Renewable Energy 74 (2015) 568–575

Contents lists available at ScienceDirect

Renewable Energy

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

Comparative cost evaluation of heating oil and small-scale wood chips produced from Euro-Mediterranean forests

Bernat Esteban, Jordi-Roger Riba*, Grau Baquero, Antoni Rius

Escola d'Enginyeria d'Igualada (EEI-Escola d'Adoberia), Universitat Politècnica de Catalunya, Plaça del Rei 15, 08700 Igualada, Catalunya, Spain

ARTICLE INFO

Article history:
Received 4 November 2013
Accepted 18 August 2014
Available online 16 September 2014

Keywords:
Wood chips
Small-scale
Cost evaluation
Sensitivity analysis
Heating oil

ABSTRACT

This work performs a cost evaluation of small-scale produced wood chips from forests in the Euro-Mediterranean region to be used for heating purposes. The study is focused on forests located in the Argençola municipality (Catalonia, northeastern Spain). The use of such easy-to-produce biofuel is appealing since it may be used as a valid substitute of heating oil to produce thermal energy in the same area where it is produced, thus minimizing transportation requirements and reducing dependence on the rising prices of heating oil. Additionally, it allows facing environmental and social concerns related to the current lack of management in the forests under analysis, which has led to an important increase in the biomass stock and wildfires risk. As wildfires in the Euro-Mediterranean region generate important impacts, an average economic cost of wildfires has been evaluated in this paper. The economic assessment of small-scale production and consumption of wood chips as proposed in this study has shown interesting economic benefits when compared with current heating oil prices. Results indicate that it is a realistic option since production costs range from 12.2 €/GJ to 18.5 €/GJ depending on the applied forestry practices, whereas current cost of heating oil is about 23.9 €/GJ. A sensitivity analysis has also been conducted to assess the impact of the data with higher uncertainty on the final results. It has been shown that the key factors that determine the viability of the proposed model are heating oil price, biomass stock growth rate, transportation requirements and applied forest management practices. Results presented prove that wood chips cost is quite independent of fossil fuel prices, thus higher fossil fuel prices greatly favors the use of wood chips when produced and consumed in the same area, thus minimizing transportation requirements. In addition, higher biomass growth rates than those considered in this work may reduce the final cost of small-scale produced wood chips.

1. Introduction

Biofuels are appealing since allow mitigating global warming and contaminating emissions while reducing dependence from fossil fuels. In Spain, total sales of liquid biofuels increased in 2011 by 17% when compared to 2010 and 61% with respect to 2009 [1]. However, it is recognized that some practices related to large-scale biofuels production may generate negative environmental and social impacts [2]. On the other hand, small-scale production of biofuels promotes local biomass use, stimulates rural areas development by supporting the national energy industry [3], minimizes transportation requirements and therefore it is also attractive from an environmental point of view [4].

Mediterranean forests stimulate the socio-economic progress of rural areas while contributing in preserving biodiversity, landscape quality and carbon sequestration among others [5,6]. The Mediterranean area has been always affected by forest fires [7]. However, they have become more severe and frequent [8] mainly because of recent changes in social and climate conditions [9] which have led to stand-level fuel accumulation and landscape fuel continuity [7]. According to Ref. [10], Spanish forests have experienced an obvious population decline, a decrease in grazing livestock pressure [7] and a progressive abandonment of land by farmers since the 1950s. This lack of management has led to the abandonment of many forests with the consequent fuel load accumulation and the increase in both the number of wildfires and the total burnt area. These facts have enabled shrublands and forests expansion, thus increasing urban–wildland interfaces, thus greatly increasing wildfires risk [11].

It is recognized that to reduce catastrophic wildfires risk, landscapes should be managed to decrease overall fuel load (fuel mass

* Corresponding author. Tel.: +34 938035300; fax: +34 938031589.
E-mail addresses: jordi.riba@eei.upc.edu, riba@ee.upc.edu (J.-R. Riba).

http://dx.doi.org/10.1016/j.renene.2014.08.038
0960-1481/

per unit area) [12] and alter vegetation structure [13,14]. Therefore, fuel load may be used as an indirect indicator of fire risk [15]. High-impact fires occurrence is of special concern in dry type forests, especially those lacking of fuel reduction practices. This is the case of most Mediterranean forests [12].

Energy profile in Spanish rural areas strongly depends on fossil fuels consumption, with the consequent dependence on fossil oil markets and generation of harmful emissions. Sustainability forestry practices may contribute in reducing this dependency while promoting the use of local resources and rural areas development, therefore generating wealth and jobs [16]. Sustainability includes social, environmental and economic aspects.

Wood fuel is an interesting renewable energy resource which may be obtained mainly from cutting and clearing activities, logging residues, recycled wood or industrial by-products. It is important to highlight that the use of cost-efficient forest fuels allows mitigating greenhouse gas emissions [17]. According to Ref. [18] the technical limit of forestry and agriculture residues in Spain is about 82 TWh/y, equivalent to 4.95% of the primary energy consumed in Spain during 2008.

