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Pre-Feasibility Study of a Biogas Pant for Cattle Farms Based in Pakistan

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ABSTRACT

This work presents a technical, environmental and financial pre-feasibility study for a biogas plant for a cattle farm based in Pakistan. In the status quo, the farm is using electricity off the national grid and the heating requirement is fulfilled using gas heaters. A substitute heat and electricity generating biogas plant is proposed in the study, where biogas production is mainly from the cattle manure, due to its abundance in the farm area. Power generation can be done using a Biogas Generator of specifications according to biogas generation, which is dependent on the amount of manure available and waste heat is recovered from the generator to pre-heat the input slurry to the biogas digester. The financial and environmental study was carried out using RETScreen™. An efficiency of 52% is achievable from this biogas plant with total revenue of USD 19,356 per annum.

Key words: Anaerobic Digester, Biogas,Cattle Manure, Feasibility, RETScreen™

INTRODUCTION

As the world is moving towards a more enhanced stage with ever growing technological advancements and improving standards of living, the energy requirement of the world is increasing on a daily basis [1–5]. In the status quo, the power generation sector mainly relies on fossil fuels, a limited resource which is susceptible to extinction in the near future, thus the need for renewable energy is becoming significant [6–9]. Over the past couple of centuries, consumption of fossil fuel has increased exponentially resulting in a rapid increase in depletion rates. According to data retrieved from Ecotricity UK, depletion of fuels has become rapid and the world is likely to run out of extractable resources by the year 2085 [10,11]. The depletion of fuels is such that the world will run out of Oil by 2051, out of gas by 2060 and coal by 2085 [12]. It is due to this reason that a lot of investment is being done in the renewable energy sector in order to gradually move towards an alternative energy production and decrease the exhaustion of current fossil fuel reserves. According to 'Our World in Data' the investments made in renewable energy, by technology went up to 300 billion US Dollars in the year 2015 [13].

Energy sector in Pakistan is majorly dominated by oil and gas with up to 80% of production being done using said fuels. Besides oil and gas, Pakistan is also consuming Liquefied Natural Gas (LNG) and coal. Oil is imported from the Middle East mainly Saudi Arabia and Gas from Iran [14]. Pakistan currently has a total installed power generation capacity of 33,836MW, facing a shortfall of about 3000-4000MW and in order to cater to this shortfall without having to increase import of fuel, the Government of Pakistan has set its goal to achieve 30% renewable energy in its energy mix by 2030. A lot of effort is being done in order to achieve this goal with hydropower constituting a share of 13% in the energy mix while other renewable energy sources playing a minor role in the status quo.

Biogas production and potential from cattle manure is an extremely feasible option given the high population of cattle (including buffalos) and poultry present in the county [15]. Biogas potential in Pakistan according to theoretical calculations goes up to more than 4000MW, which will definitely help in fighting the energy crisis issue [16].

The energy content present in biomass can be converted into useful form of energy called bioenergy through various conversion processes. Conversion process selection depends on factors such as type and quantity of biomass feedstock; desired form of energy and project specific factors [17]. The two main conversion types can be classified as:

- Thermo-chemical conversion

- Bio-chemical conversion

Various bioenergy conversion techniques are used to convert energy contained in the biomass to useful energy which can be used to meet the energy demands of the developing world. Anaerobic digestion (AD) is one of the most effective processes. Anaerobic digestion is a natural microbiological process in which microorganisms break down organic matter into useful products [18]. The process occurs in a confined space in the absence of oxygen, where bacteria breakdown organic matter into smaller chemical compounds which results in the production of biogas.

The process of anaerobic digestion is highly dependent on the process temperature that highly influences the biogas quality and quantity. The microorganisms performing the process of digestion are categorized according to the process temperature. Thermophilic bacteria operate in the temperature range between 50-60^{o}C, psychrophiles operate at 12-24^{o}C, whereas mesophilic bacteria operate between 22-40^{o}C. Methanogenic bacteria are sensitive to temperature fluctuations of +/-1^{o}C for thermophiles and +/-3^{o}C for mesophiles [19]. These temperatures affect biogas production to a great extent and the adaptability to the new temperature takes more time.

PROBLEM STATEMENT

The main concern of the cattle farm owners with manure is the problem of storage and management of the waste, as a very large area is required to stock the manure and that land cannot be used for any other purpose besides storage of manure. Storage and management of manure only constitutes to an increase in the operational costs of the farm without providing any benefits to the stakeholders.

