Economic Analysis of Electricity Generation from Chicken Manure by Plug Flow Anaerobic Digester and CSTR Anaerobic Digester

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Abstract

This research was aimed to study the investment efficiency in electricity generation from chicken manure by utilizing the systems of plug flow anaerobic digester and the completely stirred tank reactor (CSTR) anaerobic digester. In this research, the chicken manure from a chicken farm in Eastern Thailand is used as a model. The criteria applied in study included Net Present Value (NPV), Internal Rate of Return (IRR), Benefit/Cost Ratio (B/C Ratio), Payback Period (PB) and Unit Cost (UC). Both systems used chicken manure 90 tons per day to generate electricity by plug flow anaerobic digester which has the capacity to generate 600 kW of electricity while CSTR anaerobic digester had the capacity to generate 1,616 kW of electricity. Based on the measure of the electricity from renewable biogas and the project which runs for 20 years, it was found that electricity generation from chicken manure by plug flow anaerobic digester had an NPV rate of 70,138,270 Baht, 24.90% of IRR, 1.41 of B/C Ratio, 3 years and 8 months of Payback Period, and Unit Cost 2.73 Baht/unit while that from chicken manure by CSTR anaerobic digester had a NPV rate of 88,923,974 Baht, 10.60% of IRR, 1.09 of B/C Ratio, 7 years and 6 months of Payback Period, and Unit Cost 6.08 Baht/unit. In conclusion, both systems have the significant investment efficiency.

Keywords: Poultry manure; Biogas production; Electricity generation; Project feasibility; Thailand

Introduction

Rationale of the study

In recent years, Thailand has encountered the energy problems which causes the country to import the fossil fuels from foreign countries such as natural gas, coal, and oil for generating electricity in order to serve the steadily increasing demand for the growing industrial sector. Consequently, the Ministry of Energy (Thailand) has prepared a plan to develop renewable energy and alternative energy at 25% in 10 years (2012 - 2021) so as to reduce the energy import from foreign countries and to address the global warming. The plan typically focuses on energy security for the country, which biogas is one of the important targets for the promising energy source (DEDE, 2014). Hence, the government encourages people to take biogas as a fuel source for generating electricity which was already approved in principle of the purchase of electricity from renewable energy adder systems to be Feed–in Tariff (FiT) system. The electricity generation from biogas project supports Very Small Power Producers (VSPP) which has caused the biogas energy project smaller than 10 MW in 2015 for 20 years (NEPC, 2015).

Table 1 Potential of biogas production from wastewater and livestock manure from the ranch of Thailand in year 2014 (DEDE, 2014)

Ranch	Amount (farm)	Potential of biogas production (106 Cubic meter year-1)
Chicken farm	6,281	336.82
Cow/Buffalo farm	5,617	245.50
Duck farm	168	8.41
Sheep/Goat farm	46	0.10
Swine farm	2,541	288.78

Biogas is a renewable energy made by microbial fermentation of waste in anaerobic condition. These wastes include waste from cattle, pigs, or poultry wastes from a wide variety of agricultural products of Thai agricultural sector. Instead of disposing these wastes to unapproved disposal locations, which causes the environmental pollutants to human and creatures. The waste can also be used as the efficient fuel, thus help reduce the cost for water treatment by aeration technologies (ERDI - Nakornping, 2015).

Table 1 shows the potential of biogas production from wastewater and livestock manure from the ranch of Thailand in year 2014. At first glance, it can be seen that chicken farms has the most capability to produce the natural gas (about 336.82 million cubic meters per year) compared with the other livestock farms. The wastes from poultry farms can be transformed into biogas before using as an alternative energy forms such as direct heat combustion, fuel in propulsion machinery, and that for generating electricity which can reduce the usage of fossil fuels (DEDE, 2014).

