

Research Application Summary

Economic viability of biogas energy production from family-sized digesters in Uganda

Walekhwa, P.N.¹, Lars, D.² & Mugisha, J.¹

¹Department of Agricultural Economics & Agribusiness, Faculty of Agriculture, Makerere University, P.O. Box 7062, Kampala, Uganda

²Swedish Chemicals Agency, P.O. Box 2, SE-172 13, Sundbyberg, Sweden

Corresponding author: walepet@yahoo.co.uk, walepet@agric.mak.ac.ug

Abstract

Biogas energy is being evaluated to augment traditional energy sources in Uganda. However, its development remains rudimentary partly because of the lack of information regarding its economic viability. Based on primary data on households in Central and Eastern Uganda and the use of three economic decision criteria; Payback period, Net Present Value and Internal Rate of Return, this study assessed the economic viability of biogas energy production in Uganda. Empirical results showed that biogas energy production was economically viable. Policy options that could bolster the economic viability of biogas energy production in Uganda have been highlighted.

Key words: Biogas energy, economic viability, fixed-dome, Uganda

Résumé

L'énergie du biogaz est en cours d'évaluation afin d'augmenter les sources d'énergie traditionnelles en Ouganda. Cependant, son développement reste en partie embryonnaire à cause du manque d'informations quant à sa viabilité économique. Sur la base de données primaires des ménages en Ouganda central et oriental et en utilisant les trois critères de décision économique (la période de remboursement, la valeur actuelle nette et le taux de bénéfice interne), cette étude a évalué la viabilité économique de la production d'énergie du biogaz en Ouganda. Les résultats empiriques ont montré que la production d'énergie du biogaz était économiquement viable. Les options politiques qui pourraient soutenir la viabilité économique de la production d'énergie du biogaz en Ouganda ont été mises en évidence.

Mots clés: énergie du biogaz, viabilité économique, dôme fixe, Ouganda

Background

The history of biogas energy use in Uganda is relatively old, dating back to the 1950s when the Church Missionary Society first introduced the technology (Nabuuma and Okure, 2004;

Pandey *et al.*, 2007). Since then, there have been numerous efforts by the Government of Uganda to promote the technology and attract households to switch to this form of cleaner but with limited success (Pandey *et al.*, 2007). Recently, there have been renewed efforts to popularize biogas energy by mainly Non-Governmental Organizations (NGOs) (Walekhwa *et al.*, 2009).

In Uganda, biogas energy is attracting more attention from both public and private initiatives because of its advantages over other energy sources (Walekhwa *et al.*, 2009). The main factor in favour of this technology lies in its environment friendliness allowing for efficient waste utilization and nutrient recycling. It is a versatile source of energy which meets several end uses, including cooking, lighting and power generation (Rubab and Kandpal, 1996). When used as a cooking fuel, it provides for better combustion than the less efficient cooking fuels like fuelwood. It is comparatively clean and hygienic (Jingura and Matengaifa, 2008) as bacteria and other pathogens are destroyed through anaerobic treatment. By substantially reducing drudgery for women (Mwakaje, 2008), indoor smoke and resultant ocular and respiratory infections, biogas digesters contribute to improved health and reduction in medical expenditure (Srinivasan, 2008). The technology has no geographical limitations (Taleghani and Kia, 2005). It is produced mainly from raw materials that are locally available making it a cheaper and simpler option (Gautam *et al.*, 2009). Biogas technology leads to a reduction in greenhouse gas emissions (Han *et al.*, 2008), eutrophication and air pollution, and improves utilisation of crop nutrients (Lantz *et al.*, 2007). Generally, biogas digesters have come to symbolize access to modern energy services in rural areas and are slated to considerably improve health and sanitation, and to yield significant socioeconomic and environmental benefits (Srinivasan, 2008).

Despite its long history in Uganda, and the numerous advantages, the development and utilization of this desirable, modern, ecology-oriented and friendly form of appropriate technology and its adoption rates in Uganda remain dismal (Pandey *et al.*, 2007; Mwakaje, 2008). This could partly be because of the lack of information regarding the economic viability of biogas energy production rendering the potential of this environmentally friendly technology not being fully exploited.

