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Research paper

Economic and environmental assessment of agro-energy wood biomass supply chains

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ABSTRACT

The aim of this study is to conduct an economic and environmental assessment of forest biomass for heating, in particular two types of firewood and three types of wood chips were analyzed. Regarding economic aspects, an analysis was made of production costs and revenues (per tonne of biomass), considering all the stages involved "from the woods to the mouth of the boiler." For the environmental analysis, conducted using life cycle assessment, the stages taken into account went from "the woods to the heat produced". The wood biomasses were compared to each other and to fuel oil and natural gas. The economic analysis showed that at current market prices it is more profitable to produce firewood rather than wood chips. As concerns the environmental aspects, the results of the LCA showed that, for the same heat output, forest wood-based fuel has an environmental impact lower than fuel oil, but still higher than natural gas. There are no big differences in the impact of various wood fuels. In the conclusion, some ways for improvement have been proposed, in terms of both the economic competitiveness of the agro-energy supply chains considered and the reducing of their environmental impact.

1. Introduction

Renewable energies already play a role of national and international importance as a result of the need to replace traditional energy sources and to fulfil the commitments endorsed as part of the Kyoto protocol to contrast the ongoing climatic change, complying also with the measures known as "20-20-20" [1].

Within the category of renewable energy sources, there is growing interest in agro-energies in particular. Back in 2005, the European Union issued its "European Biomass Action Plan" [2], with which it aimed to encourage and increase the use of energy sources obtained from forestry, agricultural and waste material, as also the production of biofuels for transport.

Forest biomass is widely available in Europe, but it is largely unused. In the European Union, only 65% of annual forest growth that could be harvested is used [2]. Although the low utilization is due no doubt to economic reasons (negative values of stumpage and greater competitiveness of the imported product), it is reasonable to assume that the annual amount harvested can at least double, and its use for energy could be a driving force in this direction.

The supply chains for wood biofuels are short chains, which implies proximity between the places of energy consumption and production. The short supply chain has several advantages in the agro-energy sector: from an environmental perspective, it minimizes transport emissions; from an economic perspective, it reduces the number of operators involved in the value chain, ensuring greater distributional equity and profitability for producers, an essential aspect for supply chains in which the profit margins are very low, as in this case; lastly, from the social point of view, it creates jobs locally.

Surely, profitability of wood supply chains strictly depends on how these are organized, and which technical parameters are involved. However, the future prospects of the biomass market for energy use will also be strongly affected not only by economic profitability but also by the problem, first raised in 2010 by some scientists [3,4], of their actual environmental sustainability.

What is being questioned is their alleged "carbon neutrality." The logic behind the assumption that wood biomass has "zero greenhouse effect" is that their combustion or decomposition is part of the natural carbon cycle and does not increase the amount of carbon in circulation; on the contrary, when forest biofuels replace fossil fuels, they are attributed with the merit of reducing greenhouse gas emissions [3,4].

The new hypothesis that is now taking hold is that bioenergy is

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not always "carbon neutral," and erroneous accounting may inappropriately stimulate the use of forest resources, taking the wood away from alternative uses having a lesser impacts on climate change [3,5]. It has been observed that the combustion of biomass replaces fossil emissions with its own emissions, which can also be higher per unit of energy [3]; that greenhouse physics is indifferent to the origin of the pollutant, and once a molecule of CO_2 enters the atmosphere its warming capacity is the same, irrespective of its origin [5]; that the different time scales with which the fossil and biogenic carbon interact with the carbon cycle must be taken into consideration [6]; that the shift from fossil fuels to energy from wood biomass could lead to an increase of the levels of greenhouse gases in the atmosphere for at least a number of decades [7–9]. The challenge to the principle of carbon neutrality of biomass is obviously a crucial issue for supportive policies and incentives for bioenergy and will require the development of new greenhouse gas accounting models [6].

The complex picture outlined above makes evident the need to deepen knowledge about the actual economic and environmental impact of the use of wood biomass.

