Life Cycle Assessment (LCA) in Combustion Processes of Agricultural Biomass Pellets

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Abstract The objective of this work is to evaluate the environmental impact associated with the emissions and uses of natural sources through life cycle assessment with the purpose of suggesting an efficient and sustainable solution to the energy problem of non-interconnected zones in Colombia. The work represents an environmental evaluation of the rice husks pellets combustion process. The process is divided into six stages: transport, drying, crushing, compaction and biomass combustion. The cradle to grave Life Cycle Assessment was enabled by integrating them into a single process. The environmental profile obtained reflects that the stage of biomass combustion exerts an influence on both, the entry and exit impact categories.

Keywords: • Life Cycle Assessment (LCA) • Combustion • Biomass • Pellets • Environmental impact •

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1 Introduction

Every process is affected by the inevitable wear and tear over time, which decreases its efficiency and increases its environmental impact. The Life Cycle Assessment (LCA) is an engineering tool that enables us to classify, quantify and monitor these impacts throughout the life cycle of a product or activity - from the extraction of raw materials until they become waste (Hsiao and Surendra, 2011). This approach is known as the "cradle to grave" analysis (Benveniste et al., 2011).

Because of the environmental impacts that the exercise of progress has caused in the habitat, the industry has focused efforts in conjunction with the scientific community in finding energy alternatives that mitigate environmental damage and in turn combat other forms of pollution through reuse of waste. Biomass, e.g. waste of the agricultural industry, can be used as fuel to generate electrical energy. However, it can still be questioned, if biomass-based energy generation is a good environmental choice with regards to the impact on greenhouse gas emissions (Kimming, et al., 2011). Even though, the LCA methodology is well established, the literature is not very specific on the LCA of combustion processes or cogeneration of energy from biomass. For this reason, a research work was conducted aiming to propose a more detailed methodology that is tailored to this type of processes.

2 Methodology

We propose an LCA methodology for evaluation of rice husk pellets combustion process. The methodology is based on the ISO 14040 (1999) standard and comprised of four elements. The elements that structures the LCA are not only sequential, but they are also iterative with each other, as shown in Figure 1.

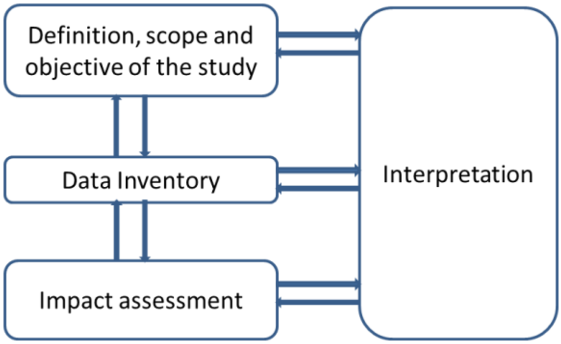

Figure 1: The four elements that structures the LCA, source: Amaya et al, 2008.

2.1 Definition of objectives and scope of the study

The definition of scope and the objectives is the first stage of the LCA. The goal of this study was to examine environmental sustainability of the agricultural type biomass combustion system through the technique of LCA.

The systems involved in the LCA analysis of the biomass combustion were: agricultural activity, crushing, drying, compaction and combustion of biomass (see Figure 2). The hierarchy proposed by ISO 14040 was followed regarding the allocation rules. For the phases of process for which no primary data found we resorted to the use of data in published literature. For the resulting emissions, the energy consumed in the combustion process, electricity and steam the data was collected from sources such as Knospe and Walleser (2010); Gutierrez and San Miguel, (2015); John Carroll, J. F. (2013).

We have to note that the construction stage or the maintenance of the infrastructure of the plant, economic factors, social factors, and catastrophic natural phenomena were not considered in the study. In addition, certain environmental impacts were not covered in full, due to the difficulty in collecting the data for local conditions.