As pointed out by Girardin et al. [19], forest resources should be used in such a way that long-term ecosystem functionality is preserved. Therefore, allowed management interventions should guarantee forests structures similar to those found in natural ecosystems [19].

In this paper, the economic feasibility of small-scale produced wood chips is analyzed and the final production cost is compared with the current heating oil market price. Wood chips are appealing because they present improved combustion performance when compared to the direct combustion of logs. The study is focused in the Mediterranean forests of the municipality of Argençola (Catalonia, northeastern of Spain).

This paper proposes forests management practices based on sustainable environmental criterions which promoting biodiversity while periodically decreasing biomass/fuel stock, thus increasing forests productivity and minimizing wildfire risk (see details in Section 2). This paper analyzes different management methods of the undergrowth to reduce the fuel load in order to reduce wildfires risk. It also proposes the production and consumption of the wood chips in the same area, therefore minimizing transportation requirements. The direct use of wood chips as fuel in heating systems has several benefits since they almost do not generate co-products and allow consuming the raw materials in the same territory. This system increases the energy and economic values of the forestry products, thus promoting woodland' owners to take care of the forests maintenance while reducing the risk of degradation, wildfires and desertification. Additionally, the proposed system enhances the socio-economic development of rural areas. According to a study focused on the Argençola municipality, the total biomass extracted from this area could feed 50% of all thermal residential needs [20].

It is worth noting that although the results presented here are particular for the area analyzed, they may also be extended to other regions with similar characteristics. Therefore, these results may be useful for decision-makers to develop policies focused on promoting the on-site consumption of small-scale produced wood chips by applying environmentally friendly forestry management techniques while reducing wildfires risk.

2. Materials and methods

2.1. Goal and scope and system boundaries

The goal of this paper is to conduct a comparative economic cost evaluation of two fuels for heating systems, i.e. forest wood chips and heating oil. As explained, the wood chips are obtained from forests located in northeastern Spain.

The functional unit used in this study is one GJ of heat energy obtained from each fuel, which allows comparing the cost of the two evaluated fuels when an identical amount of energy is considered. This value is calculated from the lower heating value (LHV) of each particular fuel. The LHV of heating oil is 43.35 GJ/t [21], whereas the LHV of dry wood chips is 18.60 GJ/t [22], which decreases when increasing the moisture content.

The boundaries of this study comprise the production cost of forest chips in the municipality of Argençola as fuel for household heating systems and the comparison with heating oil cost. Fig. 1 shows the processes involved in the production of wood chips, which are detailed in Section 2.3.

As shown in Fig. 1, the system boundaries of the wood chips system comprise the forest maintenance practices, the logs chipping and screening operations, the transport of the wood chips to the woodstore, the drying and storage processes and the transport to the consumer. Therefore, the cost of producing the wood fuel amount equivalent to one GJ of heat energy is obtained when considering all these operations. The wood chips production costs under different scenarios are compared with the current cost of heating oil.

2.2. The area under study

Data provided in this study is focused on the municipality of Argençola (latitude: 41.552954–41.625280, longitude: 1.398165–1.512279, 450–765 m above sea level), which is placed in Anoia region, in the province of Barcelona (Catalonia), situated in the northeastern of Spain. This study is centered in Catalonia because it is one of the Spanish autonomous communities with more availability of wood biomass resource [18,23]. Currently, as explained, most of the forests are virtually abandoned with a consequent significant growth of the biomass stock, thus notably increasing the risk of wildfires, especially during summer season [6]. The municipality of Argençola has a total area of 4710 ha, the forest area comprising about 2200 ha, mainly composed of pine trees (*pinus halepensis* and *pinus nigra*, accounting for 95% of the total forest area) and conifers and oak trees (5% of the total forest area). Its climate is predominantly characteristic of Mediterranean forests.

Nowadays, in the analyzed area there is an average of about 63.2 t_C/ha (carbon tons per hectare) in stock [20], with an annual mean growth potential of 0.8 t_C/ha [24]. This result is in close agreement with data presented in Ref. [18], in which the annual growth rates for pines and oaks is, respectively, 1.6 and 1.0 t_{dry_wood}/ha (dry wood tons per hectare). With these values, and supposing 95% and 5% composition of pines and oaks, respectively, the annual mean growth rate results in 1.57 t_{dry_wood}/ha, which roughly corresponds to 0.8 t_C/ha [25]. A very similar result may be obtained from data presented in Ref. [26]. However, a mean recovery factor of 0.75 is supposed, which leads to a conservative practical annual growth rate of about 0.6 t_C/ha, which is used in this paper for calculation purposes. The maintenance strategy is based on an average intervention every 23 years which should ensure to reduce the carbon stock to an average value of about 50 t_C/ha. This maintenance periodicity guarantees that the average biomass stock in the analyzed forests remains almost constant over time. For further details, readers are addressed to Ref. [23].

2.3. Management practices considered

As explained, Spanish forests have experienced a progressive abandonment since the 1950s [10], being this the current situation