COMMUNITY DEVELOPMENT MODEL WITH BIOGAS GRID CASE STUDY: MAE THA COMMUNITY, MAE ON DISTRICT, CHIANG MAI

รูปแบบการพัฒนาชุมชนด้วยโครงข่ายก๊าซชีวภาพ กรณีศึกษา: ชุมชนแม่ทา อำเภอแม่ออน จังหวัดเชียงใหม่

PHOOSITA CHAISOMBAT

THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR

THE DEGREE OF DOCTOR OF PHILOSOPHY

COMMUNITY ENERGY AND ENVIRONMENT

GRADUATE SCHOOL

CHIANG MAI RAJABHAT UNIVERSITY

2017

The Title	Community Development Model with Biogas Grid
	Case Study: Mae Tha Community, Mae On District, Chiang Mai
The Author	Phoosita Chaisombat
Program	Community Energy and Environment
Thesis Advisors	
Chair Man	Dr. Hathaithip Sintuya
Member	Dr. Worajit Setthapun
Member	Assistant Professor Dr. Prapita Thanarak

Dissertation Defense Committee

P. Watcharadumrongsak ....Chairman

(Dr. Passawat Watcharadumrongsak)

C. Sirisamphanwong ....Member

(Assistant Professor Dr. Chatchai Sirisamphanwong)

....Member

(Dr. Hathaithip Sintuya)

....Member

(Dr. Worajit Setthapun)

P. Thanarak ....Member

(Assistant Professor Dr. Prapita Thanarak)

Graduate School at Chiang Mai Rajabhat University approved this thesis as partial fulfillment of requirements for the Degree of Doctor of Philosophy in Community Energy and Environment.

....Dean of Graduate School

(Assistant Professor Dr. Kamolnut Pholwan)

Date......................................

The Title : Community Development Model with Biogas Grid
Case Study: Mae Tha Community, Mae On District, Chiang Mai

The Author : Phoosita Chaisombat

Program : Community Energy and Environment

Thesis Advisor

: Dr. Hathaithip Sintuya Chairman

: Dr. Worajit Setthapun Member

: Assistant Professor Dr. Prapita Thanarak Member

ABSTRACT

The objective of this research was to investigate the community development model with biogas grid in Mae Tha community. This research was conducted in both quantitative and qualitative aspects by dividing into 3 parts. The first part was the evaluation of biogas potential in the community. The second part was the feasibility analysis of biogas grid by analyzing the appropriateness in technique, economics, and operation.The third part was the construction of a community development model with biogas grid.

The results of biogas potential evaluation in the community revealed that there were 1,500 households in the community with a total of 128 livestock farms including dairy farms, beef cattle farms, and pig farms. There was a total of 5,152 animals which could produce 2,100 cubic meters of biogas per day, equivalent to 996 kg of liquefied petroleum gas per day.Thus, the renewable efficiency in the community was capable of producing biogas.

The results of a possibility analysis of biogas grid by analyzing the appropriate technique revealed that the community had the potential for producing biogas from 3,000 cubic meters of dairy cow dung. According to the possibility analysis, the Geographical Information System (GIS) was used to analyze the biogas grid of the community for 1,500 households within the radius of less than 5 km and the nearby livestock farms so that it is proper to conduct in the part of techniques. The results of the possibility analysis of biogas grid by analyzing the appropriate economics reveal that the government section should support at least 15% of the investment budget in order for the biogas to be sold at 28 baht/ kg, which was equal to the LPG price rate in the market. This would make the biogas cost-effective in economic term. The results of possibility analysis of bio gas network by analyzing the appropriate operation in the community reveal that Mae Tha community was a strong community feasible to conduct the biogas grid project.

The analysis and construction of the biogas model in the community were conducted through using the pattern and protocol of a cooperative to reduce expenses and to increase income as well as to create the economy cycle in the community. Moreover, it also reduces the pollution problems and accidents from delivering the LPG. It reinforces the energy security at the community level.

