18th Brazilian Congress of Thermal Sciences and Engineering
November 16-20, 2020 (Online)

ENC-2020-0560
ECONOMIC VIABILITY TO USE METHANE GENERATED FROM LANDFILL AS FUEL FOR POWER GENERATION

Marshell Ferreira Almeida Ferraz
Ricardo A. Santos
Luiz Antônio Alves
Muriel de Pauli
Julio C. Berndsen
UNIAVAN - Centro Universitário Avantis. Av. Marginal Leste, 3600 - Estados, Balneário Camboriú - SC, 88339-125
marshell.ferreira.almeida7@gmail.come-mail

Lauber S Martins
Núcleo de Pesquisa e Desenvolvimento de Energia Autossustentável – NPDEAS, Universidade Federal do Paraná. Cx. P. 19011-81531-990-Curitiba, PR, Brasil.
Department of Physis, Andrews University, Berrien Springs, United States
lauber@andrews.edu, lauber@ufpr.br

Abstract. *Energy resources are subjects of great interest of governments around the world. Due to their strategical nature, those resources has generated geopolitical disputes since the first Industrial Revolution. In the second half of the 20th century, with the expansion of the urban-industrial environment, mainly in Latin America and Southeast Asia and, consequently, the population growth, there was an exponential increase in energy demand. In recent years, the energy issue has brought new discussions: international agencies, governmental institutions and society, energy consumption, natural resources, climate change and, mainly, the energy security of more developed countries. Despite the technological advances provided by the Technical-Scientific Informational Revolution of the last four decades, the main resource of the energy matrix is the same since the Second Industrial Revolution (1850): oil, coal as the second largest demand and natural gas in third place. However, despite of investments in alternative sources – solar, wind, geothermal, fossil fuels remain to be the primary source of energy worldwide. The diverse energy matrix of Brazil demonstrates that the nation is inserted in this new scenario of changes and discussions about climate change and sustainable development. Those discussions have led the country to investigate alternatives to become not dependent of foreigner fuel. Investments in biofuel production from sugarcane and construction of hydroelectric plants, put Brazil on the same level of the countries with the cleanest energy matrix in the world.*

Keywords: oxy-methane combustion, Electric Power Generation, Sustainability, Environmental Analysis

1. INTRODUCTION

Energy resources are subjects of great interest of governments around the world. Due to their strategical nature, those resources has generated geopolitical disputes since the first Industrial Revolution. In the second half of the 20th century, with the expansion of the urban-industrial environment, mainly in Latin America and Southeast Asia and, consequently, the population growth, there was an exponential increase in energy demand. In recent years, the energy issue has brought new discussions: international agencies, governmental institutions and society, energy consumption, natural resources, climate change and, mainly, the energy security of more developed countries [1].

Despite the technological advances of the last four decades, provided by the Technical-Scientific Informational Revolution, the main resource of the energy matrix is the same since the Second Industrial Revolution (1850): oil, coal as the second largest demand and natural gas in third place. However, even though a lot of investment has been made in renewable energy research – solar, wind, geothermal, fossil fuels remain to be the main source of energy worldwide. [1-2].

The energy matrix in Brazil is more diverse than the other countries around the world. Almost half to the energy sources of Brazil is from renewable energy, such as hydroelectric and biomass. [10].

The Brazilian diverse energy matrix shows that the nation is inserted in the new scenario of changes and discussions about sustainable development, which has led the country to investigate alternatives to become not dependent of foreigner fuel. Investments in biofuel production from sugarcane and construction of hydroelectric plants, put Brazil on the same level of the countries with the cleanest energy matrix in the world [10-11].

It is worth mentioning that energy demand will grow in the coming years, mainly in so-called emerging countries. The growth of the population also brings the growth of urban and industrial areas. As those areas become more attractive from the commercial and business point of view, more companies settle around highly populated areas, which will naturally demand more energy consumption and generation.

It is important to emphasize that there are efforts to invest and increase energy consumption from renewable sources such as solar and wind. Countries such as the United States, China and Germany are increasingly investing in research to make the capture and distribution of energy from wind and sun more efficient [2, 5-6].

The population growth brings not only the increase in energy consumption and demand, but also in the generation of solid waste. We look for ways of saving the environment and the finite natural resources using renewable energy but we must not forget that solid waste is also an environmental issue. Most of the global solid waste is dumped in non-regulated landfills and methane, originated by the anaerobic decomposition of organic matter, is emitted to the atmosphere [7]. Bacteria breaks the molecules of the organic matter and the methane generated by the landfills can be used as fuel in power plants.

