Energy Potential of Biogas Production from Animal Manure in the Lao People's Democratic Republic

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***Abstract*— *This paper presented a study of biogas production potential from animal manure in the Lao People Democratic Republic (Lao PDR). The data from four kinds of animal such as cow, buffalo, pig and chicken were surveyed and calculated in order to know the potential of biogas production. The feasibility study of biogas production from pig farm in a case study was also done in order to know the investment cost as the net present value (NPV), the internal rate of return (IRR), the payback period (PB) and the benefit cost ratio (B/C). From a study, it was found that the Lao P.D.R had 31,747,297 of all animals and the potential for biogas production was 807 million m^3/year, which can produce the electricity of 1,163 million kWh/year. The highest potential for biogas production are in Salavanh, Savannakhet and Champasak provinces, which had the potential to produce 162.96, 123.51, and 70.72 million m^3/year of biogas, respectively. In addition, from the feasibility study in a case study with 520 pigs, it was revealed that biogas production from pig manure was a high feasible project, which can produce biogas of 175.3 m^3/day or 245 kWh/day of electricity. The project cost is amount 174.70 million kip of investment for biogas production system. From the economic analysis of this study, it was found that the NPV was 144.77 million kip, the IRR was 22.96%, PB was 4.1 years and the B/C was 1.82. This project is suitable for investment and it can be a data base for set up the policy to promote the biogas production in the Lao PDR.*

***Keywords*— Energy potential, biogas, animal manure, feasibility study.**

1. INTRODUCTION

The Lao People's Democratic Republic (Lao P.D.R) has total population of 6.5 million people in year 2010, and the most of population about 80 percent were agriculture, especially rice farmer and rancher. Since the Lao P.D.R opened the country in 1986, it made the Lao P.D.R economic continuously grows up to now, and caused of energy consumption increasing. Although the Lao P.D.R is a country that can produce the power electricity from several large dams and sell the electricity to neighbor countries, there is a lack of domestic electrical energy at some time. Besides, the Lao government has the policy to increase an electrification rate up to 90 percent by 2020 [1], and has the policy to promote the use of renewable energy. However, the Lao P.D.R has insufficient information on the production of electricity from renewable energy sources, particularly the production of biogas from animal manure.

The objective of this work is to study an energy potential of biogas production from manure in the Lao People Democratic Republic (Lao P.D.R). The datum of four kinds of animals, consisting of cow, buffalo, pig and chicken were collected and investigated. Then, the biogas production potential will be calculated from animal manure. The case study of biogas production in pig farm will be studied to know the economic feasibility of biogas production project in Lao PDR.

Therefore, researchers are interested in study the potential of biogas production from animal manure to obtain the information and helpful guidelines for further alternative energy development in Lao PDR

2. RESEARCH METHOD

The research method was divided in to four main components, which are data collection, data analysis, economic analysis and data summary.

2.1 Data Collection

The data was collected from the Department of Livestock and Fisheries, Ministry of Agriculture and Forestry. The obtained information consists of

1) The number of animals and farm in nationwide, there are four kinds of animals consisting of cow, buffalo, pig and chicken.

2) The farm's location and name's farmer in the provinces.

In addition, the data for case study feasibility was also collected by interview with the staff working in the Animals Research Centre, the Pig and Poultry Breeding Station, Ministry of Agriculture and Forestry in Lao PDR.

2.2 Data Analysis

The data analysis was divided in two parts as follow:

1) In order to know the energy potential of biogas production. Four kind of animals manure such as cow, buffalo, pig and chicken were collected. The gathering of

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each manure has the ratio of 50%, 50%, 80% and 90%, respectively [2].

2) From the case study, the amount of pig was analyzed to find the feasibility of the biogas production project. Four financial analyses were used to study the project feasibility, there were the net present value (NPV), the internal rate of return (IRR), the payback period (PB) and the benefit cost ratio (B/C).

2.3 Economic Analysis

The economic analysis of this project was considered by the four economic parameters as follow [3].

1) Net Present Value: NPV

The NPV is the difference between the net present value of income and expenses over the life of the project. NPV is an indicator of net benefit of the project as the equation below:

$$NPV = PVB - PVC \quad (1)$$

where the PVB is the present value of benefit and PVC is the present value of cost. If the NPV is more than 0 (zero), the benefit of project is more than the project cost. The project is high feasible for investment.

