



# Environmental assessment of small-scale production of wood chips as a fuel for residential heating boilers



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## ABSTRACT

This work performs a comparative life cycle assessment (LCA) of two fuels for heating boilers, namely wood chips and oil. The LCA methodology allows comparing the environmental impacts of the two analyzed fuels, thus assessing which is environmentally more advantageous. The study is focused on Mediterranean forests located in the Argençola region (Catalonia, northeastern Spain) by applying forest management practices focused to ensure a sustainable exploitation. The direct use of wood chips as a fuel for boilers simplifies notably the number of processes involved in producing such a fuel. The results presented clearly show the environmental benefits of using small-scale produced wood chips instead of fossil oil by analyzing representative impact categories defined by the CML and EDIP methods, even when considering the changes in the carbon stock in the forests under analysis due to the management approach adopted. A sensitivity analysis has also been conducted to assess the impact of the data with higher uncertainty on the final LCA results.

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## 1. Introduction

During the last decades there has been a continuous increase in energy consumption worldwide [1]. This has inevitably contributed to increases in greenhouse gas (GHG) emissions, thus forcing the making of regulations and policies aimed to reduce GHG emission rate [2]. It is recognized that a partial substitution of fossil fuels by renewable energy resources may lessen net carbon dioxide emissions, thus helping to mitigate climate change [3,4]. Biomass, which can be understood as stored energy [5–7], is a renewable fuel source that has been used since ancient times and it is recognized as a significant constituent of the future energy mix [8]. Furthermore, biomass in general and forests in particular act as a carbon sequestration sink [1], thus helping offsetting different CO<sub>2</sub> emission sources [9].

Mediterranean forests have developed under the influence of human activities since antiquity [10]. They have been traditionally a supply of numerous resources, including timber, firewood or provisions from hunting among others. Mediterranean forests facilitate the socio-economic progress of rural areas [11] and contribute to the food security of local communities and the preservation of

environmental aspects such as carbon sequestration, landscape quality and biodiversity among others [12]. Today's lifestyle has changed dramatically, thus leading to important changes in the use and management of Mediterranean forests. In many Mediterranean areas, especially in the northern regions, conventional forest uses have been disappeared. This lack of management has led to an abandonment of such forests and to a significant growth of the forest stock, thus increasing notably the risk of wildfire, especially during summer season [12]. It is recognized that the management policy greatly influences the forests productivity and the greenhouse gas mitigation potential, since the higher the productivity the higher the mitigation potential [3]. However, it is also recognized that the use of forest biomass fuels may also present some drawbacks including the diminishment of carbon stock in the forests, potential problems for biodiversity or the need of substituting biomass for wood products for other materials among others. As a consequence, it is of crucial importance to take into account all the above-mentioned aspects when making policies affecting the management of Mediterranean forests.

Life cycle assessment (LCA) is a recognized tool to make decisions, since it allows evaluating the environmental impact of a particular management system. It also allows comparing its impact with those of other management systems.

This work proposes to manage the forests according to the thesis in Refs. [13], which are based on practices to ensure a sustainable exploitation while promoting forests biodiversity. These practices

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guarantee an intervention to protect the forests from the damages to which they are exposed while guarantying their conservation, since well-conserved forests promote biological biodiversity and an additional source of income. The aim of this study is to compare from an environmental point of view the behavior of oil fueled heating boilers against boilers fueled by small-scale locally produced wood chips. For this purpose, a comparative life cycle assessment (LCA) is conducted, which allows evaluating the environmental profiles of the two above-mentioned fuels along their life cycle. According to Ref. [5] the most important sources of GHG generated by oil boilers are CO<sub>2</sub> emissions. In most studies, heating boilers fueled by wood chips are considered almost carbon-neutral since CO<sub>2</sub> emissions released to the atmosphere during their use have been previously captured by the growth of the primary forest biomass (PFB). Although most of the LCAs assume that heating fuels obtained from biomass are carbon neutral, this assumption may not always be accurate. As stated by Johnson [14], a carbon stock change should be considered. In this study this assumption is applied. Specifically, we take into account the stock change caused by human intervention due to the applied forest management policy.