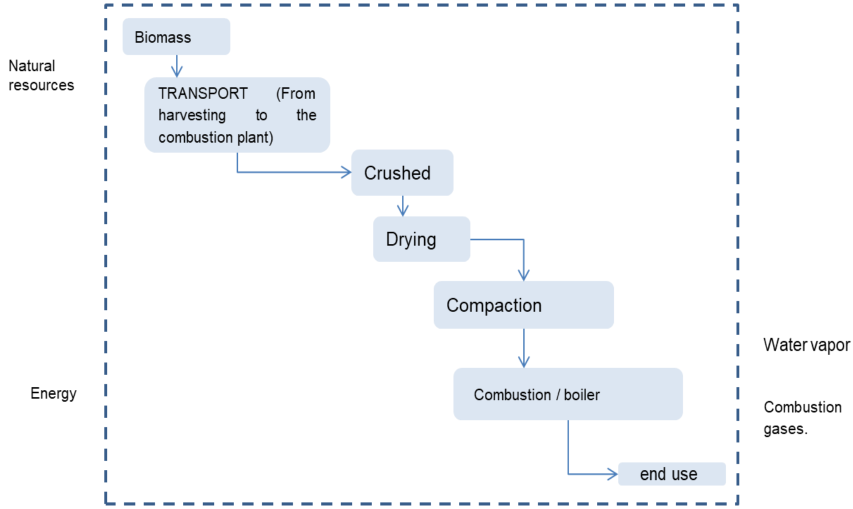

Figure 2: The systems involved in the LCA of biomass combustion.

2.2 Inventory analysis

This LCA stage has taken into account the environmental and energy flows of the raw materials and processes that have been included in the life cycle of the combustion process of the rice husk pellets.

At the first stage of agricultural activity, the identification and accounting of environmental flows were done. The production of rice husks, associated with energy, was accounted. All related work with the agricultural part, as well as all the production processes and transportation of supplies was accounted (Nishihara, et al., 2015). It was considered that the land was savannah type and did not have high vegetation. In addition, rotation was not performed with another crop.

LCA study assumed that the land is productive for at least five years. This cycle was repeated until the completion of the LCA. Additionally, no effects were considered for the use of agrochemicals (herbicides, pesticides, insecticides) because the lack of the data and minimal contribution to overall results.

The integration of the carbon and nitrogen cycle was considered at the stage of rice cultivation. During the rice cultivation, a quantity of CO2 from the atmosphere is captured to several destinations: a part is fixed in the biomass that is harvested, another part in the biomass that remains in the ground and another part returns to the atmosphere by the mechanism of respiration of the plant (Pechón, et al., 2006). For atmospheric decay of CO2 emissions from combustion of biomass pellets be should consider the basic principles remain unchanged: if biomass is replanted, emissions from combustion are neutralized by CO2 removal during regrowth; if biomass is not replanted, bio CO2 emissions become anthropogenic CO2 (Cherubini et al., 2011). Also, it was only considered that there is a net fixation of C on the ground represented as a percentage of CO2 incorporated by the plant (Figure 3). However, a sensitivity analysis was carried out for this percentage taking as initial value 56.8% (average obtained from studies for other crops). It should be noted that the percentage of CO2 fixation for stubble was considered 56.8% (Da Costa, 2005). Regarding nitrogen, it is found mainly in the plant, in plant residues, in mineral nitrogen and in humified organic matter. There are nitrogen fluxes between these components and with the medium outside them. The most important inputs were: biological nitrogen fixation, fertilization and larger outflows are volatilization. On the other hand, it was considered that there is a net fixation of N on the ground due to the presence of non-symbiotic bacteria that do not exceed 15 kg / ha year (Amaya, et al., 2008).

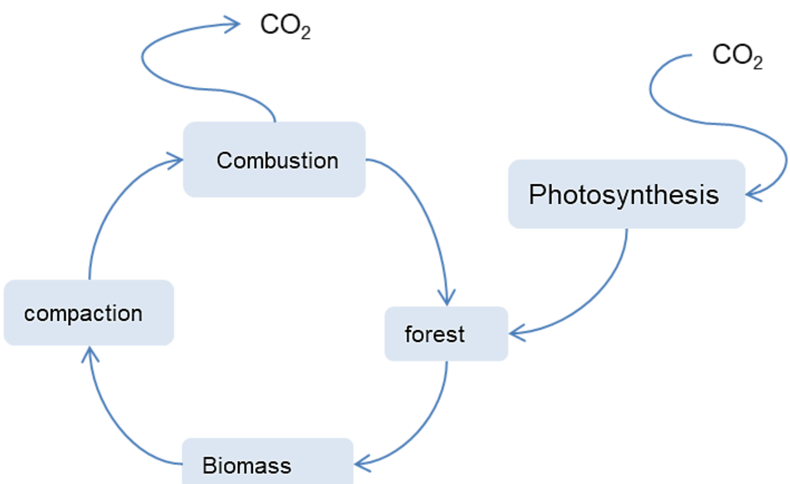

Figure 3: Biomass combustion process cycle, source: own.

