JEAS
Journal of Engineering and Applied Sciences13 (2018), 40-53

JOURNAL OF ENGINEERING AND APPLIED SCIENCES

ECONOMIC VIABILITY OF BIO-ENERGY PLANTS FOR LOCATION ANALYSIS IN PARTS OF ANAMBRA STATE OF NIGERIA

Chukwuma, C. E[1*], **Ndrika, V.I.O**[2] and **Chukwumuanya, E. O**[3]

[1]*Department of Agricultural &Bioresources Engineering,Faculty of Engineering, NnamdiAzikiwe University, Awka, Anambra State, Nigeria*
[2]*Department of Agricultural Engineering, Michael Okpara University of Agriculture Umudike, Nigeria, Nigeria*
[3]*Department Of Industrial/Production Engineering, Faculty of Engineering,NnamdiAzikiwe University, Awka, Anambra State, Nigeria*

[*]CorrespondingAuthor's E-mail: ecchukwuma12@gmail.com

Abstract

The need for proper location studies, distance and transportation cost optimization of hauling of wastes from generation centres to centralized treatment centres cannot be overemphasized. The goal of this study is to evaluate the economic viability and to optimize these available sites considering investment cost, operational cost etcwhich are critical factors in siting of facility. Three locations were selected as suitable regions for siting biogas plant in Anambra State based on previous studies. The regions includes: Onitsha North, Njikoka and DunukofiaLocal Government Area (L.G.A) of Anambra. Economic parameters for location decisions such as Investment, maintenance, operational costs were used to determine the biogas profitability for the three locations.The economic viability study was carried out using biogas profitability index value. The result of the study shows that the profitability index value is 1.498894, 1.732658, and 1.433577 for Onitsha North, Njikoka, Dunukofia L.G.A respectively. Njikoka has the highest investment cost as well as the highest profitability index value, while Dunukofia has the lowest investment and the lowest biogas profitability index value.

Keywords:Economics, Bio-energy, Centralized Location, Centralized, Anambra State

1. Introduction

In the present day, the need, and practice of reclamation of bio-wastes produced from animal waste is gaining approval from developed and developing countries of the world as a result of the impact of climate change on the human environment. Small scale biogas plants are rarely used on farm level across the study area by farmers, despite the energy crisis confronting the country at large. The current trend towards sustainable renewable energy in developing countries calls for a systematic approach of farm waste management and treatment, which can be achieved only by a strategic planning approach. One of the biggest barriers in utilizing biogas potential in the study area is the dispersion of livestock farms across the state which are relatively small farms that are not capable of having economically viable biogas production.Although there are potential economy of scale for the centralized digester, manure transportation and handling costs can offset the economic savings if there are not sufficient farmers willing to participate in close proximity to the proposed facility (ESA, 2011).

Hence the need for proper location studies, for distance and transportation cost optimization of hauling of waste from generation centres to centralized treatment centres (biogas plant).A few of the key parameters influencing the viability of community biogas digesters in Anambra State will be the distances between bio-waste sources and central digesters, feed in tariffs, manure prices, willingness to invest in biogas production industry, maintenance cost etc.In 1984, the first centralized biogas plant was established in Demark. This plant, like most of its successors, was equipped with combined heat and power production facilities, as heat was supplied to a nearby village and electricity was sold to the electricity grid (Hjort-Gregersen, 1999). In Countries such as Denmark and Germany, the centralized biogas plants have been developed since 1980s and proved to be economically viable [Kurt 2002; Weiland 2003].Ghafoori and Flynn (2006) on biogas plant feasibility study in Red Deer County in Canada noted in their study that small farm based manure digesters are less cost effective than centralized units that receive manure from many producers. They noted that farmers that want to process manure and produce power are better off, to transport their manure than to process it on site. For the mixed farming area that they intensively studied, it was observed that even a feedlot with 7,500 beef cattle could not make power from manure as economically as a centralized digester, and the cost penalty is greater for smaller farms. The critical factor favouring a centralized digester they reported is the lower capital cost per unit of input/output realized in a large economically sized plant; this savings is greater than the cost of transporting manure to and digestate from the plant.

A recent study conducted by Chukwuma (2016) on suitability analysis for location of biogas plant in Anambra state indicates that three locations were classified as the most suitable location: they include Onitsha, Njikoka and Dunukofia LGAs of Anambra State. As a further study, the objective of this research is to determine the economic viability of centralized biogas plants in these three locations and its economic viability using profitability index methodology.

