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Article

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The economic value and satisfaction of substituting LPG in households by a biogas network: A case study of Bo Rae Subdistrict in Chai Nat Province Thailand

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Abstract

Economic value and satisfaction of substituting LPG by a biogas network in households of Bo Rae Subdistrict, Chai Nat Province, Thailand were investigated. This project was undertaken through collaboration between the Ministry of Energy and Phairat Farm. The Thai Government supported investment in the construction of biogas production and network piping systems for transporting biogas to households. Phairat Farm allocated an area of land to construct the biogas production system and provided support with the raw materials for biogas. These raw materials were pig manure and wastewater as by-products from pig farming. Income and expenses of a 15-year plan project were considered and analysed to assess the economic value using net present value (NPV), internal rate of return (IRR) and payback period (PB) in 3 case; (1) income came from payment for biogas by each household at a rate of 50 baht per month and selling dried sediments from the biogas production system, (2) income came from substituting LPG at price of 30 THB/kg and (3) income came from payment for biogas by each household, selling dried sediments, substituting LPG and selling carbon credit. Results showed that only the first case was not profitable because payback period over 15 year. Then, a biogas user satisfaction survey was also conducted using 136 questionnaires. The samples size was determined by Taro Yamane's equation to achieve 95% confidence level and $\pm 5\%$ uncertainty. Data were collected and analysed to measure satisfaction level in three aspects; (1) an analysis comprising management, usage, and maintenance of the biogas system, (2) environmental impact and (3) overall satisfaction level. Results showed that the samples were very satisfied with management, usage and maintenance of the biogas system. Income was only the main influential factors. For the environmental impact and overall satisfaction level, the samples were also very satisfied.

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Keywords: Economic value; Satisfaction; Biogas network; Biogas; Pig farm; Household

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1. Introduction

Nowadays, animal husbandry in Thailand has expanded significantly to meet the increasing demand for meat consumption. Many Thais prefer to consume pork. Rising consumption trends have resulted in pig farmers increasing both pigs and pig farm numbers. According to the Department of Livestock Development [1], there were 10,587,303 pigs in Thailand in 2018, and the number of pig increased by 3.88% from 2017. Manure and wastewater from the pig farms cause pollution which adversely impacts the ecosystem. Communities around the pig farms are affected by environmental pollution in the form of odour, wastewater and increased numbers of insects as carriers of various diseases. One solution to the problem is fermenting pig manure and wastewater in digester reactors to produce biogas. This will reduce the impact on the environment and also produce by-products in the form of biogas and good fertiliser from fermentation of the sewage. The biogas system is a suitable method that helps reduce the pollution problems mentioned above, while also producing a renewable form of energy for cooking within the household [2,3]. Biogas is produced by fermentation of organic matter via biological methods under anaerobic conditions. The components of biogas are 50%–70% methane (CH_4) and 30%–40% carbon dioxide (CO_2), with small amounts of other gases such as oxygen (O_2), hydrogen sulphide (H_2S), nitrogen (N_2) and vapour [4]. Thailand has been supporting biogas technology since the 1960s through government sectors. However, in the early days, biogas projects were unsuccessful because the constructed systems could not be operated profitably. Consequently, the Department of Agriculture Extension in association with Chiang Mai University and Deutsch Gesellschaft fur Technisch Zusammenarbeit (GTZ), conducted the Thai-German biogas promotion project using a fixed dome system for small animal farms. Since 1995, biogas technology has been widely utilised in medium and large-sized farms. Biogas technology has been extensively supported by the Energy Policy and Planning Office as the primary sector in financial, construction and research promotions in Thailand [5].

The data from the Department of Alternative Energy Development and Efficiency [6] showed that biogas production using pig manure corresponds to the Alternative Development Plan of Thailand (AEDP2015). Biogas is an interesting alternative energy that can be a fuel for cooking instead of liquid petroleum gas (LPG) in the household. Therefore, the Department of Alternative Energy Development and Efficiency, Ministry of Energy proposed the concept of utilising pig manure for biogas production via the biogas network project. This project involved collaboration between the Ministry of Energy and Phairat Farm. The Thai Government supported investment in the construction of biogas production and network piping systems for transporting biogas to households. Phairat Farm has raised approximately 2800 pigs per set (2 sets in 1 year) and allocated an area of land to construct the biogas production system and provided support with the raw materials for biogas. The biogas network project provides biogas as a replacement for LPG to nearby households of Bo Rae Subdistrict in Chai Nat Province, Thailand as showed in Fig. 1.