3 Results

The inventory of impact categories, taking into account the activities in each stage of the process, is presented in Table 1. The inputs and outputs of the system are shown in Table 2.

Table1: Inventory of impact categories

Phase	Activity
Agricultural	1. Preparation and attention of the soil, agronomic techniques and fertility. 2. Maintenance and planting 3. Fertilization 4. Collection of biomass 5. Fruit transport
Drying and crushing	6. Biomass drying 7. Crushing of biomass
Compaction	8. Pressing biomass in the form of pellets
Biomass combustion	9. Rice husk combustion
End of life	10. Waste management 11.Emissions management

source: own

The inputs and outputs of the system were defined as seen in table 2

Table 2: The inputs and outputs of the system

PROCESS	CONSUMPTION					
	Means Materials	Quantity (kg)	Electric power	Quantity (kWh)	Waste Generated	Quantity (kg)
Agricultural	Gasoline	0,0009				
Drying			Dryer	2,6404		
Crushed			shredder	0,1932		
Compaction	Rice husk	1,2				
Biomass combustion	Biomass pellets	3			Combustion gases	1

source: own

Figures 4 and 5 show impacts of the agriculture stage against each of the categories carried out by SimaPro 8.5. The energy use for field work has the highest score (145 µPt) in the Fossil depletion category. The highest percentage of participation impacts belong to human health, environment and resources.

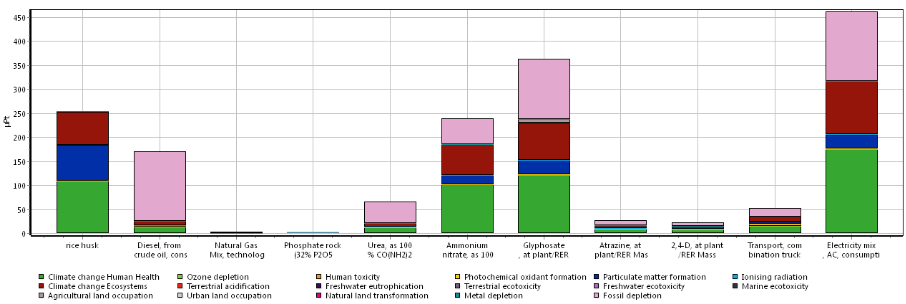

Figure 4: Analysis of the impact of the stage agriculture in each category.

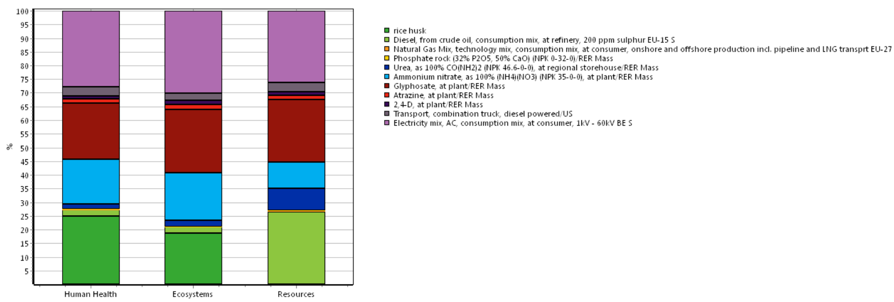

Figure 5: Evaluation of the damage of the steppe agriculture in human health, environment and resources.

Figures 6 and 7 show the impact analysis of the drying stage for each of the categories. The use of energy is the one that has the greatest impact. The reason was necessity to perform a forced drying in order to have the desired percentage of humidity. This is reflected in the same way in the evaluation of impacts on human health, environment and resources.

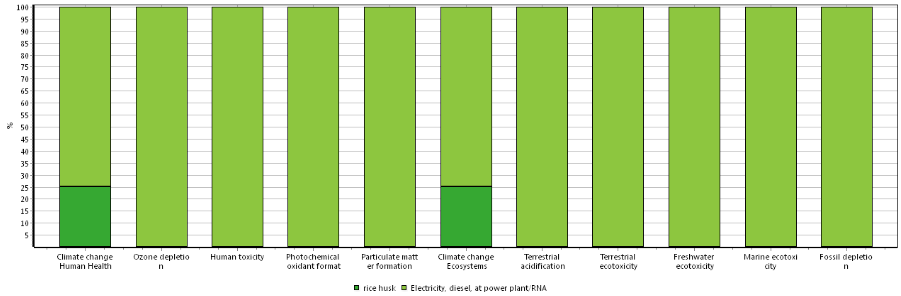

Figure 6: Analysis of the impact of the drying stage in each category.

