Life cycle assessment of the use of biomass as energy source in Northern Greece

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Abstract
Decrease of fossil fuel consumption in the energy sector is an important step towards more sustainable energy production. On the other hand, domestic and imported biomass or biofuels used for energy purposes play an important role in many future energy scenarios and national policies. Generally speaking, biofuels have been evaluated as an ecologically benign alternative to fossil fuels. The aim of this paper is the life cycle analysis (LCA) using biomass for energy purposes. The LCA is applied as a computational tool for assessing systems to biofuel feedstocks. Specifically, the LCA of the wood pellet will be studied, which was selected as biomass. Furthermore, the LCA will be analyzed (such as the stages are mentioned and what it involves and is intended for) and for this reason there will be a case study of wood pellet production from a pellet factory in the area of Western Macedonia (Kozani). In fact, a techno-economic study will be carried out (the case study, which will include all the costs, the calculation of all pollutant emissions, solid and liquid waste from the birth of the raw material to final consumption of pellets based on the characteristics, dynamics and customer base of the plant pellet production.
Keywords: biomass; Life cycle analysis; pellet energy; Western Macedonia

1. Introduction

Bioenergy, particularly solid biomass, is the most important renewable energy source in Europe. Energy resources are important for ensuring a reliable national energy supply to the population with electricity and heat (Dincer and Zamfirescu, 2011). The most important forms of biomass are as follows: wood/forestry, agriculture/livestock, bio-treated fluids etc.

In the regional prefecture of Kozani the winter temperatures are very low and so the choice of wood pellets as a fuel in domestic boilers affects the environment and it is a good economic solution to cover the energy needs of homes, especially in settlements. Therefore, one purpose of Life Cycle Analysis (LCA) is to record all amounts related to solid, liquid waste, gaseous pollutants, quantities of raw materials, and amounts of energy used. Furthermore, after the calculated environmental impacts there will be a basic guide in order to find ways to produce and transport wood pellets so as to reduce environmental impacts.

2. Methodology

In this study, the LCA of wood pellets produced by ELPIS M. S.A. was selected. ELPIS M. S.A. is located at the 5th kilometer of the National Road of Kozani – Larissa in Greece. The company is supplied with sapwood by sawmills based in Aridea, Grevena, Karditsa, Kozani and Trikala. The timber comes from the mountain range of Pindos.

ELPIS M. S.A. applied the SETAC (Society of Environmental Toxicology and Chemistry) methodology for the LCA, which includes the four following phases: 1) goal and scope definition, 2) inventory analysis, 3) impact assessment, and 4) assessment of improvements. In addition, ELPIS M. S.A. also applied the ISO 14440 (2006) protocol, which is not different from the SETAC methodology in the first three phases. It only differs in the fourth phase, which includes the interpretation of the results.

The purpose of the methodology is to calculate all air pollutant emissions produced by the wheeled vehicles, the combustion, and the plant, as well as to calculate the total production and consumption cost of pellets. The inventory analysis includes data collection and processing so that they can be used to calculate raw material, waste and pollutant consumption during both each life cycle phase and the entire life cycle of biomass. The impact assessment phase aggregates all the environmental impacts quantified and calculated during the inventory analysis. SETAC improvements include measures to reduce pollutants and costs while ISO interprets the calculated results. In summary, the LCA of wood pellets produced by ELPIS M. S.A. is illustrated in Figure 1.

