Egyptian Journal of Petroleum (2017) **26**, 695–703

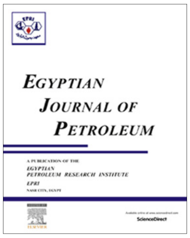
HOSTED BY

ELSEVIER

Egyptian Petroleum Research Institute

Egyptian Journal of Petroleum

www.elsevier.com/locate/egyjp
www.sciencedirect.com



FULL LENGTH ARTICLE

Feasibility study for biogas integration into waste treatment plants in Ghana

M. Mohammed [a], **I.S. Egyir** [b], **A.K. Donkor** [c,*], **P. Amoah** [d], **S. Nyarko** [c], **K.K. Boateng** [e], **C. Ziwu** [c]

[a] *Institute for Environment and Sanitation Studies, IESS, University of Ghana, Box 209, Legon, Accra, Ghana*
[b] *Department of Agricultural Economics and Agribusiness, University of Ghana, Box LG68, Legon, Accra, Ghana*
[c] *Department of Chemistry, University of Ghana, Box LG56, Legon, Accra, Ghana*
[d] *International Water Management Institute, IWMI, West Africa Office, Accra, Ghana*
[e] *Department of Material Engineering, Kwame Nkrumah University of Science and Technology, KNUST, Kumasi, Ghana*

Received 2 June 2016; revised 31 August 2016; accepted 13 October 2016
Available online 3 November 2016

KEYWORDS

Biogas;
Sewerage;
Renewable energy;
Cost-benefit analysis;
Internal rate of return;
Ghana

Abstract Biogas (anaerobic digestion) technology is one of the most viable renewable energy technologies today. However, its economic efficiency depends on the investment costs, costs of operating the biogas plant and optimum methane production. Likewise the profit level also rests on its use directly for cooking or conversion into electricity. The present study assessed the economic potential for a 9000 m^3 biogas plant, as an alternative to addressing energy and environmental challenges currently in Ghana. A cost-benefit analysis of the installation of biogas plant at University of Ghana (Legon Sewerage Treatment Plant) yielded positive net present values (NPV) at the prevailing discount rate of 23%. Further the results demonstrate that installation of the plant is capital intensive. Biogas used for cooking was by far the most viable option with a payback period (PBP) of 5 years. Sensitivity analysis also revealed cost of capital, plant and machinery as the most effective factors impacting on NPV and internal rate of return (IRR).

1. Introduction

Biogas is considered one of the alternative energy sources and is produced through anaerobic digestion from raw materials, such as agricultural residues, animal waste, municipal wastes and industrial wastes [1]. Energy generated from these sources via anaerobic digestion reduces atmospheric methane emissions and production of digestate. A number of studies have proved the effectiveness of this technology to manage organic waste [2–7] in an environmental-friendly and cost-effective manner [8–11].

Regardless of these successes and the existence of favourable conditions for its generation in developing countries, specifically in Sub-Saharan African countries, the promotion and the development of the technology have suffered a setback. These setbacks have been partly attributed to failure of governments to support the technology through a focused energy policy, lack of information regarding its economic

---

* Corresponding author.
E-mail address: akdonkor@ug.edu.gh (A.K. Donkor).

Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2016.10.004
1110-0621

viability, poor design and construction of digesters, wrong operation and lack of maintenance by users. Both operators in the industry and users have identified operation and maintenance, and after sale service as the major causes derailing the speedy adoption of the technology in most developing countries including Ghana [12]. Unlimited literature exists on the factors affecting the development, promotion and adoption of biogas energy. The most extensive has been carried out on social factors [13–15], economic factors [14,16], technical factors [16,17] and organizational factors [18].

The biogas production processes have the advantage of low energy requirement for operation, low initial investment cost and low sludge production when compared to the conventional aerobic processes [19]. The technology (biogas) has proven to be a modern energy source that has improved the life of many who have used it for decades [20] as it is less capital intensive. It is noted for generating energy, improving sanitation, and supplying nutrient rich organic fertilizer. Despite the ready availability of biogas resources, relatively few studies have focused on the economic assessment of biogas plants in ascertaining the financial viability of installing biogas plants both at the households and institutional level. A number of studies have been conducted providing information on design and investment of biogas digesters in developed countries but this is not the case for developing countries [7,21]. Nelson and Lamb [22] presented a comparison of projected and actual costs of constructing a biogas digester on a Minnesota dairy farm in the USA, the net returns from electricity annually and the payback period for the investment of the digester were evaluated. Meyer and Lorimor [23] evaluated the construction costs for two biogas digesters and estimated an 11.4% “return on investment”. The capital cost of biogas plants often varies with the size of plant, as well as availability of local material. Many studies have indicated that the operating or running cost of a biogas plant is estimated at 1–1.5% of the total construction or capital cost [24]. In a study by Adeoti et al. [25] the breakdown of the first cost of the biogas plant designed in Nigeria revealed that construction costs took about 65% while facilities, installation, labour and land accounted for the remaining 35%.