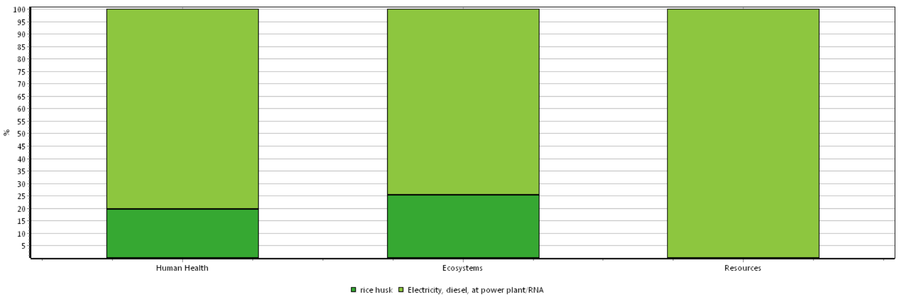

Figure 7: Evaluation of the damage of the drying stage in human health, environment and resources.

Figures 8 and 9 show the impact analysis of the grinding stage in relation to each of the categories where the use of energy is the one that has the greatest impact. The reason was the need to obtain particle sizes specific to the biomass. This is reflected in impacts on human health, environment and resources.

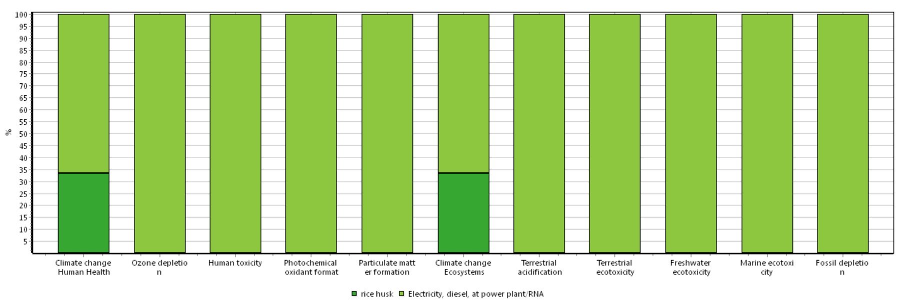

Figure 8: Analysis of the impact of the grinding stage in each category.

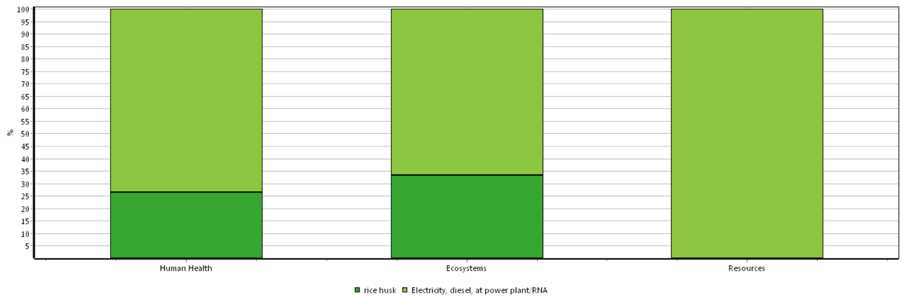

Figure 9: Evaluation of the damage of the milling stage in human health, environment and resources.

Figures 10 and 11 show the impact analysis of the compaction stage against each of the categories. The use of energy has the greatest impact due to the need of the pelletizer to heat and compress the biomass. This is reflected equally in the evaluation of impacts on human health, environment and resources.

