CHEMICAL ENGINEERING TRANSACTIONS

VOL. 65, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Eliseo Ranzi, Mario Costa

ISBN 978-88-95608- 62-4; **ISSN** 2283-9216

DOI: 10.3303/CET1865051

Comparison Analysis of an Energy Generation System Using Diesel, Natural Gas and Biogas as a Primal Fuel Resource

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With the aim to study the behavior of biogas versus different types of fossil fuels and determine the optimal fuel resource for an Energy Generation System, an electric generation system and different types of fuels were proposed to supply an energy demand of 2424 kWh/day, which is the scaled annual average of a chemical laboratory facility. This study shows the behavior of different fuels and how they affect the operating cost of the system using HOMER Pro software. The proposed system consists of different electric generators (340kW) for each type of fuel. The results of the simulation showed that the biogas works very efficiently regarding the production of polluting gases compared to the fossil fuels used in the simulation. However, the installation costs for the devices necessary to obtain biogas from a biomass resource are expensive.

1. Introduction

For more than a decade, environmental scientists, as well as many policy energetic analysts, agreed that addressing climate change with high efficiency requires a transition from fossil fuels to renewable energy sources. The issues of limited reserve of fossil fuel and negative consequences of conventional power sources lead to search more sustainable energy technology (Das and Al-Abdeli, 2017). Renewable sources integration with conventional sources (i.e., combustion engines) or hybrid power installations in remote areas are cost-effective choices (Bala 2009, Qoaider 2010). Different types of optimization methods have been explored as a part of the design process of the decentralized renewable energy system such as linear programming, goal programming, knowledge-based approach, etc. (Barrozo et al., 2017). Integration of cost-benefit dynamic behavior was simulated in software that makes possible to visualize the cost-benefit dynamic on a large scale. The single energy generation systems compounded only by a generator, and the primary load has a percent of the energy production considered as excess because the energy demand at present-day is lower than the production. (Valencia et al., 2016, a, b, c, Vanegas and Valencia 2016, a, b). Conventional systems have an inverter with a storage system to optimize and reduce the amount of fuel required as shown in Figure 1.

Homer evaluates the techno-economic feasibility as well as the environmental emissions of large varieties of technological options (Askari I 2012, Barrozo et al., 2017).

The behavior of biogas, fossil fuels, diesel and other fuels have been studied in different combinations showing their efficiency (Bhuiyan et al., 2000). Biogas plants can play a vital role in producing alternative fuel (Halder et al., 2016). Biogas not only provides the recovery of energy from domestic, commercial and industrial waste streams but also has an advantage over other renewable energy sources in the fact that it can be stored. It makes the biodiesel an essential component of the renewable energy mix (Hahn et al., 2014). Biogas production has been increasing in recent years, which can be mainly attributed to political forces (Appel et al., 2015).

Because of this, a suitable technique is necessary to size the main components, and other auxiliary components for the techno-economically and fuel efficiency evaluation, where the optimization techniques are the primary device driver of this valuation. This study shows the behavior of biogas against different types of fossil fuels, and determine the optimum fuel resource for an energy generation system. It was proposed an

Please cite this article as: Valencia Ochoa G., Obregon Quinones L., Cardenas Y., 2018, Comparison analysis of an energy generation system using diesel, natural gas and biogas as a primal fuel resource, Chemical Engineering Transactions, 65, 301-306 DOI: 10.3303/CET1865051

electrical generation system and various types of fuels to supply a load demand of 2424 kWh/day with the help of the Homer software.

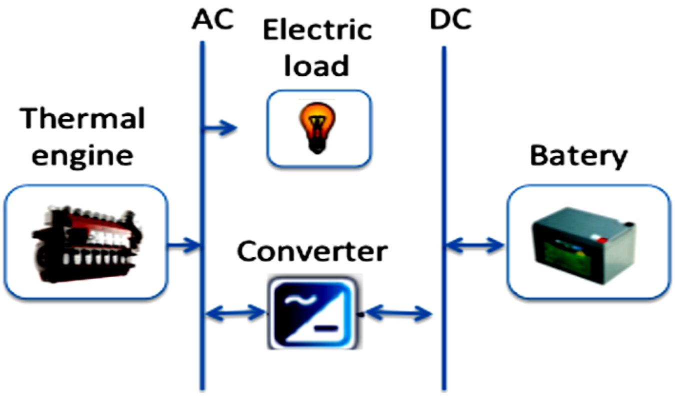

Figure 1. Conventional energy generation system

2. Methodology

It was designed a system with one electric generator to supply an energy load of 2,424.2 kWh/day. The generator is a gas micro-turbine with an output power of 340kW for the systems working with natural gas and biogas, and a diesel generator with an output power of 340 kW for the systems working with diesel, as is shown in Figure 2.