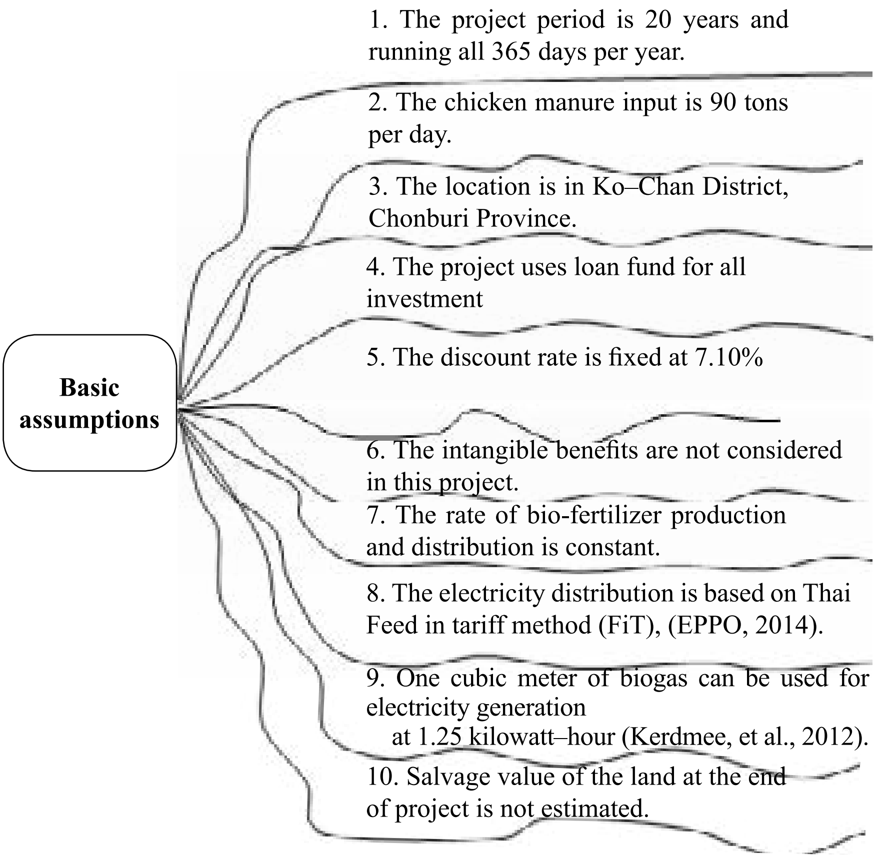


Figure 1 Basic assumptions of the project

Therefore, this research was aimed to conduct the feasibility study of electricity generation from chicken manure based on economic aspects by plug flow anaerobic digester and completely stirred tank reactor (CSTR) anaerobic digester. Also, this research was to examine the economic value from Net Present Value (NPV), Internal Rate of Return (IRR), Benefit/Cost Ratio (B/C Ratio), Payback Period (PB) and Sensitivity Analysis of project by utilizing chicken manure from a chicken farm in Eastern Thailand with project which runs for 20 years as well as to follow the Thai government policy of renewable energy adder systems. The basic assumptions of the project can be seen in Figure 1.

Research Methodology and Theoretical Background

The comparison on electricity generation project from chicken manure with plug flow anaerobic digester and CSTR anaerobic digester are planned to construct in Ko - Chan District of Chonburi Province, latitude 13° 25′ 0 North and longitude 101° 20′ 6.1 East, which the chicken manure is transported from the selected chicken farm in Sichang District of Chonburi Province with quantity of 90 tons per day.

The Chicken Manure

The layer chicken is one of the important industries in Thailand due to the rising of consumer popularity. However, the main problem for the layer chicken industry is the chicken waste such as layer chicken manure and wastewater from the slaughterhouse which causes the environmental harm, e.g., offensive odours, etc. Presently, the layer chicken manure is used for fertilizer production due to its significant amount of nutrients, which can be used in both fresh and dry layer chicken manures by sprinkle or sowing into the desired area. The chicken manure can also be used as a fuel by either direct combustion technologies or a high quality source for biogas production. The heating value of the chicken manure is in the range of 18,000 - 20,000 kJ/kg on dry and recognized as ash - free basis, compared to the low ranked coal (Yamban, 2011; Callaghan, et. al., 2002; Gelegenis et al., 2007).

Biogas and properties of biogas

Biogas is a gas resulting from the decomposition of organic matter by anaerobic bacteria in anaerobic conditions, which is basically composed by methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), which contains approximately 60 to 70% of methane (CH_4), 30 to 40% of carbon dioxide (CO_2), less than 500 parts per air one million parts (ppm) of hydrogen sulfide (H_2S). After passing the gas cleaning process, if it contains 65% of methane, the biogas will has lower heating value about 21.5 MJ/m^3. The quantity of biogas depends on the quantity of organic substances contained in the wastewater. Normally, the anaerobic decomposition process can reduce approximately 70% of Chemical Oxygen Demand (COD), which COD reduction of each kilogram can actually produce methane approximate 0.32 cubic meters (Koumphonphakdi, 2014). As for property of biogas shown in table 2, it can be seen that the energy value of biogas depends on the proportion (%) of methane contained in biogas. The biogas 1 cubic meter has heating value be equivalent or compensate to fuel energy from other sources, such as firewood, charcoal, oil, liquefied petroleum gas, and electricity as listed the table 3.

Table 2 Properties of biogas, (DEDE, 2014)

Properties of biogas	**Value**
Heating Value	21.5 MJ/m3 (refer at CH_4 60%)
Flames Speed	25 cm/s
Air to fuel ratio for combustion in theory (A/F)	6.19 m^3-air/m^3-gas
Combustion temperature in the air	650 °C
Ignition temperature of CH_4	600 °C
Heat capacity (Cp)	1.6 kJ/m^3-°C
Density	1.15 kg/m^3

Table 3 Heating value be equivalent or compensate to fuel energy from biogas 1 cubic meter (Yamban, 2011; Li et al., 2014)

Type of fuel	**The energy equivalent**
Liquefied petroleum gas (LPG)	0.47 kg
Gasoline	0.67 l
Diesel fuel	0.60 l
Fuel oil	0.55 l
Charcoal	1.50 kg
Electricity	1.2–2.0 kW-h

The Biogas Production from Layer Chicken Manure

Chicken manure has the potential to be used as raw material in the biogas production by decomposition process of anaerobic organic substance, which consists of 50 to 70% of methane, 30 to 40% carbon dioxide while the rest refers to other gases.