Another problem with cattle manure is the production of harmful gases. Manure from animals has been considered a major contributor to air pollution, releasing a number of harmful gases including ammonia, which can increase disease risk and health concerns, especially for people who live in the vicinity of a cattle farm [20].

A practical utilization of said manure would for the purposes of power generation, using Anaerobic Digestion techniques. Anaerobic Digestion provides with a simple solution for the storage, maintenance and safety problems. Moreover, the process also generates power which caters to the shortfall and can also be used for revenue generating purposes.

RESOURCE ASSESSMENT

A significant amount of biomass is available at the dairy farm in the form of cow manure. Biomass is produced on a daily basis which has high energy content and is generally sold out at a minimal cost. 6000 Kg/dayCow Manure is available. The collection of the biomass is easy as it is generally stored in a pit.

TECHNOLOGY AND PROCESS DESCRIPTION

Anaerobic digestion is the process used to produce biomass into useful energy i.e. biogas. The process of digestion occurs in a confined tank known as the digester in the absence of oxygen. It is a microbiological process where large number of bacteria breakdown organic matter into smaller chemical compounds which results in the production of biogas. The design of the digester is based on the operational parameters that are HRT (Hydraulic Retention Time), biomass availability, moisture content and temperature. Taking into account all these factors we propose a single stage continuous flow digester. The single stage continuous flow digester is the feasible option because of its small size and daily energy output and processing of the biomass. The digester will run in the mesophilic temperature range i.e. 25-45^{o}C, considering the climatic conditions of Karachi. HRT of 40 days is considered taking in account the temperature condition

Table -1 Parameters considered in production of biogas

Parameter	**Value**
Total Manure Mass	6000 Kg
Solid Content	1801.2 Kg
Moisture Content	4198.8 Kg
For 13% Solid Content	
Total Slurry Mass	13855 Kg
Cattle Slurry Characteristics	
VS Content [21]	7.5%
Biogas Yield [21]	0.340 m3/Kg of VS
Impurities Percentage	2% of total Volume
Biogas Volume = Total Slurry Mass x VS Content x Biogas Yield	353.30 m3
Filtered Biogas Volume	346.234 m3/day

The biogas produced will be used to meet the electricity demand of the dairy farm. A 30 KWe reciprocating engine generator is proposed to meet the electricity demand of the farm and to heat the bio-digester up to 32^{o}C by using an exhaust waste heat recovery system to maximize methane yield.

According to the study [22], the heating value depends on the methane yield. Cow dung produce 67.9% methane by volume giving a heating value of 27.6 MJ/m^{3}

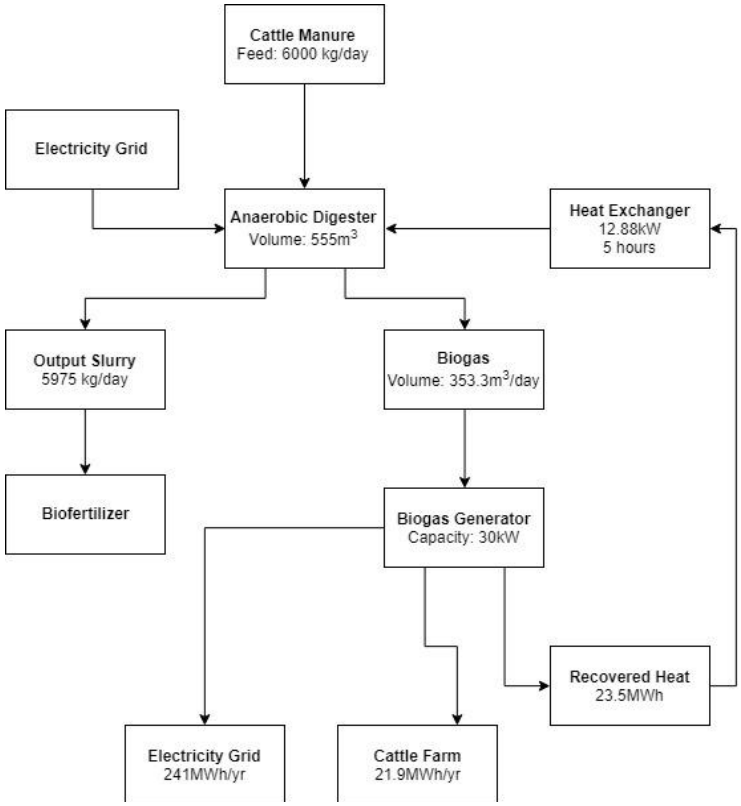

Fig. 1 General Process layout

As depicted in the figure the total electricity requirement of the farm and the digester plant is 21.9MWh/yr and 241MWh/yr is exported to the grid.