2) Internal Rate of Return : IRR

The IRR is the return from the investment. IRR is a rate that makes the present value of revenue equal to the initial investment of the project. IRR can be calculated by:

$$\sum_{t=1}^{n} \frac{R_t}{(1+k)^t} = I \quad (2)$$

where the Rt is Bt - Ct, Bt and Ct are the benefit and cost in the time during the project, k is the return of the project (IRR) and I is the initial cost . If the IRR is more than the discount rate, it can be acceptable for the project. The project will be rejectable when the IRR is less than or equal to the discount rate.

3) Payback Period: PB

The payback period is the duration (number of years) when the return is equal to investment. The PB can be calculated by

$$PB = \text{Initial Cost} / \text{Net Revenue} \quad (3)$$

If the project can be returned by short time, it is acceptable for the project.

4) Benefit Cost ratio: B/C

The B/C is a comparison between the present value of the return and the current cost of the investment and expenses. B/C can be calculated by:

$$B/C = \left(\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}\right) / \left(\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}\right) \quad (4)$$

If the B/C is more than 1, that means the return of project will be worth. However, if the value is less than 1, that means the returns from the project is not worth for investment.

2.4 Data Summary

To obtain the information in order to use and set up the policy for alternative energy promotion in Lao PDR, the energy production potential was divided by provinces and types of animal. The data from feasibility study was also summarized in this part.

3. THE ENERGY POTENTIAL OF BIOGAS PRODUCTION

From the data collection of animal farms, the Lao P.D.R has 17 provinces that having animal farms. The number of animal from four kinds of animals: cow, buffalo, pig and chicken were shown in Table 1.

Table 1. The amount of animals in Lao PDR [4] (1,000 unit)

Provinces	Cow	Buffalo	Pig	Chicken	Total
Phongsaly	23	37	170	554	785
Louang namtha	20	17	88	458	584
Oudomxay	49	44	140	1,476	1,703
Bokeo	54	24	62	402	542
Louang phabang	79	63	179	1,869	2,190
Huaphan	72	44	244	332	692
Xayabuly	117	48	133	2,205	2,504
Vientiane capital	118	18	137	1,319	1,593
Xieng khouang	167	51	66	604	889
Viengchanh	167	71	103	1,541	1,884
Boli khamxay	58	45	66	727	897
Khammoun	94	62	75	507	739
Savannakhet	398	290	281	2,882	3,852
Salavanh	149	133	794	5,329	6,405
Sekong	25	28	129	611	794
Champasak	140	133	180	4,736	5,189
Attapeu	18	42	31	413	505
Total	1,748	1,150	2,878	25,965	31,747

From the Table 1, it was found that the Lao PDR has the total number of 31.75 million animals. The most animal portion was chicken, 25.97 million animals or 81.7% of the total numbers. The next lower portions were pig, cow and buffalo respectively.

Moreover, from the calculation of the energy potential

for biogas production from animal manure, the ability of manure gathering was considered. The percentage of the manure gathering from the total manure of cow, buffalo, pig and chicken were 50%, 50%, 80% and 90%, respectively [3]. The energy potential of biogas production from animal manure was shown in Table 2.

Table 2. The energy potential of biogas production

List	Cow	Buffalo	Pig	Chicken	Total
Amount of animal (million)	1.75	1.12	2.88	25.97	31.75
Weight of manure (kg/animal)	5.44	8	1.47	0.03	
Weight of manure (million-kg/day)	9.5	9.2	4.2	0.76	23.6
Percentage can be gathered (%)	50	50	80	90	
Weight of animal manure production. (million-kg/day)	4.7	4.6	3.3	0.7	13.3
Volume of biogas can be produced (liter/kg)	90	90	340	310	
Volume of biogas production. (million-liter/day)	428	415	1,149	217	2,210
Volume of biogas production. (million-m^3/year)	156	152	419	79	807

From Table 2, it was found that the total of energy from biogas production in the Lao P.D.R was 807 million m^3/year. This was assumed to be able to produce electricity about 1,163 million kWh (1 m^3 of biogas is equivalent to 1.4 kWh). [3] In other case, 1 m^3 of biogas is equivalent to more than 1.4 kWh, which depends on the efficiency of the generator.