2.0 Material and methods

2.1 Study Area

Anambra State is one of the 36 states of Nigeria, and is located in the South East geopolitical zone of the country. The State occupies a land area of about 4,844 square kilometer and is bounded in the East by Enugu State, in the North by Kogi State, in the South by Rivers and Imo States, and in the West by Delta State.The national population census of 2006 gave the population of Anambra State as 4.06 million with a population density of 1,500 to 2,000 persons living within every square kilometer. The State is divided into 21 local government areas with Awka as its state capital. Figure 1 below shows map of Nigeria on the globe, and the three study areas on Anambra State Map indicated with arrow.

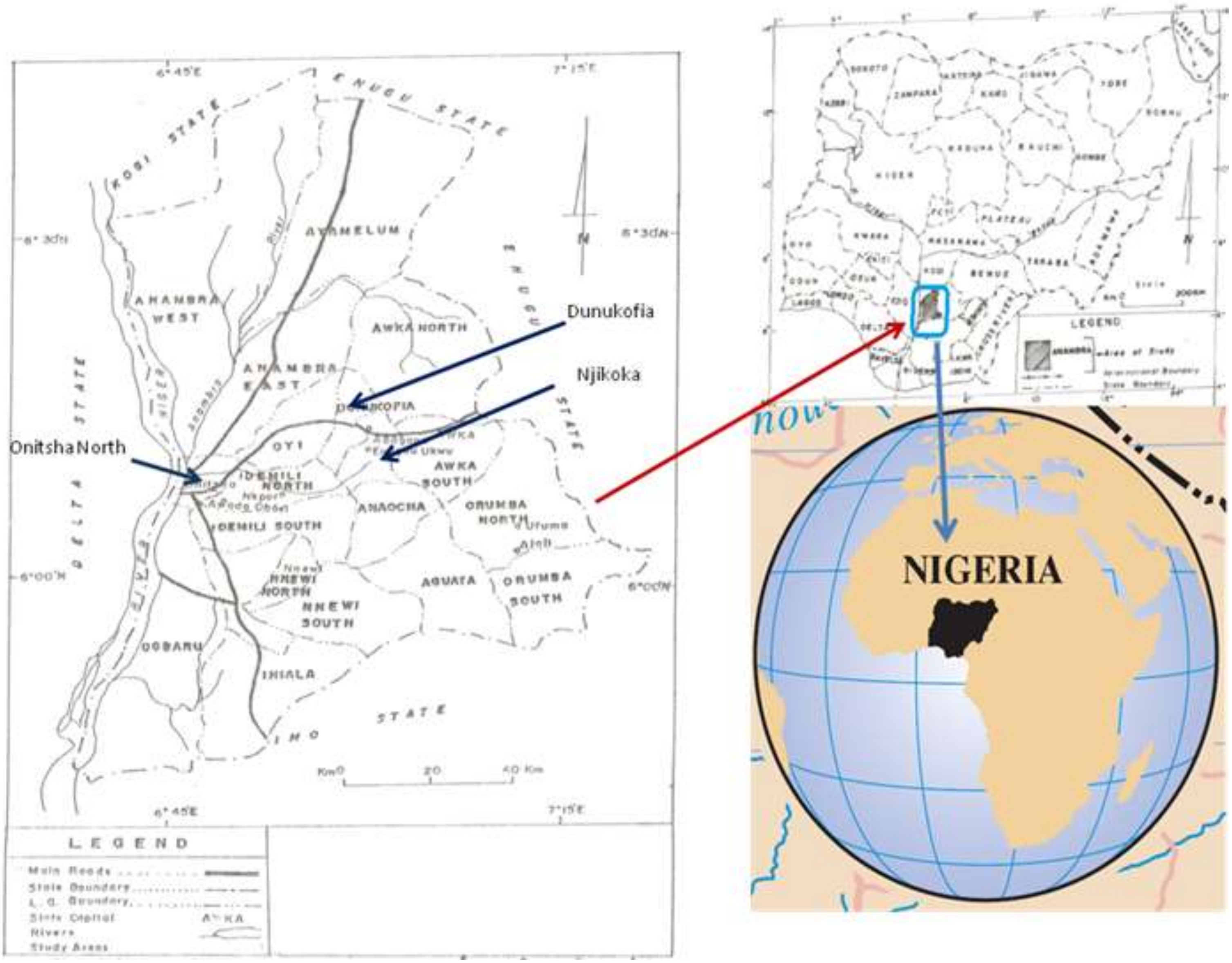

Figure 1: Map of Anambra State showing the three study areas and Nigeria showing Anambra State.

