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Methodology for the Life Cycle Assessment (LCA) in Combustion Processes Where the Fuel is Pelleted Agricultural Biomass

Yurley P. Villabona, Viatcheslav Kafarov*

Chemical Engineering Department, Industrial University of Santander, Colombia
vkafarov@gmail.com, ypvillabonad@gmail.com

Colombia, due to privileged geographical location, has a great biodiversity, with agriculture being the one of the main source of income for the country. Each year produced large amounts of residual agricultural biomass that can be used to generate energy, since it has a high calorific potential, which could remedy one of the great needs of the country because 60% of country area have not connected with national electric energy service, these are called non-interconnected zones of the country. One possibility to generate electrical energy by using this type of biomass is combustion processes (via traditional way of power generation). This thermochemical process can take advantage of the caloric power of biomass more efficiently, if it is treated with a densification processes such as pelletizing and compacting. Unfortunately densification processes for local biomass are not enough studied in Colombia, consequently to implement them must be evaluated its technical, economic and environment viability.
Therefore it is very important to implement a life cycle assessment (LCA) for densified biomass combustion process, specially taking into account that LCA researches for this type of biomass are not reported in literature. Therefore, the biomass energy projects carried out in the country were taken as process object of study, in order to provide a specific methodology for the LCA in combustion processes where the fuel is local pelleted biomass and the goal is the technical and environment improvement of the existing processes, thus, proposing a efficient and sustainable solution to the energy problem of non-interconnected zones in Colombia. The analysis of the process under research has determined a methodology which consists a study of the efficiency of the transport of the bio-mass from its collection to the place of process itself, taking into account aspects such as type of vehicle, amount transported biomass, it physicochemical composition, transportation between operating units, mass balance in the pelletizing process, energy balance in the furnace and the variation of temperature in order to achieve the maximum energy production.

1. Introduction

Modern industry has focused efforts in collaboration with the scientific community in finding energy alternatives that mitigate environmental damage and to eliminate other forms of pollution through reuse of waste. In this case is local residual biomass are using for generation of 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)
Taking into account that process is affected by the same operation cycles during a long period, being the inevitable wear and tear over time, generating losses of raw material and increase in pollutants issued to the environment, thus decreasing the efficiency of the same process, which leads to a greater environmental impact. This is where the need to monitor these negative impacts is justified and with an application of engineering tool that allows to determine them, classify and quantify them, throughout the life cycle of a product or activity (Hsiao and Surendra, 2011) from the collection of raw materials that constitute it until it becomes a waste, being this tool the life cycle analysis (LCA). That's why it is also known as the analysis "from the cradle to the grave" (Benveniste et al.,2011).

Although the LCA methodology is already determined, this only indicates the research phases that must be carried out, consisting of the definition of objectives and scope of the study, inventory analysis where the data is collected to quantify the inputs and outputs of matter and energy of the study system and the impact evaluation that is achieved by identifying, characterizing and quantifying the effects on the environment of the studied system, and the interpretation of the results identifying key points based on the results obtained in the previous phase, verifying its integrity, sensitivity and coherence, whose application is specified for each unit of the process. There is not enough information in literature about LCA of densified biomass combustion processes or cogeneration of energy from this type of biomass, for this reason a research work was developed in order to propose more detailed methodology that could be apply to this type of processes.

2. Methodology

A methodology was proposed to perform LCA, where it was taken as case study the biomass pellets of the rice husk to be evaluated in combustion processes. For the LCA was taken into account the ISO 14040 (1999) standard, that raises the four elements that structures the LCA they are not only sequential, but they are also iterative with each other, as can be seen in Figure 1.

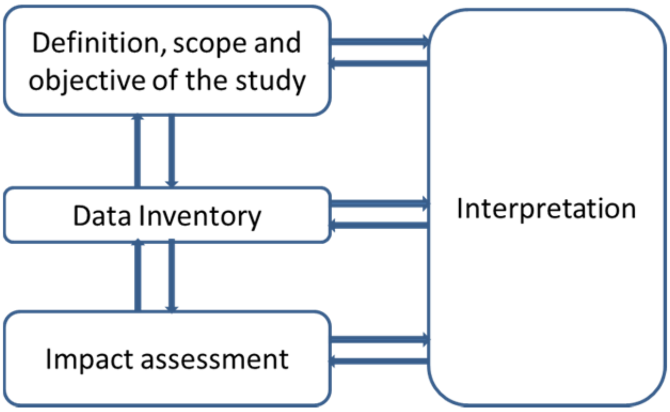

Figure 1. The four elements that structures the LCA; (Amaya et al, 2008)

2.1 Definition of objectives and scope of the study

The scope definition and objectives is the first stage of the life cycle analysis, where the study goals were defined delimiting the system of the combustion process: The purpose of this study was to examine environmental sustainability of the biomass combustion system of agricultural type through the technique of Life Cycle Assessment.

