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Environmental assessment of post-consumer wood and forest residues gasification: The case study of Barcelona metropolitan area

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ARTICLE INFO

Article history:
Received 3 November 2008
Received in revised form
8 April 2010
Accepted 16 April 2010
Available online 14 May 2010

Keywords:
Forest residues
Gasification
LCIA
Post-consumer wood
Pre-treatment
Transport

ABSTRACT

An energy and environmental analysis of post-consumer wood and forest residues gasification in metropolitan areas is carried out to determine the most critical stages of their life cycle. Life Cycle Impact Assessment (LCIA) methodology is used to identify the environmental load of three defined scenarios: (1) Post-consumer wood from recycling points; (2) Post-consumer wood from bulky wastes; and (3) Forest residues. The stages considered are biomass pre-treatment, transport and gasification. Biomass pre-treatment comprise different steps: separation, chipping, sifting, post-chipping for all the scenarios; except for the drying step which is only entailed to Scenario 3. The midpoint impact categories taken into account are: abiotic depletion (AD), global warming (GW), ozone layer depletion (ODP), human toxicity (HT), acidification (A) and eutrophication (E). Results show that, due to the high physical requirements for biomass gasification, the most appropriate biomass is that of Scenario 1, since forest residues require a drying stage, which involves high energy consumption and high environmental impact. Energy consumption in biomass pre-treatment and transport stages is low compared to the energy obtained from gasification, which represents the 5% in Scenario 1; 7% in Scenario 2; and 13% in Scenario 3. Biomass pre-treatment is associated to an important contribution in AD and ODP impact categories, calculated as 71% and 98% of the overall impact. The transport stage is of no significant influence either in the scenarios or in the impact categories (less than 24% of the overall impact). Finally, gasification represents an impact of 3–78% of the different impact categories.

1. Introduction

The use of biomass as an energy source is globally widespread, since bioenergy can be of major significance in mitigating climate change. It also provides an array of diverse sustainable development services both in industrialized countries as well in developing countries [1,2] in the EU's commitment to making the share of renewables 12% of gross energy consumption by 2010 [3]. In Spain, many policies were established to meet European targets in terms of energy production. The National Action Plan for Renewable Energy Sources increased bioenergy targets in order to reach 12% of gross consumption from renewable sources [4].

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doi:10.1016/j.biombioe.2010.04.009

This study assesses the life cycle of post-consumer wood and forest residues for energy conversion in a gasification plant located in Cerdanyola del Vallès (Barcelona). This analysis was performed within the framework of the POLICITY project, in which large urban areas in different countries are developed, particularly in the fields of energy optimization and the use of renewable energies. In this study, the case of the metropolitan area of Barcelona is presented, where a development area planned for 50,000 inhabitants consisting of eco-buildings for residential, industrial and service purposes will be established on a common basis of innovative sustainable construction. It also promotes the use of renewable energies, represented by a 1 MWe gasification plant fuelled by different types of biomass [5].

Therefore, this study applies Life Cycle Assessment (LCA) methodology in order to compare the environmental and energy impacts of post-consumer wood and forest residues, as well as analyzing and identifying the most critical stages of the system. As specified by ISO 14040-14044 [6,7], the obligatory elements (classification and characterisation) of impact assessment methods are applied. The software employed is SimaPro 7.0.1, developed by Pré-Consultants [8].

In order to achieve this goal, field work was performed to obtain local data for both the fuel consumption of the machinery involved and the gasification emissions of a pilot study carried out with different kinds of biomass. The biomass analysed in this study is differentiated as: (i) post-consumer wood generated in the metropolitan area of Barcelona; and (ii) forest residues coming from a metropolitan radius of 50 km from Cerdanyola del Vallès. Post-consumer wood is defined as non-dangerous wastes (code 030105 from the European Waste Catalogue – Waste bark and wood). They come from both collection at recycling points and the collection of bulky wastes. Forest residues are obtained from the waste generated by forest exploitation (brushes; woodchips; etc.) as a result of conventional forestry (thinning; final cuts; etc.). The gasification technology entails three main specific requirements which will make the most suitable type of biomass conditional on: (1) moisture content lower than 15%; (2) a maximum chip section of 2 cm; and (3) high biomass homogeneity.

The Life Cycle Assessment of post-consumer wood and forest residues gasification was executed on the basis of three different scenarios: (1) Post-consumer wood from the recycling points; (2) Post-consumer wood from bulky wastes; and (3) Forest residues. The results provided the project architects, engineers, businessmen and politicians with information about which stages were the most critical in relation to environmental loads and which scenario and, therefore, which type of biomass, was the most appropriate for the case study defined, results that can be thoroughly extended to metropolitan and urban areas.

2. Life cycle assessment of post-consumer wood and forest residues gasification

2.1. Goal and scope definition

The goal of this study is to evaluate and compare the resulting environmental loads associated to the life cycle of post-consumer wood and forest residues gasification, in order to compare different scenarios and to identify the most critical stages of the process. Two principal targets are defined to achieve this goal: (1) calculate the energy balance and (2) evaluate the environmental impacts, of all the stages involved in the system.

2.2. Functional unit

The functional unit of this study is defined as: 'the production of 1000 MJ of primary energy (thermal and electric) generated in a gasification plant with an efficiency of 0.588, in which the electrical efficiency is 0.284 while the thermal efficiency is 0.304.

The reference flows, known as the input of biomass needed to produce 1000 MJ of primary energy, are calculated as 0.103 ton for post-consumer wood and 0.113 ton for forest residues. These flows are calculated by means of the biomass' Low Heating Value, described below in the Data Inventory, and the cogeneration efficiency of the gasification plant. The efficiency is obtained from the Policity technical project [5], which was carried out using data from technology suppliers for the gasification plant.

2.3. Scenarios

Three scenarios are considered: (1) Post-consumer wood from the recycling points; (2) Post-consumer wood from bulky wastes; and (3) Forest residues. These scenarios were defined under the generic consideration of collection in the city centre and transport to the pre-treatment and gasification plant in the metropolitan area.

2.3.1. Scenario 1: post-consumer wood from the recycling points

This scenario comprises the user who carries the wooden waste to the nearest recycling point in Barcelona (average distance of 2.0 km). At the recycling point, this by-product is separated and classified. The resulting by-products are transported to the Waste and Packing Plant in Gavà (distance of 24.0 km), where the by-products are separated and chipped. Finally, they are taken to the gasification plant in Cerdanyola del Vallès (distance of 36.4 km).

2.3.2. Scenario 2: post-consumer wood from bulky wastes

This scenario consists of the bulky collection that is performed by the Barcelona City Council. Once collected, this waste is transported to the Waste and Packing Plant in Gavà (distance of 24.0 km), where it is classified and chipped according to its characteristics. The separated post-consumer wood has two destinations depending on the quality of the wood: (a) board industries if it's high quality wood; and (b) energy conversion systems if it's low quality wood. Finally, chipped by-products are taken to the gasification plant in Cerdanyola del Vallès (distance of 36.4 km).

2.3.3. Scenario 3: forest residues

In this scenario, forest residues are harvested in different radius of action, 30 km at the most, from the gasification plant located in Cerdanyola del Vallès. These distances are delimited from a previous study of availability of supply carried out