Additionally, regarded as one of the important factors, the affect of creation of methane as carbon to nitrogen ratio (C/N), which C/N ratio in the range of 20 to 30 (Deublein and Steinhauser, 2008; Wilkie, 2000) is considered to be appropriate for fermentation in anaerobic conditions. If C/N ratio is too high, nitrogen is applied rapidly by methanogenic bacteria in order to obtain the desired protein and inhibits the reaction with the remaining carbon in the raw material resulted in low gas production rate. On the other hand, if the C/N ratio is too low, nitrogen is released and retained in the form of ammonia (NH_4) which leads to the increasing of Potential of Hydrogen ion (pH), when pH is higher than 8.5 that it affects to be toxic to methanogenic bacteria and also results in the low gas production rate. As a result, the substance with high C/N ratio can be fermented with low C/N ratio in order to optimize the average ratio such as the case study in China which stated that the rice straw is used at the bottom of the fermenter covered by the waste from the toilets. This is similar to the research in Nepal which elephant manure is mixed with human manure in order to gain the suitable C/N ratio for biogas production (Yamban, 2011; Callaghan, et. al., 2002; Gelegenis et al., 2007).

Anaerobic Fermentation System and Information of Electricity Production.

Plug Flow Anaerobic Digester (Plug Flow)

Plug flow anaerobic digestion is an anaerobic treatment system that is typically used in animal farms. The concrete pond is characterized by a forced flow of wastewater as plug flow. On the top of the fermenter, the PVC or HDPE plastic dome is installed to retain the biogas while the fermenter is installed inside with pipeline to collect the biogas to generate electricity As illustrated in Figure 2, it can be seen that plug flow digester has functioned to decompose an organic substance in wastewater and separate the concentrated and transparent waste from each other. Additionally, the concentrated waste is fermented in small digester for 30 days (Nelson and Lamb, 2002) in order to change the organic substance in wastewater into organic acid and biogas by anaerobic bacteria. The result of the decomposition of organic substance causes wastewater with the COD drops by about 70 - 80%. Prior to run the system, the digester has to pull through the sewage sludge that it is decomposed completely approximately 1% of digester volume in order to prevent the over-accumulating sludge in the system, which the pumped out sludge is divided into two parts. The first part is that the sludge is dried out in sand bed filter while another is recycled to back into the wastewater collection pond in order to increase the amount of bacteria and mix bacterium with wastewater to make decomposition faster. Furthermore, the Biogas volume of plug flow anaerobic digester can be calculated as Eq. (1) (Koumphonphakdi, 2014). The layout of the electricity generation project from chicken manure with the plug flow anaerobic digester is also shown in Figure 3

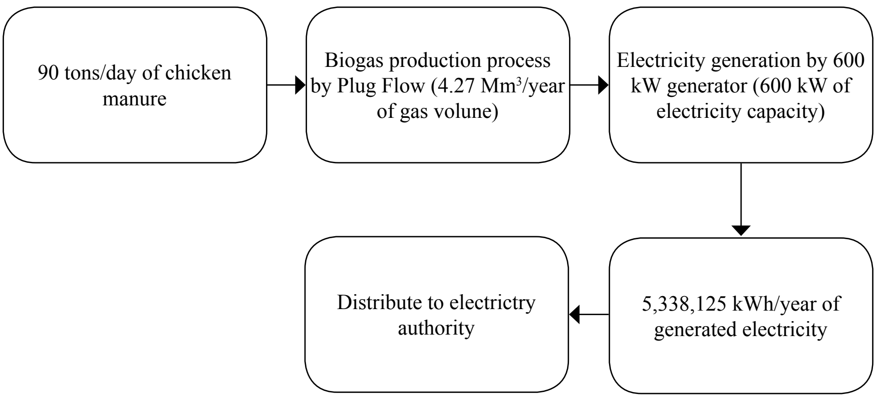


Figure 2 Block flow diagram of the electricity production of plug flow anaerobic digestion

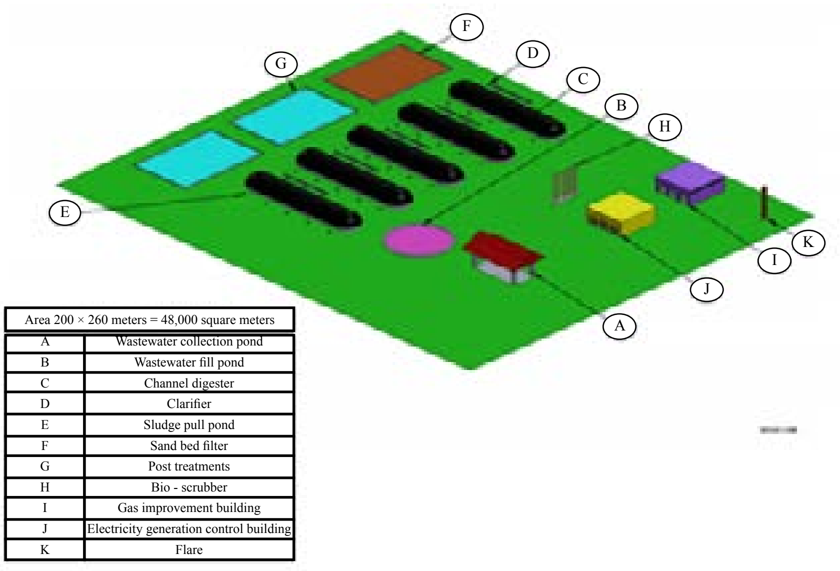


Figure 3 Layout of the electricity generation project from chicken manure with the plug flow anaerobic digester

Biogas from poultry manure = amount of used chicken manure per day (ton) × rate of biogas production (m^3/ton) (1)

where the rate of biogas production of chicken manure is 130 m^3/ton

Since this study contributes to 90 tons per day of chicken manure, it can produce biogas 11,700 m^3/day while biogas 1 cubic meter can compensate 1.25 kilowatt - hour of electric energy (Kerdmee, et al., 2012), which can generate electricity 5,338,125 kWh/year.

