biomass and bioenergy 56 (2013) 260–267

Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

Biomass logistics: Financial & environmental costs. Case study: 2 MW electrical power plants

J.A. Ruiz [a], M.C. Juárez [b,*], M.P. Morales [c], P. Muñoz [b], M.A. Mendívil [b]

[a] Escuela Técnica Superior de Ingenieros Industriales y Telecomunicación, Universidad Pública de Navarra, Campus de Arrosadía, 31006 Pamplona, Navarra, Spain

[b] Escuela Técnica Superior de Ingeniería Industrial, Universidad de La Rioja, Calle Luis de Ulloa, 20, 26004 Logroño, La Rioja, Spain

[c] Facultad de Ingeniería, Universidad Autónoma de Chile, Pedro de Valdivia 641, Providencia, Santiago, Chile

ARTICLE INFO

Article history:
Received 3 January 2013
Received in revised form
17 May 2013
Accepted 20 May 2013
Available online 14 June 2013

Keywords:
Transportation
CO_2 emissions
Costs
Crop and collection areas
Logistics
Pruned vine shoots

ABSTRACT

Biomass is so diverse that special care must always be taken in designing plants to handle biomass-based fuels and in the process for its collection, preparation and transportation, because its energy density is such that far greater volumes need to be transported than in the case of fossil fuels. This means higher costs and more associated CO_2 emissions.

This paper examines the following points concerned with the logistics of biomass: optimum biomass transport distances to plants, transport costs, CO_2 emissions relative to CO_2 avoided and the surface areas required to grow or collect biomass.

Particular emphasis is placed on the logistics of biomass-fired electric power plants rated at 2 MW electrical, a size that enables electric power distribution to be decentralised.

The findings reveal that the maximum cost of logistics (not including any collection and preparation stages) is €11.05 per tonne, with emissions amounting to 0.69% of the total CO_2 avoided, for the worst-case scenario of distances averaging 100 km around the plant.

1. Introduction and objectives

Ambitious policy objectives have been set to increase the contribution of biomass to the energy supply in industrialised countries, but biomass resources are rather limited and expensive in many cases. Therefore, optimal use of resources is desirable to produce as much energy at as low a cost as possible [1].

The use of biomass to produce energy instead of conventional fossil fuels results in a net reduction of greenhouse gas emissions and in the replacement of non-renewable energy sources. However, generating energy from biomass is currently rather expensive due to technological limitations in terms of lower conversion efficiencies, and to logistical constraints.

In particular, the logistics of biomass fuel supplies are likely to be complex owing to the intrinsic characteristics of the feedstock, such as its limited period of availability and scattered geographical distribution [2].

The major challenges faced by these energy conversion technologies include how to collect, prepare (chipping, briquetting, etc.) and transport biomass to electric power plants with the lowest possible financial and environmental costs, and how to assure supplies over time.

* Corresponding author. Tel.: +34 941 299 520.
E-mail address: manuel.juarez@unirioja.es (M.C. Juárez).

0961-9534/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biombioe.2013.05.014

2. Background

In the assessment of biomass logistics, several aspects need to be considered:

- Primary energy used in the collection and transportation stages
- Optimum biomass collection distances from plants
- Logistics costs
- CO_2 emissions derived from logistics phase
- Biomass crop and collection areas

2.1. *Primary energy used in the collection & transportation stages*

Calculations of the primary energy in biomass must be adjusted downwards to take into account the energy consumed in collecting it, preparing it and transporting it to the gates of the power plant [3].

Some authors estimate that the adjustment required could be as much as 4–7% in the collection and transportation stages (see Fig. 1) or 2–4% if it is in pellet form [4].

Tolosana et al. study "three residual forest biomass harvesting methods in Spanish hybrid poplar plantation" and conclude that the method based on two powerful chippers mounted on forest forwarders and complemented with high capacity farm tractors with specialised trailers and large mobile platform trucks is the most productive, but high relocation costs make it feasible only for large enterprises and plantations.

