance travelled and fuel consumption. In Canada, recent work by Ref. [27] incorporates uncertainty into the optimization of a forest biomass plant supply chain by the formulation of a stochastic programming model.

Overall, the growing use of forest biomass for energy production increases the need for effective planning systems to manage and plan the forest fuel supply chain. This is particularly important as the values of the assortments are very low. It is critical to establish a low-cost system in order to remain profitable. In this article we will focus on the transportation part of the chain. There are three main alternatives to improve the transportation given that other restrictions are fixed. For a single company it may be possible to change the time, for example, the month in which the transport is done. The reason for this is that the forest fuel is typically available throughout the year since each harvest area is generally harvested one year earlier and the forest fuel dries on location. A second alternative is to replace one assortment with another. This is possible as the demand at heating plants is given in energy, MWH, and not in assortments. Depending on the equipment at the heating plant, however, there may be some limits in the mix of different assortments. The third alternative is to collaborate with one or several companies. This is very interesting as the coverage of supply areas for each company may not represent the locations of heating plants. Also, from one year to another, there may be large changes in the contracts awarded to the heating plants. Hence, the demand locations may change drastically between years.

To test the potential of these alternatives, we make use of a case study. This case study consists of registered forest fuel transports carried out in Sweden in 2012. A total of 200,000 transports are registered. The information was provided by SDC (www.sdc.se), which is a central organization in Sweden often called the IT (information technology) hub of Swedish forestry. SDC manages and administers the majority of the forestry transportation data in Sweden. It acts as an independent organization to ensure that correct information is used in the invoicing procedures between forest companies and transport organizations.

This article has three main contributions. Firstly, it is the first time a complete country-wide analysis of the forest fuel transports is done. Secondly, we propose and measure potential savings using three different alternatives. And thirdly, we analyse and propose some cost allocation methods to support the collaboration of the companies. While most recent literature in collaborative transportation assumes a full description of the characteristic function,

Download English Version:

https://daneshyari.com/en/article/1732083

Download Persian Version:

https://daneshyari.com/article/1732083

Daneshyari.com