2.2 Economic Analysis

The goal of this study is to assess the economic viability of biogas energy centres, considering important economic parameters such as investment cost, operational cost etc. These are critical factors in siting of facility. The profitability analysis will be used to select the best site from the three major regions that were classified as the best sites which are located in Onitsha, Njikoka and Dunukofia L.G.A of Anambra State. Pofitability analysis implies that at some point in the operations, total revenue is above total cost. It computes the amount of goods required to be sold just to cover cost. Profitability analysis can be especially useful in location analysis when the costs of each location is known. This study applies cost benefit analysis in comparing location alternatives on the basis of quantitative factors (ie transportation cost, quantity of manure available etc) that can be expressed in terms of total cost. Basic steps in the profitability analysis includes: (a) Determination of the variable and fixed cost (b) Determination of revenue to be accrued from selling bio-product and services (c) Computation of profitability index based on (a) and (b) above.

The total cost for sitting the central sitting of biogas plant is divided into investment cost (fixed cost) and variable cost. Fixed cost comprises of land, property taxes, insurance, equipment, and building while the variable cost include labor, materials, transportation costs, and variable overhead.

2.3 Estimation of Investment or Capital Cost

Capital costs for the construction of this type of Anaerobic Digester AD plants was assumed to be a function of the plant nominal capacity, according to a moderate scale economy. A plot of investment cost against biogas electrical power production in Kilowatts of electricity (KWe) is shown in Figure 2 was used in investment cost estimation of biogas plant in this study.

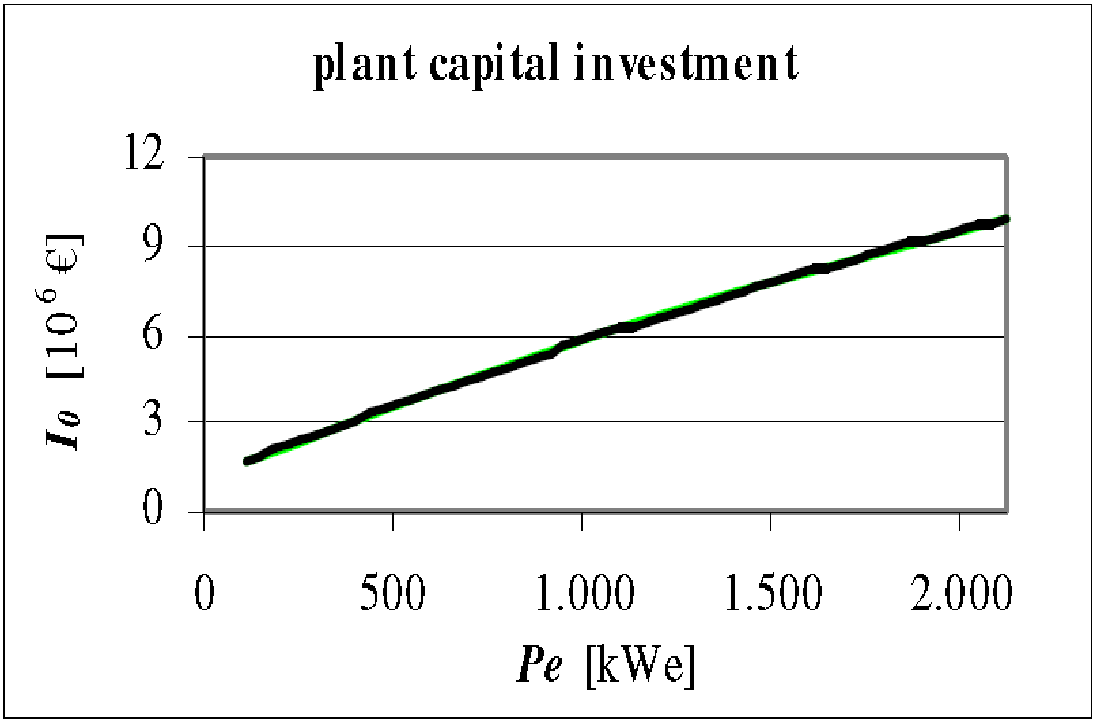

Figure 2: Capital investment (I_o) as a function of AD plant nominal capacity.
Source: (Florese et al., 2008)

