

Overview and status of biogas production in Zambia

Agabu Shane^{1,2}, Shabbir H. Gheewala^{1,2,*}, George Kasali³

¹The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, 126 Prachauthit Road, Bangkok 10140, Thailand

²Centre for Energy Technology and Environment, Ministry of Education, Thailand

³School of Mathematics and Natural Sciences, The Copperbelt University, P.O. Box 21692, Kitwe, Zambia

Abstract:

Despite research work and implementation of biogas having started as early as in the 1980s, Zambia has lagged behind in the adoption and use of biogas in the sub-Saharan Africa. The study established that there is a biogas theoretical potential of 76PJ per annum from animal manure and crop residues. This is sufficient to provide energy for cooking and lighting in more than 3 million households. Lack of funding, lack of policy, regulatory framework and strategies on biogas, unfavorable investor monetary policy, inadequate expertise, lack of awareness of the benefits of biogas technology among leaders, financial institutions and locals, resistance to change due cultural and traditions of the locals, high installation and maintenance costs of biogas digesters, inadequate research and development, improper management and lack of monitoring of installed digesters, complexity of the carbon market, lack of incentives and social equity are among the challenges that have derailed the adoption and sustainable implementation of domestic biogas production in Zambia. Unless these are addressed, it is unlikely that the biogas sector in Zambia will flourish.

Keywords: Biogas; Social; Technical; Economic; Challenges; Zambia

*Corresponding author. Tel.: +66-2-4708309 to 10 ext4140

E-mail address: shabbir_g@jgsee.kmutt.ac.th

1. Introduction

Successful implementation of biogas projects which reduce greenhouse gas (GHG) emissions and substitute fossil fuels and non-organic fertilizers can attract funding under the Clean Development Mechanism (Rgens et al, 2006). Biogas provides clean and efficient energy, reduced prevalence of chronic diseases associated with use of biomass in a traditional way and its production creates jobs (Walekhwa, 2009). Despite the health risks, 2.5 billion people globally use traditional biomass (Abeliotis and Pakula, 2013). With the huge potential and abundant feedstock, biogas production can resolve energy and environmental problems in the sub-Saharan Africa (Parawira, 2013). Most installed domestic biogas digesters in sub-Saharan Africa are non-operational (Amigun et al, 2012).

In Zambia, the National Institute for Scientific and Industrial Research installed 18 domestic digesters ranging between 4-26m³ during 1982 to 2004. The installations were funded by donors, but are currently non-operational (Kasali, 2008). Between 2008 and to date, the Water and Sanitation Council of Zambia and its co-operating partners have installed more than 60 biogas digesters of size between 4-80 m³ with funding from donors, individual companies and clients (Grafnitz et al., 2012). Biogas production projects have been unsuccessful in Zambia and it is unlikely that even with the renewed efforts it will be successful, unless adoption and implementation obstacles are addressed. The study evaluated biogas potential from animal waste and crop residues, reviewed current status of biogas production, identified obstacles to adoption and implementation of biogas production and made recommendations.

2. Methodology

The study reviewed various biogas production information and data available from scientific research reports, journal publications and organizational reports available in Zambia, sub-Saharan Africa and other Developing Countries. The theoretical biogas potential from animal dung was calculated using formulas (1) to (3).

$$BP = \frac{N * VS * B_o * 365 * 1.67 * 23}{10^6} TJ / y \quad (1)$$

Where: BP= theoretical biogas potential (TJy⁻¹), N=population of each animal category, VS= volatile solids (kg^h⁻¹d⁻¹), B_o= methane potential (m³kg VS⁻¹), 23=calorific value of biogas at 60% methane.

$$R = C_p * RPR \quad (2)$$

$$TMP = R * TS * VS * MP \quad (3)$$

Where: R=crop residue (ty⁻¹), C_p=crop produced (ty⁻¹), RPR=residue to product ratio, TMP=methane produced (m³y⁻¹), TS=total solids (%), VS=volatile solids (%), MP= methane potential (m³kg⁻¹VS). Statistical data on livestock and crop production were obtained from the FAOSTAT (2013) database and the Central Statistics Office (2012).