With the intent of solving an environmental problem and use that solution as source of a renewable energy, we herein propose an economic viability study of the use of methane as fuel of a power plant. The landfill under study is managed by a consortium composed of 15 cities members named "Consórcio Intermunicipal do Médio Vale do Itajaí". According to the consortium, the amount of organic waste generates methane up to 150 000 tons per year.

2. METHODOLOGY

There are several methods by which one can estimate the amount of biogas generated by a landfill throughout its lifespan. The model named Landfill Gas Emission, developed by EPA (Environmental Protection Agency) is largely used around the world including in Brazilians cities. We will use this method in our study.

This method takes into account the variation of gases in the lifespan of the landfill according to the following kinetic first order equation:

$$Q_{CH_4} = L_0 R(e^{-kc} - e^{-kct}) \tag{1}$$

Q_{CH_4} is the amount of gas generated during the year, m^3/year; L_0 is the potential of generating methane per weight of waste, ton/year; k is the methane generation rate per year, 1/year; t is the time since the organic matter was dumped in the landfill, years and c is the time since the landfill was closed (c = 0, for active landfill).

Taking in consideration the amount of rain, snow or hail per year at the landfill (1582 mm/year), we can estimate the amount of methane generated throughout the years. The figures below show the amount of methane generated in the active landfill (Figure 1) and in the closed landfill (Figure 2). We can observe that even though the amount of methane decreased after 18 years, the landfill still produces methane for more 15 years even when it is inactive.

Payback period is defined as the amount of time needed for the investor to recover the cost of the installation, meaning the time necessary for the investor to have its investment money back. We know that that period varies and it is preferred to have the minimum payback period possible.