The quantity of fertilizer from plug flow anaerobic digester can be calculated as Eq. (2), (ERDI - Nakornping, 2015).

$$\text{Quantity of fertilizer occurs} = \frac{\text{amount of chicken} \times \text{weight of chicken} \times 0.45}{500} \quad (2)$$

where rate of bio–fertilizer distribution is 1,800 Baht/ton.

Completely Stirred Tank Reactor (CSTR) Anaerobic Digester (CSTR)

Electricity generation by completely stirred tank reactor (CSTR) anaerobic digestion is a process to make chicken manure as a biogas. The system begins with the wastewater from the process and the raw materials used in the fermentation are trasnferred into the inside of reactor directly and mized with impellers, such as screw paddle or gas diffusion in order to increase the mixing rate between the microorganisms and nutrients in the reactor (Tauseef et al., 2013; O'Flaherty et al., 2009). This can also improve the decomposition performance of organic substance in wastewater within the retention time (HRT) of 30 days (Wilkie, 2005; Rico et al., 2011). When the reaction is processed within the tank, biogas is produced before transferring the gas to generate electricity as shown in Figure 4. The majority of the electricity is sold to industrial users, while some is delivered back to the CSTR system. After the biogas is produced, the waste is transferred to the storage ponds for the wastewater treatment process and disposed to the enviromental whereas the sludge from the system will be sent to the sludge landfill site in order to convert them into organic fertilizer (Tachantuek, 2013). The layout of the electricity generation project from chicken manure with the plug flow anaerobic digester is shown in Figure 5.

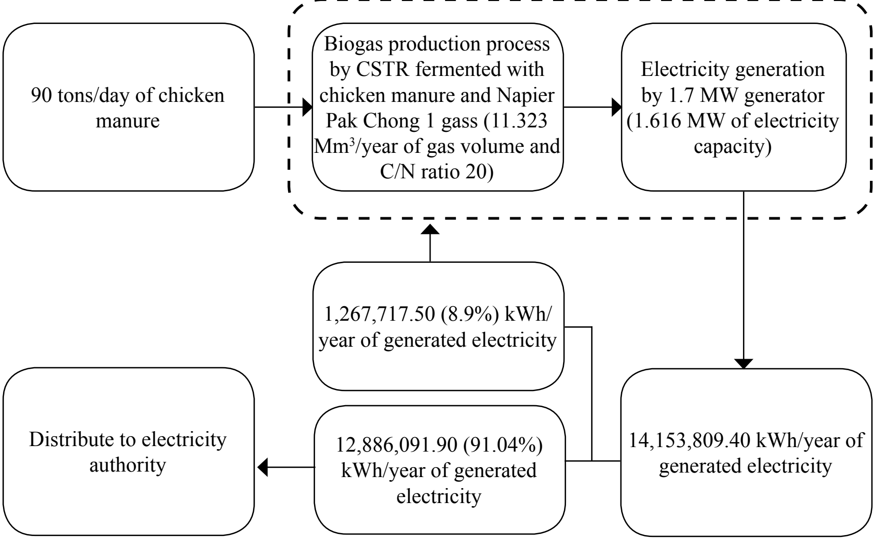


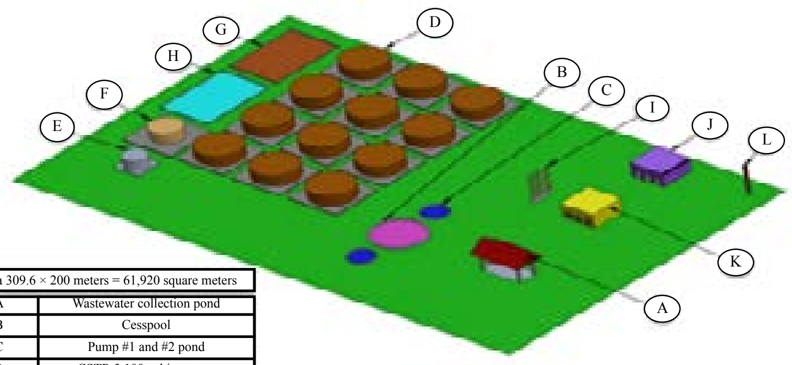
Figure 4 Block flow diagram of the electricity production of CSTR anaerobic digestion

From previous research, it was found that a chicken generates the amount of chicken manure equal to 0.1 kg (Metcalf, 2004; Batzias et al., 2005). When the chicken manure composes 90 tons per day with napier Pak Chong 1 grass (Xie et al., 2011; Liubarskij et al., 2006) to generate electricity by (CSTR) anaerobic digestion, the system will provide regular capacity for the annual demand. The Total volume of biogas (m^3) − volume of biogas from Napier Pak Chong 1 grass and volume of biogas from chicken manure − can be calculated as equation (3), (4) and (5), respectively (Tachantuek, 2013).