They therefore stress the importance of taking into account the amount of biomass to be processed when establishing the cost of investment in equipment needed for collection and chipping. They find that other systems are better suited to smaller quantities of biomass, mainly because of equipment investment costs [5].

It is found that it may be economically and environmentally feasible to transport biomass over long distances, but that primary energy use, costs and CO_2 emissions are lower at local level [4]. However, factors of economy of scale must also be considered in regard to transportation, especially by sea.

2.2. *Optimum biomass collection distances from plants and logistics costs*

Sala et al. cite 50 km from the electric power plant as the maximum distance over which biomass can feasibly be collected [6]. Several authors consider 20–30 km for small-scale plants of around 2 MW electrical [7–11]. Krukanont et al. [12] take a distance of 35 km in their approach for determining the viability of electric power plants fired by biomass.

According to Singh et al. [13], the unit collection cost of biomass depends upon the spatial density biomass recovery cost and the unit transport cost of biomass. The results of transportation analysis indicate that the unit cost of transport decreases with increasing distances for various modes and systems of transport. The cheapest mode of transport for loose biomass up to 30 km is tractor–wagons and beyond 30 km it is trucks.

However other studies find 100 km to be the maximum distance for trucks, and propose that trains be used for longer distances [14,15].

Göran et al. discuss the need to think of biomass in global terms and to set up a market for the transportation of large quantities of biomass over long distances of up to 1200 km. They stress that the associated environmental impacts are then not so high [16]. For transportation of biomass across 1100 km those impacts may be estimated at around 21–28 € MWh^{-1}, or 22–25 € MWh^{-1} if it is pelletised [4].

Hamelinck et al. [14] find that the most economical way of transporting biomass in various formats from either Scandinavia, Latin America and Eastern Europe to Western Europe is by sea from Latin America (>10,000 km) in pelletised form. This costs about 55 € t^{-1}, though the figure could be reduced to €40 per dry-weight tonne delivered, enabling electricity to be produced at 35 € MWh^{-1}, which would make this a strong competitor for fossil fuels.

The biggest differences between Latin America and Europe are shown to lie in the price of biomass itself: preparation and transportation costs are very similar.

The bigger the power plant the further it is necessary to go to collect biomass, and the design of the logistics involved must be changed accordingly (Fig. 2): the main changes are in the means of transport used and the morphology of the biomass carried.

In local transportation around 75% of the cost of moving, transporting and delivering herbaceous biomass to plants from temporary storage locations is accounted for by the cost of trucks. Therefore, the optimum number of trucks for shipping biomass to plants must be available, so that suitable productivity levels can be ensured and trucks do not stand idle. This raises the price of the biomass delivered.

Ravula et al. draw up models of the biomass loading network and of truck movements with a view to minimising the logistical costs of biomass [17].

An H. et al analyse loading and unloading costs, taking transport costs as constant, and examine large-module packaging solutions, which greatly reduce loading and unloading times and associated costs [18].

Fan et al. compare various biomass transportation systems, looking at the shape of bales and the means of transport used (Table 1):

Their results show that option A is the most economical when storage capacity is less than 110,000 tonnes. For larger storage capacities option D is more cost-effective [19].

Judd et al. do not consider it financially viable to densify biomass for transportation over distances of less than 81 km [20].

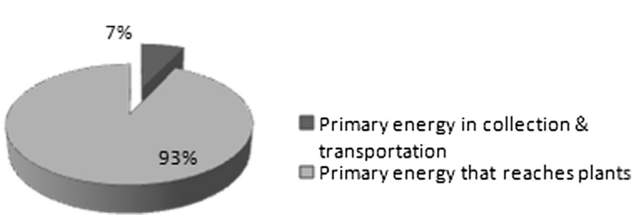

Fig. 1 – Maximum percentage of primary energy from biomass consumed in the collection & transportation stages [4].