3. Results and Discussion

3.1 Biogas Theoretical Potential

The study estimated a potential of 76 PJy⁻¹ of biogas from animal manure and crop residue. In Tanzania, Ng'wandu et al. (2009) estimated that on average a family of six consumed 2.55 m³ d⁻¹. In Nigeria, a family of 9 consumed 2.4 m³d⁻¹ (Iroli et al., 2000). In Cambodia, 0.8 – 2.5 m³ is used d⁻¹HH⁻¹ of 5 (Mustonen et al., 2013). In Zambia a family of 6 used 2-2.5 m³ of biogas for cooking and lighting (Kasali, 2008); the estimated biogas potential would serve more than 3 million households if each household consumed 3 m³d⁻¹.

3.2 Biogas potential from animal manure

Using equation (1) and taking methane to be between 50 and 70 % in composition of the biogas (Bond and Templeton, 2011), the calorific value of the biogas as 23MJ/m³ (Rao et al., 2010) a total biogas potential of 33,900 TJy⁻¹ was estimated (Table 1).

Table 1 Biogas Potential from Livestock and Humans (FAOSTAT, 2013; CSO, 2012; Okello et al, 2013)

Source of Feedstock	Population (Million)	VS (kgd ⁻¹)	B _o (m ³ kg ⁻¹)	BP (TJ)
Cattle	3.250	2.67	0.20	24,331
Goats	2.350	0.33	0.31	3,370
Pigs	0.725	0.59	0.31	1,859
Sheep	0.230	0.30	0.31	300
Chickens	36.500	0.02	0.18	1,842
Human	13.064	0.06	0.20	2,199
Total				33,901

3.3 Biogas potential from crop residues

The total potential from crop residues was estimated at 41,847TJ as shown in Table 2.

Table 2 Crop Residue Biogas Potential (FAOSTAT, 2013; Koopmans and Koppejan 1997; Okello, 2014)

Crop Name	Product (kg)	RPR	Crop Residue (kg)	TS (%)	VS (%)	MP (m ³ /kg VS)	TBP (TJ/y.)
Sugarcane Bagasse	2,798	0.33	923.34	24	87	0.45	3,332
Sugarcane tops/leaves		0.05	139.90	90	98	0.33	1,564
Maize Stalk	1,780	2	3,559.15	74	82	0.28	23,227
Maize Cob		0.3	533.87	30	94	0.6	3,470
Other Crops		-	-	-	-	-	10,254
Total Biogas Potential (Dasapra, 2011; Deublein and Steinhauser, 2008; Musoline et al, 2014)							41,847

3.4 Technical Challenges

Inadequate policy and lack of strategy (Jumbe et al., 2009; Mfunne and Boon, 2008), inadequate expertise and training (Mwirigi et al., 2009) resulting into low levels of research and development in research and high learning institutions and inappropriate management and monitoring of installed biogas digesters (Kasali, 2008) has rendered adoption and implementation of biogas production a big challenge in Zambia. Sudden changes in investment policy have resulted in unfavorable policies at times. Though water is available in abundance at about 38.5 billion m³ (Uhlendahla et al., 2011; Nyambe and Feiberg, 2008), there is an economic scarcity of water in Zambia. Though abundant underground, in rivers and lakes is not made available to the locals. Land tenure affects biogas production in the sense that those without titled land find it risky to install a biogas digester, a borehole and any fixed assets as they are bound to be removed from that piece of land as they are illegal squatters (Smith, 2004). Though technically available feedstock may not be practically available for biogas production due to animal grazing patterns, distance between animal dwellings and installed digesters and inability to co-digest.

3.5 Social Challenges

There has been no biogas production awareness program and strategies (Suberu et al., 2013) to educate the leaders, lending institutions and beneficiaries in Zambia. This has resulted into formulation of inadequate policy and strategies (Bensah and Hammond, 2010), lack of funding of biogas projects and failure to maintain installed digesters. There has been social inequity among the urban and poor rural households (Sebitosi and Pillay, 2005). Most digesters are installed in urban or peri-urban leaving out the remote areas. Local have also resisted change from use of woodfuel to biogas (Gebreegziabher et al, 2014). Sometimes the resistance is due to cultural and traditions of the locals. It is a taboo for a woman and members of a royal family to collect cow dung or any form of manure (Kasali, 2008). There is collaboration between researchers and project implementers but it is inadequate (Mwakaje, 2007) as its limited to seminars and conferences. There is political will in the current leadership in Zambia, but what lacks is passing the right information to these leaders. Therefore what is required is to put up a program of awareness of benefits of biogas production not only to the beneficiaries but also to the leaders.