The systems involved in the LCA of biomass combustion were: agricultural activity, milling, drying, compaction and combustion of biomass as seen in Figure 2. Due to limited information it was not taken into account the construction stage, the maintenance of the infrastructure of the plant, economic factors, social factors, and possible catastrophic natural phenomena. Certain environmental impacts were not covered completely, due to the difficulty in collecting data for local conditions. Regarding the allocation rules the hierarchy proposed by ISO 14040 was followed.

For the stages of process in which they were not found primary data, it was resorted to the use of data from literature. In the case of the resulting emissions and the energy consumed in the combustion process, electricity and steam, just like the combustion gases, data was taking from sources such as Knospe and Walleser (2010); Gutierrez and San Miguel, (2015); John Carroll, J. F. (2013).

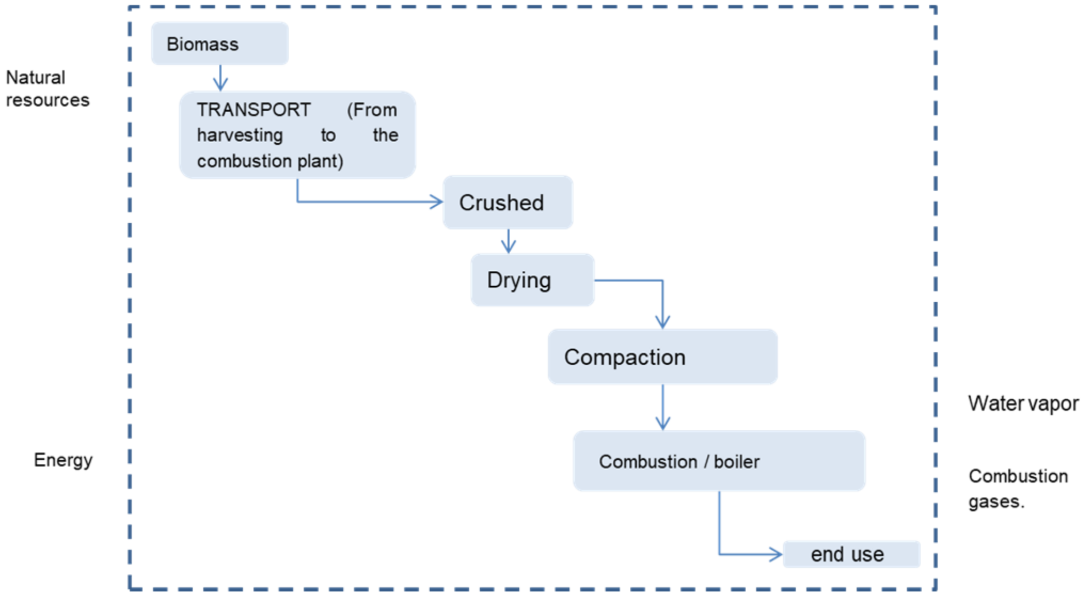

Figure 2. The systems involved in the LCA of biomass combustion

2.2. Inventory analysis

For this stage of the LCA were accounted for environmental and energy flows of the different raw materials and processes involved in the life cycle of the combustion process of the rice husk pellets through the development of mass and energy balances.

At the first stage (agricultural activity) was taken into account the identification and accounting of environmental flows involved, energy associated with the production of rice husks and work related with the agricultural part, as well as all the production processes and transportation of supplies (Nishihara, et al., 2015). For this, it was considered that the land in which the crop was developed was savannah type and did not have high level of vegetation. In addition, was not performed rotation with another crop.

During the time of study of the LCA it was established that the land would be productive for at least five years. This cycle was repeated until this study time of the LCA was completed. Additionally, no effects of the use of agrochemicals (herbicides, pesticides, insecticides, among others) were considered because there is no data regarding these and according to the literature there contribution is minimal.

