Austin Chemical Engineering

Open Access

Austin Publishing Group

Research Article

Feasibility of Biogas Utilization in Developing Countries: Egypt a Case Study

Mohamed El Zayat[1]*, Mohamed G Hassan[2], Christopher I Taylor[3] and Salah El Haggar[4]

[1]Environmental Engineering PhD Program, American University in Cairo, Egypt

[2]Energy and Petroleum Engineering, American University in Cairo, Egypt

[3]Chemical Engineering Department, Loughborough University, UK

[4]Department of Mechanical Engineering, American University in Cairo, Egypt

***Corresponding author:** Mohamed El Zayat, Member (ASCE/EWRI), Environmental Engineering PhD Program, The American University in Cairo, P.O. Box 74, New Cairo 11835, Egypt

Received: March 25, 2015; **Accepted:** July 02, 2015; **Published:** July 09, 2015

Abstract

One of the main concerns of implementing Anaerobic Digesters (AD) that result in releasing biogas is the disposal of large quantities of organic wastes in an economically and sustainable manners. This paper evaluates the economic sustainability of implementing anaerobic digesters and capturing the released biogas for energy utilization in contained communities in rural areas in Egypt. The experimental data conducted from anaerobic digester on a pilot scale were scaled up and used to perform the economic viability of the proposed project. The reactor was fed by liquid cow manure with Chemical Oxygen Demand (COD) varies between 7500-8000 mg/l at 35˚C for 6 days retention time. It was found that, the reactor is capable of producing 0.53 Nm3 of biogas per m3 reactor per day. The economic viability of a project extends beyond the initial financial analysis. It entails analyzing the data using shadow prices as to elimination price distortions, analyzing the indirect costs and benefits of the project, and looking at the overall effect of the project on the economy. The economic indicators are based on the Net Economic Present Value (NEPV) and Economic Rate of Return (ERR) that is resulted from optimal energy production and dig estate application. Through economic evaluation, the Egyptian government can determine which projects will be of benefit to the economy and which will be costly, decisions on which governments formulate their policies. The study concludes that the project will help contribute to the sustainable development of Egypt through its contribution to the environmental, economic, and social pillars. The highest NEPV and ERR were observed by earning carbon credits from reducing greenhouse gas emissions under Kyoto Protocol as a Clean Development Mechanism (CDM) project or Clean Development Mechanism of Program of Activities (CPA). The revenue from the CDM/CPA can overcome any financial barriers, encourage decision makers, and provide foreign exchange for the country. Moreover, the project has a positive value added and creates new jobs. Thus, it would be in the best interests of the economy as a whole for projects like this are implemented on a greater scale.

Keywords: Anaerobic Digesters; Biogas; Economic Indicators

Abbreviations

AD: Anaerobic Digesters; CERs: Certified Emission Reductions; CDM: Clean development mechanism; CNG: Compressed Natural Gas; COD: Chemical Oxygen Demand; CPA: CDM Programme of activities; EB: Economic Benefit; EC: Economic Cost; ERR: Economic rate of return; F_I: Lang Factor; F_{ic}: Multiplication factors for indirect costs; F_{dc}: Multiplication Factor for direct costs; FD: Fixed Dome; HLR: Hydraulic Loading Rate; HRT: Hydraulic Retention Time; I_f: Complete plant cost; I_{MPEC}: Costs of main equipment once installed; IPCC: Intergovernmental Panel on Climate Change; LR: Loading Rate; MBTU: Million British Thermal Unit; MPEC: Main Plant Equipment Cost; NCF: Net Cash Flow; NEPV: Net Economic Present Value; OFMSW: Organic Fraction of the Municipal Solid Waste; PBP: Payback Period; POA: Programme Of Activities; SDR: Social Discount Rate; UASB: Up-flow Anaerobic Sludge Blanket; UNFCCC: United Nations Convention on Climate Change; VFR: Volumetric Flow Rate; WACC: Weighted Average Cost of Capital

Introduction

Biogas is produced from anaerobic degradation of organic substrates, such as animal manure, organic fraction from municipal solid waste, agricultural wastes and food processing by-products. Biogas is a naturally produced mixture of Methane (CH_4), Carbon Dioxide (CO_2), and other trace impurities like Hydrogen Sulphide (H_2S), Water Vapor (H_2O), Nitrogen (N_2) and Oxygen (O_2). The major constituents of biogas are CH_4 and CO_2 with a concentration varies from 55 to 65% and 40 to 45% respectively [1]. Biogas formation through fermentation of organic material has the potential of tackling contemporary challenges: the degradation of biomass, production of renewable as well as environmentally friendly energy and a fertilizer by-product. Biogas is a clean renewable energy that promises to be a good alternative for fossil fuels. As a consequence, biogas can be utilized in a variety of different applications including cooking, heating, generating electricity, and transport to supplement Compressed Natural Gas (CNG) usage [2]. Hence, biogas technology has been an attractive prospect across the world. Biogas is generated from an organic anaerobic digestion process which requires a symbiotic mixture of certain bacteria and organic material [3]. The biogas generation rate depends on various factors, such as pH, temperature, Hydraulic Retention Time (HRT), Carbon to Nitrogen