FINANCIAL MODELING AND RESULTS

The following financial assumptions were made

- Project Lifetime: 15 years
- Debt ratio of 50% with an interest rate of 13.3% and term of 15 years
- Feed in Tariff $ 0.11/KWh

The total initial cost of the plant installation is USD 21,970. Table shows the breakdown of the capital cost.

Table -2 Capital Cost Breakdown

Equipment	**Cost ($)**
Digester:	
Body Material	3,550
Structure Material	970
Insulation Material	450
Installation and labour Charges	970
Slurry Preparation Area:	
Material and manufacturing Cost	1,290
Mixing Propeller and Motor	650
Heating System:	
Exhaust Gas Heat Exchanger	150
Pump	65
Piping	320
Biogas Generator	5,160
Biogas Scrubber	970
Gas Storage Tank	2,580
Slurry Feed Pump	100
Valves and pipe Fittings	195
Pressure and temperature Sensors	156
Total	**17,576**
Total with Contingency Factor 1.25	**21,970**

The annual operational and maintenance cost of the plant is $ 7,830. The breakdown of the cost is shown in Table 3.

Table -3 Operational and Maintenance Cost

Parameter	**Cost ($)**
Electricity Consumption of AD and Farm (13,468.5 KWh)	900
Water Consumption (764,553 Gallons)	3,700
Maintenance Cost	1,345
Labour Cost	1,940
Total	**7,830**

The revenues of the plant mainly rely on the electricity exported to the grid as per the approved feed in tariff. The heat and electricity requirements of the farm will be fulfilled without any additional costs/bills and besides the cost savings from not having to pay for said utilities, the farm will also be able to generate revenue from selling to the national grid according to the feed in tariff rate set by the Government of Pakistan for Anaerobic Digestion. The annual savings for the project are calculated to be USD80.31/MWh which corresponds to a total annual saving of USD 19,356. Table 6 shows the annual O&M costs for the project and the net revenue generated per year.

Table -4 Operational and Management cost of running the plant and net annual cash flow

Parameter	**Cost ($)**
Annual Costs and debt payments	
O&M Costs	7,830
Debt Payments – 15 years	1,722
Total annual costs	**9,552**
Annual Savings and Revenue	
Fuel cost – base case	2,409
Electricity Export Revenue	26,499
Total Annual Savings and Revenue	**28,908**
Net Yearly Cash Flow	**19,356**

The annual cash flow has a significant exponential growth after the debt is paid off and the project starts earning revenue from sale to the national grid with a significant accumulated cash flow of funds at the end of the project amounting up to USD 1,800,000. The payback period of the project is between 16-18 months. Fig. 2 illustrates the annual cash flow of the project.

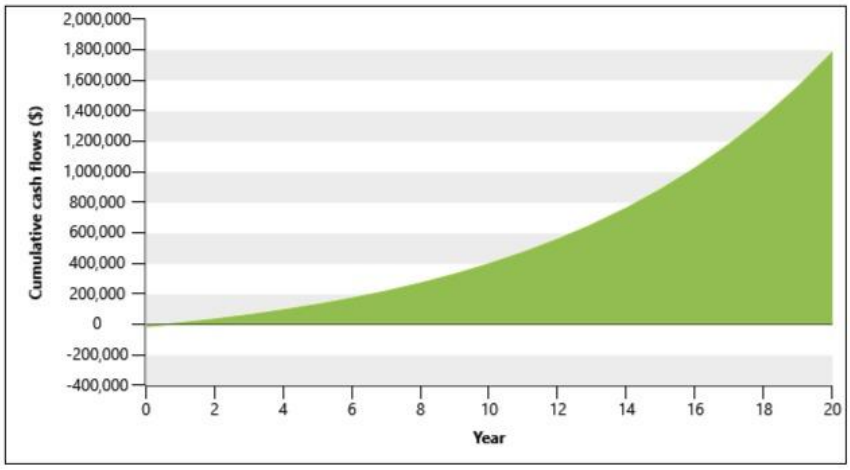

Fig. 2 Annual Cash Flow

ENVIRONMENTAL IMPACT

Power generation using a biogas generator greatly reduces the dependency on naturally occurring fuels such as coal and petroleum constituents. This results in a reduce in the overall Green House Gas emission into the environment by a factor of 88.5 tonnes of CO_x per annum which is equivalent to 20 cars not being used per year. This is shown in the data analysis performed using RETScreen in Fig. 3.