Several studies conducted in literature focused on economic aspects of forest biomass (e.g. technical and cost limitations of harvest residues recovery [10]; costs estimation of wood chip production [11]; calculation of parameters like net revenue, breakeven prices and price elasticity of firewood and wood chips [12]), or on environmental ones (e.g. environmental impact of fuel chips [13] or in general of forest logging residues [14]; environmental impacts of roundwood supply chain [15]; analysis of different wood assortments for the production of raw wood, without considering residues [16]). Other studies, discussed beyond in the article, focused on both economic and environmental aspects of different types of wood biomass [17–20]. All these studies underlined how the specificity of the chain, and aspects like chain topology, type of organization, management and regulation, systems of price, exc. can sensibly affect both economic and environmental results.

In this context, the aim of this study is to conduct a specific economic and environmental assessment of forest biomass for heating (firewood and wood chips). Five final types of biofuel were taken into consideration: two types of firewood, obtained with different removal systems, and three types of wood chips, differing in terms of processing and final destination. This type of analysis attempts to be as exhaustive as possible, taking into account both main wood products and residues and, in relation to the items analyzed, not only economic or environmental aspects but both of them, considering standard, therefore repeatable, organizational procedures.

Regarding the economic aspects, an analysis was made of the production costs and revenues per unit (per tonne) and per hectare, considering all the stages involved in the production of wood fuel "from the woods to the mouth of the boiler." For the environmental analysis, conducted using the life cycle assessment (LCA) methodology, the stages taken into account instead went from "the woods to the heat".

While most of the environmental studies on forest biomass focus only on greenhouse gases and energy use [13], here a multiplicity of impact categories is considered. This because, together with the analysis of the influence on climate change mitigation (evaluating which of the chains analyzed has lower emissions into the air of CO_2, methane and other greenhouse gases) there are other environmental impacts that should be taken into account in the assessment of the environmental sustainability of biofuels [13].

Moreover, the different wood biomass fuels were compared to each other and to some fossil fuels used for heating (fuel oil and natural gas). After having analyzed the main economic and environmental results, some ways for improvement have been proposed, in terms of both the economic competitiveness of the agro-energy supply chains considered and the reducing of their environmental impact.

2. Materials and methods

Five types of wood biomass chains were analyzed: firewood obtained using traditional skidding systems, firewood obtained using aerial cableway removal systems, class B wood chips (for biomass power stations), class A2 wood chips (for industrial thermoelectric power plants), class A1 wood chips (for domestic heating systems).

The above mentioned chains were analyzed in the context of Italian forests, companies and markets, however these present characteristics that are extendible also to other international contexts. The chains were analyzed in the period of time between 2013 and 2015.

The main data related to the technical analysis of the chains were collected through field visits to two big companies well established on the market, performing interviews with expert witnesses. The two companies have been chosen as a reference model after an extensive analysis of several companies located within the national territory, as they were found able to well represent the two most common types of techniques practiced in the sector (traditional skidding and aerial cableway removal systems). These direct inquiries led to the identification of the production techniques, worksites and operating performance parameters that reflect the choices widely practiced by companies in this type of industry. These items are explained in details in subsection 2.2. Also the makeup of the machinery, the prices of new machinery and of wood assortments were inferred by direct interviews with expert witnesses of the main logging companies and consequently estimated. For the environmental analysis, in addition to the primary data, which were collected through the above mentioned field visits, some secondary data were needed, mainly taken from Ecoinvent database [21].

From a methodological point of view, the technical parameters identified were applied to one hectare of "typical coppice," in order to quantify elements useful for subsequent economic and environmental assessments.

The economic analysis was performed per tonne of wood biomass and per hectare. The stages considered in the analysis went "from the woods to the mouth of the boiler." The environmental analysis, performed by means of LCA, was made per tonne of wood biomass, and the stages taken into account instead went from "the woods to the heat," i.e. up to the combustion of the biomass considered.

The following subsections present a brief description of the wood biomass supply chains analyzed (subsection 2.1), the characteristics of the "Typical Coppice" which has been taken into consideration as technical reference, together with description of typical worksites, the production process, including some assumptions made (subsection 2.2). Next, more details about the economic and environmental methodologies implemented are presented (subsections 2.3 and 2.4).

2.1. Firewood and forest chips supply chains

The raw material at the base of the firewood supply chain comes entirely from the woods. The final wood fuel is represented by firewood, the qualitative and commercial characteristics of which are defined by the UNI CEN 14961:2005 standard. There are various commercial sizes, characterized by different lengths and diameters. On the basis of the moisture content, the firewood is divided into