‘Biogas for distributed power generation and safe drinking water with Stirling engine’

Md. Ershad Ullah Khan

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Executive Summary

Introduction:

The supply of clean energy and safe drinking water is a primary and basic requisite for the sustainable development of any country both socio-economically and environmentally. The modern world faces a great challenge in these two sectors because it is becoming increasingly difficult to access and afford clean decentralized power and safe water in both developed and developing countries. Most of the energy is harnessed from combustion of fossil fuels with serious consequences for the environment. In order to reduce the pollution and minimize the pressure on limited fossil fuels, the world must look for alternative energy.

Despite increasing global economic growth more than one third of the population still lack access to clean drinking water. Hence the challenge is to overcome this problem using technologies that would have the least impact on the environment.

Bangladesh is a heavily overpopulated country with over 80% of the population living in rural areas. They lack access to modern daily facilities like electricity, safe water and gas etc. In fact, they are not connected to the national grid electricity because of lack of grid infrastructure and inadequate power generation. Thus tremendous challenges remain in terms of sustainable development and human welfare.

The economics of large scale power productions make it difficult to cater for the need of small villages. Small scale power plants run with local resources is the most viable solution for the remote areas and poor dwellers.

Most of the water treatment plants are very big, they are run by chemical reagents and can be very expensive although the level of remaining arsenic in drinking water higher than standard level. Therefore, these types of plants are not feasible, viable or suitable for small scale communities and local rural areas operation.

Objectives:

The main objectives of this investigation and survey is to determine a feasible solution for the rural population to access small scale power and arsenic free drinking water in local communities without taking any socio-economic and environmentally burdens. Considering the above arguments, biogas driven Stirling engine for micropower generation and Membrane Distillation process for arsenic free drinking water will play a significant role to meet the basic criteria in both socio-economic and environmental contexts in rural areas in Bangladesh. It not only resolves the current safe water and electricity crisis but also provides a long term sustainable path.

Finally, the project has focused more precisely on two main objectives

- to help alleviate poverty, grow opportunities and increase quality of life in the rural and remote areas of Bangladesh by providing distributed electricity services and safe drinking water to all and
- to reduce future greenhouse gas emissions by supporting sustainable development path toward universal electrification.

This work presents the evaluation of utilizing biogas for distributed power generation and integrated membrane distillation (MD) unit for supply of safe drinking water in isolated and rural communities of Bangladesh. The analysis includes technical, economical and environmental characteristics for the introduction of this new integrated system. This project also shows how the system promotes the development of sustainable paths in developing countries.

A 70 m^3 digester will be considered for delivering the required amount of biogas which is operated at a constant digester temperature of 40 ^oC. The digester produces 250 m^3/day with 60-65% CH_4, and generated biogas can produce 4-5 kW electricity via a Stirling engine and simultaneously serve as a clean cooking fuel. Waste heat available from the Stirling engine can be readily employed in the heat-driven MD water purification process, which is capable of removing arsenic and other harmful contaminants.

Methodology:

In order to meet these mentioned objectives, an appropriate methodology was adapted to promote a feasible solution which will achieve sustainable development in isolated and rural areas. It is difficult to predict what the exact solution will be but the model developed is a close approximation. The approach was to suggest alternative pathways overcome the present man made predicament. Solution to the problems of developing countries is always difficult because of different economical, technical and managerial problems.

Among other different problems, remote areas of Bangladesh struggle for their basic needs like safe drinking water and electricity. This project model tries to mitigate, against these problems by changing the present conditions at the village level in Bangladesh.

This method can provide three different necessary outputs (distribute power, safe drinking water and nutrients fertilizer) all from one input which is manure. Biogas is a bi-product of anaerobic digestion and it can provide valuable outputs like electricity and safe water.

