ISSN 2250-3153

Containerizing Biogas: Design and development of portable low cost Biogas bottling system

Mr. Arulanandam Kajavatan BSc Eng.(Mora),MSc (Soton), Mr. Uthayakumar Nitharsan

Sri Lanka German Training Institute, Killinochi, Jaffna.
Faculty of Engineering, University of Jaffna.

Abstract- Bottling biogas, a renewable energy using anaerobic digestion of organic waste, enhances rural economy by decentralizing biogas utilization. New opportunities emerge in rural area not just lowering their living cost via self-producible fuel. Bottled raw biogas can be marketable as a fuel or for upgrading the biogas. This lower cost bottling system costs less than five thousand Sri Lankan rupees (Rs 5000) and can be used with minimum technical knowledge especially about safety precautions. The bottled upgraded biogas can be used for various applications including electricity generation, fueling vehicles and heating. The side product - slurry is a good fertilizer, can be marketable too. The biogas bottling system motivates villagers to utilize their waste to produce biogas and enables new income opportunities while experiencing hygienic lifestyle through better organic waste management.

Index Terms- Biogas, anaerobic digestion, economy, catalyst and sustainable energy.

I. Introduction

Containerizing biogas overcome the key challenge of storing biogas and using it as an alternative energy in various application. It motivates biogas production both in domestic sector and industrial sector, and accomplish better organic waste management practices. As a result, there will be reduction on fuel import including natural gas, environment safety will be ensured and business opportunities will rose in alternative energy sector.

As a method for organic waste management, biogas technique facilitates number of benefits. First of all, the reduction of organic waste reaching landfills causes the production of methane which is 25 times more potent than carbon dioxide. According to Australia’s national greenhouse inventory data, for every tons of food waste not sent to landfill, 0.9 tons of CO2 is saved (Food | Learning and Teaching Sustainability, n.d.). Slurry, the digested organic part, side product of biogas plant, is used as fertilizer for agricultural needs. Scalability of the plant is entirely depending on investor. It reduces the cost of living and creates opportunity for new businesses.

This research, a simple low cost biogas portable bottling system/tool is designed for domestic purposes. This promotes containerized biogas business opportunity and other opportunities such as biogas power generation and biogas based heating system. The following section provides detail design of proposed tool. Then challenges on development are discussed. After analysis, identified suggestions are discussed. Finally, significant of this research output is noticeably concluded.

II. Background study of Biogas

Biogas is formed by microbiological process of decomposition of organic matter in the absence of oxygen called anaerobic digestion. Hydrolysis, acidogenesis, acetogenesis and methanogenesis are the main for steps in anaerobic digestion process (Reena Victor, S Shajin, R.M.Roshni & S.R.Asha, 2014). The rate of biogas yield depends on various condition including temperature, stirring speed, feed concentration and catalyst concentration (Reena Victor, S Shajin, R.M.Roshni & S.R.Asha, 2014).

a. Selection of biogas plant for fabrication

The general selection criteria of a biogas plant are based on availability of the amount of biomass and application area: domestic or in households, industries and agricultural areas and metropolitan area where sanitary sewer system available. Additionally, allocated budget, customer expectation are also influenced in selecting a biogas plant. Digester, a gas collector, an inlet for feeding waste material, an outlet for outlet for digested slurry and a system or outlet to release gas are the major components of a biogas plant. In our research, we identified three type of plant that is suitable for domestic areas, industrial and agricultural areas and metropolitan areas.

Domestic plants (or mini plant) are generally used in households to reduce the utility of firewood. The following figure shows a simple domestic usage. Kitchen waste is primarily used as the feed for the digester. These type of mini plant cost around Rs 1000 for construction.

Figure 1: A domestic biogas digester (Mini Bio-gas plant using food waste, decomposable organic material and kitchen waste, n.d.)

Ferro cement Biogas plant or plant using plastic material such as 1000 liter water tank as in figure 2 is more appropriate in agricultural areas and industrial areas. The Ferro cement plant is a cost effective design of fixed dome type biogas plant but the plant cost considerably higher than the second one for same capacity. In general 1000 liter biogas cement plant cost around Rs 400000 while the floating dome biogas plant construction costs between Rs 50000 – 75000.

