

# Computational Simulation of the Gas Emission in a Biomass on Grid Energy System Using HOMER Pro Software

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To reach the Sustainable Development Goals and delivering on the Paris Agreement on climate change mitigation, a Biomass on grid power system is proposed to supply 33,640 kWh/day, which is the average annual energy consumption from a group of office buildings. This study shows the behavior of the gas emission of a Biomass on Grid Energy System Using HOMER Pro Software, composed by two 500 kW biogas-powered electric generator, using different types of biomass resource from the Colombian Caribbean Region like manure obtained from the livestock sector and solid urban organic waste. The simulation results showed some emission decrease when operating on the grid the Biogas generator such as the carbon dioxide, the sulfur dioxide and the nitrogen oxides on 11.6% while the carbon monoxide increased on 8.7% concerning the power supply system through electrical grid coming from thermoelectric power plants and hydroelectric power plants.

## 1. Introduction

Global surface temperatures have augmented by 0.8°C over the 20th century, and Earth's mean temperature is predicted to increase by 1.4-5.8°C during the twenty-first century (IPCC. 2017). With the Industrial Revolution, atmospheric GHGs and their radioactive forces have progressively increased. Activities like combustion, deforestation, biomass burning and some agricultural land use pattern had either increased emissions from global carbon stocks and decreased the capacity of global carbon sinks to absorb these gases (Greene CH & Pershing AJ. 2007). Methane and nitrous oxide, two of the most important greenhouse gases in the atmosphere after water vapor and CO<sub>2</sub>, have also increased gradually (Prather M. et al. 2001). The extended amount of greenhouse gases (GHG) production, primarily carbon dioxide (CO<sub>2</sub>), produced by human activities and their influence in the planet climate conditions became a significant ecological and political challenge (Mondani et al. 2017). Economic uncertainties and environmental constraints regarding fossil fuels have encouraged initiatives for renewable energy sources and assessment of their life cycle impacts (Esteves et al. 2017). For example, the goal of reducing greenhouse gas (GHG) emissions by 20% in the EU is envisaged to be achieved by a reduction in GHG emissions in sectors governed by the Emission Trading Scheme (ETS) of 21% by 2020, and a reduction in emissions from non-ETS sectors of 10% by 2020 relative to 2005 levels. The ETS covers large energy users (such as electricity and heat production with a thermal rating more than 20 MW). The non-ETS sectors include agriculture, residential energy consumption, and transportation. In addition to the GHG emission reduction targets, the EU also aims to ensure a renewable energy share of 20% by 2020 and a minimum share of renewable energy in the transport of 10% by 2020 (O'Shea et al. 2017). Average global consumption of petroleum fuels was about 93.8 million barrel/day in the year 2015 and is in constant growth (EIA n.d.). Large use of fossil fuel leads to depletion of its reserve causing to the energy crisis. In addition to this, as emission norms are getting more stringent, the emissions including nitrogen oxide (NO<sub>x</sub>), sulfur oxide (SO<sub>x</sub>), particulate matter (PM) and greenhouse gas from diesel engines need to be decreased (McCormic et al. 2005). Use of renewable fuels is an option to address the issues including energy crisis and emissions.

Bio-fuels (biodiesel and biogas) produced from biomass can be considered as the best option and has the most significant potential, which meets these requirements and could insure fuel supply in the future. Several

studies are available trying to quantify global biomass potential (Hoogwijk M. et al. 2005), present a viable alternative option to replace fossil fuels. In this context, the European Commission Directive 2009/28/EC for transportation sector aimed to replace 10% of fossil fuel with biofuels by the year 2020 (Commission n.d.). Non-edible oils are extracted from the fruit seeds of *jatropha curcus*, *pongamia pinata*, *moha*, *under*, *saemaruba*, etc. which contain approximately 25% of the oil whereas the remaining 75% consists of seed cake. Transesterification of non-edible oils produces biodiesel. The seed cake left after oil extraction from the fruits could be used for biogas production (Chandra et al. 2012). Anaerobic digestion and biogas production from brewing residues offer a viable option for achieving a considerable reduction in fossil fuel use (Rodríguez et al. 2017), consequently reducing energy and residue disposal costs while reducing the carbon footprint as well. Brewing residues include brewery wastewater, surplus yeast and brewery spent grain (BSG) (Panjicko et al. 2017). HOMER is an abbreviation of Hybrid Optimization Model for Electrical Renewable; this software can be able to simulate and optimize power supply systems with renewable energies and different types of generators, from internal combustion engines to hydrokinetic turbines. HOMER can determinate the optimal system from multiple proposals through economic analysis and a greenhouse emission study (Barrozo Budes et al., 2017), (Barrozo Budes et al., 2017), (Barrozo Budes et al., 2017). The renewable energy generating devices has been determined has the best choice in many fields of the power supply systems, using HOMER pro software (Valencia Ochoa et al., 2016), (Vanegas Chamorro & Valencia Ochoa, 2016), (Valencia Ochoa, et al., 2016), (Valencia Ochoa, et al., 2016), (Vanegas Chamorro, et al., 2016).