Keywords: Biogas, Biogas Grid, Community Energy, Economics

หัวข้อวิทยานิพนธ์ : รูปแบบการพัฒนาชุมชนด้วยโครงข่ายก๊าซชีวภาพ กรณีศึกษา: ตำบลแม่ทา อำเภอแม่ออน จังหวัดเชียงใหม่

ผู้วิจัย : ภูษิตา ไชยสมบัติ

สาขาวิชา : พลังงานชุมชนและสิ่งแวดล้อม

อาจารย์ที่ปรึกษาวิทยานิพนธ์

: อาจารย์ ดร.หทัยทิพย์ สินธุยา อาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก

: อาจารย์ ดร.วรจิตต์ เศรษฐพรรค์ อาจารย์ที่ปรึกษาวิทยานิพนธ์ร่วม

: ผู้ช่วยศาสตราจารย์ ดร.ประพิธาริ์ ธนารักษ์ อาจารย์ที่ปรึกษาวิทยานิพนธ์ร่วม

บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อศึกษารูปแบบการพัฒนาชุมชนด้วยโครงข่ายก๊าซชีวภาพซึ่งจะใช้วิธีการดำเนินการวิจัยทั้งเชิงปริมาณและคุณภาพ โดยแบ่งการศึกษาและวิจัยออกเป็น 3 ส่วน คือ ส่วนที่ 1 การประเมินศักยภาพทางด้านพลังงานทดแทนของชุมชน ส่วนที่ 2 วิเคราะห์ความเป็นไปได้ของโครงข่ายก๊าซชีวภาพ โดยวิเคราะห์ความเหมาะสมทางด้านเทคนิค ด้านเศรษฐศาสตร์และด้านการดำเนินการ และ ส่วนที่ 3 สร้างรูปแบบการพัฒนาชุมชนด้วยโครงข่ายก๊าซชีวภาพ

ผลการศึกษาและวิจัยการประเมินศักยภาพทางด้านก๊าซชีวภาพของชุมชน พบว่า ชุมชนเป็นชุมชนขนาดเล็ก จำนวน 1,500 ครัวเรือน มีการทำฟาร์มปศุสัตว์จำนวนทั้งหมด 128 ฟาร์ม ประกอบไปด้วยฟาร์มโคนม ฟาร์มโคเนื้อ และฟาร์มหมู มีจำนวนสัตว์ทั้งหมด 5,152 ตัว ซึ่งสามารถผลิตก๊าซชีวภาพได้ 2,100 ลูกบาศก์เมตร ต่อวัน โดยเทียบได้กับก๊าซหุงต้ม 966 กิโลกรัม ต่อวัน ดังนั้นศักยภาพด้านพลังงานของชุมชนตำบลแม่ทาเหมาะสมต่อการผลิตก๊าซชีวภาพมากที่สุด

ผลการวิเคราะห์ความเป็นไปได้ของโครงข่ายก๊าซชีวภาพโดยวิเคราะห์ความเหมาะสมทางด้านเทคนิค พบว่า ชุมชนตำบลแม่ทามีศักยภาพในการผลิตก๊าซชีวภาพจากมูลโคนม ขนาด 3,000 ลูกบาศก์เมตร ในการวิเคราะห์ความเป็นไปได้ทางด้านเทคนิค โดยใช้ระบบสารสนเทศภูมิศาสตร์ (Geographic Information System : GIS) เพื่อวิเคราะห์โครงข่ายก๊าซชีวภาพของชุมชน พบว่า ชุมชนตำบลแม่ทามีการตั้งบ้านเรือนแบบหนาแน่นในบริเวณที่ใกล้เคียงกัน จำนวน 1,500 ครัวเรือนในรัศมีไม่เกิน 5 กิโลเมตร และมีฟาร์มปศุสัตว์อยู่ใกล้เคียงพื้นที่ชุมชน จึงมีความเหมาะสมในการดำเนินการทางด้านเทคนิค