The integration of the carbon and nitrogen cycle at the stage of rice cultivation was considered. During development of rice cultivation, it captures a quantity of CO_2 from the atmosphere that has 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 CO_2 emissions from combustion of biomass pellets the basic principles remain unchanged: if biomass is replanted, emissions from combustion are neutralized by CO_2 removal during regrowth; if biomass is not replanted, bio CO_2 emissions become anthropogenic CO_2 (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 CO_2 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 CO_2 fixation for stubble was also considered 56.8% (Da Costa, 2005).

Regarding nitrogen, it was accumulated mainly in the plant, in plant residues, in mineral nitrogen and in humified organic matter. There are nitrogen fluxes between these parts of the plants and also with the medium outside them. From one hand the most important inputs were: biological nitrogen fixation, fertilization and larger outflows were volatilization. On the other hand, it was considered that there is a net fixation of N on the ground due to the presence of bacteria non-symbiotic that do not exceed 15 kg / ha in year (Amaya, et al., 2008).

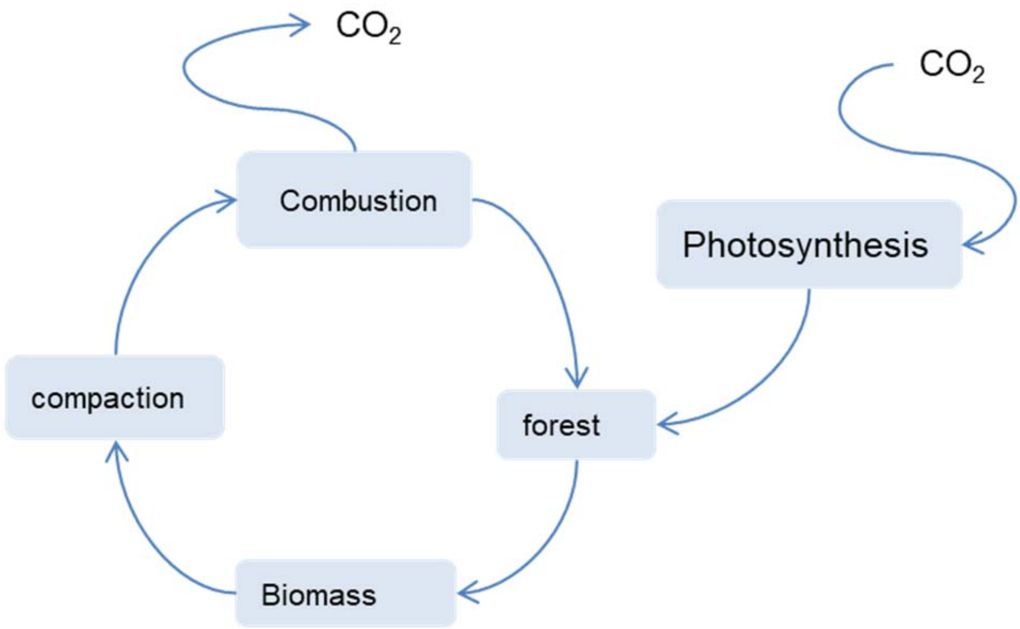

Figure 3. Biomass combustion process cycle

3. Results

The inventory of impact categories was carried out and shown in Table 1, taking into account the activities in each stage of the process.

Table1. Inventory of impact categories

Phase	Activity
Agricultural	1. Preparation 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. Milling of biomass
Compaction	8. Pressing biomass in the form of pellets
Biomass combustion	9. Pellets (rice husk) combustion
End of life	10. Waste management 11.Emissions management

The percentages of participation of each of the stages defined for the environmental analysis are shown in Figure 4, this analysis was made with the help of Simapro software. 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 5).
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 category of impact was represented by means of the category indicator, which is based on diverse environmental effects caused by the different substances which composed it. In the classification of emissions each environmental effect was associated with the impact categories in which it has demonstrated; for example, CO_2 is associated with climate change.

Once the data is classified, the impact of these was made for each of the categories using the equivalence factors and the following equation:

$$impact\ category\ indicador = \sum_i m_i * equivalente\ factor \quad (1)$$

Where m_i is the emission of the resource used and (equivalence factor) i is proper for each resource. With the results obtained the participation percentage was calculated for each of the stages considered for the process of combustion of rice husk pellets in the different impact categories.
The environmental profile reflects that the combustion stage has a greater participation in the emission of CO_2 in all categories and the other stages contribute in a smaller proportion, as can be seen in figure 5. It is important to clarify that at this stage the emission of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are generated among other gases.