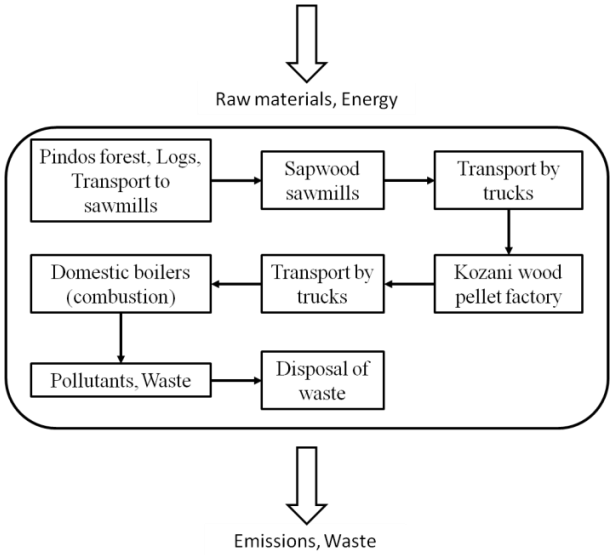

Figure 1. LCA of wood pellets produced by ELPIS M. S.A. in Kozani

In this case study, all emissions of pollutants and waste resulting from the raw material up to the burning of pellets were calculated for the whole of the Prefecture of Kozani, specifically for the period from September 2018 to April 2019. Moreover, transportation and supply costs of raw materials were estimated. Regarding the data needed for the calculations, the fuel consumption of trucks in liters per km was obtained by ELPIS M. S.A., the kilometric distances were obtained by the Greek website www.apostaseis.gr, and the emitted pollutants in grams per ton from combustion of sawdust in the dryer and pellets in boilers were obtained by Wang et al. (2017) and Ferreira at al. (2018), respectively.

3. Results and Discussion

The heating needs of the houses for the period from September 2018 to April 2019 led to the production of 1,000 t of wood pellets by the ELPIS M. S.A. factory. This implies that 2,000 t of sawdust was demanded, since 2 t of sawdust is needed to produce 1 t of wood pellets. The total purchase and transportation costs of the sawdust raw material for the period from September 2018 to April 2019 were amounted to EUR 133,050 (ELPIS M. S.A.).

The consumption of diesel fuel when moving trucks from the mountain range of Pindos to the associated sawmills is: 669.94 L, the consumption of diesel fuel when moving trucks from the sawmills to ELPIS M. S.A. is 3,808.98 L and the consumption of diesel when moving the trucks from ELPIS M. S.A. to the settlements (customers) is 4,215.64 L. In addition, the total transportation cost of wood pellets to the settlements is equal to EUR 5,901.896. Finally, the total pollutant emissions of the domestic boilers, installed in the houses of the settlements, in the regional prefecture of Kozani during the combustion of pellets are CO 22,429.81 kg, NO_x 370.68 kg, SO_2 623.08 kg, PM 246.25 kg and the ash produced is 5.005 kg.

Table 1. The air pollutants generated by the burning of sawdust in the dryer **(A)**, generated when moving trucks from the mountain range of Pindos to the cooperating sawmills (timber transport) **(B)**, generated when moving trucks from the sawmills to ELPIS M. S.A. (sawdust transport) **(C)**, generated during the movement of the trucks by ELPIS M. S.A. to the settlements, namely Aiani, Akrini, Argilos, Vatero, Velvento, Galatini, Drepano, Koila, Krokos, Lefkovrisi, Lefkopigi, Mavrodendri, Mikrovalto, Nea Haravgi, Neo Klitos, Xirolimni, Petrana, Pontokomi, Protochori, Servia, Siatista, Tranovalto, (pellet transport) **(D)**

Air pollutants (Kg)	CO	NO_x	SO_2	PM	HC
A	200.4	69.2	80	24.6	-
B	0.67	8.71	-	0.067	0.027
C	12.58	109.01	-	0.84	2.1
D	16.86	113.82	-	1.26	2.53

4. Conclusions

Interpreting the results based on ISO 1440 (2006), it is noted that the use of pellets reduces the amount of pollutants emitted into the atmosphere, thus contributing to the reduction of both air pollution and heating costs. However, in order the wood pellets to reach at their final destination, namely the consumer, there are several stages, as described above. What is more, the kilometer distances and the classification of trucks in the EURO classes affect the emissions of pollutants. More specifically, more pollutants are emitted by older technology trucks. Based on the SETAC methodology, conditions and decisions related to the wood pellet LCA should be improved. To that end: (i) the fleet should be renewed by new technology trucks, (ii) the distances covered by wheeled vehicles should be reduced, and (iii) environmental-friendly fuels should be used by vehicles, so that emissions and air pollution are reduced. Finally, ash produced by combustion can be used as a fertilizer for plants.

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