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Life cycle environmental impact of firewood production – A case study in Italy

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HIGHLIGHTS

- LCA of firewood short and long supply chains has been performed.
- There are different critical values of transportation distance for impact categories.
- A sustainable forest management can completely offset the fossil CO_2 emission.

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ABSTRACT

The forestry sector is showing an increasing demand for documentation about its environmental performance. Concerning forest operations, many studies have revealed remarkable differences in environmental impact mainly due to differences in location, forestry practice and technologies. As a consequence, reliable information on environmental performance for forestry operations and wood supply chain is considered to be crucial.

This work aims to evaluate the environmental impacts of the firewood supply chain from high stand beech forest in North-Eastern Italy. Two scenarios have been considered: the first scenario investigates the firewood supply chain based on the wood harvested from the local forest, while the second one investigates the supply chain based on wood imported from the Balkans' area.

The differences between the two scenarios are assessed through a "gate to grave" life cycle assessment for the impact categories: Global Warming Potential (GWP) and Ozone Depletion Potential (ODP); Photochemical Ozone Creation Potential (POCP) and Human Toxicity Potential (HTP). The functional unit is 1 MJ of energy produced by firewood.

The study has shown that there are different critical values of transportation distance for impact categories.

Although most of the chemicals emitted in the life cycle of firewood cannot be offset, a sustainable forest management can completely offset the fossil CO_2 emissions of the short and the long supply chain by saving less than 10% of the net increment.

1. Introduction

In the last years the world energy demand has rapidly increased as a consequence of the worldwide economic growth and development. The global total primary energy supply more than doubled between 1971 and 2011 [1] and is expected to increase at higher rates in the next decades. With the current energy policies, the market energy consumption is estimated to increase by 44% from 2006 (497 EJ) to 2030 (715 EJ) [2]. The World Economic Outlook (WEO) 2013 projections are even worse, stating that by 2035 electricity demand will be almost 70% higher than current demand, driven by rapid growth in population and income in developing countries [1]. This growth will cause a progressive depletion of fossil resources and make the availability of conventional oil and natural gas geographically restricted [3,4]. Furthermore in 2011 the energy sector was responsible of 42% of the total greenhouse gas emissions, significantly contributing to climate change, while transport accounted for 22%, industry 21%, residential 6% and others 9% [1].

Therefore the replacement of fossil fuels with renewable resources is considered to be crucial. Among different ways of

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producing renewable energy, biomass represents one of the most promising energy source. Wood has been the first fuel historically adopted before being replaced by fossil fuels. Worldwide bioenergy provides today only 10% of the world's total primary energy supply and most of this is used in the residential sector for heating and cooking purposes [5]. Wood is largely available and, if correctly managed through a sustainable management, can represent un unlimited source. In developing countries traditional bioenergy use (fuelwood and charcoal) still dominates since up to 95% of national energy consumption relies on biomass [6].

In Italy a large portion of the harvested wood is used for the production of firewood that is primarily burned for domestic heating. A survey conducted by APAT–ARPA [7] shows that 25.6% of the Italian families uses firewood for domestic heating, percentage which increases to 38.7% for the families living in the mountain areas. According to the Istat/Eurostat data reported in Pettenella et al. [8], the wood harvested in Italy for energy purpose reached 70% of the total harvested wood in 2011, considerably higher if compared to the share below 50% recorded in the seventies. Based on the National Action Plan for the Renewable Energy, the total solid biomass, the main component of which is woody biomass, should cover the 8% of the electricity production and the 54% of the thermal of Italy by 2020 [9] according with the European Union target of a 20% of energy produced by renewable resources by 2020 [10]. Among the different types of woody materials used for domestic heating in Italy, 92% is constituted by firewood, 4.5% by pellet and 3.5% others [7]. Although the increasing demand of firewood represents a potential field of economic growth for the wood sector in Italy, in the last decades a dramatic increase of importation of firewood has been observed. In 2012 Italy was acknowledged as the first importer of firewood of the world [11] a large part of which originating from the Balkans' area. The massive importation of firewood from this area is mainly due to the overall lower cost of labor and of raw materials encountered in these Countries, according to the Kyoto Protocol classified as countries with "economy in transition" indicating the specific socio-economic conditions characterizing the transition phase from previous totalitarian regimes [12].