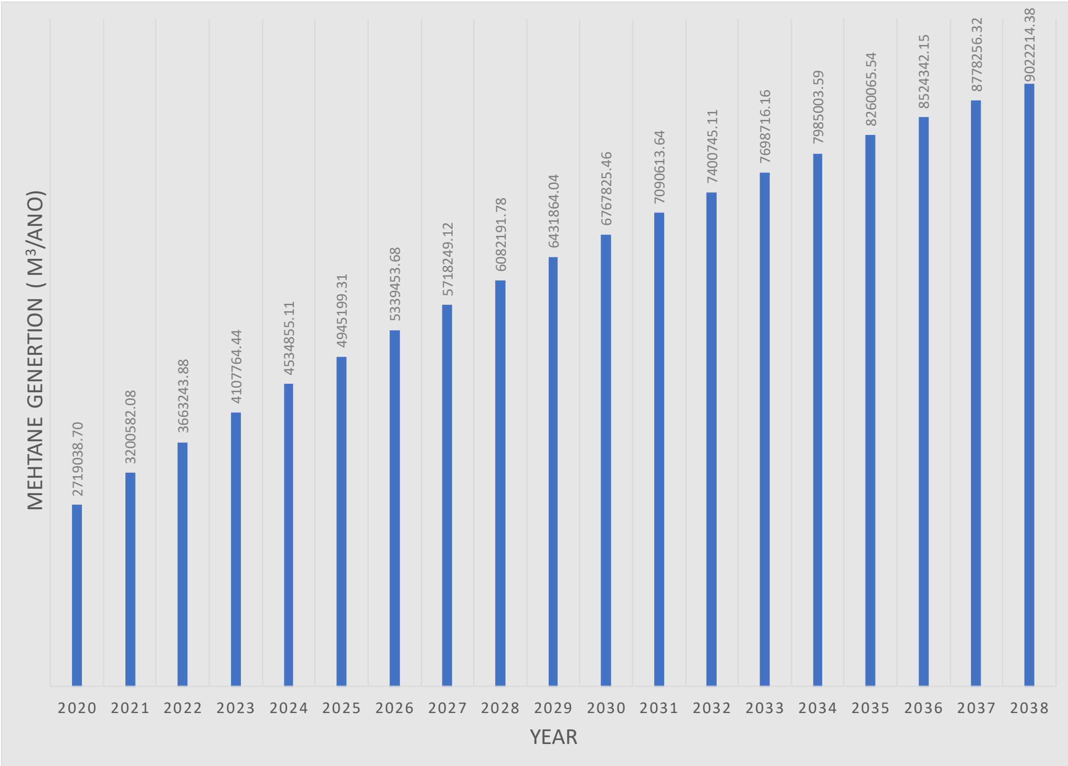

Figure 1. Amount of methane generate per year – landfill active

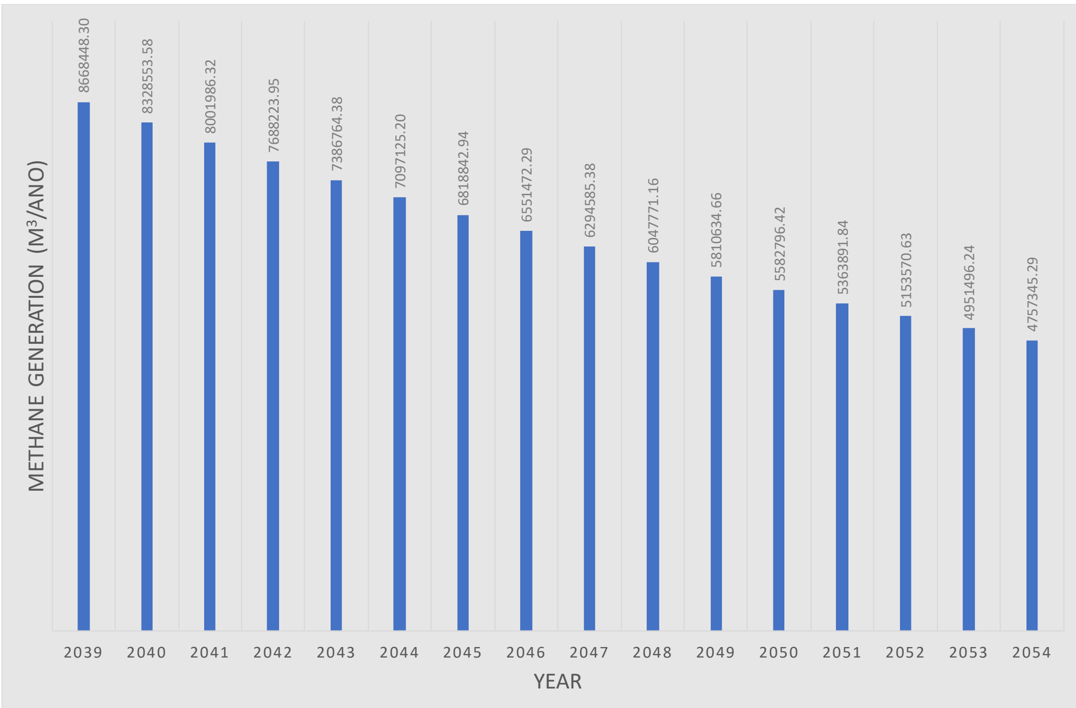

Figure 2. Amount of methane generate per year – landfill closed

3. RESULTS AND ANALYSYS

The operation of the plant is performed on a monthly basis with the methane produced by the landfill being delivered to the plant. That strategy is used since the plant has no demand for the garbage needed to keep the methane production in hours. In order to keep it viable, the plant must be able to perform at least 86 cycles for 11 days in a month considering the production during a period of 8 h.

Landfill operation data are listed in the table below by production.

Consume in MW per year, per Landfill	1
Time of cycle	1
Fuel Consumed by Cycle	2636.8
Energy Produced By Cycle	9.4
Average Price of MW	175.8

Estimated Profit per Year (without taxes)				
Landfill Production				
Year	CH_4 Produced (m^3)	Energy Produced (MW)	Number of Cycles	Profit per Year (without taxes)
2020	2719038.704	9692.17	1031	R$ 1,703,884.36
2021	3200582.084	11408.84	1214	R$ 3,709,558.80
2022	3663243.878	13058.20	1389	R$ 6,005,189.95
2023	4107764.444	14642.88	1558	R$ 8,579,408.46
2024	4534855.109	16165.43	1720	R$ 11,421,290.74
2025	4945199.309	17628.28	1875	R$ 14,520,341.57
2026	5339453.684	19033.76	2025	R$ 17,866,477.21
2027	5718249.123	20384.14	2169	R$ 21,450,009.33
2028	6082191.78	21681.57	2307	R$ 25,261,629.48
2029	6431864.042	22928.13	2439	R$ 29,292,394.20
2030	6767825.459	24125.80	2567	R$ 33,533,710.71
2031	7090613.639	25276.52	2689	R$ 37,977,323.16
2032	7400745.115	26382.12	2807	R$ 42,615,299.40
2033	7698716.161	27444.36	2920	R$ 47,440,018.34
2034	7985003.595	28464.96	3028	R$ 52,444,157.67
2035	8260065.538	29445.53	3133	R$ 57,620,682.23
2036	8524342.149	30387.66	3233	R$ 62,962,832.69
2037	8778256.325	31292.84	3329	R$ 68,464,114.77
2038	9022214.384	32162.54	3422	R$ 74,118,288.83
Landfill Closed				
2039	8668448.298	30901.39	3287	R$ 79,550,752.66
2040	8328553.578	29689.69	3159	R$ 84,770,199.65
2041	8001986.321	28525.50	3035	R$ 89,784,982.29
2042	7688223.95	27406.96	2916	R$ 94,603,125.61
2043	7386764.377	26332.28	2801	R$ 99,232,339.93
2044	7097125.203	25299.73	2692	R$ 103,680,033.27
2045	6818842.943	24307.68	2586	R$ 107,953,323.16
2046	6551472.287	23354.52	2485	R$ 112,059,048.07
2047	6294585.384	22438.74	2387	R$ 116,003,778.30
2048	6047771.161	21558.86	2294	R$ 119,793,826.56
2049	5810634.662	20713.49	2204	R$ 123,435,258.01
2050	5582796.418	19901.26	2117	R$ 126,933,900.00