## 2. Methodology

This section of the paper contains specific information from the electric generation devices and also the software implemented to carry out the different simulations and the current development of this research. The load profile used for this simulation had an annual scaled average of 33,640 kWh/d with a pike of 7,160.8 kW and an average of 1,401.6 kW. With a supply system compounded by two biogas energy generators (500 kW), and a bio-digester as shown in Figure 1, also the electrical grid is used to supply the amount of energy that the biogas generators cannot contribute to the system. The biogas generators work in parallel with the electrical grid so that when the generators cannot supply the total energy demand in a specific time, the electrical grid begins to work and provide the rest of energy necessary to the right system function

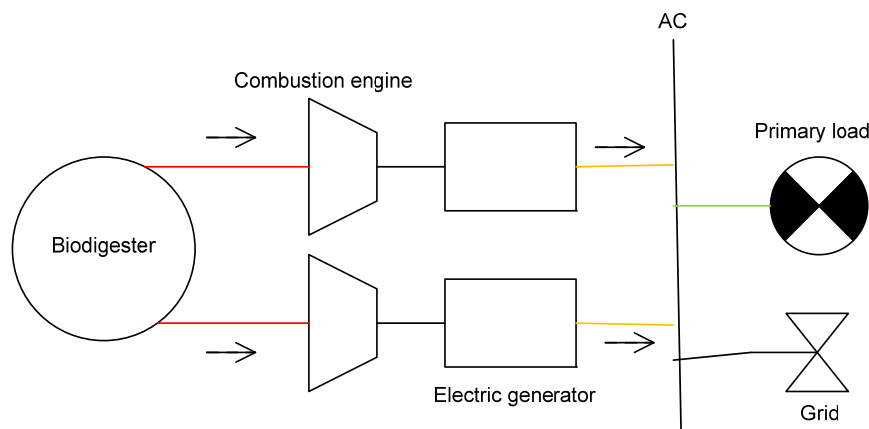


Figure 1: Biogas energy generator (500 kW).

The fuel used to the right function of these generators is biogas, which is obtained through anaerobic digestion from biomass resource storages; these storages are located in the Caribbean Colombian region more specifically near Barranquilla. Biomass for biogas production can be derived from livestock sector manure, which is compounded of three sectors (Poultry, Bovine, and Porcine); also, the biomass can be obtained from urban organic solid waste, which is complicated of two areas (Commercial centers & Marketplaces and Pruning) for this region. The availability of these resources as shown in Table 1 is a significant factor to consider. If the availability is not sufficient to generate the necessary amount of biogas, then the biogas generators could not supply the total amount of energy required, and the electrical grid begins to work. Therefore the amount of greenhouse gases emissions is higher (this is explained because the thermal energy plants in the Caribbean region use diesel and charcoal generators to work.)

Table 1: Resource availability; where CC&MP is commercial centres & market places

|                        | Livestock sector |         |         | Urban organic solid waste |         |
|------------------------|------------------|---------|---------|---------------------------|---------|
|                        | Poultry          | Bovine  | Porcine | CC&MP                     | Pruning |
| Availability (ton/day) | 327.49           | 3063.71 | 69.9    | 26.77                     | 5.45    |

The biogas is a gas which is generated in the environment or in specific devices, by the biodegradation reaction of organic matter, through the action of microorganisms and other factors without oxygen (this is an anaerobic ambient). The final product is a mixture compounded by methane (CH<sub>4</sub>) between 40% and 70%, and carbon dioxide (CO<sub>2</sub>), containing little proportions of another gases as hydrogen (H<sub>2</sub>), nitrogen (N<sub>2</sub>), oxygen (O<sub>2</sub>) and hydrogen sulphur (H<sub>2</sub>S).