Although the use of firewood imported from abroad can be economically convenient, it may have negative consequences on the environment.

To evaluate the environmental impacts produced by the firewood supply chain the Life Cycle Assessment (LCA) is the internationally recognized tool. LCA, as defined by the ISO 14040 [13] and ISO 14044 [14] standards, is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [13].

Through the LCA it is possible to quantify the environmental impacts in all the phases of the supply chain, from the acquisition of the raw materials from the environment, until the production, distribution and use of the final product. The LCA allows to evaluate the environmental impacts for different impact categories for the compartments: air, water and soil. As far as the air compartment is concerned, the LCA includes some global scale impact categories such as the Global Warming Potential (GWP) and the Ozone Depletion Potential (ODP) and some local/regional scale impact categories such as the Photochemical Ozone Creation Potential (POCP) and the Human Toxicity Potential (HTP). The GWP or "greenhouse effect" produces an increase of temperature in the lower atmosphere that can lead to climate and environmental changes. The ODP regards the decomposition of the stratospheric ozone layer that causes an increase in the incoming UV-radiation that leads to impacts on humans, natural organisms and ecosystems. No matter where the contributing substances are emitted they contribute to the same phenomenon and GWP and ODP impact categories are therefore considered to be global.

At local scale, the LCA takes into account the photochemical ozone creation and the potential effects of emissions on human health throughout the POCP and the HTP categories. Particularly, all the considered impact categories have an effect on human health but the HTP takes into account also the heavy metals and particles (dust).

For the European forestry and wood products sector, the first LCA studies appeared in the 1990s with the aim to scientifically analyze the impacts arising from non renewable inputs into a system [15]. Although LCA techniques of forest production have been already conducted, consistent and comprehensive LCA studies are still lacking for the forestry sector [15]. As emerged from the literature, there is heterogeneity in the evaluation methods, regarding the use of different indicators, system boundaries, allocation procedures [15–17], functional units and reference systems. This means that outcomes are often not immediately comparable and of difficult interpretation and there is at present no commonly accepted methodological approach for conducting an LCA in the forestry sector [15].

As far as the global warming is concerned, biomass is considered to be carbon neutral [6,15,18–31] since it is considered that the carbon dioxide released in the combustion phase equals the carbon dioxide absorbed during the growth of a same amount of biomass in forest.

However this assumption does not consider the emissions of fossil origin generated throughout the life cycle of the product. In this regard, the distance traveled from the site of acquisition of the raw material to the utilization site may play an important role in the overall carbon footprint [32–36]. It is known that transportation is an important source of carbon dioxide emissions, which have potential impact on climate change [37]. However it is not known at what distance this impact becomes critical for the firewood supply chain. From the analysis of the literature, contrasting conclusions have been reached about the impact of transportation on the whole life cycle assessment of bio-energy [32–36,38,39].

Furthermore, although the impact on global warming is considered to be crucial, some studies have shown that combustion can have a high impact on photochemical smog and human toxicity [35,36,40] but it is not known how a long supply chain would influence these impact categories.

Although the emission of pollutants might be critical in the firewood combustion phase, several studies have demonstrated the overall benefit for the environmental associated with the use of wood instead of traditional fossil fuels such as coal and natural gas [6,41–43], which, according to Cherubini and Strømman, represents the main driving forcing for promoting the production and use of bio-energy [44]. A recent study of Puettmann and Lippke simulated different fuel-substitution scenarios and proved that all of them resulted in a decreased GWP. Moreover it was shown that larger benefits were obtained producing heat instead of electricity, since using woody biofuel for electricity production was somewhat less effective in lowering carbon emissions than when it was used for heat energy [45].

The environmental impact is also associated to the heating system technologies. Single home domestic biomass heating systems are typically stoves of 5–15 kW nominal power [40,46,47]. Other domestic heating systems may include solar panel, heat pump and gas boiler [40,48]. A comparison of the different heating systems showed that wood stove had the lowest impacts on climate change and fossil depletion but the highest impacts on human toxicity and particulate matter formation [40].

As a renewable material, the harvested wood in forest can be replaced in a relatively short time through the carbon absorption in forest. By saving a part of the biomass increment, a sustainable forest management can aim at offsetting the emissions of the entire firewood supply chain. Given the high number of factors