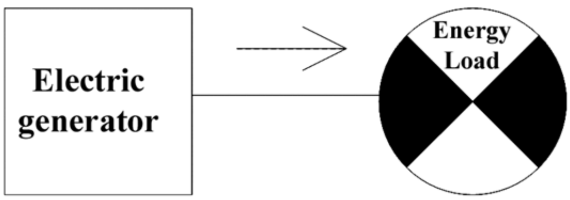

Figure 2. system scheme

Three types of fuel were selected for this simulation, natural gas, biogas, and diesel.
The natural gas is a hydrocarbon compounded by a mixture of light gases which contains methane as the main resource in the mixture, carbon dioxide, nitrogen, sulphuric acid or helium are other elements that could be present in the mixture, it forms when many layers of decomposing plants, and animal matter are exposed to intense heat and pressure below the land surface for millions of years. This fossil fuel is obtained throw drilling on gas deposits inside the earth's crust, and his price for this study case is 0.28 €/m^3.

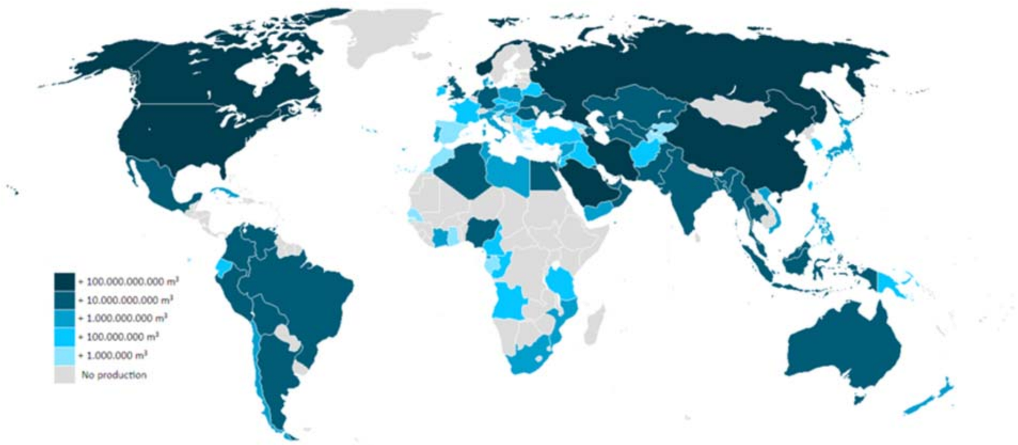

Figure 3. Natural gas production from all around the world

The biogas is a renewable fuel obtained from biomass through anaerobic digestion from sewage treatment plants, dumps, plants for the processing of waste and animal waste. The anaerobic digestion is a process where the biodegradable material is discomposed in an environment without oxygen, where microorganisms degrade the material causing the release of gases (CO_2 and CH_4 with the highest proportion) that are implemented as a fuel resource to generate heat and power. The biomass resources available are manure from livestock sector, urban organic solid waste, and others from the agricultural sector. Besides, biogas can be used to generate bio-methane that is fuel for vehicles or can be used to create organic compost. For this study case, the biomass resource is obtained from manure livestock sector with a price of 21.28 €/ton.