The software implemented to simulate this study case was HOMER Pro ®, which can be able to analyse and optimize each system purposed, then the software realize a comparison for all results to determinate the optimal system based on the operational cost and the greenhouse gas emissions.

### 3. Results Analysis

To carry out the right development of this study case, is necessary the implement of the power devices to generate an estimate for the load profile, the Table 2 shows the devices implemented on this simulation to generate the load profile.

Table 2: Power devices implemented for the simulation

| Component                        | Energy load (Watts) | Units |
|----------------------------------|---------------------|-------|
| Sylvania led continuum 32W WW SP | 32                  | 6     |
| Cooling system 24000 BTU/h       | 2440 ON; 2 OFF      | 1     |
| High-end table computers         | 150 ON; 3.3 OFF     | 10    |

It is important to highlight that the simulation consists of an office centre to which a large number of work stations belong in each building, and the devices previously shown make up the main demand for energy for one of those workstations.

In this way, the values for the demand of energy was determined, the annual scaled average is 33,640 kWh/d, with an average of 1,401.6 kW and a pike of 7,160.8 kW. Likewise the nominal values for the system working with the electrical grid were determinate to realize a comparison with the system working with a biomass resource, as shown on the Table 3.

Table 3: Control data for only grid supply

| Emission        | Amount (kg/year) |
|-----------------|------------------|
| Carbon dioxide  | 7'760,075        |
| Sulphur dioxide | 33,643           |
| Nitrogen oxide  | 16,453           |
| Carbon monoxide | 0                |

Greenhouse gas emissions are a negative factor in a power supply system, it can get big damage to the environment and it can bring too expensive cost from government fines because long amounts of greenhouse gas emissions; therefore, it is an important factor to analyse in a supply system. For this study case the comparison between the biomass production sectors and the greenhouse gases production as shown of Figure 2, to determinate the optimal sector to use as a biomass supply sector.

It can be seen that when the electrical grid is working alone without the biogas generators, then the CO<sub>2</sub> production are the highest of this comparison as the others emissions too. The emissions from the livestock sector manure (Poultry, Bovine, and Porcine) are the same; this could be because the availability of these resources is more significant in comparison with the urban organic solid waste, and therefore the production of electricity from the generator is the maximum and is constant. The municipal organic solid waste has a lower amount of output and the generator can work efficiently. Therefore the grid begins to work and complete de energy demand.

When the grid works alone exist a relative production of greenhouse gasses because the energy from the grid is generated through energy generation plants with biggest electric generators working with diesel, carbon or natural gas; therefore HOMER takes a relative production of greenhouse gasses for this situation.