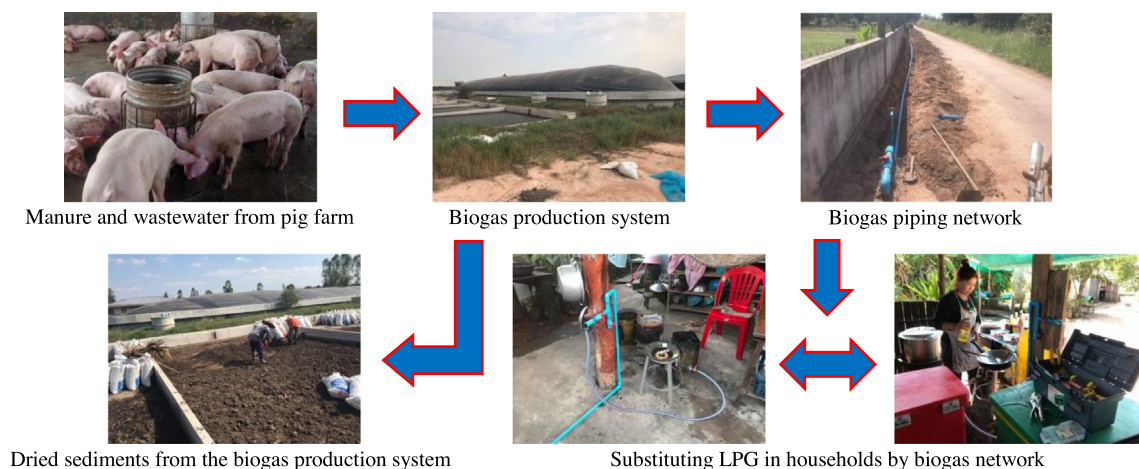


Fig. 1. Substituting LPG in households by a biogas network at Bo Rae Subdistrict.

Using biogas reduces the household energy cost and encourages community engagement with the pig farm. Here, the economic value and satisfaction of substituting LPG by a biogas network in households of Bo Rae

Subdistrict was investigated. Results will be useful to evaluate problems in biogas management, utilisation and system maintenance, as well as the feasibility of replacing LPG with biogas to improve environmental sustainability.

2. Material and methods

The biogas production system of the Biogas network project at Bo Rae Subdistrict in Chai Nat Province, Thailand was constructed as a channel type with a size of 1000 m³. The main pipe with for gas transmission was 4.362 km long and the branch pipe was 8.6 km long as illustrated by Fig. 2. The biogas was transported to 206 households as a replacement for LPG. The project expended an energy conservation fund of 6,650,000 THB [7]. Data were collected after the construction of the biogas production and gas transmission system complete. In order to analyses the suitability of the biogas network project, the equivalent energy analysis used a heating value according to reference data of Department of Alternative Energy Development and Efficiency, which stipulates that biogas has a heating value of 20.23 MJ/m³ and LPG (heat) has a heating value of 49.29 MJ/kg. LPG has an emission factor equal to 3.1133 kgCO_{2eq}/kg according to reference data of Thailand Greenhouse Gas Management Organization (TGO).

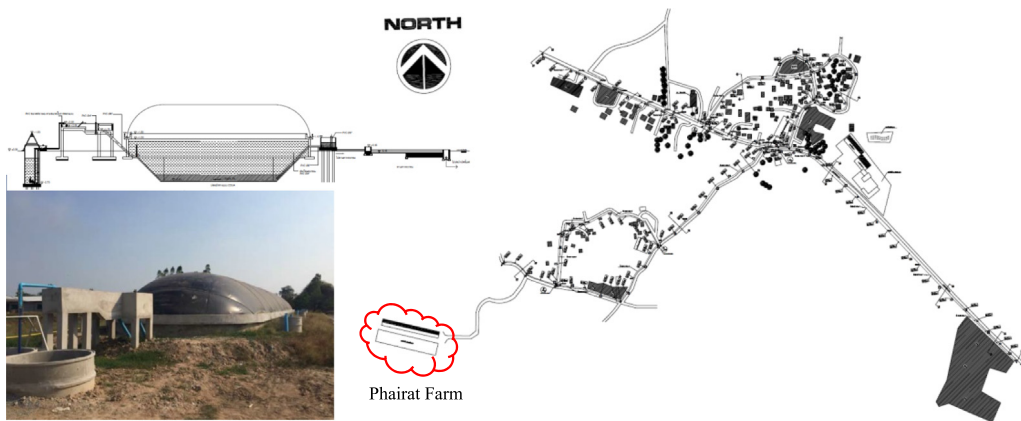


Fig. 2. The biogas production system and piping network at Bo Rae Subdistrict.