Literature Summary

A number of studies have shown that economic factors significantly influence the adoption and development of biogas

energy (Hall *et al.*, 1992; Ni and Nyns, 1996; Adeoti *et al.*, 2000; Akinbami *et al.*, 2001; Walekhwa *et al.*, 2009) but few have extended their analyses to investigate economic viability of biogas energy. Abort and Vancil (1977) attributes this to lack of knowledge about economic viability of energy recovery systems to three key issues: (1) what exact percentage of the waste refuse used in the recovery systems is of potential use; (2) what percentage can be recovered; or (3) establishing its market value after the recovery process. They further advise that each resource recovery plant location presents a different set of economic and operational parameters that must be defined and that the accuracy of these estimates determines the prospects for success of a particular waste recovery facility. Srinivasan (2008) observed that domestic biogas programs were often justified on the basis of the private benefits and costs accruing to the individual households. However, the economic surpluses from domestic biogas programs are generally realized beyond such narrowly defined project boundaries. This implies that the total benefits accruing from the installation of biogas plants should exceed the benefits to the individual who invests in, receives or runs the service. Society is perhaps, likely to benefit more than the individual recipient does. There is need therefore to quantify the economic benefits accruing from biogas systems if their real potential is to be justified.

Rubab and Kandpal (1996) undertook a financial evaluation of biogas technology in India using cost functions. They found out that the unit cost of useful energy delivered by a biogas plant for cooking, lighting and mechanical power generation was less than several other resource technology combinations for the same end-use. Adeoti *et al.* (2000) recognized that the development and utilization of this appropriate technology remained unpopular in Nigeria, partly because of lack of information on its economic viability. Singh and Sooch (2004), in their comparative study of different biogas plant models in India underscored the importance of determining economic viability of family size biogas plants as a vital ingredient in the development of biogas technology.

These studies generally affirm that the economic appraisal of the technology is required to quantify the significant benefits and costs accruing to biogas energy production and utilization. Further, in order to promote the diffusion of biogas technology, it is necessary that the viability of these systems be established. Inadequate information about the economic viability of biogas

energy production systems could be a hindrance to potential investment in this sector, perhaps accounting for its dismal performance in Uganda. This paper envisaged that to stimulate public and private interest and attract any large-scale capital investment in biogas technology, there was a need to investigate and avail information on the economic viability of biogas in Uganda to guide potential investors in the industry.

A fundamental question that has for long remained unanswered which this study attempted to address was: How economically feasible is biogas energy production from family-sized digesters in Uganda? Put differently: “Does biogas energy production from family-sized digesters have lower costs relative to the associated benefits?” More specifically the research aimed at assessing the economic viability of biogas energy production from fixed dome biogas family-sized digesters, hereafter also referred to as family-sized biogas plants, and attempted to take into account the costs and benefits accrued to the overall biogas energy production chain.

Study Description

The study sites were the districts of Luwero, Nakaseke and Nakasongola in Central Uganda, and Mbale, Sironko and Manafwa in Eastern Uganda. These districts were selected for the study because they have been specifically targeted by NGOs promoting biogas technology in Uganda. They had also been identified as districts with high concentrations of households with operational digesters and confined animal feeding operations (Walekhwa *et al.*, 2009).

A sampling frame of 150 households with operational plants was obtained from NGOs involved in promoting biogas technology in Uganda from which 120 households were randomly selected and interviewed. After thorough data cleaning, a final sample of 100 households formed the basis of the analysis. The study used standard analyses of economic viability of biogas energy production systems that emphasize primarily on direct financial costs and benefits associated with biogas production (Yiridoe *et al.*, 2009).

A comprehensive estimation of costs of the three most common biogas plant capacity designs (8, 12 and 16m³) was undertaken. This was followed by the economic valuation of benefits of biogas energy from the digesters. An overall economic evaluation of the viability of biogas energy production model was then undertaken by use of economic decision criteria commonly used

to evaluate the viability of alternative investment opportunities. These included net present value (NPV), internal rate of return (IRR) and payback period (PBP) (Yiridoe *et al.*, 2009). This is important because the use of biogas-based systems often leads to both tangible and intangible benefits (Adeoti *et al.*, 2000).