The nominal capacity for biogas plant was estimated based on Pantaleo et al., (2013), the gross electrical power Pe(kWe) of a biogas plant, can be expressed as a function of the input biomass according to the equation 1 :

$$P_e = [(Q_p \times TS_p \times VS_p \times BY_p \times BA_p) + (Q_c \times TS_c \times VS_c \times BY_c \times BA_c)]\frac{CH_4 \times LHV \times \eta_e}{H} \quad 1$$

Where Q_p (t/yr) and Q_c (t/yr) arerespectivelytheannual poultry biowaste and annual cattle biowasteconsumptionofthebiogaspowerplant, TS (%),VS (%), BY (N m^3/t) and BA (%) arerespectivelythetotalsolids percentage, volatilesolidspercentage,biogasyieldofthevolatile percentage and biogas availability ofthebiomass;CH_4 (%) isthe percentage ofnaturalgasinthebiogasand LHV (kW h/Nm^3)is the low heating value of natural gas; η_e is the electric efficiency of the power plant and H the annual operating hours (h/yr). The values of the parameters used in the above equation are shown in Table 1 below:

Table 1: Average Biogas composition values

S/N	Onitsha	Njikoka	Dunukofia
Q_p [c] (Ton)	57,412.95	63,914.07	54,982.76
Q_c [c] (Ton)	6,914.6	6,914.6	6,914.6
TS_p [b] (%)	20	20	20
TS_c [b] (%)	8.5	8.5	8.5
VS_p [b] (%)	80	80	80
VS_c [b] (%)	80	80	80
BY_p [b] (%)	4.75	4.75	4.75
BY_c [b] (%)	0.25	0.25	0.25
BA_p [b] (%)	70	70	70
Heating Value[b] MJ/Nm³	25.2	25.2	25.2
Electric efficiency[a]	0.44	0.44	0.44
Annual Operation Hour[a] (hours/yr)	7468	7468	7468

Source: [b]AlSeadi et al., (2008);[a]Florese et al., (2008); [c]Author's research

$Q_p$was estimated by summing up all the livestock waste generation point within a distance of 40km to each of the three locations. Höhn et al., (2014) reported that a maximum transportation distances for raw materials vary from 10 to 40 km. In the present study the upper end was used to estimate the collection area and associated biogas production potential. Distance above 40km was excluded in the available waste because of economic considerations.

Capital cost of a project does not always vary linearly with plant capacity. The cost of a specific item depends on size or scale and can usually be correlated by the approximate relationship. Equation 2 below proposed by Marouli and Maroulis,(2005) and Figure 2 above were used to approximate the investment cost of the biogas plant.

$$\frac{C_1}{C_2} = (\frac{Q_1}{Q_2})^n \quad 2$$

Where C1 = cost of the item at size or scale Q1; C2 = cost of the reference item at the size or scale Q2.n = scale exponent or cost capacity factor. Amigun and Blottniz(2010) determined capital cost relationship for small–large scale biogas systems and reported that the value of n for small and large scale biogas plant is 1.21 and 0.8 respectively. The value of n=0.8 was used in the estimation of the investment cost of the biogas plant since the capacity of the proposed plants would be a large scale operating bio-energy plant.

2.3 Estimation of Variable Cost

The variable cost consists majorly of transportation cost, operational cost and maintenance cost. The transportation cost was estimated using equation 4 below (Fiorese et al., 2008)

$$T_c = \sum_{i=1}^{N} \sum_s [(V_{tc} * d_{ij} + F_{tc}) a_{ij} * x_{ij}] \quad 3$$