Citation: Zayat ME, Hassan MG, Taylor CI and Haggar SE. Feasibility of Biogas Utilization in Developing Countries: Egypt a Case Study. Austin Chem Eng. 2015;2(2): 1017.

(C/N) ratio…etc. [4]. In 2005, Laaber found that the median biogas productivity is 0.89 Nm^3/m^3 reactor/day after evaluating more than 35 plants. In this study, the physical experiments were conducted in the Egyptian climatic conditions so that the biogas productivity could improve the reliability of the economic evaluation.

In contained rural areas in Egypt, tons of biomass is available for production of biogas. By installing biogas units in the households, the animal manure which is currently disposed of in an unsustainable way will be fermented in biogas digesters and a significant amount of methane emission can be avoided which has twenty one times the global warming potential of carbon dioxide. The potential utilization of the digestate as fertilizers can also reduce dependence on energy intensive mineral fertilizers [5]. Accordingly, proper functioning for anaerobic digesters in rural areas can provide multiple economic benefits to the users. Biogas projects can also get the finance from the certified emission reductions as a Clean Development Mechanism (CDM) project or Program of Activity (PoA CDM). In 2009, the UNEP stated that the number of biogas projects that are under validation, requesting registration or registered is 516, or 11.6% of the CDM projects [6]. The CERs or carbon finance will make such projects more economically viable in Egypt either as a CDM project or PoA.

Biogas plants in households have many positive environmental impacts. It is very important to specify such environmental benefits in order to optimize them. Biogas installations reduce the emission of greenhouse gases by substituting conventional fuels and synthetic fertilizers. Biogas utilization leads to reduced dependence on non-renewable fuel sources, and hence preserves nature resources. Improved manure management practices result in reducing ground and surface water pollution and odor. One of the main significant positive effects relies on improving human wellbeing due to the reduction of pathogens from untreated organic wastes. Besides biogas, the digestate application to land is the most attractive option in terms of environmental issues, because it allows nutrients to be recovered and reduces loss of organic matter suffered by soils under agricultural exploitation [7].

The aim of this research project was to ascertain the economic feasibility in developing a small scale biogas system which would be built in contained rural areas in Egypt. The anaerobic digester would treat all organic food, incorporate biogas scrubbing/drying equipment to purify the methane to allow its use as a source of energy supply, and produce a by-product fertilizer which would generate another source of income. The study assesses the socio-economic impacts on households in rural areas.

Materials and Methods

Biogas formation

Figure 1 illustrates the four step process which converts organic matter into Biogas. The bacteria form a symbiotic relationship with each other as the intermediate products, such as Acetate, are required by the methanogenic bacteria to create the methane in biogas. The acetogenic bacteria prefer acidic conditions, pH less than 6.8, and are easier to cultivate than the methanogenic bacteria, which prefer pH conditions of 6.8-7.5 [3].

Other than pH there are many other factors which control the biogas formation process. Biogas formation occurs between 4 and 75°C. The effect of temperature on the behavior of the biogas formation process can be split into three bands. These are the psycophillic (4-20°C), mesophillic (20-42°C), and the thermophilic (42-75°C) [8].

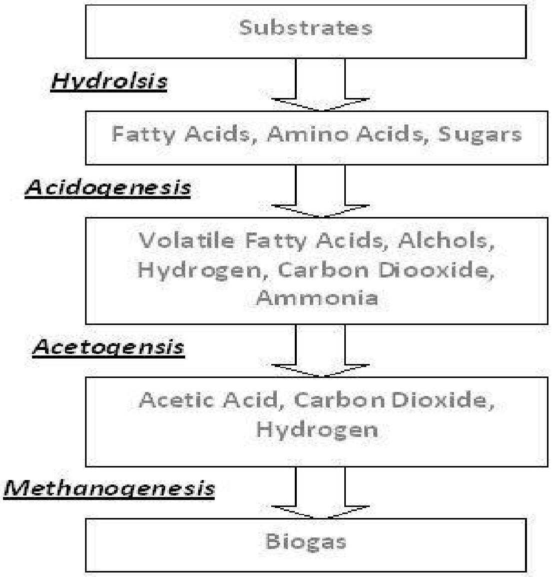

Figure 1: Biogas Formation Processes.