All the three decision criteria were used because they consider different (but complementary) attributes of economic viability. Consistent results from the three decision criteria can help improve robustness of the analysis, as well as increase confidence in the viability of the investment opportunity. Finally sensitivity and break-even analysis through varying of parameter values on costs and revenues of the three biogas plant capacity designs (8m³, 12m³ and 16m³) was undertaken.

Research Application

The empirical results showed that biogas energy production was economically viable with a PBP of 1.17, 1.08 and 1.01 years for 8m³, 12m³ and 16m³ biogas plants, respectively. The positive NPV results of Uganda Shillings 11 million, Uganda Shillings 18 and Uganda Shillings 24,000 for the 8m³, 12m³ and 16m³ plants, respectively also showed that the biogas systems were economically viable. The most profitable levels of the plants were determined through sensitivity and break-even analysis. Results suggested that at 12% discount rate, for the biogas systems to remain profitable, the total costs for the plants should not exceed Uganda Shillings 18 million for the 8m³ plants, Uganda Shillings 27 million for the 12m³ and Uganda Shillings 37 million for 16m³ plants with the corresponding total operating and maintenance (O&M) not exceeding Uganda Shillings 5 million, Uganda Shillings 8 million and Uganda Shillings 11 million for the respective biogas plants. However, at the discount rate of 24%, the total costs should not exceed Uganda Shillings 6 million for the 8m³ plants, Uganda Shillings 15 million for the 12m³ and Uganda Shillings 20 million for 16m³ plants with the corresponding total operating and maintenance (O&M) costs not exceeding Uganda Shillings 5 million, Uganda Shillings 7 million and Uganda Shillings 10 million, respectively. The annual interest rates at which households should borrow to invest in biogas systems and remain economically viable should not exceed 36 % for 8m³ plants, 37% for the 12m³ and 39% for 16m³ biogas plants. The study also revealed that the viability of biogas plants was greatly affected by variation in discount rates and capital and O&M costs.

The study highlighted the following policy options that could bolster the economic viability of biogas energy production in

Uganda. Given the high interest rates in Uganda, few households can afford to borrow to invest in biogas energy production. This justifies some form of state support in the initial phase of dissemination of the technology in form of financial support to potential biogas energy producers through use of innovative financial instruments such as the use of preferential lending rates, micro-credits, revolving funds, involvement of local financial institutions in providing low-interest credits and improved service for households and local private companies involved in biogas energy development.

The use of fiscal policy instruments to make biogas energy production more economically viable through reducing taxes on major tradable inputs required by households and companies involved in biogas energy technology R&D, innovation, market expansion and demonstration is recommended. Alternatively, direct subsidies at the early stages of establishing biogas plants would also boost their economic viability considering the high initial cost of installation.

Households need to constantly monitor the cost structure of their biogas systems to avoid incurring losses as revealed by break-even sensitivity analysis results. Given that the commercial interest rate in Uganda is about 24% for short-term loans, households need to ensure that the total costs for the plant should range between UGX 6 million and UGX 20 million per year, depending on the size of the plant.

There is need for an efficient and effective way of collecting and utilizing cattle dung resource to ensure sustained biogas sufficiency and reliability. One of the most feasible ways is to ensure that the prospective biogas producers possess a sufficient number of cattle.

Deliberate planning should be directed towards capacity building through training of required human resource and information sharing amongst households in biogas plant construction, maintenance and appropriate designs. This will cut down capital and operating and maintenance (O&M) costs considerably and make biogas energy production more economically viable. Also to increase household capacity building in biogas technology to increase self sufficiency in basic repair and maintenance works, demonstration biogas projects should be revived and set up especially in places where the potential of the technology has been known to be high.

Through sensitization and awareness campaigns, the economic benefits of slurry can be highlighted to households who often attach little economic value to it. Few households know the monetary benefits attributed to the use of slurry in agricultural production and in improving sanitation and health conditions. The monetary benefits of this readily available source of rich low cost fertilizer should be highly published in order to enable households appreciate the full economic potential of family-sized biogas plants. This will promote use of the local low cost fertilizer (slurry) in agricultural production and also improve hygiene in the countryside. In this way, biogas plants will be more economically viable and have greater appeal to households than simply viewing them as a source of biogas for cooking and lighting only.