*Where a_{ij} is the b*iomass available in the *i*-th demand point, *s*=1 for poultry biowaste and *s*=2 cattle biowaste; x_{ij} is the fraction of biomass in the *i*-th livestock site or abattoir centre conferred to the *j*th plant. The value of $x_{ij}$was taken to be 1, since all the waste in each demand points should be treated.The transportation cost comprises of both fixed costs (F_{tc}) representing loading and unloading operations, and variable costs (V_{tc}) which is a function of distance as shown in Figure 3 (adapted from Ghafoori*et al.*, 2007).The transportation costs (T_c) considered the cost of manure transportation cost to the plant only without including digestate round-trip transportation costs, this is based on the fact that majority of livestock farms and abattoir centres does not really need the digestate for farming, the cost of digestate transportation will be incurred by farmers who needs the digestate for farming needs.. Dij is the Euclidean distance (in km) between the demand points and the suitable points. The value of d_{ij} was estimated based on upper distance of 40km, the Euclidean distance was multiplied with the factor 1.4 so as to determine the actual distance (Leduc et al., 2010).

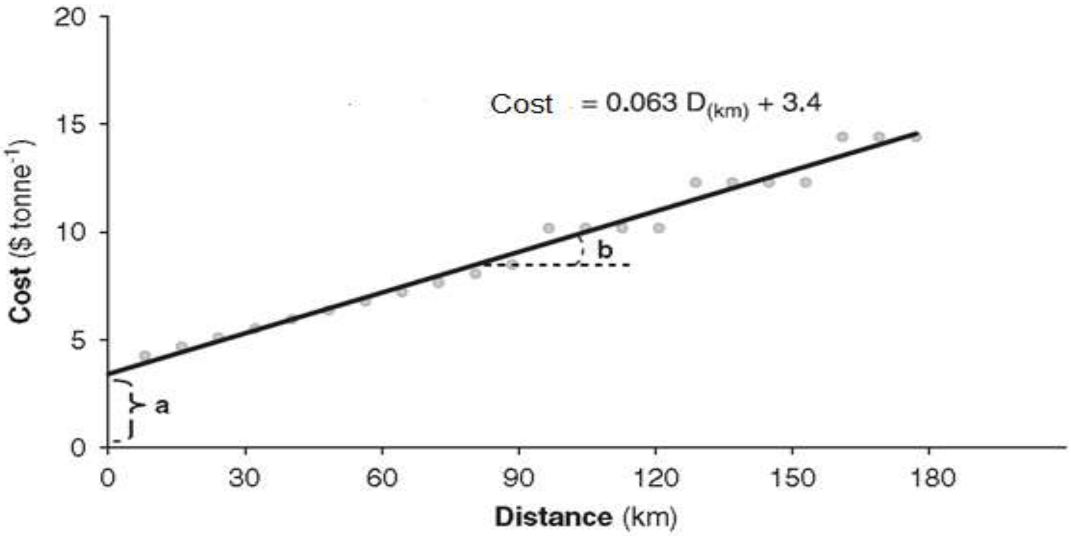

Figure 3: Cost of transporting manure by truck: ‘‘a’’ is the distance fixed cost, and the slope ‘‘b’’ is the distance variable cost.

Source: Ghafoori et al., (2007)

2.4 Estimation of Plant Operational Cost

The operational cost for biogas plant consists of personnel (labour) costs and overheads; cost of consumable like lime and active carbon, for the removal of odours and other noxious gases; pretreatment of feedstock cost etc.Sotirios et al., (2010) proposed that 3-5% of the total investment cost should be used for the operational.3% of the investment cost was used as the operational cost.

Plant maintenance costs (P_{main}) was calculated as a fraction of gross energy outputE_o.Fiorese et al., (2008), proposed the gross energy output to be given by:

$$E_o = \frac{1}{3.6} * (1 - f_{el}) * \eta_{el} * LHV_{*\sum_i^N \sum_s a_i} * VS_{c,p} * BY_{c,p})x_{ij} \quad 4$$

x_{ij} are the fractions of biomass in the i-thbiowaste site conferred to the jth plant; f_b is Organic fraction in the s-th biomass; $BY_{c,p}$ is the Biogas yield for biomass s; LHV Biogas low heating value; f_{el} is the electrical auto-consumption fraction; η_{el} is the electrical efficiency of the biogas plant. The above equation was multiplied by 3% to obtain the plant maintenance value.