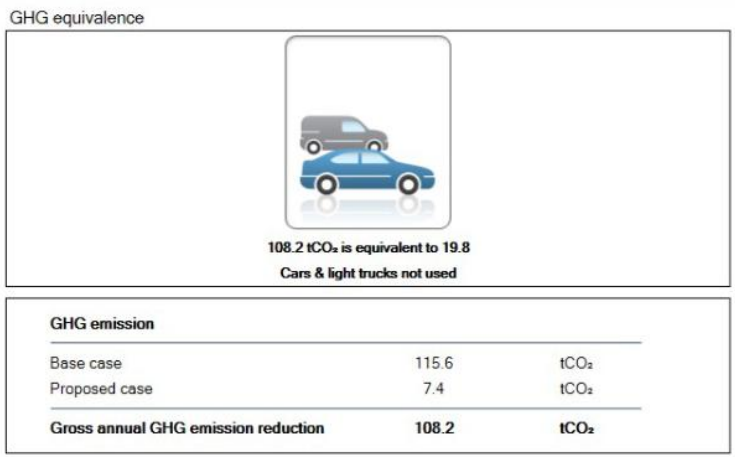

Fig. 3 GHG Equivalence

Another advantage of using this technique for power generation in terms of environmental impact is the reduction in unsafe odors and a decrease in the production of harmful gases produced from stagnant cattle manure, thus decreasing the health and disease risk in the said farm.

SOCIAL IMPACT

In terms of social impact, the project will contribute to the social as well as economic well-being of the farm area in the form of

- Job creation
- Revenue generation from the electricity sold to the national grid
- Infrastructure improvement
- Technological Improvement for the society as a whole
- Contribution to Government of Pakistan's plan of taking increasing the percentage of Renewable Energy up to 30% in the energy mix of the country by the year 2030

CONCLUSION

A pre-feasibility assessment has been conducted for the usage of cattle manure for the production of biogas which can be further used for meeting the energy needs of the cattle farm based in Karachi, Pakistan. The analysis also shows promising financial results, with high revenue generation and a surprisingly small payback period. From the social point of view, the project will have an impact by bringing employment in the local community and also by being a contributor in the Government's plan of increasing the percentage of renewable energy in Pakistan's energy mix by the year 2030. The analysis also emphasized on the environmental aspect of the project. Installation of a biogas plant adds value to the cattle manure, which is available in an excess by generating energy from waste and will also contribute in decreasing the carbon footprint of Pakistan.

REFERENCES

[1]. A.A. Zaidi, F. Ruizhe, A. Malik, S.Z. Khan, A.J. Bhutta, Y. Shi, K. Mushtaq, Conjoint effect of microwave irradiation and metal nanoparticles on biogas augmentation from anaerobic digestion of green algae, Int. J. Hydrogen Energy. 44 (2019) 14661–14670. doi:10.1016/j.ijhydene.2019.02.245.

[2]. A. Malik, S.R. Qureshi, N. Abbas, A.A. Zaidi, Energy and exergy analyses of a solar desalination plant for Karachi Pakistan, Sustain. Energy Technol. Assessments. 37 (2020) 100596. doi:https://doi.org/10.1016/j.seta.2019.100596.

[3]. Y. Cai, X. Li, A.A. Zaidi, Y. Shi, K. Zhang, R. Feng, A. Lin, C. Liu, Effect of hydraulic retention time on pollutants removal from real ship sewage treatment via a pilot-scale air-lift multilevel circulation membrane bioreactor, Chemosphere. 236 (2019) 124338. doi:https://doi.org/10.1016/j.chemosphere.2019.07.069.

[4]. Y. Cai, T. Ben, A.A. Zaidi, Y. Shi, K. Zhang, Nitrogen removal augmentation of ship sewage by an innovative aerobic-anaerobic micro-sludge MBR technology, Process Biochem. 82 (2019) 123–134. doi:https://doi.org/10.1016/j.procbio.2019.04.020.

[5]. R. Feng, A.A. Zaidi, K. Zhang, Y. Shi, Optimisation of Microwave Pretreatment for Biogas Enhancement through Anaerobic Digestion of Microalgal Biomass, Period. Polytech. Chem. Eng. 63 (2018) 65–72. doi:https://doi.org/10.3311/PPch.12334.

[6]. A.A. Zaidi, F. RuiZhe, Y. Shi, S.Z. Khan, K. Mushtaq, Nanoparticles augmentation on biogas yield from microalgal biomass anaerobic digestion, Int. J. Hydrogen Energy. 43 (2018) 14202–14213. doi:https://doi.org/10.1016/j.ijhydene.2018.05.132.