Experimental design

Reactor technology: Two reactor technologies of interest are the Up-flow Anaerobic Sludge Blanket (UASB) digester and the Fixed Dome (FD) digester. The UASB digester consists of a vertical plug flow reactor which is packed with a suitable material that allows a bacteria film to grow on its surface. The bio-film on the packing material creates a high surface area for the reaction to occur. The packing material is retained in the digester by simple gravitational setting which allows high bacteria culture retention, leading to reduced operational costs. The start-up period for the UASB has been quoted to be 4-16 days [8]. To reduce the start-up period of the reactor it is possible to use material from other digesters to increase bacteria biodiversity.

Biogas production

A bench scale anaerobic digester was used in performing the physical experiments. The anaerobic digester equipment used is an Arm field Ltd ANAEROBIC DIGESTER (W8) ®system. The Up-flow Anaerobic Sludge Blanket (UASB) type reactor equipped with two 5 liter packed bed each reactor has gas sampling and collection facilities. The reactors may be operated in series or parallel flow arrangement using variable speed peristaltic pumps. The temperature of the feed flow rate to each reactor can be adjusted to any temperature up to 55°C. Figure 2 shows a schematic diagram to the used AD equipment at the laboratory.

The equipment is designed as a bench top training facility and as a means of providing operational process data for plant design purposes. The average yield of biogas and COD reduction data was experimentally investigated in order to profile the performance of the reactor which allowed scalability. The pH of the process fluid was also

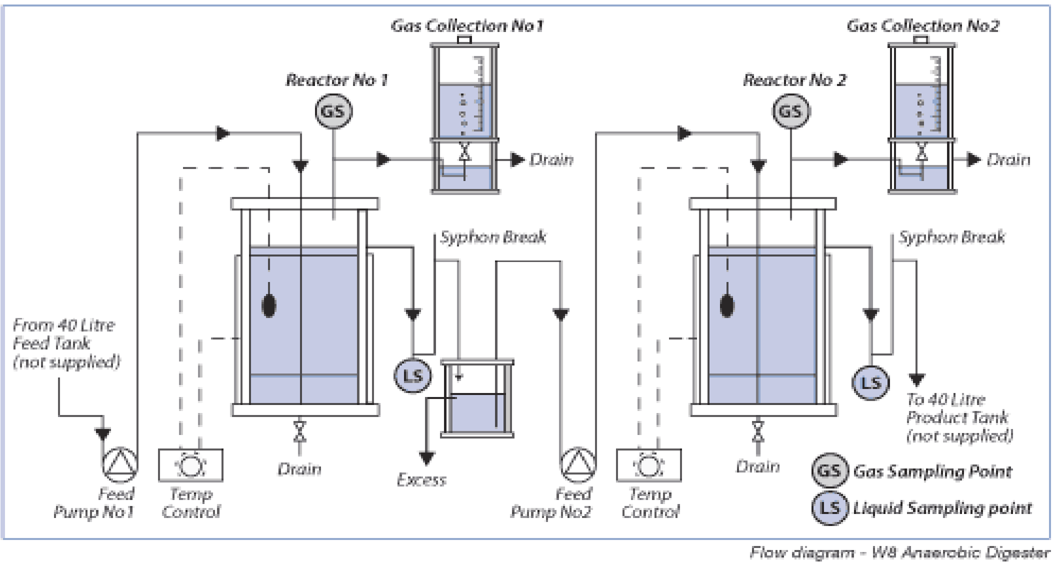

Figure 2: Flow Diagram Illustrating the Armfield Ltd ANAEROBIC DIGESTER (W8) ®System (Source: http://www.discoverarmfield.co.uk/data/w8/).

identified. For the purpose of the study, the reactor was fed by liquid cow manure with solid content less than 1%, which was created to have a COD value within the range of 7500-8000 mg/L. The feed is considered to be a low strength feed which was delivered at a constant 1.7 L/day which meant an organic retention time of approximately six days. The temperature was set to 35°C+_0.5 and controlled by the inbuilt Proportional – Integral – Derivative (PID) controller for all the testing.

In order to determine the Hydraulic Loading Rate (HLR), the reactors were fed with two variable speed peristaltic pumps which control the volumetric flow rate. In order to calibrate the device, the system was initially filled with water and the pump speed was set up. A portable calibrated pH meter was used to monitor the pH of both the influent and effluent flows. The pH was maintained in the range of 6.8 – 7.5 in order to ensure proper operation of the AD device.

The Chemical Oxygen Demand (COD) was determined by using two useful equations in order to profile performance in terms of COD.