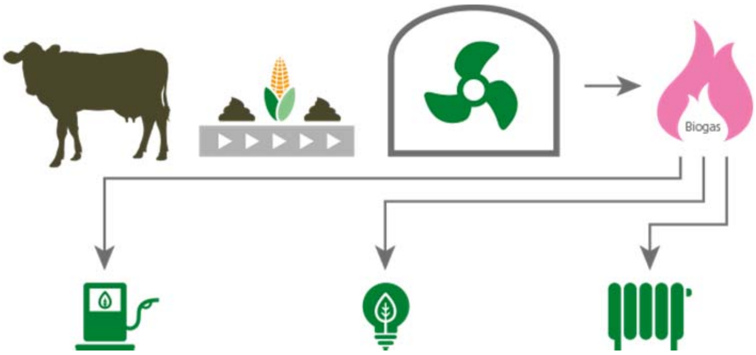

Figure 4. Biomass processing cycle and main uses of biogas fuel

Finally, the Diesel or diesel oil is a fossil fuel obtained from petroleum and his price for this study case is 0.57 €/L. The diesel is compounded by 75% of saturated hydro carbons (principally paraffin) and 25% of aromatic hydro carbons (including naphthalene and alkane benzenes).

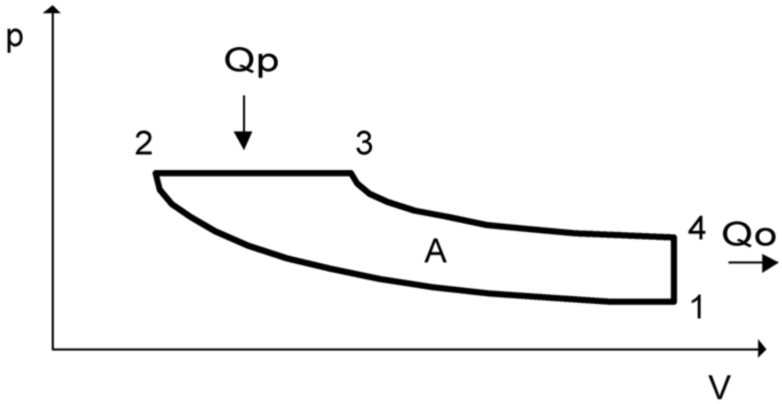

Figure 5. Diesel engine thermal cycle, where Qp is the heat in and Qo heat out, A is the net work, p is pressure and V is spceficic volume

The software HOMER uses the following equations to calculate the total net present cost (*NPC*) to represent the system's life cycle cost, the capital recovery factor (*CRF*), and the cost of energy (*COE*), which is the average cost per kilowatt-hour ($/KWh) of electricity produced by the concerned system.

$$NPC\ (\$) = TAC/CRF \quad (1)$$

Where *TAC* is the total annualized cost.

$$CRF\ (\$) = ((1+i)N)/((1+i)N-1) \quad (2)$$

Where N is the number of years, and i is the annual real interest rate (percentage).

$$COE\ (S) = Cann,/E \quad (3)$$

Where $Cann$, is the annual total cost, and *E* is the total electricity consumption in kWh/year (Hosney et al., 2014).

3. Results Analysis

An economic comparison between the Biogas, Natural gas and Diesel was necessary to determine which option is the best to use as the less expensive fuel resource in the proposed system, as is shown in Figure 6.

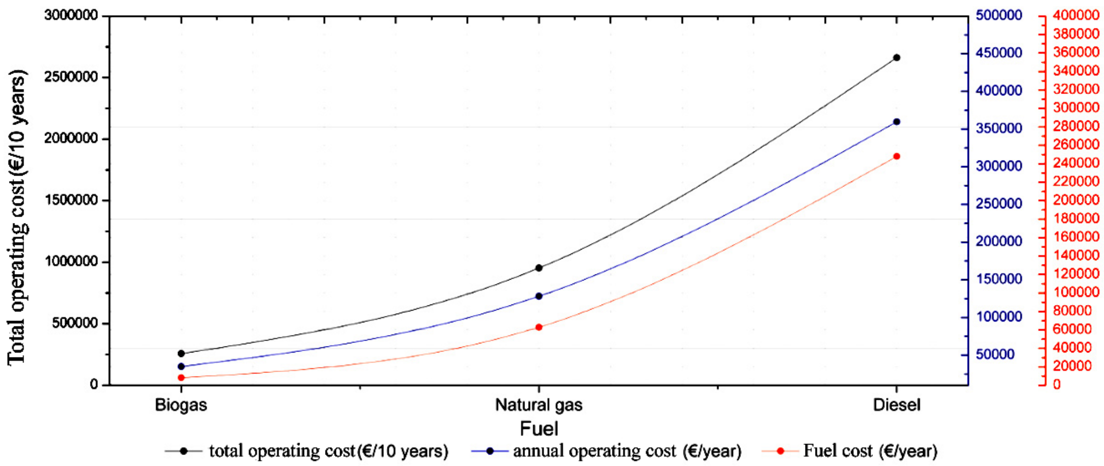

Figure 6. Comparison of total operating costs among Biogas, Natural gas, and Diesel