3.6 Economic Challenges

Lack incentives have rendered the adoption and implementation of biogas low in the sub-Saharan Africa and indeed in Zambia (Mukumba et al., 2012). Bureaucracy in Zambia (Osafa, 1988) discourages investors in bioenergy. Creation of financing capital has been a problem because lending institutions perceive the bioenergy sector as of high risk and cannot put money into it (Mwirigi et al., 2009). Due to inadequate financing, there has been very low investment and low research and development in renewable energy in Zambia (Mfunne and Boon, 2008). To install a biogas digester in a developing country like Zambia, one needs between US\$435 and US\$1,677 (Surendra et al., 2014). This cost is too high for an average sub-Saharan African household (Amigun et al., 2012). Studies in Zambia show that this cost is even higher at between US\$600 and US\$1,900 (Kasali, 2008) and this is high when compared with the average monthly household income (CSO, 2012). Zambia has not benefited from the CDM funds due to registration complexities (Hofmann and Khatun, 2013).

4. Conclusion

Lack of financing, inadequate policy and strategies, high capital and maintenance costs, lack of trade and investment incentives, complexity of the carbon market, resistance to change, lack of co-operation, inadequate research and development, low levels of full time equivalent researchers at PhD level, inadequate expertise and training and unfair social equity are some of the factors that have hindered biogas adoption and implementation in Zambia. If these challenges have to be overcome there should be an awareness program for leaders, financiers and beneficiaries. The

leaders will be able to formulate appropriate policies and strategies and the financiers will be able to give out loans for biogas production while the beneficiaries will know the procedures to follow in getting loans and appropriate certification.

5. References

- Abeliotis, K., and Pakula, C. 2013. Reducing health impacts of biomass burning for cooking: the need for cook stove performance testing. *Energy Efficiency* 6: 585–594.
- Amigun, B. and Blottnitz, H. 2007. Investigation of scale economies for African biogas installations. *Energy Conversion and Management* 48: 3090-3094.
- Amigun, B., Parawira, W., Musango, J.J., Aboyade, A.O. and Badmos, A.S. 2012. Anaerobic Biogas Generation for Rural Area Energy Provision in Africa. *Biogas*: 35 – 62.
- Bensah, E.C. and Hammond, A.B. 2010. Biogas technology dissemination in Ghana: history, current status, future prospects, and policy significance. *Energy and Environment* 1(2): 277-294.
- Central Statistics Office (CSO). 2012. Living Conditions Monitoring Survey Report 2006 and 2010, Lusaka.
- Dasappa, S. 2011. Potential of biomass energy for electricity generation in sub-Saharan Africa. *Energy for Sustainable Development* 15: 203–213.
- Deublein, D. and Steinhauser, A. 2008. An Introduction to Biogas from Waste and Renewable Resources (pp. 58 – 62 and 116). Wiley-VCH.
- Food and Agriculture of the United Nations (FAO). 2013. FAOSTAT [Online]. Available at http://faostat3.fao.org/faostat-gateway/go/to/download/P/*/E [Accessed on 20 July 2014].
- Gebreegziabher, Z., Naik, L., Melamu, R. and Balana, B.B. 2014. Prospects and challenges for urban application of biogas installations in Sub-Saharan Africa. *Biomass and bioenergy* 30: 1 -11.
- Graefnitz, T., Hoffmann, T., and Kellner, C. 2012. Feasibility study report of the Kanyama Fecal Sludge Management Project: Report on WASAZA's contribution to the planning phase.
- Hofmann, M. and Khatun, K. 2013. Facilitating the financing of bioenergy projects in the sub-Saharan Africa. *Energy Policy* 52: 373-384.
- Ilori, M.O., Oyebisi, T.O., Adekoya, L.O. and Adeoti, O. 2000. Engineering design and economic evaluation of a family sized biogas project in Nigeria. *Technovation* 20: 103-108.
- Jumbe, C.B.L., Msiska, F.B.M., Madjer, M. 2009. Biofuels development in Sub-Saharan Africa: Are the policies conducive? *Energy Policy* 37: 4980–4986.
- Kasali, G. 2008. Feasibility of biogas technology: The Zambian experience, *Biogas for a better life: An African Initiative*.
- Koopmans, A. and Koppejan, J. 1997. Agricultural and forest residues generation, utilization and availability, regional consultation on modern applications of biomass energy, 6 -10 January, Kuala Lumpur, Malaysia.
- Mfuno, O. and Boon, E.K. 2008. Promoting Renewable Energy Technologies for Rural Development in Africa: Experiences of Zambia. *J. Hum. Ecol.* 24(3): 175-189.
- Mustonen, S., Raiko, R., and Luukkanen, J. 2013. Bioenergy Consumption and Biogas Potential in Cambodian Households. *Sustainability* 5: 1875-1892.
- Musoline, W., Esposito, G., Lens, P., Spagni, A. and Giordano, A. 2013. Enhanced Methanol Production from Lignocellulosic Waste Co-digested with anaerobic sludge from pulp and paper mill treatment process in lab-scale digesters: *Bioresources Technology* 148: 135 – 243.
- Mwakaje, A.G. 2007. Dairy farming and biogas use in Rungwe district, South-west Tanzania: A study of opportunities and constraints, *Renewable and Sustainable Energy Reviews*, Article in press.
- Mwirigi, J.W., Makenzi P.M., and Ochola W.O. 2009. Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya. *Energy for Sustainable Development* 13: 106–115.
- Ng'wandu, E., Shila, L.C., and Heegde, H.E. 2009. Tanzania Biogas Programme Implementation: 18.