[7]. G. Mehdi, N. Ali, S. Hussain, A.A. Zaidi, A.H. Shah, M.M. Azeem, Design and Fabrication of Automatic Single Axis Solar Tracker for Solar Panel, in: 2019 2nd Int. Conf. Comput. Math. Eng. Technol., 2019: pp. 1–4. doi:10.1109/ICOMET.2019.8673496.

[8]. N. Saleh, K. Mushtaq, A.A. Zaidi, S. Abbasoğlu, S. Faiz Ahmed, Design and performance analysis of a solar powered hybrid rickshaw for commercial use in Pakistan, J. Environ. Sci. Technol. 9 (2016) 472–480. doi:10.3923/jest.2016.472.480.

[9]. A.A. Zaidi, R. Feng, A. Malik, Z.S. Khan, Y. Shi, J.A. Bhutta, H.A. Shah, Combining Microwave Pretreatment with Iron Oxide Nanoparticles Enhanced Biogas and Hydrogen Yield from Green Algae, Process. . 7 (2019). doi:10.3390/pr7010024.

[10]. A.A. Zaidi, A. Malik, K. Mushtaq, F. Ruizhe, Progress of Microalgal Biodiesel Research in Pakistan, J. Plant Sci. Curr. Res. 2 (2018) 2–7.

[11]. K. Mushtaq, A.A. Zaidi, S.J. Askari, Design and performance analysis of floating dome type portable biogas plant for domestic use in Pakistan, Sustain. Energy Technol. Assessments. 14 (2016) 21–25. doi:10.1016/j.seta.2016.01.001.

[12]. A.A. Zaidi, S.A. Ahmed, S. Zhou, Y. Feng, Y. Zhu, A. Malik, Comparative and numerical evaluation of methanol blends in CI diesel engine, in: 2018 IEEE 5th Int. Conf. Eng. Technol. Appl. Sci., 2018: pp. 1–7. doi:10.1109/ICETAS.2018.8629171.

[13]. Y. Cai, A.A. Zaidi, P. Sun, Y. Shi, K. Zhang, A. Lin, Effect of Volume Loading Rate and C/N on Ship Domestic Sewage Treatment by Two Membrane Bioreactors, Period. Polytech. Chem. Eng. (2017).

[14]. G. Mehdi, An Experimental and Comparative study about the engine emissions of conventional diesel engine and dual fuel engine., Sukkur IBA J. Emerg. Technol. 1 (2018) 81–87.

[15]. Y. Shi, K. Huang, R. Feng, R. Wang, G. Liu, A.A. Zaidi, K. Zhang, Combined MgO nanoparticle and microwave pre-treatment on biogas increase from Enteromorpha during anaerobic digestion, IOP Conf. Ser. Earth Environ. Sci. 450 (2020) 12025. doi:10.1088/1755-1315/450/1/012025.

[16]. S. Faiz Ahmed, K. Mushtaq, A. Ali, Design and performance analysis of floating dome type portable biogas plant for domestic use in Pakistan-manufacturing cost optimization, Biotechnology. 15 (2016) 112–118. doi:10.3923/biotech.2016.112.118.

[17]. Y. Cai, A.A. Zaidi, Y. Shi, K. Zhang, X. Li, S. Xiao, A. Lin, Influence of salinity on the biological treatment of domestic ship sewage using an air-lift multilevel circulation membrane reactor, Environ. Sci. Pollut. Res. 26 (2019) 37026–37036. doi:10.1007/s11356-019-06813-4.

[18]. T.A. Seadi, D. Rutz, H. Prassl, M. Köttner, T. Finsterwalder, S. Volk, R. Janssen, Biogas Handbook, 2008. doi:10.1533/9780857097415.1.85.

[19]. Q. Zhang, J. Hu, D.J. Lee, Biogas from anaerobic digestion processes: Research updates, Renew. Energy. 98 (2016) 108–119. doi:10.1016/j.renene.2016.02.029.

[20]. T. Burton, C.H; Turner, Manure Management: Treatment Strategies for Sustainable Agriculture, CemegrefFA, Rennes, France, 1999.

[21]. A. Wu, D. Lovett, M. McEwan, F. Cecelja, T. Chen, A spreadsheet calculator for estimating biogas production and economic measures for UK-based farm-fed anaerobic digesters, Bioresour. Technol. 220 (2016) 479–489. doi:https://doi.org/10.1016/j.biortech.2016.08.103.

[22]. M.N. Ukpai, P. A.; Nnabuchi, Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digester, Adv. Appl. Sci. Res. 3 (2012) 1864–1869.