Figure 2: (a) Floating-drum biogas plant using 15000 liter water tank (b) Ferro cement biogas plant at Mahadeva Achchiramam - Killinochi

The following figure depicts a typical plant for a metropolitan area. Other than producing biogas, the cost of solid waste management dramatically reduced for urban council. Urban council can generate income from biogas and fertilizer while treat the municipal waste environment friendly.

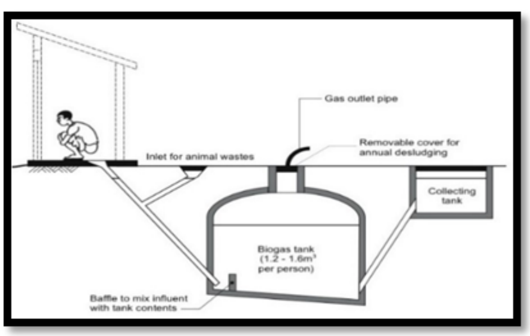

Figure 3: Biogas model for metropolitan area

b. INCREASE THE RATE OF BIOGAS PRODUCTION

The rate of biogas yield depends on various condition including temperature, stirring speed, feed concentration and catalyst concentration (2). Catalyzed biogas generation is a well-known technique to enhance the biogas yield of a plant. Other techniques are also used to increase the rate of biogas production including black coating for digester, recycling slurry and variation in operating condition.

Indian Institute of technology researchers (New Delhi) tried different techniques to enhance the biogas production including the application of various catalysts (Yadvika, Santosh, T.R. Sreekrishnan, Sangeeta Kohli & Vineet Rana, 2004). In our research, we tested parthenium (natural catalyst), yeast and vinegar with cow dung and food waste. Cow dung produce biogas effectively when parthenium is added.

c. PURIFYING BIOGAS

Biogas appliance are fabricated using metal and plastic which are vulnerable due to hydrogen sulfide when exceeds 100 ppm (Jerry Hughes Martin II, 2008). Biogas contains considerable amount of CO2 and other substances as listed in the following comparison table (Michael Andrea, Jason Aspell, Peter Epathite & James Faupel, 2011). Raw biogas can't be directly used for vehicles or electricity engines due to presence of other substance in higher percentage. Therefore, generated biogas has to be subjected for purification process in order to improve the flammability by removing CO2 and H2S.

Substance	Biogas [%]	Natural Gas [%]
Methane (CH4)	50 - 60	97
Carbon Dioxide	34 - 38	2.6
Nitrogen (N2)	0 - 5	0.4
Oxygen (O2)	0 - 1	-
Water vapour-H20	6	-
Hydrogen Sulfide	Trace	-

Table 1: comparison of biogas and natural gas.

The amount of H2S in raw biogas varies between 0 to 7000 ppm which depends on the type of waste. For example, hydrogen sulfide amount in biogas of swine waste is 600 to 4000 ppm and biogas from cattle manure contains 600 to 7000 ppm H2S (Jerry Hughes Martin II, 2008). Thus, raw biogas must be upgraded to operate vehicles and power engines. As shown in the following figure, steel wool is a cheap and widely used technique to upgrade biogas by scrubbing hydrogen sulfide (Michael Andrea, Jason Aspell, Peter Epathite & James Faupel, 2011). Due to large surface area of steel wool, this method is more effective to absorb and remove hydrogen sulfide from raw biogas. Activated carbon impregnated with potassium iodide can also be used to remove H2S from biogas (Government of Alberta, n.d.).Membrane technique is another technique for hydrogen sulfide purification. Removing hydrogen sulfide prolong the lifetime of biogas appliance and reduce the cost of maintenance.

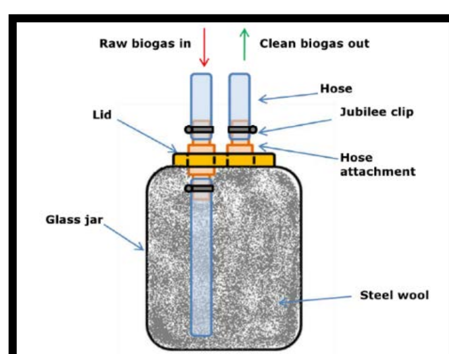

Figure 4:H2S scrubbing unit.