Acknowledgement

The authors gratefully acknowledge the financial support from Sida/SAREC for funding this study under the Joint Makerere University and Swedish University of Agricultural Sciences (SLU) PhD training and capacity building project.

References

- Abort, J.G. and Vancil, R.M. 1977. A graphical approach to determine the economics of recovering resources from municipal solid waste. *Conservation and Recycling* 1:299-314.
- Adeoti, O., Ilori, M.O., Oyebisi, T.O. and Adekoya, L. O. 2000. Engineering design and economic evaluation of a family-sized biogas project in Nigeria. *Technovation* 20:103-108.
- Akinbami, J.F.K., Ilori, M.O., Oyebisi, T.O., Oyebisi, I.O. and Adeoti, O. 2001. Biogas energy use in Nigeria: current status, future prospects and policy implications. *Renewable and Sustainable Energy Reviews* 5:97-112.
- Gautam, R., Baral, S. and Herat S. 2009. Biogas as a sustainable energy source in Nepal: Present status and future challenges. *Renewable and Sustainable Energy Reviews* 13:248-252.
- Hall, D.O., Rosillo-Calle, F. and deGroot, P. 1992. Biomass energy and lessons from case studies in developing countries. *Energy Policy, Renewable Series*. pp. 63-73.
- Han, J.L., Mol, A.P.J., Yonglong, L. and Zhang L. 2008. Small-scale fuelwood projects in rural China- Lessons to be learnt. *Energy Policy* 36:2154-2162.
- Jingura, R.M. and Matengaifa, R. 2008. The potential for energy production from crop residues in Zimbabwe. *Biomass and Bioenergy* 32:1287-1292.
- Lantz, M., Mattias, S., Björnsson, L. and Börjesson, L. 2007. The prospects for an expansion of biogas systems in Sweden

- Incentives, barriers and potentials. *Energy Policy* 35:1830-1843.
- Mwakaje, A. G. 2008. Dairy farming and biogas use in Rungwe district, South-west Tanzania: A study of opportunities and constraints. *Renewable and Sustainable Energy Reviews* 12:2240-2252.
- Nabuuma, B. and Okure, M. 2004. The state of biogas systems in Uganda. Faculty of Technology, Makerere University, Proceedings of the Dissemination Workshop on Utilization of Urban Market Crop Wastes in Crop/Livestock Production in Kampala, December 2004.
- Ni Ji-Quin and Nyns, E. 1996. New concept for evaluation of biogas management in developing countries. *Energy Conversion and Management* 37:1525-1534.
- Pandey, B., Subedi, P. S. and Monroe, I. 2007. Biogas for a better life: An African initiative. Report on the feasibility for a national household biogas commercialization program in Uganda. Prepared for the Dutch Ministry of Foreign Affairs by Winrock International, Discussion paper. Un-published report.
- Rubab, S. and Kandpal, T. C. 1996. A methodology for financial evaluation of biogas technology in India using cost functions. *Biomass and Bioenergy* 10:11-23.
- Singh, K.J. and Sooch S.S. 2004. Comparative study of economics of different models of family size biogas plants for State of Punjab, India. *Energy Conversion & Management* 45:1329-1341.
- Srinivasan, S. 2008. Positive externalities of domestic biogas initiatives: Implications for financing. *Renewable and Sustainable Energy Reviews* 12:1476-1484.
- Taleghani, G. and Kia, A.S. 2005. Technical–economical analysis of the Saveh biogas power plant. *Renewable Energy* 30: 441–446.
- Walekhwa, P.N., Mugisha, J. and Lars D. 2009. Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications, *Energy Policy* 37:2754-2762.
- Yiridoe, E.K., Gordon, R. and Brown, B.B. 2009. Nonmarket co-benefits and economic feasibility of on-farm biogas energy production. *Energy Policy* 37:1170-1179.