Equation 1: Percentage of COD Removal (ARMFIELD W8® User manual)

$$Percentage\ COD\ \text{Re}moval = \frac{COD_{in}(mg/l) - COD_{out}(mg/l)}{COD_{in}(mg/l)} * 100$$

Equation 2: COD Volumetric Loading Rate (ARMFIELD W8® User manual)

$$Volumetric\ Loading\ Rate(kgCOD/m^3) = \frac{COD_{load}(kg/day)}{Volume\ of\ the\ \text{Re}actor(m^3)}$$

COD measurements were taken from the reactor feed and effluent at certain intervals. The standard approved method No. 52220B, namely open reflux method was used. A 5 ml samples were diluted by using de-ionized water in order to meet the reading ranges of the HACH® COD meter. 2 ml of each diluted sample was added to the HACH® prepared chemical vials while 2 ml from the de-ionized water was mixed with another vial to allow a blank datum. The vials were heated to150°C for two hours and then cooled to room temperature. The samples were read by the HACH® DR/2000 direct reading spectrophotometer.

Economic analysis

This section identifies the equations used to perform the economic viability for the proposed study. The economic viability entails analyzing the data using shadow process as to elimination price distortion, analyzing the indirect costs and benefits of the project, and looking at the overall effect of the project on the economy. The Payback Period (PBP), Economic Rate of Return (ERR), and Net Economic Present Value (NEPV) are the economic indicators used to evaluate the project. Equation 3, shown below, was used to calculate the PBP from an investment. To be used in the study, it is required the estimation of initial capital costs and expected yearly profits.

Equation 3: Investment Pay Back Period

$$Pay\ Back\ Period(Years) = \frac{Initial\ Capital\ Cost(USD)}{\Pr ofits(USD/Year)}$$

The ERR is the discount rate that will equate the NEPV of the Economic Benefit (EB) and Economic Cost (EC). NEPV was calculated using Equation 4 as follows:

Equation 4: Net Economic Present Value Equation

$$NEPV = -C_o + \sum_{i=1}^{T} \frac{NCF_i}{(1+SDR)^i}$$

In formula 5, the C_o is the initial investment which is a negative cash flow. The NCF_i is the net cash flow for year *i* while SDR is the social discount rate.

Equation 5: Complete Cost Equation [9]

$$I_f = f_i \sum (MPEC)$$

Where: I_f= Complete plant cost; f_I= Lang factor; MPEC =Main plant equipment cost

Equation 6: Initial Cost Equation [10]

$$I_f = I_{MPEC} * (1 + \sum f_d) * (1 + \sum f_{\dot{c}})$$

Where: I_{MPEC} – Costs of main equipment once installed; f_{dc} –

Multiplication factor for direct costs such as piping, instrumentations and buildings; f_{ic} – Multiplication factors for indirect costs such as engineering fees and contractors

The Lang factor approach was used to scale the cost of all of the different components required for the installation of a biogas system. Equation 5 and Equation 6 are used in the Lang factor approach to estimate costs of specific components which requires the selection of a numerical Lang factor. The Lang factor changes depending on the scale of the system which is being designed, as well as on the other factors such as location. It is important to select a suitable Lang factor when completing an economic study using the method in order to produce reliable results. Equation 6 was included as it shows the two components which make up the Lang factor; these are the direct and indirect costs.

Unlike the financial feasibility studies where the rate of return compared by the Weighted Average Cost of Capital (WACC), the ERR is compared with the social discount rate in order to know whether the project is viable or not. The social discount rate is the rate at which the value placed by society on future benefits and costs declines over time. The social discount rate reflects the social opportunity cost of capital, so that it provides the link between costs and benefits occurring at different time. According to the UN-ECLAC [11], little consensus exists on the choice of an appropriate SDR of the economics of climate change. A significant interest rate variation of 8-15% was reported by developing countries. Since no risk premium is anticipated in this analysis, 8% interest rate was used as the social discount rate. The estimation of no risk premium was based on that renewable projects are social capital projects.

Revenues from carbon finance

The *Clean Development Mechanism (CDM)* allows for the establishment of emission-reduction projects in developing countries that can earn Certified Emission Reduction (CER) credits, each equivalent to one tone of CO2. The benefit of carbon finance depends on the amount of the CERs per digester concerning the AD size and baseline emissions in the absence of the project activity. The emission reduction from a biogas digester is based on avoiding combustion of fossil fuels and on reducing methane emissions from the agricultural waste management. There are several potential approved methodologies that are appropriate to the proposed project issued by the United Nations Convention on Climate Change (UNFCCC). Those methodologies are approved for application both to CDM project activity and to CDM Programme of Activities (CPA) under a Programme of Activities (PoA) [12]. The estimated annual CERs for biogas CDM program varies from 1.76 to 7.0 tCO_2/ household [13].