The potential of biogas production which was pig's manure has the highest 419 million m^3/year or 52% of the total energy potential. The next highest potential was the manure of cow, buffalo and chicken which had a portion of 19%, 19%, and 11%, respectively. The percentage of volume of biogas was shown in Figure 1.

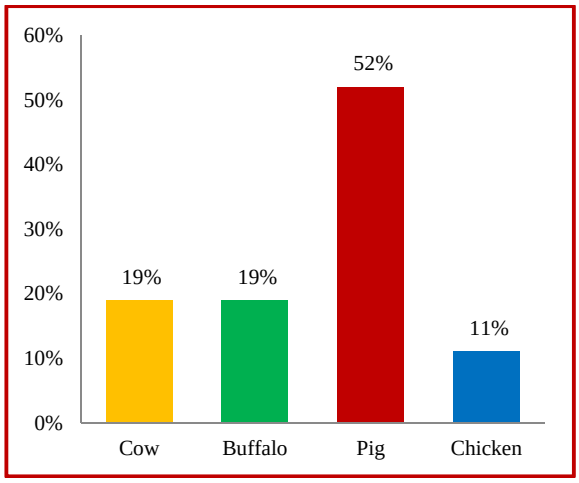

Fig. 1. The percentage of volume of biogas production.

Furthermore, consider the energy potential of biogas production segmented by provinces, it was found that the potential area was divided in to 3 groups as shown in Figure 2.

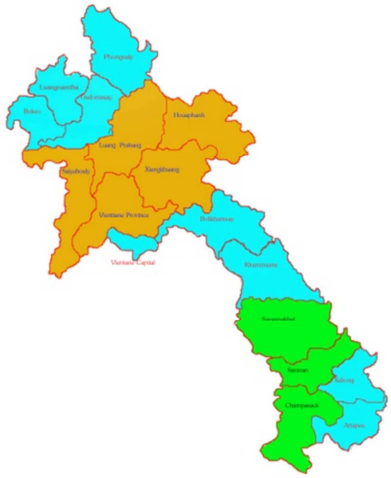

Fig. 2. Map of energy potential of Lao P.D.R.

From Figure 2, three groups were the high potential provinces (Green), the middle potential provinces (Yellow), and low potential provinces (Blue), respectively. The high potential group has an energy potential more than 70 million m^3/year of biogas production. The provinces in this group were Savannakhet, Salavanh and Champasak provinces. The middle potential group has an energy potential of biogas production between 37 to 70 million m^3/year. The low potential group has an energy potential less than 37 million m^3/year of biogas production. The average biogas product for each level was shown in Table 3.

Table 3. The average of energy potential in Lao P.D.R

Rank	Provinces	Amount of animal (10^3 unit)	Biogas production (m^3/year)	Average (m^3/year)
High potential	Savannakhet	3,852	123.51	119.06
	Salavanh	6,405	162.96	
	Champasak	5,189	70.72	
Middle potential	Huaphan	692	48.85	44.03
	Louang phabang	692	47.18	
	Xayabuly	2,504	44.20	
	Vientiane capital	1,593	42.92	
	Xieng khouang	889	37.00	
Low potential	Phongsaly	785	33.51	25.47
	Louang namtha	584	18.36	
	Oudomxay	1,703	34.17	
	Bokeo	542	18.28	
	Viengchanh	1,884	33.19	
	Boli khamxay	897	23.07	
	Khammoun	739	29.07	
	Sekong	794	26.70	
	Attapeu	505	12.95	

4. CASE STUDY

A feasibility of biogas production project was studied by using economic analysis. The pig farm with 520 pigs were selected to use in this study. The basic data of the case study were shown below

1) The farm has the average of electrical consumption of 3,453 kWh/month or 2,689,822 kip/month (1 kWh equivalent to 799 kip)

2) The pig are 520 pigs, which consists of male pig, sow and piglet with the number of 20, 100 and 400, respectively.

4.1 Estimation of Potential Biogas in the Farm

The biogas production potential was calculated and shown in Table 4.

From table 4, it was found that there was 644.60 kg/day and the biogas potential can be produced 175.33m^3/day. This can be able to produce electricity about 245kWh/day.