The plot has three different scales in the Y axes with the purpose to see the trend of each line. The total costs are different to the fuel costs because it was considered the installation costs according to the energy resource technology typically used in this type of generation system. It can be seen that the Biogas is the fuel with the less annual and total cost determined through the simulation. Also, it shows that the biogas is the fuel resource with less amount of consuming material for the system. However, it is necessary to remember that the Biogas is not a fossil fuel and his combustion capacity is limited in comparison with the natural gas and the diesel. For this reason, if the system presents a pike of energy demand at any time, the system cannot work efficiently.

The combustion of diesel is the most powerful method because it is a derivate from hydrocarbons. Therefore, it is possible that the system can generate long amounts of energy and present a small percentage as excess, see Figure 7. It is important to know that an excess of energy represent higher cost from fuel consumed because all that energy is completely lost. A simple situation can explain the excess of energy or the lack of energy. If the energy demand is higher than the production, the system experiment lack of energy and its functionality becomes deficient. However, if the production of energy is higher than the energy demand, the system experiment excess of energy, therefore the system can consume long amounts of fuel causing a high operating cost and greenhouse emissions.

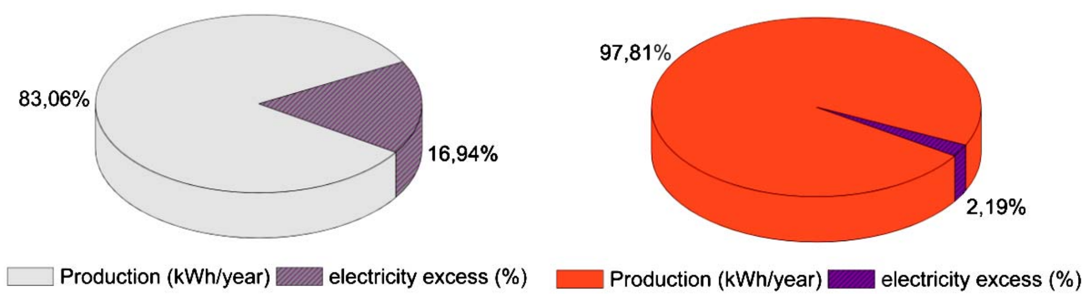

Figure 7. Production vs. electricity excess. Left (diesel), right (biogas and natural gas)

The electricity production for the diesel was of 1'112,101 kWh/year, and the production of the natural gas and the biogas was 905,163 kWh/year.
It can be seen that the system working with diesel generate a higher amount of energy with an excess of 16,94% of the electricity production. It is necessary the implementation of a storage system to save all the excess of energy and use it when the energy demand is more than the production. However, the natural gas and the biogas presents a low energy excess, and the implementation of a storage system can be omitted for this case study.
Table 1 shows a comparison of the different types of greenhouse emissions for the fuels simulated.

Table 1. Greenhouse emissions for each type of fuel

Fuel	CO_2 (kg/year)	CO (kg/year)	unburned hydrocarbons (kg/year)	particulate material (kg/year)	sulphur dioxide (kg/year)	nitrogen oxide (kg/year)
Biogas	65	2.41	0	0.0679	0	5.05
Natural gas	506,798	1,685	0	47.5	0	3,536
Diesel	954,051	6,490	263	26	2,338	519

It can be seen that the biogas produces the lowest greenhouse emissions in comparison with the other fuels. It can be used in distributed generation systems in rural areas, places where the availability of natural gas may be compromised, while natural gas is used in conventional electricity distribution services. Environmentally, the use of biogas contributes to the decontamination of waste and the reduction of soil, air and water pollutants, contrary to natural gas. Regarding the agricultural aspect, biogas can be considered as a natural fertilizer, which generates in its production effluents concentrated in nutrients such as nitrogen, phosphorus and potassium.