Results and Discussion

Biogas production from the bench scale reactor

Initial COD profiling of various manure and water mixtures was performed in order to obtain the feed mixture. Results from feed mixture profiling are displayed in Table 1.

Using the data collected from feed profiling as a basis, 35 kilograms of cow manure was mixed with 30 liters of water to create a 7500-8000 mg/L COD feed for the main study. This feed mixture was filtered through a 1 mm mesh in order to reduce the solid content to less than 1% after sufficient time to allow the organic material to be extracted from the solids. The liquid feed then was delivered to the reactor at 1.70±0.05 L\day for fourteen days. This study was conducted after the reactor start-up period. The rate of Biogas production was monitored using the calibrated gas collection vessels on the W8®system. The influent and effluent COD concentrations were measured at various intervals using the method outlined in the previous section. The pH throughout the experiment remained in the optimum band for the Mesophillic bacteria, 6.8-7.5. The average results from the reactor study are displayed in Table 2.

Table 1: Initial COD profiling of various manure and water mixtures.

Manure: Water Ratio (kg:L)	COD (mg/L)
1:20	2400
1:8	2800
1:5	3000
1:2.5	6000
1:0.85	7700
1:0.5	10000

Table 2: Average results of the main experiment which was conducted after the start-up period.

Volumetric Flow Rate	1.70+_0.05	L/day (Retention Time–6 days)
Influent COD	7700	mg/L
Effluent COD	900	mg/L
Biogas Production Rate	0.0053	Nm^3/day
COD Influent Loading Rate	13.2	g/day
COD Effluent Unloading Rate	1.6	g/day
COD Removal	88	%

The influent and effluent COD loading rate was calculated using the following equation:

Equation 7: Influent and Effluent COD loading rate

$$COD\ LR(g/day) = COD\ Concentration(g/l) * VFR(l/day)$$

Where: LR –Loading Rate (g/L); VFR – Volumetric Flow Rate (L/day).

The influent loading and effluent unloading rate data was then used in Equation 1 to calculate the COD removal percentage, which was calculated to be 88%. The volumetric loading rate was calculated to be 1.32 kg/m^3 using Equation 2.

From this data it can be seen that the 0.01 m^3 UASB reactor running at 35° C and the conditions imposed by the feed is capable of producing 0.0053 Nm^3 of biogas per day. Scaling up to 1 m^3 suggests that the biogas yield per m^3 of reactor is 0.53 Nm^3 per day.

The aim of the physical experiments on the $W8^R$ system was to allow the selection of the suitable reactor yields and local operating conditions which would support the economic study. Due to the low strength feed, it is considered that the yield of 0.53 Nm^3 of biogas per m^3 reactor per day is a conservative estimation of a full scale reactor performance. The value of 0.89 Nm^3 from literature was used for an average reactor performance scenario. Thus, the economic analysis was performed for these two scenarios.

Reactor sizing for economic analysis

Reactor properties

In order to complete the economic feasibility study, the biogas reactor was sized so that it would be suitable for treating the animal manure as well as organic food waste generated on contained rural areas in Egypt. To size the reactor, certain parameters had to be set in order to define the biogas system. The selected parameters concerning the biogas reactor and operation are:

- Reactor volume was designed around a twenty day organic retention time in accordance with other full scale biogas plants, which operate at 35°C.

- The feed was designed around 10% organic solid food content and 90% feed mixture which constitutes as slurry feed.

- The composition of the Biogas for the economic calculations was selected to be 65% CH_4, 34% CO_2, and 1% impurities which are considered to be a typical composition produced by biogas systems [14].

- The expected conservative and average fertilizer yields were assumed to be 2 and 3% respectively of the total annual feed to the biogas system.

It was assumed that a biogas system will be installed for every 400 inhabitants (80 households). According to the IPCC 2006 guidelines, the annual Municipal Solid Waste (MSW) generation per capita in Egypt is approximately 0.29 tones. Therefore, the total amount of food waste to be treated in the biogas system is 116 tones/annum. In addition to the food waste, it was assumed that 50% of the households possess one cow. The average manure generation is 0.024 m^3/day/cow. As such, the amount of manure that will be delivered to the AD is 0.96 m^3/day.