Table 4. The biogas production potential in the farm

List	Male pig	Sow	Piglet	Total
Amount of pig	20	100	400	31.75
Weight of manure (kg/animal/day)	1.83	1.40	1.17	
Weight of manure (kg/day)	36.60	140.00	468.00	644.60
Percentage can be gathered (%)	80	80	80	
Weight of animal manure production. (kg/day)	29.28	112	374.4	515.68
Volume of biogas can be produced (liter/kg)	340	340	340	
Volume of biogas production. (liter/day)	9,955	38,080	127,296	175,33

4.2 Economic Analysis of the Project

The economic analysis was done and based on the following conditions;

i) Project period is 15 years.

ii) Discount rate is 10%.

iii) Operation days are 365 days.

iv) Technology of Biogas is MC-UASB (Medium Farm Channel Up flow Anaerobic Sludge Blanket) is used [5].

v) The size of biogas system is selected to be 200 m^3.

The project cost for construction of biogas system was shown in Table 5, and the operating cost and return from biogas system were shown in Table 6 and Table 7, respectively.

Table 5. The project cost of building biogas systems.

Investment cost	Amount (kip)
1. Biogas production system	56,348,750
2. Power house	10,355,000
3. Power generator (15 kW)	53,000,000
4. Consultant	53,000,000
5. Transportation	2,000,000
Total	174,703,750

Table 6. The operation and management cost of biogas production system (O&M).

O&M cost	Amount/year (kip)
1. Labour	7,512,000
2. Maintenance of generator	17,490,000
3. Electricity price	3,600,000
Total	28,602,000

Table 7. The returns from biogas system

Volume of biogas production. (m^3/day)	175.33
1m^3 of biogas equivalent to 1.4 kWh	1.4
Energy power (kWh/day)	245
Electricity price (kip/kWh)	779
Total of Amount/year (kip)	70,605,168

From table 5 to table 7, the total project cost for investment of biogas production system was 174,703,750 kip (Lao currency), the operation and management cost was 28,602,000 kip/year, and the returns from biogas system was 70,605,168 kip/year. Thus the net revenue of this project was calculated as below:

Net Revenue = Revenue - Payment (O&M)

= 70,605,168 - 28,602,000

Net Revenue = 42,003,173 kip/year.

4.3 Economic Calculation

The net present value (NPV) can be calculated from investment cost and the present value of benefit (PVB). The PVB means the conversion of all revenue of the project to the revenue in the present as the following the equation;

$$PVB = FV / (1+r)^n \quad (5)$$

$$= \frac{42,003,172}{(1+0.1)^1} + \ldots + \frac{42,003,172}{(1+0.1)^{15}}$$

PVB = 319,479,473 kip

From equation (1), NPV can be calculated by

NPV = PVB− PVC

NPV = 319,479,473 - 174,703,750

NPV = 144,775,723 kip

From the calculation, it was found that the NPV of the project during 15 years was 144,775,723 kip.

The internal rate of return (IRR) can be calculated from investment cost (I) and revenue of project (R) from equation (2) as follows:

$$\frac{42,003,172}{(1+k)^1} + \ldots + \frac{42,003,172}{(1+k)^{15}} = 174,703,750$$

k = 0.2296 or IRR = 22.96 %

From the calculation, it was found that the IRR of the project was 22.96%.

The payback period (PB) can be calculated from equation (3) as follow:

PB = Initial Cost / Net Revenue

PB = 174,703,750 / 42,003,172

PB = 4.16 years

The result has shown that the PB of the project was 4.16 years.

The benefit cost ratio (B/C) can be calculated with comparison the present value of benefit (PVB) and investment cost from equation (4) as follow:

$$B/C = \frac{319,479,473}{174,703,750} = 1.82$$

The result has shown that the B/C of the project was 1.82.

All results of financial analysis can be shown in Table 8.

Table 8. The result of economic analysis of the farm

NPV (kip)	IRR (%)	PB (year)	B/C (kip)
144,775,723	22.96	4.16	1.82

4. CONCLUSION

From the study, the results revealed that the Lao P.D.R has a potential of biogas production from animal manure of 807 million m^3/year or 1,163 million kWh. The result can give important data of biogas production potential to Lao P.D.R for encouraging and developing the alternative energy within the country.

Moreover, from the financial analysis of the case study, it was found that the net present value (NPV) at discount rate (10%) was 144,775,723. It has profit from the investment. The internal rate of return of the project (IRR) was 22.96%, which was more than the discount rate. The payback period was 4.1 years and the benefit cost ratio (BCR) was 1.82. The project of biogas production was acceptable and feasible to promote in Lao PDR.

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