Total volume of biogas (m^3) = Volume of biogas from napier Pak Chong 1 grass + Volume of biogas from chicken manure (3)

Volume of biogas from napier Pak Chong 1 grass = amounth of used napier Pak Chong 1 grass per day x rate of biogas production of napier Pak Chong 1 grass (4)

Volume of biogas from chicken manure = Quantity of used chicken manure per day x rate of biogas production of chicken manure (5)



Area 309.6 × 200 meters = 61,920 square meters	
A	Wastewater collection pond
B	Cesspool
C	Pump #1 and #2 pond
D	CSTR 3,100 cubic meters
E	CSTR 1,500 cubic meters
F	Sludge pull pond
G	Sand bed filter
H	Post treatments
I	Bio - scrubber
J	Electricity generation control building
K	Flare

Figure 5 Layout shows the electricity generation project from chicken manure with CSTR anaerobic digester

Referring to the equation, the rate of biogas production of napier Pak Chong 1 grass is equivalent to 190 m^3/ton whereas rate of biogas production of chicken manure is equivalent to 130 m^3/ton (Tachantuek, 2013). In addition, sinne the amount 90 tons per day of chicken manure can produce biogas 31,022.05 m^3/day, the produced biogas is 11,323,212.5 m^3/year, which can also be calculated the amount of generated electricity as equation (6), (Tachantuek, 2013).

$$\text{Amount of generated electricity (kWh/year)} = \text{amount of produced biogas } (m^3/\text{year}) \times \text{replacement rate } (\text{kWh}/m^3 \text{ biogas}) \quad (6)$$

The replacement rate is equal to 1.25 kWh/m^3 biogas (Kerdmee, et al., 2012).

Biological sludge of (CSTR) anaerobic digestion can be accounted as 20% for the amount of napier Pak Chong 1 grass while 20% for the amount of chicken manure can calculate the amount of biological sludge from the equation (7) as follows (Tachantuek, 2013):

$$\text{Biological sludge} = 0.2\,(\text{amount of used chicken manure per day} + \text{amount of used napier Pak Chong 1 grass per day}) \quad (7)$$

where rate of bio–fertilizer distribution is 1,800 Baht/ton.

Economics Analysis

From the study of economic analysis of electricity generation from chicken manure by plug flow anaerobic digester and CSTR anaerobic digester, the investment costs, the operation costs, and the revenue from the project have been considered to cover the economic aspects as follows (Tongply, 2010; Wresta et al., 2015);

1. Net Present Value (NPV) is the difference between the present value of cash inflow and the present value of cash outflow. NPV is used in capital budgeting to analyze the profitability of a projected investment or project. Normally NPV must be higher than zero. The NPV can be calculated as equations (8).

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} \qquad (8)$$

NPV = net present value

Bt = Benefit of the project in the t

Ct = Cost of the project in the t

t = year of the project t = 1,2,...,n

n = Total period of the project (year)

r = Discounting rate = the average rate of return or minimum

2. Internal Rate Return (IRR) is the return on investment throughout the project period in percentage or discounting rate that net present value becomes zero or a rate that return and cost discount to equal present value. This rate is the rate of investment capabilities to cover the investments cost, which can be calculated as equation (9).

$$IRR = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \left[\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}\right] + C_0 = 0 \qquad (9)$$

IRR = Internal Rate Return

B_t = Benefit of the project in the t

C_t = Cost of the project in the t

C_0 = The cost of initial investment

t = year of the project t = 1,2,...,n

n = Total period of the project (year)

r = Discounting rate = The average rate of return or minimum

3. Benefit Cost Ratio (B/C Ratio) is the value of present value of benefit divided by present value of cost throughout the duration of the project period, which can be calculated as equations (10).

$$B/C\ ratio = \frac{\sum_{t=0}^{n} B_t (1+r)^{-t}}{\sum_{t=0}^{n} C_t (1+r)^{-t}} \qquad (10)$$

B_t = Benefit of the project in the t

C_t = Cost of the project in the t

t = year of the project t = 1,2,...,n

n = Total period of the project (year)

r = Discounting rate = The average rate of return or minimum

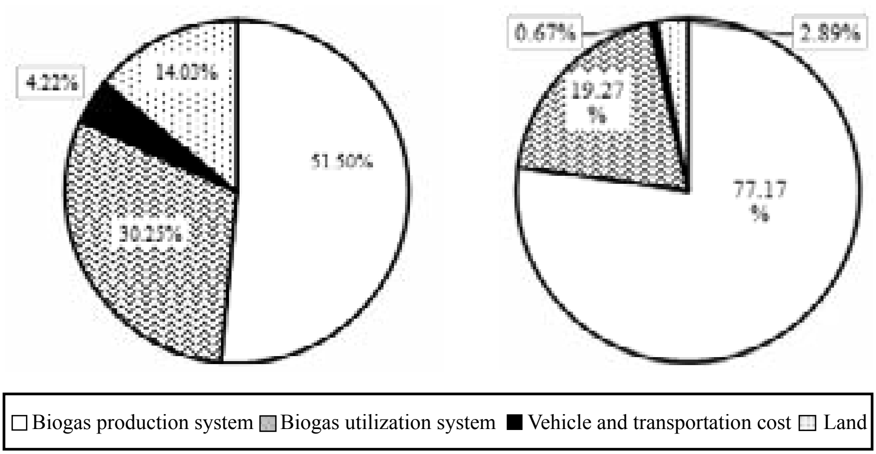
The level of the decision–making criteria is acceptable when BCR is higher than 1 which indicates that the project is cost - effective in the investment.