Water scrubbing, pressure swing absorption (PSA), chemical and physical absorption and cryogenic processing are commercially available techniques to upgrade raw biogas (Rimika M K & Virendra K V, 2010). Water scrubbing is a cost effective and suitable technique to absorb CO2 meanwhile it reduce H2S even further (Rimika M K & Virendra K V, 2010). The major disadvantage of water scrubbing is the requirement and post treatment of large amount of water (Lenntech, n.d.).

d. Bottling biogas

Bottling raw biogas decentralize the biogas production. Since biogas upgrading requires skilled labor, the bottled raw biogas can be collected and centralizing the purification process. Upgraded biogas can be bottled again in cylinder. Moisture can be removed using silica gel crystals. Raw biogas cylinders and upgraded biogas cylinder should not be mixed due to the presence of hydrogen sulfide in raw biogas. Domestic LPG cylinders are chosen for bottling biogas since they are available in the local market. According to ISO standards, domestic LPG cylinder can be filled up to 14 bar pressure level (Rimika M K & Virendra K V, 2010).

Masters students of university of Notingham - Michael A, Jason A, Peter E and James F designed and developed a low cost bottling system as shown in the figure 5(a). Their prototype of biogas bottling system cost 75 sterling pounds which is equal to 15 000 Sri Lankan rupees. According to our study, compressor head with motor is used in most of the biogas bottling systems. The following figure 5(b) shows the low cost biogas bottling system constructed in Thailand (Rimika M K & Virendra K V, 2010). . Figure 6 depicts the low cost small-scale compression and bottling unit constructed at IIT Delhi and typical cost of the small-scale dispensing system is € 3500 (Rimika M K & Virendra K V, 2010).

a b

Figure 5: (a) Biogas bottling system (Nottingham) and (b) Biogas upgrading and bottling system in Thailand

a b

Figure 6: (a) Biogas dispensing system (IIT) and (b) Compressor head with motor

e. Applications of Biogas

Biogas is used for a number of applications both in domestic sector and industrial sector. Many countries focus on biogas related research including innovative biogas appliance and biogas powered vehicles. A picture gallery of innovative biogas appliance is presented in Appendix B.

Biogas can be used directly for cooking as a fuel using biogas stoves which works with biogas preassure range from 0.007 bar to 0.014 bar (Energypedia, n.d.). Hong Kong based company; Huamei International Green Energy Holding Co released their innovative product - biogas rice cooker for domestic purpose (Green Energy Huamei Int, n.d.). Biogas powered thermal radiant heaters are used to maintain certain temperature to raise young stocks. Biogas is used in incubators to imitate and maintain specific temperature for eggs (Energypedia, (n.d.). Biogas powered boilers can be used for heating during winter period.

Upgraded biogas can be directly used for petrol powered vehicle and biogas blended with diesel is used for diesel powered vehicles. The emission is lower than natural gas and diesel (Rimika M K & Virendra K V, 2010). Biogas powered bus and train is in use in Sweden (Rimika M K & Virendra K V, 2010). Biogas powered motorbike was developed in many countries including Japan.

Electricity can be generated in two ways: using biogas powered engines or using biogas fuel cell. In rural areas, biogas lamp can be used to fulfill lightning requirements. Additionally, through a catalytic chemical oxidation methane can be used in the production of methanol production.

III. Proposed design and utilization of biogas bottling tool

The following figure depicts the design of the biogas bottling tool. Raw biogas from plant's gas holder inflate into compressor via inlet valve and compressed and intake into cylinder via outlet valve. The valve system controls the biogas intake and compression.

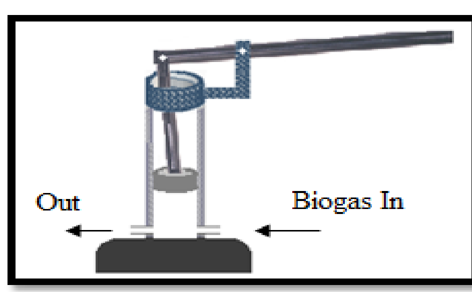

Figure 7: proposed design of the system

In order to maximize the utility of biogas, we identified that our low cost bottling system can be used to collect raw biogas from various household. The collected raw biogas can be upgraded and bottled again for various applications. As shown in the figure 7, centralized biogas purification center is more appropriate and effective approach because of the requirement of technical skills to upgrade raw biogas and the required capital for purification unit.