2.1. Investigation of economic value

Government financial support for investment in the construction of biogas production systems and piping network amounted to 6,650,000 THB. Income for the project came from payment for biogas and maintenance cost; each household paid at a rate of 50 baht per month. Initially, there were 206 households. Other income came from selling dried sediments from the biogas production system. Project expenses were labour cost, electricity and maintenance costs. Income and expenses of the biogas network project are shown in Table 1. The project consisted of an economic value study of a 15-year plan. Data were analysed to represent the economic value of this project using net present value (NPV), internal rate of return (IRR) and payback period (PB) in 3 cases as follow:

- Case 1 Income came from payment for biogas by each household at a rate of 50 baht per month and selling dried sediments from the biogas production system.
- Case 2 Income came from substituting LPG at a price of 30 THB/kg (industry rate) and selling carbon credit.
- Case 3 Income came from payment for biogas by each household, selling dried sediments and selling carbon credit.

2.2. Satisfactory survey

The survey population and sample were determined using the Taro Yamane equation [8], calculated by Eq. (1) with confidence level set at 95% and allowable error of ± 0.05 . The sample population was determined at 136 from a total of 206 biogas users in Bo Rae Subdistrict.

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Table 1. Income and expenses of the biogas network project.

Specification	Unit	THB/unit	Income	Expense
<u>Income</u>				
Household payment	206 households	50 THB/month	123,600 THB/year	–
Selling dried sediments	84,000 kg/year	2 THB/kg	168,000 THB/year	–
Substituting LPG	38,506 kg/year (biogas 104,244 m ³ /year)	30 THB/kg	1,155,186 THB/year	–
Carbon credit	119,880 kg-CO ₂ /year	8.26 THB/kg-CO ₂	990,220 THB/year	–
<u>Expenses</u>				
Construction cost				
- biogas production system	–	2,453,208 THB	–	2,453,208 THB
- network piping system	–	3,926,274 THB	–	3,926,274 THB
- other devices	–	270,068 THB	–	270,068 THB
Labour cost	1 labour	9,000 THB/month	–	108,000 THB/year
Electricity cost	10 kWh/day	4.00 THB/kWh	–	14,600 THB/year
Maintenance cost				
- biogas production system	Estimation 3%	–	–	73,596 THB/year
- network piping system	Estimation 0.5%	–	–	19,634 THB/year
Changing device of biogas production system (every 4 year)	Estimation	–	–	350,000 THB/year
Changing device of biogas transmission system (every 3 year)	Estimation	–	–	81,020 THB/year

Tools applied in this research included a questionnaire for surveying the biogas users; content was divided into five parts as follows:

- 1st part; questions asking for sample demographics as gender, age, status, education, occupation, income and number of household members.
- 2nd part; questions asking for information regarding biogas management, utilisation and system maintenance.
- 3rd part; questions enquiring about the feasibility of replacing household LPG usage by biogas.
- 4th part; questions concerning the environmental suitability of the biogas production system
- 5th part; requests, additional opinions and suggestions regarding the biogas network project.

Data were collected and analysed to measure satisfaction level in three aspects as follows:

- (1) An analysis comprising management, usage and maintenance of the biogas system,
- (2) Environmental impact
- (3) Overall satisfaction level

The satisfaction survey indicates the answer options on a scale of 1–5; 1 is very dissatisfied, 2 is dissatisfied, 3 is neutral, 4 satisfied and 5 is very satisfied.

After data analysing, the level of satisfaction was interpreted as follows:

- 4.21–5.00 Very satisfied
- 3.41–4.20 Satisfied
- 2.61–3.40 Neutral
- 1.81–2.60 Dissatisfied
- 1.00–1.80 Very dissatisfied

3. Result and discussions

3.1. Economic value of an investment in the biogas network to substitute LPG usage in households

The Economic value study of a 15-year plan was shown in Table 2. Results showed that only the first case (Case 1) was not profitable because of the payback period over 15-year plan. Although the Thai Government funded the

Table 2. Economic value study of a 15-year plan.