4. Conclusions

Considering that the development of thermal generation engines has a high degree of advance and high efficiency, there are still many aspects to be explored when they operate with different fuels such as renewable energy sources like biogas. It presents the best economic benefits together with the natural gas at high load rates, producing the lowest greenhouse gas emissions.
The use of thermal generation engines located strictly in the place of final use of energy has many benefits. It favors the industry sector and an entire country by saving primary energy, reducing losses in power grids, obtaining high reliability due to its nature in distributed generation, causing diversification of energy sources and reduction of greenhouse gas emissions. These benefits can be enhanced when biogas is used as an energy resource.
The implemented model with the assistance of HOMER pro aimed simulates different operational scenarios when using natural gas, biogas, and diesel as energy resource on the systems. It reduces the cost of implementation and helps to choose the most appropriate architecture based on the local condition of the place so that the energy project can be done. The simulations results evidenced that the energy production system using biogas is efficient despite several constraints.

Acknowledgments

This research was supported by the Engineering Faculty of Universidad del Atlántico and the Energy Department of Universidad de la Costa.

References

Appel F., Ostermeyer-Wiethaup A., Balmann A., 2016, Effects of the German Renewable Energy Act on structural change in agriculture—the case of biogas. Utilities Policy, 41, 172-182

Askari IB, Ameri M., 2012, Techno-economic feasibility analysis of stand-alone renewable energy systems (PV/bat, Wind/bat, and Hybrid PV/wind/bat) in Kerman, Iran, Journal Energy Sources, Part B: Economics, Planning, and Policy, 7, 45–60.

Barrozo F., Valencia G., Cárdenas Y., 2017, An economic evaluation of Renewable and Conventional Electricity Generation Systems in a shopping center using HOMER Pro, Contemporary Engineering Sciences, 10, 26, 1287-1295.

Bala B., Siddique S., 2009, Optimal design of a PV-diesel hybrid system for electrification of an isolated island sandwip in Bangladesh using a genetic algorithm. Energy for Sustainable Development, 13, 137–42.

Bhuiyan M., Asgar M., Mazumder R., Hussain M., 2000, Economic evaluation of a stand-alone residential photovoltaic power system in Bangladesh. Renewable Energy, 21, 403–10.

Barrozo F., Escorcia Y., Valencia G., 2017, Biomass generator to reduce the gas emission and operation cost in grid-connected, renewable energy systems, 10, 13, 311–316.

Barrozo F., Escorcia Y., Valencia G., 2017, Hybrid PV and Wind grid-connected renewable energy system to reduce the gas emission and operation cost, Contemporary Engineering Sciences, 26, 1269-1278.

Das B., Al-Abdeli Y., Kothapalli G., 2017, Optimisation of stand-alone hybrid energy systems supplemented by combustion-based prime movers, Applied Energy, 196, 18–33.

Hahn H., Krautkremer B., Hartmann K., Wachendorf M., 2014, Review of concepts for a demand-driven biogas supply for flexible power generation, Renewable and Sustainable Energy Review, 29, 383–393.

Halder P., Paul N., Joardder M., Khan M., Sarker M., 2016, Feasibility analysis of implementing anaerobic digestion as a potential energy source in the world, Renewable and Sustainable Energy Reviews, 65, 124-134.

Qoaider L., 2010, Photovoltaic systems: a competitive cost option to supply energy to off-grid agricultural communities in arid regions, Applied Energy, 87, 427–35.

Hosney F., Mohamed F., Mohamed N., 2014, Photovoltaic-Biomass Gasifier Hybrid Energy System for a Poultry House, International Journal of Modern Engineering Research, 4, 8, 51-62.

Valencia G., Vanegas M., Martinez R., 2016, Estudio de la persistencia del viento en la región Caribe colombiana con énfasis en La Guajira. Ed. Universidad del Atlántico, Barranquilla, Colombia

Valencia G., Vanegas M., Polo J., 2016, Análisis estadístico de la velocidad y dirección del viento en la Costa Caribe colombiana con énfasis en La Guajira, Ed. Universidad del Atlántico, Barranquilla, Colombia

Valencia G., Vanegas M., Villicana E., 2016, Atlas solar de la Costa Caribe colombiana, Ed. Universidad del Atlántico, Barranquilla, Colombia

Vanegas M., Valencia G., 2016, Atlas eólico de la Costa Caribe colombiana, Ed. Universidad del Atlántico, Barranquilla, Colombia