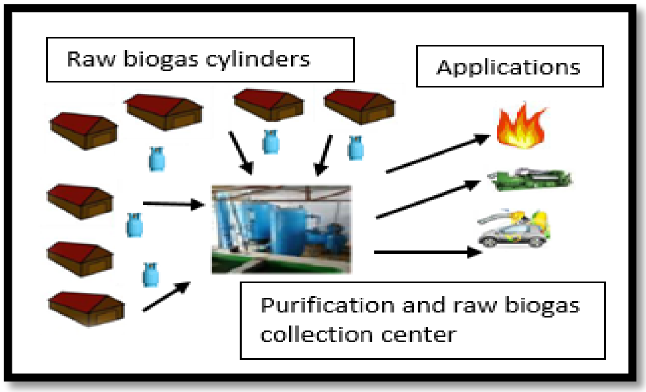

Figure 8: Proposed model for biogas utilization

IV. Development of Biogas Bottling System

Actual development slightly differs from proposed design in order to reduce the cost by selecting locally available components. In our research work, a domestic biogas plant is fabricated as shown in figure 9 (a) for testing our bottling system. A 5 liter bucket with lid, a long PVC pipe, a short pipe, gas pipe, bag to collect gas, pipe fitting materials and a bolt tab is used to construct the plant. Using a funnel, sufficient amount of organic waste and water has to be inserted. The anaerobic process occurs inside and produces methane (biogas) inside the air tight plant. The released gas is collected in the bag. The slurry can be removed through the short wider PVC pipe and can be used as a fertilizer. The total material cost of this plant is less than Rs 1000.

a b c

Figure 9: (a) Test biogas plant, (b) modified washer and (c) modified connecter for cylinder

Figure 10: Low cost biogas bottling system

Implementation of biogas filler faces slight changes due to the availability of material as shown in the figure 10. A hand pump is converted by little modification to suck and release biogas under high pressure. Two washers are mounted as in figure 9 (b) and its holes are closed using silica. A valve system is developed to inlet the gas when the pump sucks biogas and to outlet the biogas during filling it into a cylinder. Modified connecter is mounted to the cylinder which enables the gas cylinder to be fillable. A pressure gauge is mounted at the end of the pipe which is used to fill biogas into cylinder. The total material cost of the biogas bottling system is Rs 4740 as shown in the Table 2.

Component	Cost in Rs
Hand pump (450) + modification	750
2 Valve (1700) + 6 connectors (900)	2600
Connector modification	150
Pressure gauge (1000) + 8 feet pipe	1240
Total	4740

Table 2: cost of construction of bottling system.

V. Result and Analysis

There is no biogas generated during first three days when cow dung was used without catalyst. On the second day, hot water is used to maintain 67 degree Celsius as the surrounding temperature. The gas generation was not realized on the following day. Black coating for the plant doesn't show any improvement on the rate of yield of biogas. Finally, four catalysts were selected to test the best combination to use in the domestic plant.

a b c d

Figure 11: In vitro plants (a) CDY, (b) CDP, (c) CDV and (d) FWY

CDY **-** Cow dung and yeast
CDP **-** Cow dung and parthenium
CDV **-** Cow dung and vinegar
FWY **-** Food wastes (all) and yeast

As shown in the figure 11, the four in vitro plants developed using 5 liter water bottle with the above mentioned combinations were placed in a room where the temperature was 27-32C. Thereafter in 3 bottles 2Kg of cow dung was added and in the last bottle 2Kg of food waste was added. Then 2 Liters of water was added to each bottle to maintain the experiment nature in equality. Yeast, Parthenium, Vinegar were added into their ordered bottles in a same amount which was about 20g. Thereafter balloon was placed in the open end of the 4 bottles to collect the produced bio gas.

On daily basis collected gas was measured and recorded for a week. The following table shows daily biogas yield result. Based on observation, cow dung and parthenium combination is selected for domestic plant since our primary research is bottling the biogas; its rate of biogas yield is higher than other combinations.