ผลการวิเคราะห์ความเป็นไปได้ของโครงข่ายก๊าซชีวภาพ โดยวิเคราะห์ความเหมาะสมทางด้านเศรษฐศาสตร์ พบว่าภาครัฐควรมีการส่งเสริมและสนับสนุนงบลงทุนระบบไม่น้อยกว่าร้อยละ 15 เพื่อให้เกิดการซื้อขายก๊าซชีวภาพเทียบเท่ากับการซื้อขายก๊าซหุงต้ม LPG ในราคา 28 บาทต่อกิโลกรัม ตามราคาซื้อขายก๊าซหุงต้ม LPG ในท้องตลาด จึงจะมีความเหมาะสมและเกิดความคุ้มค่าทางด้านเศรษฐศาสตร์ ผลการวิเคราะห์ความเป็นไปได้ของโครงข่ายก๊าซชีวภาพ โดยวิเคราะห์ความเหมาะสมทางด้านการดำเนินการของชุมชน พบว่า ชุมชนแม่ทา เป็นชุมชนเข้มแข็งและมีความพร้อมในการดำเนินโครงการ และมีการจัดตั้ง สหกรณ์การเกษตรแม่ทายั่งยืน จำกัด เพื่อพัฒนาชุมชนในการทำการเกษตรในรูปแบบการวิเคราะห์และสร้างรูปแบบการพัฒนาชุมชนด้วยโครงข่ายก๊าซชีวภาพ โดยจะดำเนินการ โดยใช้รูปแบบและกลไกของสหกรณ์ชุมชน ทำให้เกิดการลดรายจ่ายเพิ่มรายได้ เกิดการหมุนเวียนทางเศรษฐกิจของชุมชน อีกทั้งยังช่วยลดปัญหามลภาวะทางสิ่งแวดล้อม ลดปัญหาการเกิดอุบัติเหตุจากการขนส่งก๊าซหุงต้ม LPG และเสริมสร้างความมั่นคงด้านพลังงานในระดับชุมชน

คำสำคัญ: ก๊าซชีวภาพ, โครงข่ายก๊าซชีวภาพ, พลังงานชุมชน, เศรษฐศาสตร์

ACKNOWLEDGMENT

The authors gratefully acknowledge the support provided by Research Grants by The National Research Council of Thailand (NRCT) 2016: Community Development Model with Biogas Grid. Case Study: Mae Tha Community, Mae On District, Chiang Mai

This research could be completed because of the kindness from the research committee comprising Dr. Hathaithip Sintuya, Dr. Worajit Setthapun and Assistant Professor Dr. Prapita Thanarak, who have always provided assistance with useful consultation and recommendations, and have helped to check, proof and correct all flaws and errors in this research with a great care throughout the research process. The researcher would like to take this opportunity to deeply thank all the committee members here.

Phoosita Chaisombat

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

CHAPTER 1

Introduction

Background and Significance of the Problem

From the economic and social growth; consistent economic recovery; and increasing population, the demand for consumer products increased. As a result, gross domestic product (GDP) continues to grow which would also lead to an increase in overall energy consumption. According to the study on the situation of national energy in 2017, Thailand consumes 80,752 tonne of oil equivalent : TOE which is worth over 1,072,237 million baht.This is an increasein energy consumption following the economic growth. Petroleum was the most consumed energy constituting 50.1% of the total final energy consumption, followed by electricity, renewable energy, natural gas, traditional renewable energy, coal/lignite which accounted for 20.4%, 9.1%, 7.1%, 6.6%, and 6.7%, respectively (Department of Alternative Energy Development and Efficiency [DEDE], 2017a).

