BIOMASS AND BIOENERGY 60 (2014) 203–221

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Review

The primary forest fuel supply chain: A literature review

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ARTICLE INFO

Article history:
Received 12 September 2012
Received in revised form
21 October 2013
Accepted 25 October 2013
Available online 26 November 2013

Keywords:
Forest fuel
Bioenergy
Logistics
Intermodal
Multimodal
Transportation

ABSTRACT

This paper provides a literature review of articles on the primary forest fuel supply chain which have been published in English speaking peer-reviewed journals from 1989 to 2011. The focus is on the key issues of the transportation of primary forest fuel to heat and/or power plants: (i) transportation modes, (ii) terminal types, and (iii) forest fuel supply chain management, and provides basics on the logistically relevant characteristics of wood as feedstock such as on various feedstock assortments.

The analysed supply chains include the transshipment, storage, handling (e.g. chipping) and transportation of primary forest fuel from the place of harvest to energy conversion plant. Due to spatial distribution, low mass density, low energy density and low bulk density, the transportation of primary forest fuel is crucial for economic efficiency as well as for reduced CO_2 emissions. As a consequence of forests accessibility, road transportation (after hauling the biomass to the forest road) is the first step of the modern primary forest fuel supply chain. For longer transportation distances, rail or waterway is preferred because of lower transportation costs per volume transported and lower CO_2 emissions. We highlight that some experience exists in multimodal transport, including truck, train or ship. Intermodal transport, however, has not been studied in the past and, therefore, an outlook for the research requirements is made here.

1. Introduction

Biomass as a source of energy is increasingly gaining importance due to the worldwide rising demand for energy, scarcer fossil resources, the awareness of climate change and the environmental dilemma caused by fossil and nuclear energy systems. Focussing on Europe, the domestically available bioenergy substitutes the importing of fossil fuels from instable regions of the world and ensures energy security. Rural diversification and development is a further argument for bioenergy. Figs. 1–4

Looking at the current contribution of renewable energy sources to final energy consumption within the EU, biomass has the greatest share and steady increase within the last decade [1]. In 2009, 68.6% of the gross inland consumption of renewables in the EU 27 were produced from biomass [1]. In the majority of EU countries, the main resources for renewable energy are wood, whereof primary forest fuels (PFF) have the greatest amount [1].

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0961-9534/$ – see front matter
http://dx.doi.org/10.1016/j.biombioe.2013.10.025

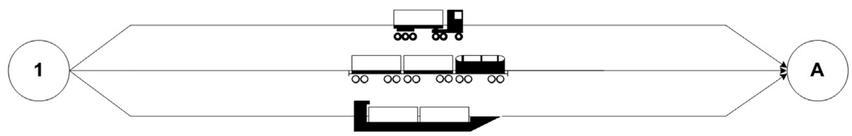

Fig. 1 – Single echelon unimodal transport (21).

The EU member states committed to realise a 20% share of renewable energy sources of the final energy consumption in 2020, leading to an increasing use of bioenergy [1,2].

Accordingly, studies proved that forests can become a major source of bioenergy, even without negative side effects, such as further deforestation [3]. Using the potentials of sustainable managed domestic woodlands is reasonable for increasing the amount of bioenergy in the energy system. Anyway, effective logistics for PFF is crucial for an economical and environmental friendly use of this energy source.

Worldwide biomass is often used in small scale applications [see e.g. Ref. [4]], but district heating systems and electricity-generating facilities have gained in importance in recent years in Europe [see e.g. Ref. [5]] as well as in other parts of the world [see e.g. Refs. [6–8]]. Due to scale effects, the costs per unit of the produced energy decrease with the size of the bioenergy conversion plant [see e.g. Refs. [9,10]]. The influence of logistics on the total costs increases with the scale of the plant [10]. Obviously, for bigger plants transportation becomes more important due to increasing feedstock draw areas and, according to Mitchell et al. [11], high transport costs limit generating capacities to typically 30 MW_{elc}. Later publications relativise that conclusion and suggest – depending on the yield density and transportation costs – optimum size up to more than 400 MW [4,12,13]. Subsequently, the Finnish plant "Alholmens Kraft" produces 240 $MW_{elc.}$ plus 60 MW of heat and 100 MW steam, burning a feedstock of approximately 45% wood based fuels, 45% peat and 10% coal [14]. However, the maximum unit size also depends on the technology used. Gasification, for example, has higher capital costs than direct combustion, but provides a higher efficiency, i.e. more electrical power is produced per unit fuel [4]. Therefore, for selecting the optimum technology and plant size, the type of biofuel and biofuel costs must also be considered [4].

PFF are not exported at a significant scale, mainly because of the relatively high transport costs [15]. Furthermore, logistics costs gain an important part on the total delivered costs of biomass [5]. It is possible to overcome this obstacle by increasing the transport density and the energy density. Therefore, pelletising and, in recent times, torrefaction of biomass gain in importance for supplying power plants from far-off sources. Accordingly, the world's largest bioenergy conversion plant Tilbury (UK) produces 750 MW_{elc}. This former coal plant is now fired entirely with biomass since 2011, and is supplied by deep sea vessels with wood pellets from North America [16].

However, transportation costs are still crucial for economic sufficiency since they represent a great amount of the total delivered costs [5,10,17–19]. Consequently, the most important cost drivers for forest fuel supply are transportation, chipping, and storage [5], with the first two processes requiring much fossil energy.

Up to now, road haulage is the dominating mode for biomass transportation. Börjesson and Gustavsson [20] argue that the energy consumption and the transport costs for longer distances could be kept rather low if the transport mode is changed, from road to rail and waterway. Similarly, Ranta and Rinne [21] point out that shifting the transportation from trucks to trains and ships would make the supply less dependent on distance and they are more environmentally friendly.

Due to the geographically dispersed source areas of biomass (see the characteristics of PFF below), an initial road transport will be necessary in most of the cases. For longer transportation distances this pre-haulage on trucks can be followed by a main haulage on trains or ships. Consequently, there is a possible need for introducing multimodal or even intermodal transport chains in the biomass sector, mainly due to the above mentioned increase in plant size and therewith the procurement areas and transport distances. Additionally, if combined heat and power (CHP) plants are located in densely populated areas according to the heat demand, truck transportation would lead to undesirable effects on the public.

The shipment of goods on two or more transportation modes (see definitions of multimodal and intermodal transport below) is gaining in importance: the transportation volumes in diverse sectors is on the rise [22] and a new research field on intermodal freight transport is emerging [23,24].

Therefore, this paper focuses on the key issues of the transport of PFF to heat and/or power plants - transportation modes, terminal types, forest fuel supply chain management – and discusses PFF characteristics and assortments. The remainder of the paper is as follows: after the basic definitions and methodology, the first chapter provides an overview on the specific characteristics of PFF affecting transportation

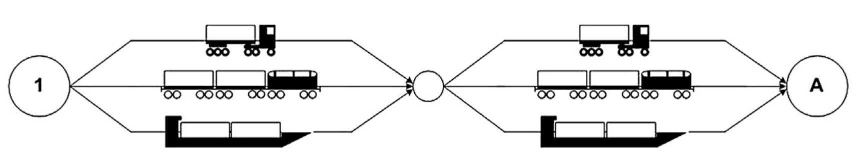

Fig. 2 – Multi echelon unimodal transport (21).