2051	5363891.839	19120.88	2034	R$ 130,295,351.37
2052	5153570.632	18371.10	1954	R$ 133,524,991.46
2053	4951496.237	17650.72	1878	R$ 136,627,988.66
2054	4757345.293	16958.59	1804	R$ 139,609,308.71

As can be seen in the table above, the landfill's operating time in full operation will be another 18 years. Its maintenance, without receiving more waste, will be 15 years, from the date of closing of the functionalities.

Payback (Estimated)		
Profit (without taxes)	R$	17,866,477.21
Operating Variable Costs		
Payments (Salaries)	R$	2,000,000.00
Energy used + transport	R$	3,500,000.00
Fixed costs of modules		
Biogas Boiler - ATTSU model HH SERIES 100	R$	1,239,000.00
Steam turbine - WEG TM FLEX line (2X)	R$	5,000,000.00
Cooling towers - Evapco model 1925E-1g (2X)	R$	680,000.00
Jacuzzi brand centrifugal pump series E - Montage 100EB6 - T	R$	42,500.00
Generator (2X)	R$	2,316,000.00
Reservoir (2X)	R$	20,000.00
Reducer (2X)	R$	2,400.00
Total Fixed Costs	**R$**	**14,799,900.00**
Variable costs		
Plant Installation Cost	R$	1,239,001,00
Other components required during installation	R$	2,000.00
Total Costs	R$	16,040,901,00
Net profit	R$	1,825,576.21
Payback Time in Years	6	

Minimum Number of cycles in a month	86
Minimum number of daily hours of production	8h
Minimum number of days of operation	11

The payback was computed deducting the cost of the installation from total annual profit, considering that it is necessary to spend 1 MW of energy per year to keep the landfill active. Therefore, considering the annual profit accumulated from 2026, deducting the variable and fix costs we concluded that the company will breakeven in 6 years. The estimate net profit is R$1,825.58, when the methane is used as a fuel of a power plant designed to generate 28.5 ton of superheated vapor and 94MW of power output with efficiency of 37%. We can then conclude that the methane generation from landfill to produce power is economically viable.

4. CONCLUSIONS

The herein work had the intent to demonstrate that cogeneration concepts have the potential to be applied in the development of sustainable solutions in different branches of society, especially addressing sensitive topics as solid waste. Energy security and the comfort that the development brings are cherished by all of us, however the population growth and such development also generated a lot of solid waste that need to be disposed, which means, the development impacts the environment.

We proposed a strategy to use the methane naturally generate by the accumulation of solid waste as fuel to be used in power plants. We showed that this strategy can be viable taking into consideration engineering and economic factors. A net profit of R$1,825.58 was estimated. As more studies can be performed as we face ever growing environmental challenges, the present work is a demonstration that sustainable development can be achieved.

5. REFERENCES

Antônio Garcia-Olivares et al.: A global renewable mix with proven technologies and common materials. In: Energy Policy 41, 2012.

Brian Vad Mathiesen et al.: Smart Energy Systems for coherent 100% renewable energy and transport solutions. In: Applied Energy 145, 2015.

https://www2.aneel.gov.br/aplicacoes/capacidadebrasil/OperacaoCapacidadeBrasil.cfm

O Setor eólico em expansão. Entrevista com Elbia Melo, presidente da Associação Brasileira de Energia Eólica. Instituto Humanitas Unisinos – IHU, 5 de fevereiro de 2013.

Henrik Lund, Brian Vad Mathiesen.: Energy system analysis of 100% renewable energy systems - The case of Denmark in years 2030 and 2050. In: Energy 34, Issue 5, 2009.

Mark Z. Jacobson, Mark A. Delucchi: Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials. In: Energy Policy 39, Vol. 3, 2011.

Nickolas J. Themelis, Priscilla A. Ulloa, Methane generation in landfills, Renewable Energy, Volume 32, Issue 7, 2007, Pages 1243-1257.