4. Payback Period is the number of years in operation that makes the value of the investment is equal to the value of the return on net cash deposits. On the other hand, it can be said that the payback period is the number of years in the making of profitability each year and has a value equal to the number of original investment, which can be calculated as equation (11).

$$\text{Payback Period} = \frac{\text{The initial investment project}}{\text{The net income per year}} \quad (11)$$

5. Sensitivity Analysis is the study in the case that the project does not conform to the expected at a variety of factors changes that affects the cost and revenue of the project. This process really helps them make better decisions in the establishment of the project.

(a) (b)



Results and Discussion

Project Investment Analysis

To estimate the investment for the project of both anaerobic digester systems the biogas production system, the biogas utilization system (electricity generator system), the vehicle and transportation cost to deliver chicken manure and the land for the project have been considered in the calculation. According to the analysis, it was found that plug flow anaerobic digester has total investment cost of 55,608,452 Baht while CSTR anaerobic digester has total investment cost of 348,398,817 Baht. This indicates that both anaerobic digester systems the biogas production system have a great impact on the investment cost, the detail for the cost for plug flow anaerobic digester, and CSTR anaerobic digester are shown in Figure 6a and Figure 6b, respectively.

Revenues and Expenses for the Project

According to the renewable energy adder systems policy of Thai government as mentioned above, both anaerobic digester systems were calculated based on the project period of 20 years with the interest rate for loan of 7.10% at the level of discount rate 7.10%.

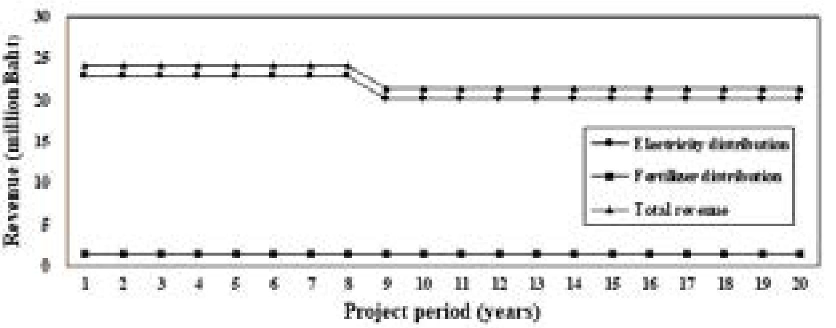


Figure 7 Revenue of electric power generation project by Plug Flow anaerobic digester

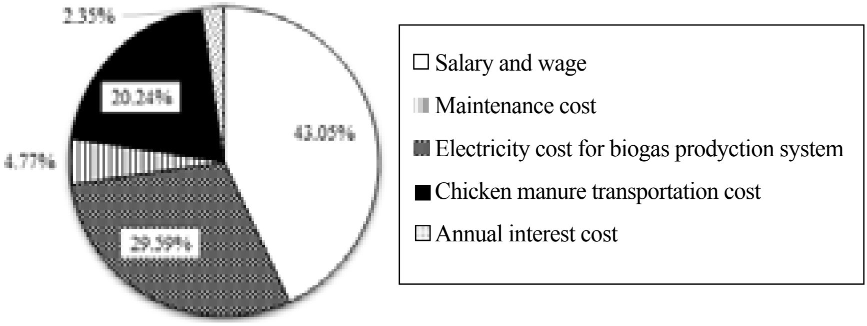


Figure 8 Operating costs proportion of electric power generation from poultry by Plug Flow anaerobic digester

Plug Flow Anaerobic Digester

Figure 7 shows the estimated revenues of electric power generation project by plug flow anaerobic digester. As being seen, the income of the project mainly came from two major sources: electricity distribution and fertilizer distribution. The annual quantity of electricity generated from plug flow anaerobic digester is estimated at approximately 5,338,125 units, with the current Thai FiT fixed rate (FiTF) (EPPO, 2014) at 3.76 baht per unit for a period of 20 years and the premium FiT rate 0.50 Baht per unit for the first 8 years, and biogas which was used as the source of electricity production for the plants that are smaller than 10 MW. Referring to the revenue from major products in Figure 7, it is shown that the amount of fertilizer (by product) from electricity generation from plug flow anaerobic digester is fixed at 722.70 tons per year, causing the constant revenue in the 20 years period of this project as illustrated in Figure 7

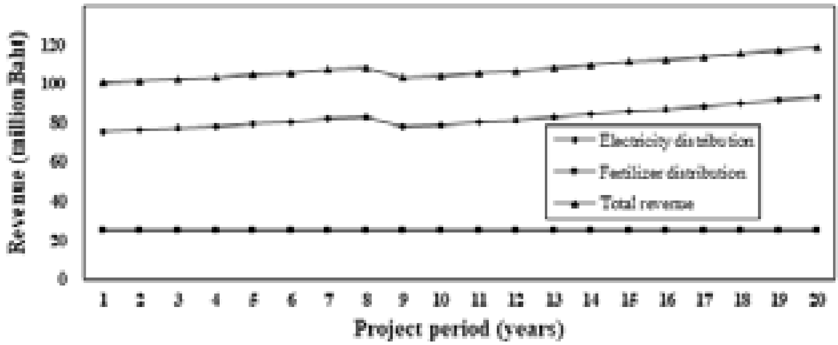


Figure 9 Revenue of electric power generation project by CSTR anaerobic digester

Figure 8 depicts the estimated expenses of electric power generation project by plug flow anaerobic digester. The total amount of annual expense in this project is 8,416,491 Baht. Definitely, the salary and wage of employers, the maintenance cost for electricity production equipment, electricity cost for biogas production system, the chicken manure transportation cost, and the annual interest rate have been taken into account. In each year, the plant has the highest expense on the salary and wage of employer followed by the maintenance cost for electricity production equipment and the chicken manure transportation cost. On the other hand, the annual interest rate and electricity cost for biogas production system has less impact to the expense for this project compared with the other expenses.