Reactor sizing

From the assumptions outlined in the previous section, the yearly feed loading requirements were calculated. The density of the organic food waste can be determined at 0.8 tones/m^3 [3]. If 116 tons of MSW to be loaded every year, it was calculated that the volumetric yearly loading requirements for organic waste only is 145 m^3. Using the 10% solid content, it was calculated that the total slurry organic food fraction is 1450 m^3. The total annual manure that will be treated by the biogas system is 350m^3. Accordingly, the total input to the digester is 1,800 m^3/year. Therefore, the volumetric loading rate of the anaerobic digester is 5 m^3/day. Based on the assumption that the organic material will be retained in the reactor for twenty days, it was calculated that the reactor volume must be 100 m^3.

Economic analysis

The economic feasibility study was completed in U.S. Dollars which required conversion of Egyptian pounds to U.S. Dollars without distortions. In 2012, Hagag identified the shadow exchange rate from 2007 to 2010 using the supply and demand approach which is based on the ratio between capital and goods inflows and outflows. The SER from 2010 to 2016 has been also anticipated on an annual devaluation value of 3%. The SER varies from 6.7 up to 8.2 EGP; as such using 6.70 EGP is a reasonable value for the current study.

Based on findings shown in the previous section that the biogas system is to treat 116 tonnes of organic food waste where the Organic Fraction of the MSW (OFMSW) is approximately 60% [3], it was calculated that 70 tonnes of organic material every year could be converted into biogas besides 350 m^3 cow manure. The biogas from food waste could yield 250-415 Nm^3/ton [3]. The experiments of biogas production from animal manure showed 0.53 Nm^3/m^3 which is considered a conservative value. An average value of 0.89 Nm^3/ m^3 was used to determine the viability of the second scenario [15]. Using the assumptions stated thus far, the yearly yield of the products and impurities which would be produced by the proposed biogas system was predicted. Since the economic feasibility study was performed into two scenarios, conservative and average approaches, Table 3 shows the predicted biogas production from a biogas system together with the amount of green fertilizers for both scenarios.

The two traded products of the biogas system are methane and green fertilizers. The produced methane can be utilized to generate electricity and replace natural gas. In both scenarios 50% of the methane yields will replace electricity from the grid and the rest will be used as household methane. The electricity tariff depends on the amount of monthly consumption per household. The national tariff of electricity increases if the consumption rate increases. The amount of generated electricity by the biogas system for each household will be equivalent to the lowest tariff category which is 0.05 EGP/ kwh. According to the African Development Bank report “Reforming Energy Subsidies in Egypt”, the subsidy rate of electricity is estimated to be 44% [16]. If the produced methane will be used as a household fuel instead of natural gas, the price of methane will be equivalent to the Free On Board (FOB) price of natural gas. Thus, the undistorted price of natural gas is the price of the exported Egyptian natural gas. The average price of the exported NG is reported at 4.5 USD/MBTU (0.16 USD/Nm^3) [17]. The average price of green fertilizer is 99 EGP/ m^3 reported by Cairo biogas operator [3]. Using the shadow exchange rate as mentioned above, the price of fertilizer will be 14 USD/ m^3.

The next step in completing the economic study was to estimate the initial capital cost for the biogas system. The initial capital cost of the system was based on an economic assessment of a similar sized biogas system which was designed to be built in Thailand [18]. The particular Thailand biogas system is made up of two 100 m^3 fixed dome bio-digesters. Scaling the costs from the two 100 m^3 Thailand biogas system has led to an initial complete plant cost estimate for the biogas system of the current study which considered of the main equipment costs and the cost of the installation. The main equipment which was considered were the reactor, feed buffer tank with mixing unit, pumps, pipes, gas storage vessel, and the scrubbing/drying equipment. Table 4 shows the economic assessment data for 100 m^3 digester without any governmental interventions.

The pricing assumes local construction materials will be used such as concrete and fiber glass. Equation 5 was used in order to break

Table 3: Predicted Biogas Yields and Green Fertilizers.

Item	Amount	Scenario 1 Conservative Yields (Nm^3/year)	Scenario 2 Average Yields (Nm^3/year)
Animal Manure	350 m^3/year	185.5	311.5
OFMSW	70 tones/year	17,500	29,050
Total Biogas yield		**17,685.5**	**29,361.5**
Methane Fraction	65%	11,500	19,000
Carbon Dioxide	34%	5,950	9,877
Impurities	1%	175	290
Green Fertilizer	**2 -3%**	**36**	**54**

Table 4: Economic Assessment Data (Pipatmanomal, 2008).

Initial Capital Cost	**USD**
Reactor, Pumps, Piping	6,620
Accessories, Buffer Tank, Mixing Unit	1,556
Scrubbing/ Drying Equipment	390
Gas storage	260
Sum	**8,827**

down the overall costs and installation costs. To do this an appropriate Lang factor was selected. Research into cost of developing small scale biogas technology in Africa has led to a Lang factor of 2.63 which was used throughout the calculations [10].