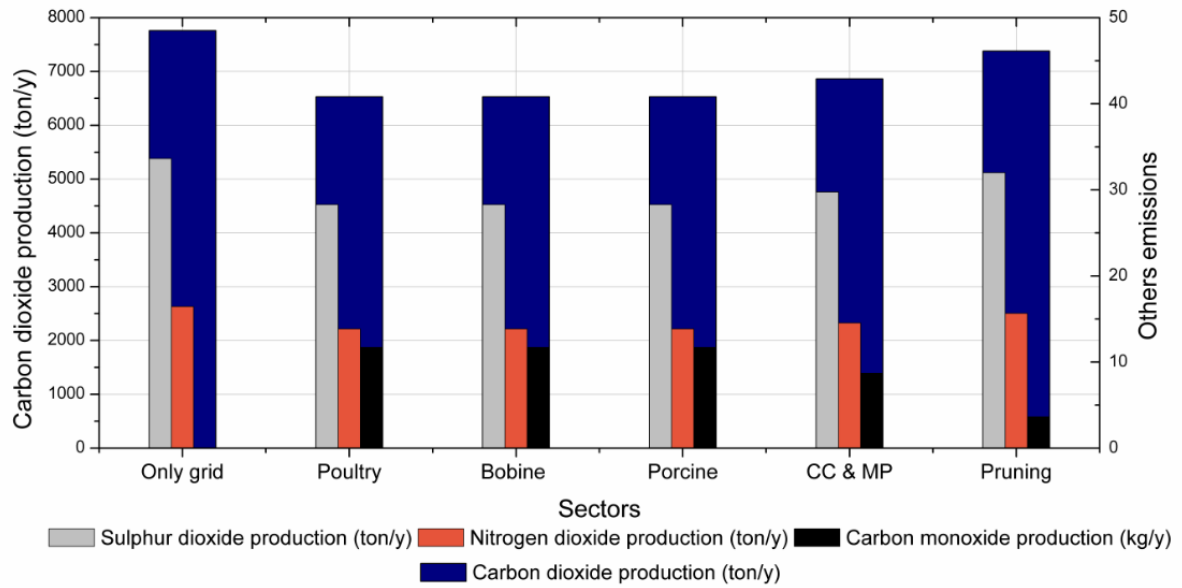


Figure 2: Comparison of greenhouse gas production from each biomass supply sector.

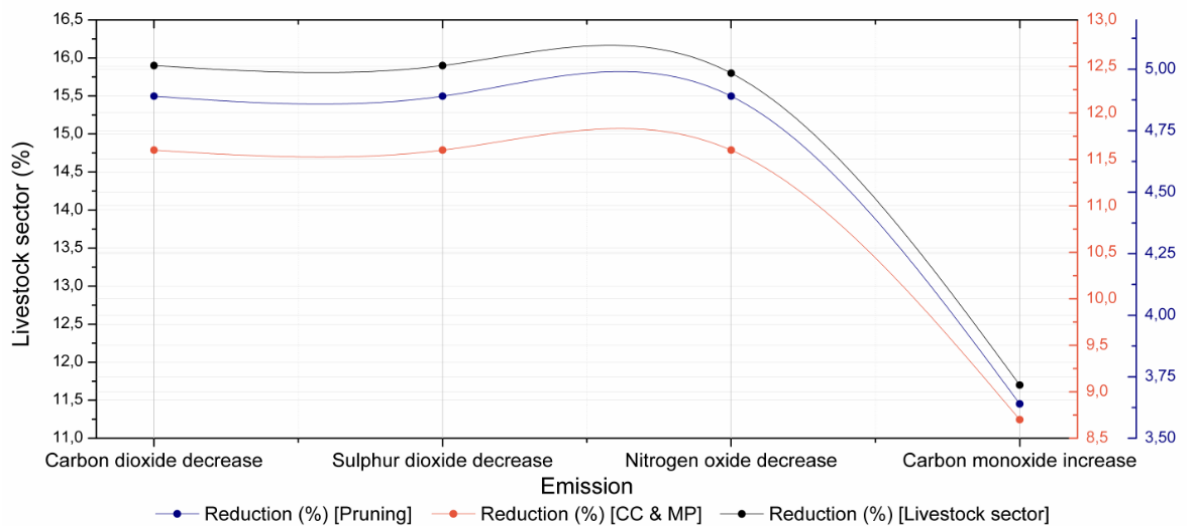


Figure 3: Greenhouse gasses vs. decrease and increase from every sector, with the Grid as the nominal measurement.

Figure 3 shows a comparative of the reduction or increase from each type of greenhouse emission for every biomass sector. It can be seen that the livestock sector presents the higher reduction, because his availability is the best in comparison with the other sectors. It is important to remember that the percentage is a data value from the system working only with the grid; therefore, if the decrease is for example (5%), it will be 5% of the greenhouse emissions from the system working only with the grid.

#### 4. Conclusions

In this article, we presented an environmental feasibility study for biogas energy grid operating with biogas obtained from biomass from livestock sector manure and urban organic solid waste, to supply the energy of a group of office buildings. The design of the system was based on the type of equipment, and the load profile of the studied area. The design of such a generation system is still needed to make more competitive integration of renewable energy sources in the energy and environmental balance of large energy production grid.

In this context, the energy conversion system using livestock sector manure which is effective environmental solutions in our site as compared to the CC&MP, which is an urban organic solid waste with energy and competitive economic advantages.

A complete HOMER model was used successfully to perform a comparative environmental study of a particular micro-power system configuration each hour of the year using some biomass supply sector such as poultry, bovine, porcine and pruning, resulting in a significant reduction of 25% in carbon dioxide production concerning the system operating only on the grid.

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