CSTR Anaerobic Digester

Figure 9 shows the estimate revenues of electric power generation project by CSTR anaerobic digester. Similar to the revenues of electric power generation project by plug flow anaerobic digester, the income of the project mainly came from two major sources: electricity distribution and fertilizer distribution. The amount of fertilizer (by product) from electricity generation from plug flow anaerobic digester is fixed at 13,994.10 tons per year, which causes the constant revenue in this project for 20 years. However, the revenue from the electricity distribution from CSTR anaerobic digester is quite different from the plug flow anaerobic digester due to CSTR anaerobic digester and the fact that it used the biomass (napier Pak Chong 1 grass). Moreover, the electricity distribution revenue from the total quantity of electricity production of 14,153,809.40 units per year is calculated based on the FiT variable (FiTv) of Thai government policy (EPPO, 2014). The FiTv rate is 2.79 Baht per unit plus variable FiT rate at 2.55 Baht per unit that vary with 3% inflation rate for 20 years including the premium FiT rate of 0.50 Baht per unit for the first 8 years as Figure 9.

Figure 10 illustrates the estimate expenses of electric power generation project by CSTR anaerobic digester. The total annual amount of expense for this project is 52,164,935 Baht, which is quite high in comparison to the plug flow anaerobic digester. It also includes the raw material cost (from chicken manure and napier Pak Chong 1 grass), the salary and wage of employers, the maintenance cost for electricity production equipment, operating cost (such as water consumption cost), chemical analysis cost (for checking the property mixer in the reactor), the chicken manure transportation cost, and the annual interest cost. As being seen from the graph, this system requires the substantial amount of raw material which leads to the highest annual expense at 71.11%. Note that the CSTR anaerobic digester does not have to purchase the electricity due to some parts of electricity can be delivered back to the CSTR system, as shown in Figure 4.

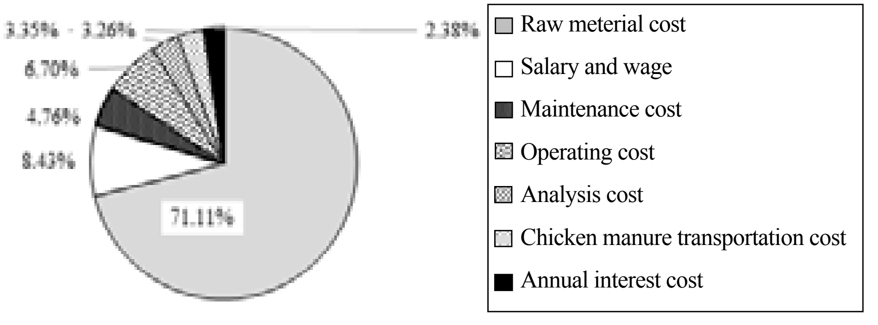


Figure 10 Operating costs proportion of electric power generation from poultry by CSTR anaerobic digester

Table 4 Financial analyses on electricity generation from chicken manure by plug flow anaerobic digester and CSTR anaerobic digester

Anaerobic Digester	Investment Cost (Baht)	Parameter			
		NPV	IRR	B/C	Payback Period
Plug Flow	55,608,452	70,138,269	24.90%	1.41	3 years and 8 months
CSTR	348,398,817	88,923,974	10.60%	1.09	7 years and 6 months

Economics Aspects of the Project

Table 4 shows the results of financial analysis on electricity generation from chicken manure by plug flow anaerobic digester and CSTR anaerobic digester. The investment cost for the plug flow system is quite lower than CSTR system for producing electricity from chicken manure at the input rate of 90 tons per day. However, CSTR anaerobic digester has higher NPV than plug flow anaerobic digester. As for the IRR, it becomes higher in the case of construction of the plug flow system, which resulted in the higher benefit to cost ratio.

According to the lower investment and better IRR, the payback period for plug flow anaerobic digester is shorter with only 3 years and 8 months compared with the CSTR which requires 7 years and 6 months. By considering all the results for economics aspects from the above analysis, the plug flow anaerobic digester is preferably used for producing electricity from chicken manure with the same input and same project period.

Sensitivity of the Project

Investments in electricity generation from chicken litter by the systems of plug flow anaerobic digester and CSTR anaerobic digester are the long term investments. Therefore, investors probably face some risks and uncertainties such as the changing cost or benefit from the production processes which significantly affect the project. In order to mitigate risk, the sensitivity analysis can be used to improve the better decision making based on certain calculations. In this project, the main parameters that affect the implementation of project includes the changing electricity purchase rate, investment cost, and annual interest rate. The sensitivity analysis for both of plug flow anaerobic digester and CSTR anaerobic digester is shown as follows.