2.5 Profitability Analysis of Centralized Biogas Plant

A situation where either the government, interested companies, NGOs and organization owns the centralized biogas plant and situation where farmer's co-operative society decides to finance and operate the biogas plant has long been sought for. The profitability analysis of centralized biogas plant was carried out in this study, this is based on Puksec and Duic (2012) centralized biogas plant assessment methodology. Nigerian Electricity Regulatory Commission seek to encourage investment in renewable energy for power generation to achieve 10% of the total energy mix, hence Feed-in Tariff structure which is renewable technology based has been established. A proposed Feed-In-Tarrif (FIT)presented by Acting Director of Electrical Inspectorate services Department is shown below:

Table 2: General Assumptions of determination of FIT in Nigeria

S/N	DESCRIPTION	UNIT	ASSUMPTIONS			
			WIND	SOLAR	SMHP	BIOMASS
1	Installed Capacity	MW	10	5	10	5
2	Capital Cost	US$/kW	2,525	5,545	3,500	4,000
3	O & M Cost (Fixed)	NGN/MW/yr	2,900,000	9,570,000	5,655,000	8,370,000
4	O & M Cost (Var)	NGN/MW	232	87	775	
5	Capital factor	%	38	33	60	68
6	Auxiliary Requirement	%	1	1	1	10
7	Economic Life	years	25	25	25	25
8	Construction Period	years	3	3	3	3

Source: Nigeria Federal Ministry of Power (2013)

A general assumption for 5MW biomass installed capacity for electricity generation is shown above. The economic life of such renewable energy is estimated at economic life of 25 years. The renewable energy FIT structure for Nigeria considered Small Hydropower (SMHP), wind power etc as sources for renewable energy plan for the country. Table 3 shows the increasing FIT applicable to biomass renewable energy source.

Table 3: Renewal Energy Feed-in-Tariff Structure of Nigeria

Renewable Energy Technology	2012	2013	2014	2015	2016
SMHP	23,561	25,433	27,456	29643	32,006
Wind Power	24,543	26,512	28,641	30,943	33433
Solar Power	67,917	73,300	79,116	85,401	92192
Biomass	27,426	29,623	32,000	34,572	37,357

Source: Nigeria Federal Ministry of Power (2013)

From the Table 3 above, FIT for biomass energy source seems to be the highest. Electricity generation using biomass renewal energy source could be a highly profitable venture in the study area. In the situation that farmers take over all of the investment as well as operating costs of the plant, then the most important parameter would be the profitability of the plant. The biogas profitability index is givenin. Equation 5 by Puksec and Duic (2012) as:

$$B_{pi} = \frac{FIT\left(\frac{B*LHV*^{\eta}{}_{el}}{1+\mathrm{Rel}}A\right)}{(I_o + C_{o\&M})} \qquad 5$$

whereB_{pi}, biogas plant profitability index.FIT, feed in tariff (₦/kWh); B, yearly biogas production (m^3/h); LHV, energyvalue of biogas (kWh/m^3); CHP efficiency; A, availability (h/year) and $R_{el/heat}$, CHP electrical energy/heat ratio.

3.0 Results and Discussions

The nominal capacity for Onitsha was estimated to be 3661.35 (kWe), while the nominal capacity for Njikoka and Dunukofia L.G.A is about 3969.46 (kWe) and 3546.18 (kWe) respectively using equation 1. Using equation 2 and Figure 2 the capital cost for each location was estimated as shown in Table 4 below.$d_{ij}$was estimated to be 2070.09km for Onitsha, 2219.95km for Njikoka and 2012.38km for Dunukofia supply points. The actual distance according to Leduc et al, (2010) was determined to be 2898.126, 3107.93 and 2817.332 respectively for Onitsha, Njikoka and Dunukofia supply points. Using equation 3, the total transportation cost per ton for the various locations were estimated to be ₦39640.7, ₦ 37010.45 and ₦ 35997.46 for Onitsha, Njikoka and Dunukofia supply points. The annual plant operational cost and maintenance cost were also obtained as stated in section 2.4 above, the values of each of these cost is shown in Table 4 below:

Table 4: Bio-energy plant costs in Naria

S/N	Onitsha North	Njikoka	Dunukofia
Investment (Fixed) Cost	3,744,950,510	3,995,101,272	3,650,494,960
Maintenance Cost	67,663.36	73,357.36	65,543.97
Transportation Cost	39640.7	37010.45	35997.46
Operational Cost	74899010.2	79902025.44	73009899.2
Total Variable Cost	75,006,314.26	80,012,393.25	73,111,440.63
Total Cost	3,894,963,139	4,155,126,059	3,796,717,841
Biogas Profitability Index	1.498894	1.732658	1.433577

From Table 4 above, Njikoka has the highest investment cost as well as the highest profitability index value, while Dunukofia has the lowest investment and the lowest biogas profitability index value. The Table also shows that increase in investment cost led to increase in the biogas profitability index. This could be attributed to profit arising from economy of scale in large scale plants.