Catalonia is one of the autonomous communities in Spain with more wood biomass resource available within its territory [15]. This work focuses on the municipality of Argençola (Catalonia), located in the northeastern Spain. It is a rural area with 2200 ha of forests which are mainly composed of pine trees (*Pinus halepensis* and *Pinus nigra*, 95%) and oak trees (5%). The average current stock of the analyzed area is 63.2 tC/ha and the yearly growth potential is 0.8 tC/ha [13]. According to a local study focused on this area [13], the total PFB extracted from the Argençola area could feed 50% of all residential boilers. Small-scale production and consumption of wood chips is proposed because it allows minimizing transportation requirements and associated environmental impacts. Although the results presented are particular for the area analyzed, they may also be extended to other regions with similar characteristics. Additional reasons for using small-scale produced wood chips in residential boilers can be summarized as follows:

- The direct use of wood chips in specially designed existing boilers allows reducing the number of processes involved in producing such a fuel while lessening the energy consumption and the associated environmental impacts.
- This simple approach enhances the potential of forest fuels to lessen net carbon dioxide emissions, thus helping to mitigate climate change.
- It promotes the management of Mediterranean forests following an environmental sustainable criterion, while decreasing the stock of organic matter, thus increasing their productivity and minimizing wildfire risk.
- It contributes to generate wealth and jobs in rural areas and also to produce energy from local resources [6].
- This proposal enables rural areas to be partially independent of the fossil fuel industry.
- It allows optimizing the utilization of local resources of the northeastern of Spain as a way of supporting the national energy industry [1].

The results presented here show the environmental advantages of the wood chips system compared to the oil system, even in a low productivity region such as the one studied. Therefore, these results may be valuable for decision-makers in order to develop policies focused on promoting the on-site consumption in domestic boilers of small-scale produced wood chips by applying environmentally-friendly forests management techniques.

## 2. Methodology

The environmental assessment carried out in this work is based on the LCA methodology, which is regulated by the ISO 14040 and 14044 [16,17] international standards. It includes four phases namely goal and scope definition, inventory analysis, impact assessment and results interpretation. The GaBi 4 software from PE International [18] has been used to conduct this LCA analysis.

## 3. Goal and scope definition

The goal of this study consists in carrying out a comparative environmental evaluation of two fuels for heating boilers, i.e. wood chips and heating oil. The scope of the study is Catalonia (northeastern Spain), since the wood chips are obtained from Mediterranean-type forests located in this area. It is worth noting that heating oil is currently the most used heating fuel in the studied area.

The straight use of wood chips in heating boilers has several advantages. It is a simpler processing system that does not generate co-products and allows the use of raw materials in the same territory. Additionally, this system adds an energy and economic value to the forest products, so owners care for the forests maintenance while reducing the risk of degradation, wildfires and desertification whereas promoting a socio-economic development of rural areas.

The functional unit used in this study is 1 kW hour (1 kWh) of thermal energy generated by the boiler, which allows comparing the environmental performance of the two fuel types evaluated.

### 3.1. System boundaries

The boundaries of the LCA performed in this study comprise the use of fossil fuel and forest chips produced in the Argençola municipality as fuels for residential heating boilers. Fig. 1 shows the

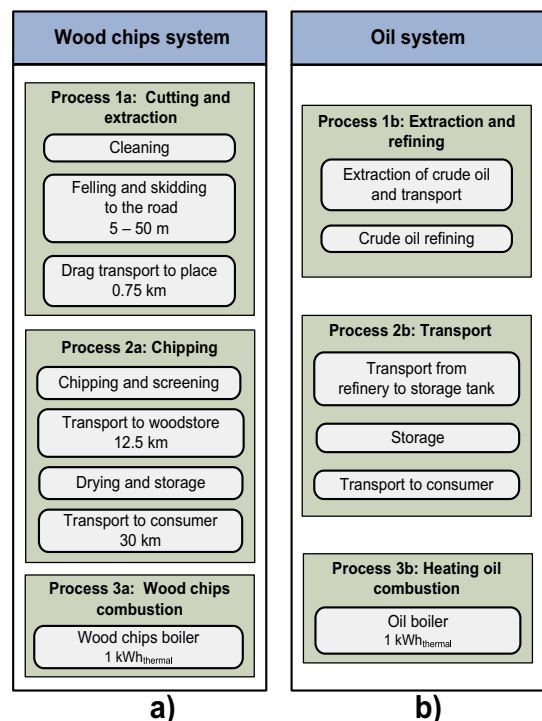


Fig. 1. System boundaries and processes taken into account in the comparative LCA performed in this study. a) Wood chips system. b) Oil system.

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