Plug flow Anaerobic Digester

Figure 11 shows the sensitivity analysis for plug flow anaerobic digester, which the electricity purchase rate from the government, investment cost, and annual interest rate significantly affect the decision making parameters (NPV, IRR, and B/C ratio) on investment of the project. According to research findings, the factor that has the greatest influence on the decision making for project investment is electricity purchase rate. The increases of electricity purchase rate resulted in the increasing of all parameters. Similar to the electricity purchase rate, the project seems to be less attractive in investment when investment cost and annual interest rate increases. Within the range of the sensitivity from this study, the project can still be profitable.

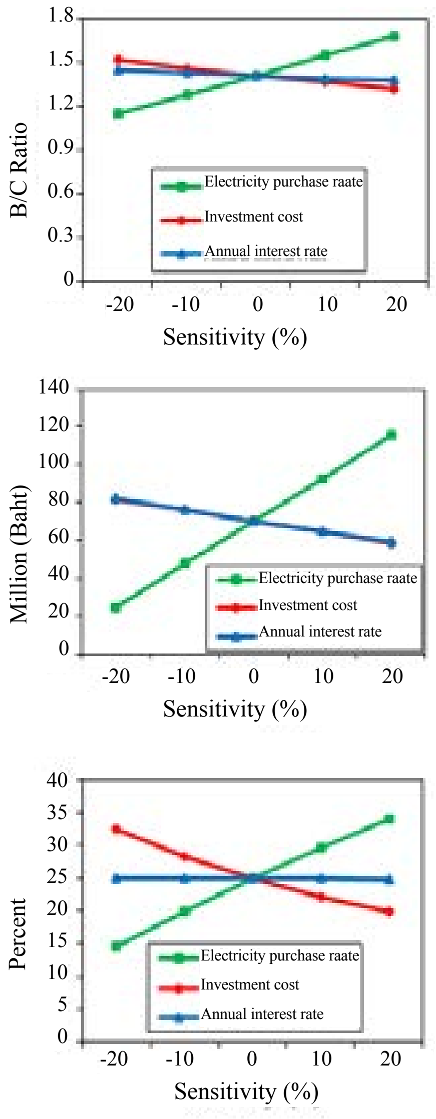


Figure 11 The sensitivity analysis for Plug Flow anaerobic digester a) NPV, b) IRR, and c) B/C ratio

CSTR Anaerobic Digester

Figure 12 shows the sensitivity analysis for CSTR anaerobic digester. Similar to the plug flow anaerobic digester, the electricity purchase rate is the most influential factor on the decision making for project investment. The increases of electricity purchase rate also results in the increasing of all parameters (NPV, IRR, and B/C ratio). Like the electricity purchase rate, when investment cost and annual interest rate increase, the project seems to be less attractive to invest but the project can still be profitable. However, when the electricity purchase rate changed to - 20%, he NPV of the project becomes negative; therefore, the electricity purchase rate can change to only maximum 15% from the project assumption. Otherwise the project has too high risk for investment.

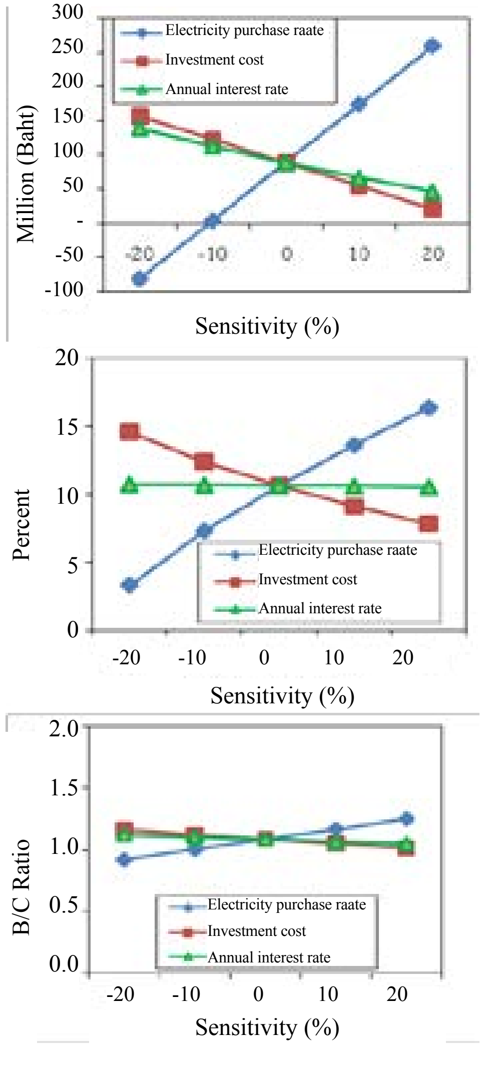


Figure 12 The sensitivity analysis for CSTR anaerobic digester a) NPV, b) IRR, and c) B/C ratio

Conclusions

From the study in economic value of investing in electricity generation from chicken manure by using the systems of plug flow anaerobic digester and CSTR anaerobic digester,it can be concluded that both systems have the possibilityand advantages in establishing a project to generate electricity. The results from sensitivity analysis of the project show thatwith the variable change the plug flow anaerobic digester can still be profitable and project are worthwhile for an investment. However, for CSTR anaerobic digester, with some variable changes, especially when electricity purchase rate decreases by 20%, the project is not achievable and not worthwhile for investment in this business.

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