The World Health Organization (WHO) has prepared guidelines on conducting cost-benefit analyses of household biogas plants, as well as published cost-benefit analyses [31]. Unlike many other renewable energy technologies (RETs) almost all expenses need to be financed upfront, with very low operating expenses (operation and maintenance costs) thereafter. Thus, the economy of an anaerobic digestion (AD) technology is characterized by high initial investment costs which will result in savings (non-monetary) with less recovery of capital investment.

There are various economic analytical tools that have been used by different researchers for estimating the financial viability of biogas projects. Some are Life Cycle Assessment (LCA), Local Economic Impact (LEI), cost-benefit analysis (CBA), Cost Effectiveness Analysis (CEA), Economic/Financial Valuation (EV), conjoint analysis and real options [32]. Unfortunately, none of these techniques have been given more attention than cost-benefit analysis where investment appraisal of project is concerned based on efficiency criteria. Hosking and Du Preez [33] referred to CBA as a standard method of comparing the social costs and benefits of alternative projects or investments. Costs and benefits in this context are measured and then weighed up against each other in order to generate criteria for decision-making. This is now very popular in many sectors. Additionally, Marchaim [34] suggested three major areas of applications in assessing the financial viability of biogas plants: individual household units, community or institutional plants and large-scale commercial operations. In each of these cases, the financial feasibility of the facility depends largely on whether outputs in the form of gas and slurry or digestate can substitute for costly fuels, fertilizers or feeds which were previously purchased, while at the same time abating pollution [35].

In Ghana, the technology began to gain interest in the 1960’s to help curb energy crisis. According to Netherlands Development Organization (SNV) [26] the country has the potential of realizing about 280 thousand domestic plants capable of producing about 6000 m^3 of liquid fertilizer daily and biogas effluent is estimated to increase agricultural production by 25%. The first biogas demonstration plant – a 10 m^3 Chinese fixed dome digester – was constructed in 1986 by the Ministry of Energy, with support from the Chinese government. Subsequently other plants were installed with the support of international organizations by the Ministry of Energy, for example, the Apollonia biogas plant which provided electric power for domestic use and bio-slurry for agriculture [27].

Despite these numerous set ups, there is scarcity of data on the financial viability of biogas plants. Most studies so far have focused on the adaptation and development of the technology for bio-sanitation interventions without energy recovery from the system [26,28–30]. Accordingly, this study ascertains the financial viability of an institutional installation of a biogas plant at University of Ghana, Accra with the option to be utilized for cooking or electricity generation.

2. Materials and methods

2.1. Study area, project description and data

Accra, the capital city of Ghana, is located between latitudes 4° and 11.5° North and longitudes 3.11° West and 1.11° East. The landscape is low-lying, 20 m above sea level with few short irregular hills and depressions in some parts of the city. About 15% of Accra is served by conventional sewerage network. Outside the sewered areas, septic tanks, public toilets, pit latrines and pan latrines are also used. Presently, less than 25% of all the sewerage treatment plants within the Accra Metropolis are functioning [37].

As part of efforts to limit or prevent the indiscriminate discharge of untreated sewage into the sea and also to resolve environmental problems in the city, the African Development Bank assisted the Ghana Government to build two (2) new sewage treatment plants, one at the University of Ghana, Fig. 1. This plant with a capacity of (9000 m^3/day) is expected to serve over 33,000 people [36]; this will receive wastes from the University of Ghana and its environs. The treatment concept of the proposed project is based on waste stabilization ponds with effluents discharging directly into the sea.

Detailed data on inputs of the most adopted dome type biogas design in Ghana were sourced from Biogas Technologies Africa Limited (BTAL), and used to arrive at various costs and benefits involved. The capacity of the plant was estimated