- Nyambe, I. and Feilberg, M, 2009, Zambia-National Water Resources Report for. World Water Day Report 3, Theme- Water in Changing World.
- Okello, C., Pindozi, S., Faugno, S., and Boccia, L. 2013. Bioenergy potential of agricultural and forestresidues in Uganda. *Biomass and Bioenergy* 56: 515 - 525.
- Osafa, D.D. 1988. Representative Bureaucracy in Zambia: Problems of Gender balancing in selected public organizations, pp. 12.
- Parawira, W. 2009. Biogas technology in sub-Saharan Africa: status, prospects and constraints: *Rev Environ SciBiotechnol* 8:187–200.
- Rao P.V., Baral S.S., Dey R., and Muntunri S. 2010. Biogas generation potential by anaerobic digestion for sustainable energy development in India. *Renewable and Sustainable Energy Reviews* 14: 2086-2094
- Rgens, J.U., Schlamadinger, B., and Gomez, P. 2006. Bioenergy and the CDM in the emerging market for carbon credits. *Mitigation and Adaptation Strategies for Global Change* 11: 1051-1081.
- Sebitosi, A.B. and Pillay, P. 2005. Energy services in sub-Saharan Africa: how conducive is the environment? *Energy Policy* 33: 2044-2051.
- Smith, R.E. 2004. Land Tenure, Fixed Investment and Farm Productivity: Evidence from Zambia's Southern Province. *World Development* 32(10): 1641-1661.
- Suberu, M.Y., Mustafa, M.W., Bashir, N., Muhamad, M.N. and Mokhtar, A.S. 2013. Power sector renewable energy integration for expanding access to electricity in sub-Saharan Africa *Renewable and Sustainable Energy Reviews* 25: 630-642.
- Surendra, K.C., Takara, D., Hashimoto, A.G. and Khanal, S.K. 2014. Biogas as a sustainable energy source for developing countries: Opportunities and challenges. *Renewable and Sustainable Energy Reviews* 3: 846–859.
- Uhlendahl, T., Salian, P., Casarotto, C. and Doetsch, J. 2011. Good water governance and IWRM in Zambia: challenges and chances, *Water Policy* 13: 845-862.
- Walekhwa, P.N., Mugisha, J. and Drake, L. 2009. Biogas energy from family- sized digesters in Uganda: Critical factors and policy implications. *Energy Policy* 37: 2754-2762.
- Wicke, B., Smeets, E., Watson, H. and Faaij, A. 2011. The current bioenergy production potential of semi-arid and arid regions in sub-Saharan Africa. *Biomass and Bioenergy* 35: 2773-2786.