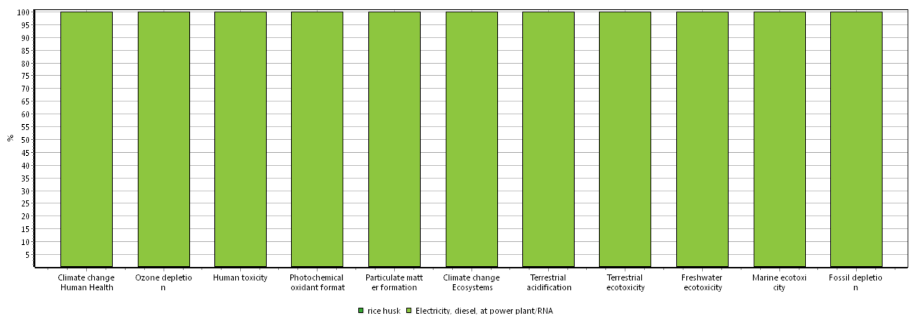

Figure 10: Impact analysis of the compaction stage in each category.

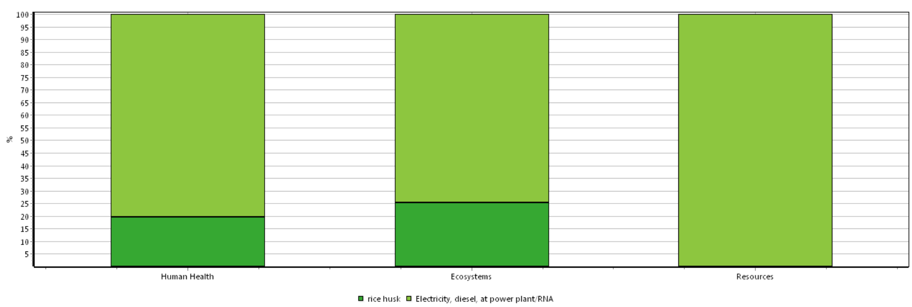

Figure 11: Evaluation of the damage of the compaction stage in human health, environment and resources.

Figures 12 and 13 show the analysis of the impact of the combustion stage against each of the categories. The use of energy is the one that has the greatest impact due to the energy needed to operate the boiler. This is reflected equally in the evaluation of impacts on human health, environment and resources.

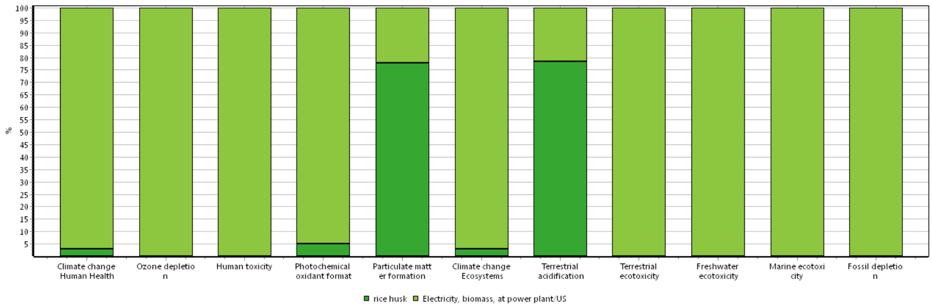

Figure 12: Analysis of the impact of the combustion stage in each category.

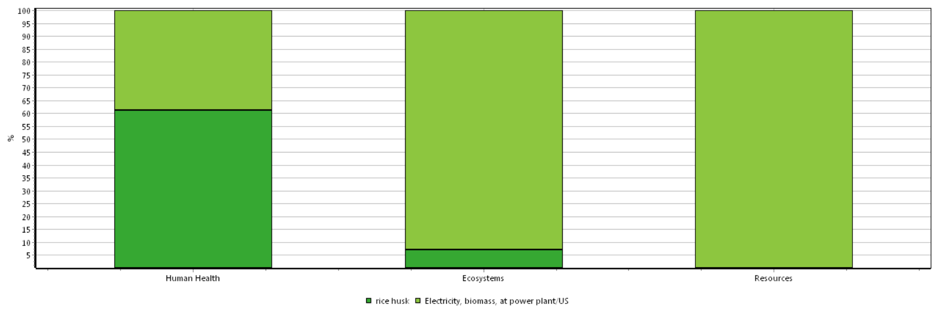

Figure 13: Evaluation of the damage of the combustion stage in human health, environment and resources.

The percentages of participation of each of the stages contemplated for the environmental analysis are shown in Figure 14. To interpret the data obtained from the inventory analysis, it was necessary to evaluate the environmental impact associated with the emissions and uses of natural sources through the analysis of the carbon footprint (Figure 15).