4.0. Conclusion

The goal of site selection optimality analysis is to select the best single site considering economic indices for bio-energy plant sitting. Biogas profitability index analysis was evaluated based on various equations on investment, operational, and maintenance costs. The result of the study indicates that Njikoka LGA has the highest profitability index with biogas profitability index of 1.7. The least total cost amongthe three locations however Dunukofia LGA is and could serve as alternative location if financial limiting conditions are placed on the bio-energy plant project. It is recommended that provision of incentives to accelerate renewable energy adoption among various stakeholders and establishment of appropriate financing schemes for investment in renewable energy projects should be implemented in Anambra State.

References

Al Seadi T, Rutz D, Prassl H, Köttner M, Finsterwalder T, Volk S, and Janssen R.(2008) Biogas Handbook. Esbjerg, Denmark: University of Southern Denmark.

Amiguna, B., and Blottnitz, H., (2010)Capacity-cost and location-cost analyses for biogas plants in Africa. Resources, Conservation and Recycling 55:63–73.

ESA, (2011).Economicfeasibilityofdairymanuredigesterandco-digesterfacilities in theCentralValleyofCalifornia.RetreivedFrom: ⟨http://www.waterboards. ca.gov/centralvalley/water_issues/dairies/dairy_program_regs_requirements/ final_dairy_digstr_econ_rpt.pdf⟩.

Florese, G., Guariso, G., Polimeni, A., (2008)Optimizing biogas production: an application to an Italian farming district. *International Congress on Environmental Modelling and SoftwareIntegrating Sciences and Information Technology for Environmental Assessment and Decision Making4th Biennial Meeting of iEMSs.*

Ghafoori, E and Flynn, P (2006) Optimum Sizing for Anaerobic Digestion. A BIOCAP Research Integration Program.

Ghafoori, E., Flynn P.C., andFeddes J.J., (2007) Pipeline vs. truck transport of beef cattle manure. *Biomass and Bioenergy*. 31(2-3):168-177.

Hjort-Gregersen, K (1999)Centralised biogas plants -integrated energy production, waste treatment and nutrient redistribution facilities. Danish Institute of Agricultural and Fisheries Economics.

Höhn, J. E.,Rasi,S.,andRintala, J.,(2014)A Geographical Information System (GIS) based methodologyfor determination of potential biomasses and sites for biogas plantsin Southern Finland. Applied Energy 113, 1–10.

Kurt, H.G., (2002). Centralised Biogas Plants -Integrated Energy Production, Waste Treatment and Nutrient Redistribution Facilities. Danish Institute of Agricultural and Fisheries Economics.

Leduc, S., Lundgren J., Franklin O., andDotzauer, E. (2010) Location of a biomass basedmethanol production plant: a dynamic problem in northern Sweden. ApplEnergy 87(1):68–75.

Marouli, A. Z., andMaroulis, Z. B. (2005) Cost data analysis for the food industry. Journal of Food Engineering. 67:289–99.

Nigeria Federal Ministry of Power (2013) Nigeria renewable energy master plan and FIT mechanism. Presented by Engr. Adebisi on 2nd Edition of the ECOWAS Renewable Energy Investment and Business Forum Accra, Ghana

Pantaleo, A., Bernardo D., andNilay, S. (2013) Assessment of optimal size of anaerobic co-digestion plants: An application to cattle farms in the province of Bari (Italy). Renewable and Sustainable Energy Reviews 20:57–70.

Puksec, T., and Duic, N (2012)Economic viability and geographic distribution of centralized biogas plants: case study Croatia. Clean Techn Environ Policy.

Sotirios, K., Ioannis, B., and Georgios, K. (2010) Development of an investment decision tool for biogas production fromagricultural waste. Renewable and Sustainable Energy Reviews 14:1273–1282.

Weiland, P. (2010) Biogas production: current state and perspectives. J Appl MicrobialBiotechnol; 85:49-60.