I_f=2.63*(MPEC)

8827 =2.63*(MPEC)

MPEC = 3,356 USD

Therefore the estimated main plant equipment costs for the biogas system is 3,234 USD. In order to obtain the initial capital cost including the installation costs, Equation 6 was applied. The multiplying factors of both direct and indirect costs were obtained from similar projects in a rural African country since it was hard to calculate them. The multiplication factor for direct costs (F_{dc}) such as piping, instrumentations and buildings was estimated at 1.3 while the multiplication factors for indirect costs (F_{ic}) such as engineering fees and contractors was estimated at 0.11 [10]. Therefore, the total initial capital cost is 8,568 USD. Maintenance and repair operating cost was assumed 10% of initial capital costs.

Carbon finance

The amount of CERs that can be generated from the current project is simply the amount of assumed annual CERs multiplied by the number of households and the unit price of CER. Based on the literature, the minimum expected amount of CERs per household (1.7 tCO_2/year) was used in the conservative approach scenario while 4.35 tCO_2/year was utilized in the second scenario. Since the number of households served by the biogas system is 80; therefore, the total CERs amount for the conservative and average approach are 140 tCO_2/year and 384 tCO_2/year respectively. The lowest recorded price of CERs was used which is 6.5 USD [19].

It was assumed that the current project will earn carbon credits as a single CDM project. However, it is worth mentioning that the transaction costs are reduced in CPA since it counts for other individual activities in multiple sites at the same time.

Economic indicators

The economic analysis was performed on a life time period of 10 years. Using the yearly operating costs and income from utilizing methane and fertilizer as a basis, the estimated yearly profits were calculated. The yearly profits and the initial capital costs were then used to calculate the expected Payback Period (PBP) using Equation 3. The ERR and the NEPV were computed for both scenarios using Equation 4. Table 5 shows the economic indicators. In addition to the economic indicators, economic contribution or indirect effects of the biogas facilities will be measured in terms of value added, employment, and foreign exchange earnings. The value added is a major economic indicator to explain to what extent the project is valuable. By subtracting the transfer abroad from the domestic value added, we can obtain the national value added. The domestic value added is measured as the difference between the gross output (i.e., wages, net benefits…) and the material inputs. The gross output of the biogas system exceeds the material inputs. The domestic value added is equal to the national value added as the transfer abroad is zero. Therefore, the value added is a significant positive value. The project leads to employment generation where more employees will be required to maintain the new project. The new job roles generated by the project will bring about a more technically savvy pool of laborers. The project is projected to earn yearly foreign exchange as certified emission reductions from the UNFCCC as a CDM project.

By comparing the ERR to the SDR at 8%, it is obvious that the project is economically viable only with the CDM revenues in the first scenario. On the other hand, the second scenario shows that the ERR is higher than the SDR with and without CDM revenues. In addition to the ERR, the NEPV is positive. However, we can conclude that implementing biogas system in rural areas in Egypt is economically viable taking into consideration the economic contributions.

Conclusion

•The project will help contribute to the sustainable development of Egypt through its contribution to the environmental, economic, and social pillars. The proposed project is economically viable whether there is CDM revenue or not. However, the CDM revenue can raise the economic attractiveness of the project.

•The project can also be applied in any developing country.

•The project has positive value added, creates job opportunity, and can earn foreign exchange as a CDM project. Thus, it would be in the best interests of the economy as a whole for projects like this are implemented on a greater scale due it is positive impact on the society.

•Biogas is utilized as a green energy source, reducing greenhouse

Table 5: Economic Analysis Indicators.

		Scenario 1 *Conservative Approach*	**Scenario 2** *Average Approach*
Outcome(USD/year)			
Initial Capital Cost		8,568	8,568
Operation and Maintenance Cost		857	857
Income(USD/year)			
Electricity		82	135
Natural Gas		920	1520
Green Fertilizers		504	756
CERs		910	2262
Economic Indicators			
W/OCDM	Pay Back Period (years)	13.20	5.5
	ERR	Negative	12.61%
	NEPV (USD)	-4, 214	1,861
With CDM	Pay Back Period (years)	5.5	2.04
	ERR (%)	12.68%	43.32%
	NEPV (USD)	1,892	17,039

gas emissions such as CO_2, which increases the quality of life of society.

•The positive impact of reducing air pollution and enhancing the air quality guarantees that the workforce as well as the nearby receptors is no longer affected by the greenhouse gas emissions which leads to less incidence of hospitalization due to air pollution.

•Implementing new technology will lead to tech and knowledge transfer. The project showcases an innovative way to use biogas from animal manure and solid waste for energy generation in Egypt.