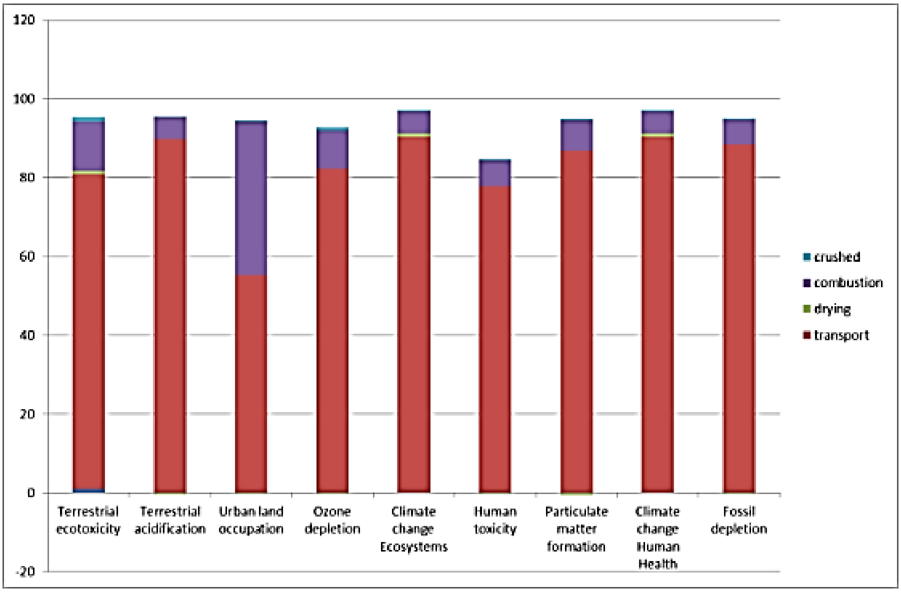

Figure 14: The data obtained from the inventory analysis, source: own.

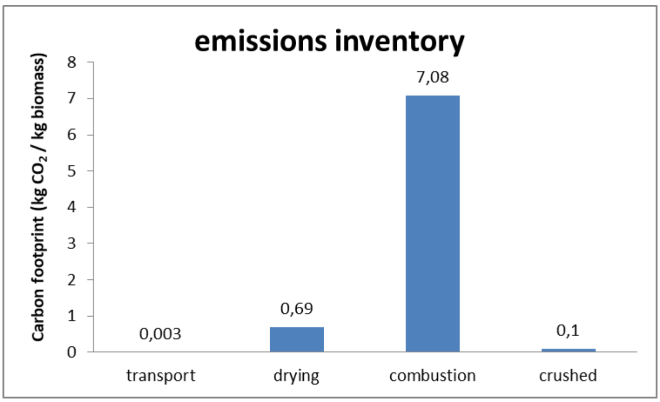

Figure 15: The analysis of the carbon footprint, source: own.

To interpret the obtained data of the inventory analysis, it was necessary to evaluate the environmental impact associated with emissions and uses of natural sources. Each impact category was represented by means of the impact category indicator (I_IC), which is a sum of different environmental interventions caused by the different substances that make it up. In the classification of emissions, each environmental intervention was associated with the impact categories in which it has an effect. For example, CO2 is associated with climate change. Once the data is classified, the addition of these was made for each of the categories using the equivalence factors (f_Ei) and the following equation:

$$I_{\mathrm{IC}} = \sum_i m_i * f_{\mathrm{E}i} \quad (1)$$

Where mi is the emission of the resource i used and f_Ei is the corresponding equivalence factor. With the results obtained the participation percentage was calculated which each of the stages has considered for the process of combustion of rice husk pellets in the different impact categories.

The environmental profile reflects the combustion stage as one with the greatest impacts in the emission of CO2 in all categories. The other stages contribute to a smaller proportion, as can be seen in Figure 15. It is important to clarify that emission of sulphur dioxide (SO2) and nitrogen oxides (NOx) are generated among other gases at this stage.

4 Conclusions

The work constitutes an environmental evaluation of the process of combustion of biomass pellets. The process was divided into different stages: transport, drying, crushing, compaction and biomass combustion

Through the quantification of the inflows and outflows in the different stages of the process, it was possible to determine the emissions most relevant in each of them together with their associated energy consumption.

The environmental profile elaborated reflects that the stage of biomass combustion exerts the greatest influence on both, the entry and exit impact categories.

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