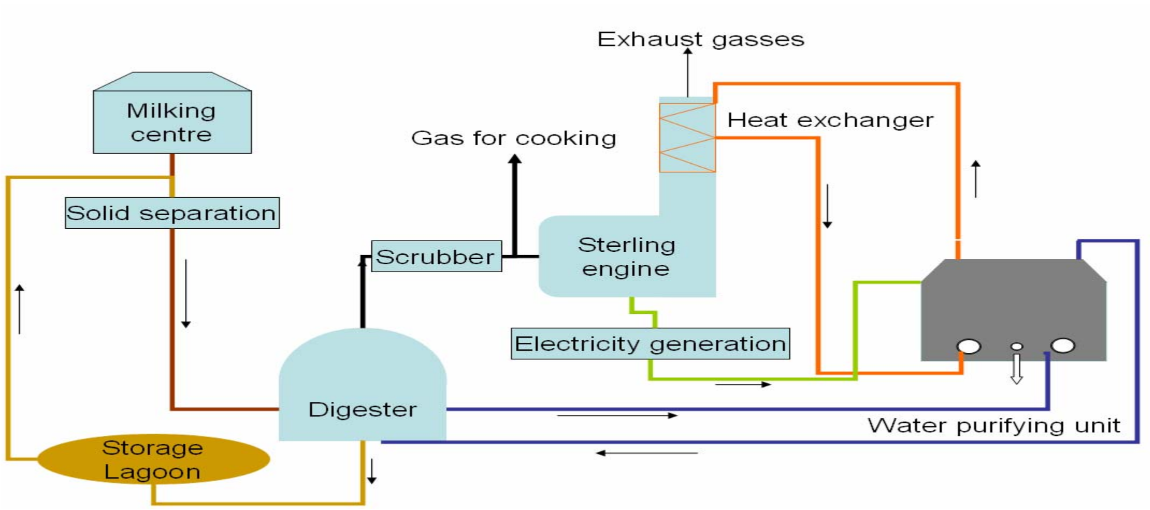

Figure: Process Diagram

In short, a plug flow digester will be used to supply the biogas at constant operating temperature of 40^{o}C. Firstly, Stirling engine is used to generate the rated amount of electricity, around 4-5 kW. A Free Piston Stirling engine has been chosen due to the logistic benefits with external combustion of biogas. Generated biogas from digester is burnt in biogas burner and after combustion; combusted flue gas will be passed through Stirling engine heater. After heated up the Stirling engine operating gas, exhausted flue gas goes through heat exchanger to heat up feed water in Membrane Distillation (MD) unit. Therefore, Membrane Distillation can be run with remaining and waste energy of exhausted flue gases after Stirling engine. MD unit will consisting of two MD modules in series to supply 25-40 litres/hr high quality pure water and will be distributed through the pipe line or bottled water to the village dwellers. At night, electricity consumption will be reduced in village areas; therefore excess biogas can be stored and used for cooking purpose in residential areas also.

Gas produced in the digester was flushed through a hydrogen sulphide scrubber and collected in a gas storage bag. The produced gas was used to produce electricity and hot water using co-generation system. The heating of digester and manure before being added to the digester was achieved by the cooling water circuit from MD. Moreover, the digested nutrients effluent can use for irrigation purpose.

One of the main issues discouraging the dairy operation for digester and Membrane Distillation technology is the high capital investment necessary for installing the system. A plug flow system is suitable for tropical countries. Stirling engine is better for small scale power generation but the problem is that this is not a mass production technology. MD process is well known technology which provides clean drinking water and can be run by low grade waste heat. This technology consumes small amount of electricity and requires low pressure compared to other technical options. At present, the main barrier for MD is capital cost and it is closely related to the feed water temperature. If the feed water temperature is high, operating and maintenance is lower, and then MD is more competitive technology compared to others.

Conclusion:

Bangladesh is an agriculture based country, therefore biogas potential is enough in rural areas. But there are some problems with manure collection facilities meaning people need to know the proper way to store and transport manure and vegetable residues. So, animal husbandry or dairy farm could play an effective role to provide necessary feedstock to the digester.

The cost of modules greatly affects the annual operating costs. The annual operating cost is $2,380 when the price of modules is $12300. If the modules were mass produced then the annual costs would go down considerably to $1,191(modules price $1470). Annual costs are estimated for a life time of 20 years and annual inflation rate is 7%.

According to the above considerations and costs estimation, it is seen that Specific cost for unit production of safe water 6$/$m^3$ (modules cost $12,352) and specific cost for electricity $0.045/kWh while the local electricity price is $0.06/kWh.

A Biogas burner and Stirling engine also provides more essential feedback by generating electricity. Finally, the system was integrated with Membrane Distillation unit in order to supply safe water to the village dwellers.

If this method is used appropriately, it may improve the quality of life and provide income generating opportunities. Sustainable development requires a model that specifically addresses social, economic and environmental issues. This considered model describes how a Stirling engine and MD unit provides these elements, creating income generating activities.

Keywords: Anaerobic Digestion; Biogas Burner; Stirling Engine; MD process; Integrated & Distributed generation.