•The project also encourages private partnership and government to mitigate climate change.

•The biogas is one of the cheapest eco-friendly technologies for small scale projects compared to solar and wind energy for instance. Moreover, it helps in alleviating another environmental issue which is getting rid of organic waste and animal manure in a sustainable manner.

References

1. Harold H. “Alternative Energy Sources- Biogas Production” The proceedings of London Swine Conference. 2007.
2. Krause, L, Diaz NN, Edwards RA, Gartemann KH, Krömeke H, Neuweger H, et al. “Taxonomic Composition and Gene Content of a Methane-Producing Microbial Community Isolated from a Biogas Reactor”. Journal of Biotechnology. 2008; 136: 91-101.
3. Christopher IT, Hassan MG, Sherif F Ali. “Integrated Portable Biogas Systems for Managing Organic Wastes” Proceedings of WSEAS conference Tunisia. 2010.
4. Yadvika, Santosh, SreekrishnanTR, Kohli S, Rana V. “ Enhancement of Biogas Production from Solid Substrates using Different Techniques – a Review” Journal of Bioresource Technology. 2004; 95: 1-10.
5. Pöschl MS, Ward P Owende. “Evaluation of Energy Efficiency of Various Biogas Production and Utilization Pathways” Journal of Applied Science. 2010; 87: 3305-3321.
6. Daniel B, Ksenia B, Martin B, Elke F, Zoran K. “PoA CDM Mannual- Mini Biogas Plants for Households” UNEP, Working Paper No.8. 2009.
7. Gebrezgabher SA, Meuwissen MPM, Prins BAM, Oude Lansink A. “Economic Analysis of Anaerobic Digestion – A Case of Green Power Biogas Plant in the Netherlands” NJAS-Wageningen Journal of Life Science. 2010; 57: 109-115.
8. Saleh M, Usama F. Mahmoud “Anaerobic Digestion Technology for Industrial Wastewater Treatment” Proceedings of Eight International Waste Technology Conference, IWTC8. 2004; 817-833.
9. Amigun B, Von Blottnitz H. “Capital Cost Prediction for Biogas Installation in Africa: Lang Factor Approach”. Journal of Environmental progress and Sustainabel Energy. 2009; 28: 134-142.
10. Amigun B, Von Blottnitz H. “Cost Analyses and Predictions for a Fuel Ethanol Plant in a Rural and Landlocked African Country: Lang Factor Approach”. Journal of Production Economics. 2009; 119: 207-216.
11. UN-ECLAC. “An Assessment of the Economic Impact of Climate Change on the Transportation Sector in Barbados” United Nations Economic Commission for Latin America and the Caribbean. 2011.
12. UNFCCC. “Executive Board of the Clean Development Mechanism Thirty – Fifth Meeting Report” United Nations Framework Convention on Climate Change – secretariat. 2007.
13. Hayashi D, Marr M, Michaelowa A, Niemann M, Neufeld C, Oppermann C, et al. “PoA Blueprint Book- Guidebook for PoA Coordinators under CDM/JI” KFW Bankengruppe. 2009.
14. Sherif F Ali, Hassan MG. “Biogas, and Investment Opportunity, and Waste Management Tool in Egypt” Proceedings of International Conference on Renewable Energies and Power Quality, ICREPQ’10. 2010.
15. Laaber MR, Kirchmayr R, Madlener, Braun R. “Development of an Evaluation System for Biogas Plants” Research Program “Energie Systeme der Zukunft”, Austrian Federal Ministry for Transport, Innovation, and Technology. 2005.
16. Hagag F. “Economic and Financial Valuation of the Marble Industry In Egypt” Master Thesis, The American University in Cairo. 2012.
17. Egypt Independent “Egypt Finalizing Plan to Raise Gas Export Prices” Egypt Independent Online Newspaper. 2012.
18. Pipatmanomai S, Kaewluan S, Vitidsant T. “Economic Assessment of Biogas-to-Electricity Generation System with H2S Removal by Activated Carbon in Small Pig Farm” Journal of Applied Energy. 2009; 86: 669-674.
19. Sethuraman D, Natalie Obiko. “Carbon Credits Becoming ‘Junk’ Before 2013 Ban Closes Door: Energy Markets” Bloomberg. 2011.

Austin Chem Eng - Volume 2 Issue 2 - 2015
ISSN : 2381-8905 | www.austinpublishinggroup.com

Citation: Zayat ME, Hassan MG, Taylor CI and Haggar SE. Feasibility of Biogas Utilization in Developing Countries: Egypt a Case Study. Austin Chem Eng. 2015;2(2): 1017.