Day	CDY (ml/Kg)	CDP (ml/Kg)	CDV (ml/Kg)	FWY (ml/Kg)
1	Very low	Very low	Very low	Very low
2	2.7	6.9	3	7.3
3	3.1	7.4	2.6	7.7
4	4	7.8	3.6	8
5	3	6.5	3.2	7
6	2.8	7	2.8	7.4
7	3.3	7.6	3.4	7.1

Table 3: Daily biogas yield for one week. (cm3)

Self-prepared air bag is repaired due leakage and it is important to make sure that the bottling process performed outside. The pressure level should not go beyond the recommended threshold pressure. Our device successfully transfers the gas from air bag to cylinder.

VI. Future Work and Recommendation

Replacing the ordinary pump by the pump where pressure gauge attached cost an additional amount of Rs 200. In this case, pressure gauge is not required thus Rs 1000 can be saved. Substituting pressure gauge attached hand pump, the cost of production can be further optimized to Rs 3800. A nozzle with clipping feature on the connecter enables the user to inflate the biogas easily into cylinder.

VII. Conclusion

Empowering energy economy directly impacts positively on national economy. Biogas is a sustainable energy source which enhances the economy of rural areas thus rural area will be developed and generates more opportunities in rural areas which directly impact the national employment. In contract, in urban areas, this technology significantly support for green waste management and its benefits. Our portable low cost biogas bottling system is affordable to anyone and promotes biogas production by effectively decentralizing biogas utility.

VIII. CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

Figure 12: Complete system without pressure gauge

References.

[1] Food | Learning and Teaching Sustainability. (n.d.). Retrieved from http://sustainability.edu.au/about-sustainability/food/

[2] Reena Victor, S Shajin, R.M.Roshni & S.R.Asha. (2014). Augmentative Invention of Biogas from the Agronomic Waste Using Facultative Anaerobic Bacterial strain. Tamil Nadu: International Journal of Current Microbiology and Applied Sciences. Retrieved from http://www.ijcmas.com/vol-3-4/Reena%20Victor,%20et%20al.pdf

[3] Mini Bio-gas plant using food waste, decomposable organic material and kitchen waste. (n.d.). Retrieved from http://www.instructables.com/id/Bio-gas-plant-using-kitchen-waste/

[4] Yadvika, Santosh, T.R. Sreekrishnan, Sangeeta Kohli & Vineet Rana. (2004). Enhancement of biogas production from solid substrates using different techniques—a review. Bioresource Technology, 95(1), 1-10.

[5] Jerry Hughes Martin II. (2008). A New Method to Evaluate Hydrogen Sulfide Removal from Biogas. (Unpublished master's thesis). North Carolina State University

[6] Michael Andrea, Jason Aspell, Peter Epathite & James Faupel. (2011). Design and development of a biogas compression and storage system. (Unpublished master's thesis). University of Notingham

[7] Government of Alberta. (n.d.). Biogas: Cleaning and Uses. Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex12276

[8] Rimika M K & Virendra K V. (2010). Evaluation of Existing Low Cost Gas Bottling Systems for Vehicles Use Adaption in Developing Economies: prepared for Foundation for Innovation and Technology Transfer. Retrieved from http://www.valorgas.soton.ac.uk/Deliverables/120825_VALORGAS_241334_D5-2_rev[0].pdf

[9] Lenntech. (n.d.). Gas purification techniques - Water-scrubber – lenntech. Retrieved from http://www.lenntech.com/air-purification/gas-purification-techniques/water-scrubber.htm.

[10] Energypedia. (n.d.). Biogas Appliances. Retrieved from https://energypedia.info/wiki/Biogas_Appliances.

[11] Green Energy Huamei Int. (n.d.). Biogas rice cooker. Retrieved from http://www.huameienergy.com/Products.asp?id=68&classid=101.

Authors

Mr. Arulanandam Kajavatan, BSc Eng (Hons), MSc. Sri Lanka German training institute, kajavatana@yahoo.co.uk

Uthayakumar Nitharsan (3rd Year Engineering Student), Faculty of Engineering, University of Jaffna, uthayanithu@gmail.