Specification	Case 1	Case 2	Case 3
Net present value (THB)	7,121,264	27,680,671	7,731,941
Internal rate of return (%)	N/A	30%	12%
Payback period (year)	>15	3.35	6.68

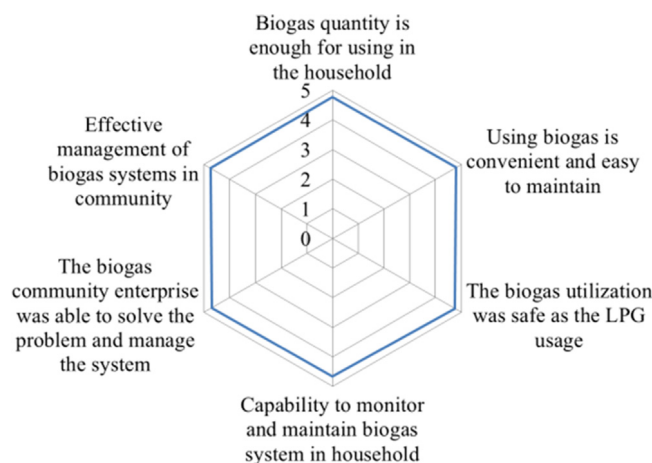
total investment of this project, the income of Case 1 was not sufficient for expenses. Therefore, other income should be added to make the project profitable and sustainable. Case 2 and Case 3 were profitable and sustainable because incomes were more than expenses.

3.2. General information

Demographic information of the samples included gender, age, status, highest education, main occupation, average household income and number of household members. The survey data revealed that most samples were female, accounting for 74.2%, with 73.3% 51 years or above. A total of 73.3% of the samples were married, 63.3% graduated from elementary education (Prathom 4–6), 34.2% had other occupations such as housekeepers or unemployed, while 31.7% were farmers. For monthly income, 60.0% of the households had an average monthly income of 5000 THB or less. Households mostly comprised 2 people at 31.9% of the total.

3.3. Information regarding biogas management, utilisation and system maintenance

Satisfaction levels were expressed as 4.78, 4.80, 4.76, 4.66, 4.70 and 4.74 respectively as illustrated by Fig. 3.

**Fig. 3.** Satisfaction survey for management, operation and maintenance of the biogas system.

With regard to biogas management, utilisation and system maintenance, results showed that biogas users were satisfied with the services, for example, biogas quantity is sufficient for use in the household and using biogas is convenient and easy to maintain. Moreover, biogas utilisation was safe, similar to LPG usage, with the capability to maintain the biogas system in households and effective management of biogas systems in the community. In case of biogas malfunction, the community enterprise was able to solve the problem and manage the system.

The collected data revealed that after setting up, the biogas network system could reduce environmental problems of pig farms (odour, wastewater, disturbing insects). Also, overall satisfaction of biogas household users was rated as very satisfied.

3.4. Feasibility of using biogas to replace LPG

Regarding LPG replacement feasibility by biogas, most of the samples utilised LPG at 54.2%, with maximum usage of 0.5 tanks per month, while biogas price was expected to be 50 THB monthly. When this price was compared

to the LPG cost of 181.5 THB per month, it was concluded that the utilisation of biogas by Bo Rae Subdistrict in Chai Nat Province was feasible and appropriate.

3.5. Inferential statistical analysis results for hypothesis testing

- Hypothesis testing of biogas user satisfaction on biogas management, utilisation and system maintenance was investigated using one-way ANOVA statistical analysis [9], with a significance of 0.05. Analysis results showed that general information did not affect satisfaction regarding biogas management, utilisation and system maintenance.

Hypothesis testing for biogas user satisfaction in environmental suitability was analysed using one-way ANOVA statistical method with significance of 0.05. Results indicated that personal information of income significantly affected the satisfaction in regard to the environment; high-income biogas users would first consider the environmental consequences to the community. By contrast, other personal information did not affect satisfaction, as shown in Table 3.

Table 3. Relationship between personnel data and biogas user satisfaction for environmental suitability.

Personal data	t-test	F-test	Sig.	Results
Sex	−0.104	–	0.917	Not related to hypothesis
Age	–	1.085	0.371	Not related to hypothesis
Status	–	0.152	0.859	Not related to hypothesis
Education background	–	1.875	0.092	Not related to hypothesis
Occupation	–	0.874	0.481	Not related to hypothesis
Income	–	2.317	0.047*	Related to hypothesis
Family number	–	0.301	0.936	Not related to hypothesis

4. Conclusions

Data were analysed to represent the economic value of a 15-year plan by using net present value (NPV), internal rate of return (IRR) and payback period (PB). Results showed that the project bears highly expenses that could not be profitable if the incomes only came from payment for biogas by each household at a rate of 50 baht per month and selling dried sediments. Therefore, other income such as carbon credit value should be added to make the project profitable. A biogas user satisfaction survey was also conducted using 136 questionnaires. The collected data were analysed to measure satisfaction in three aspects; (1) an analysis comprising management, usage and maintenance of the biogas system, (2) environmental impact and (3) overall satisfaction level. Results showed that the samples were very satisfied with management, usage and maintenance of the biogas system. Income was only the main influential factors. For the environmental impact and overall satisfaction level aspect, the samples were also very satisfied.

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