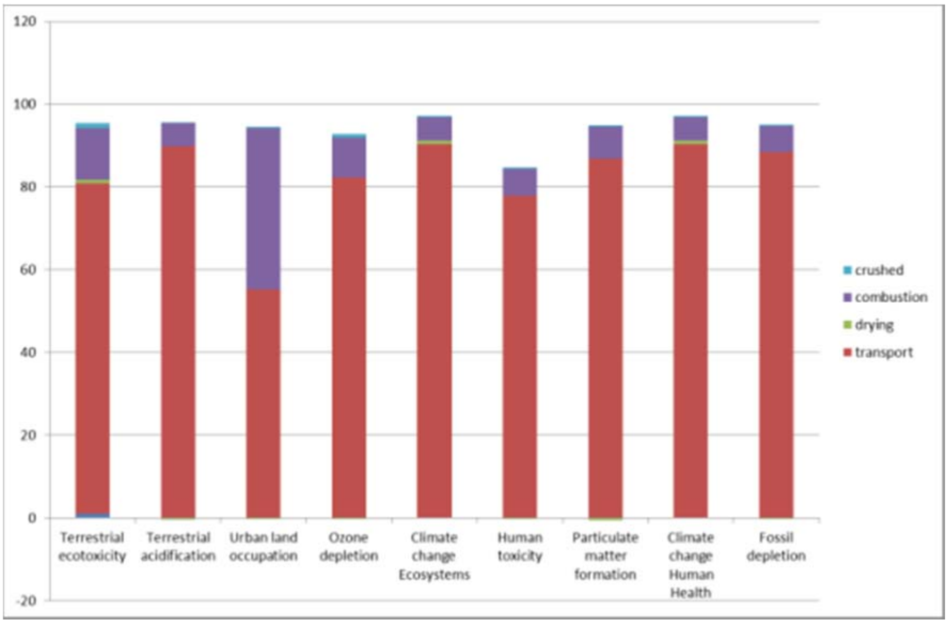

Figure 4. The data obtained from the inventory analysis.

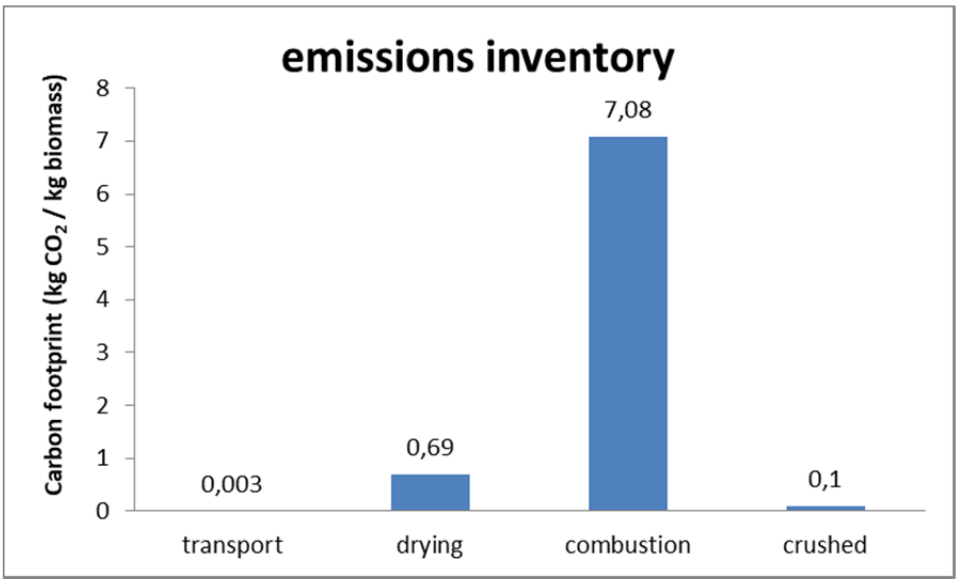

Figure 5. The analysis of the carbon footprint

4. Conclusions

The present work represent an environmental evaluation of the process of combustion of local residual biomass pellets that was divided into six stages: transport, drying, crushed, compaction and biomass combustion; and later integrated as one process with simultaneous implementation of the methodology of the cradle to the cradle in the LCA.

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

The elaborated environmental profile reflects that the stage of biomass combustion represent the main influence at the environment on both, the exit impact categories and the entry impact category.

Acknowledgments

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