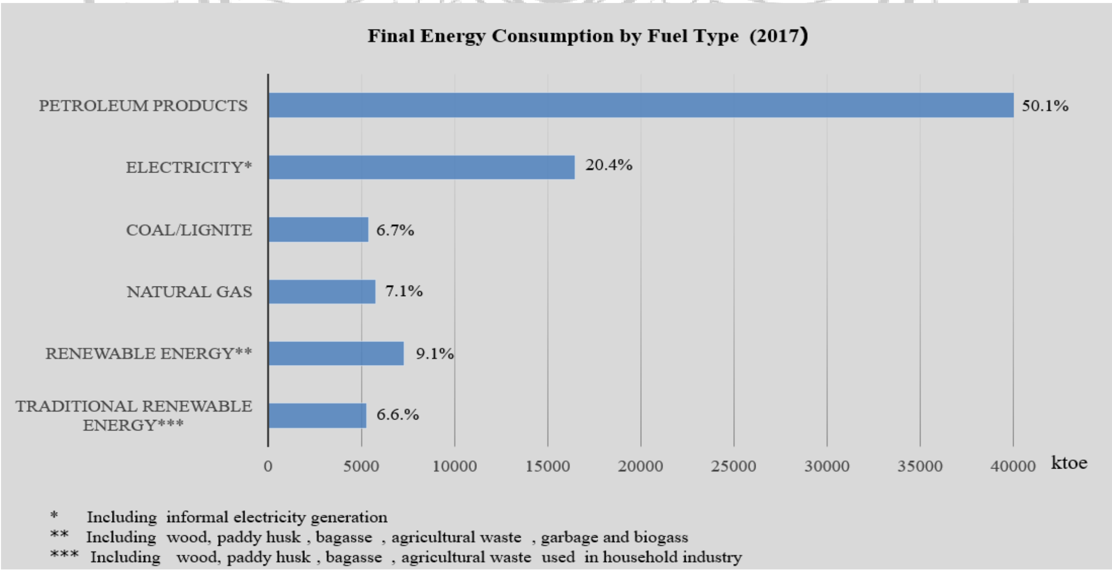

Figure 1.1 Final Energy Consumption by Fuel Type in 2017

Source: DEDE, 2017a

From the issued governmental policy to promote the domestic utilization of renewable energy and energy efficiency enhancement through a reduction of Energy Intensity (EI), it was estimated that in 2017, Thailand consumed 11,698 kilotonne of oil equivalent : KTOE, a 5.9% increase of the same period of the previous year. The Energy Intensity remained consistently and proportionally decline when compared to 2010, the base year of the 20-year (2011-2030) energy conservation plan and the 2015-2036 energy conservation plan.

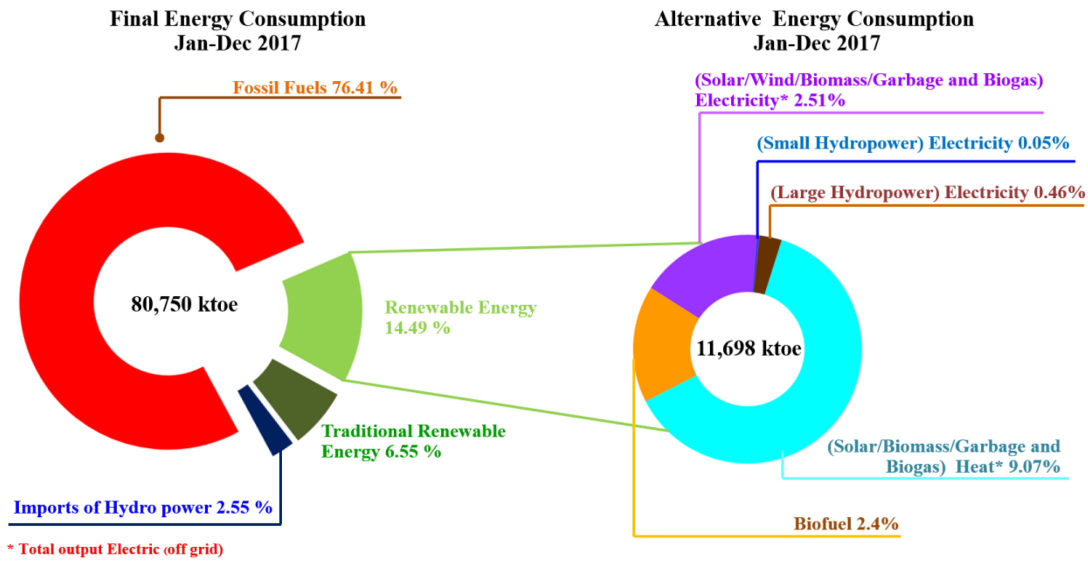

Figure 1.2 The proportion of the final energy consumption and the alternative energy in 2017

Source: DEDE, 2017a

In 2017, the energy production yielded 74,398 KTOE comprising 64.8% commercial production out of the total energy production. Other renewable energy and traditional renewable energy contributed 23.7% and 11.5%, respectively, to the pool. The commercial energy production yielded 48,213 KTOE comprising 7,099; 4,118; 32,121; 4,464; and 411 KTOE of crude oil, lignite, natural gas, condensate, hydroelectricity, and others, respectively.

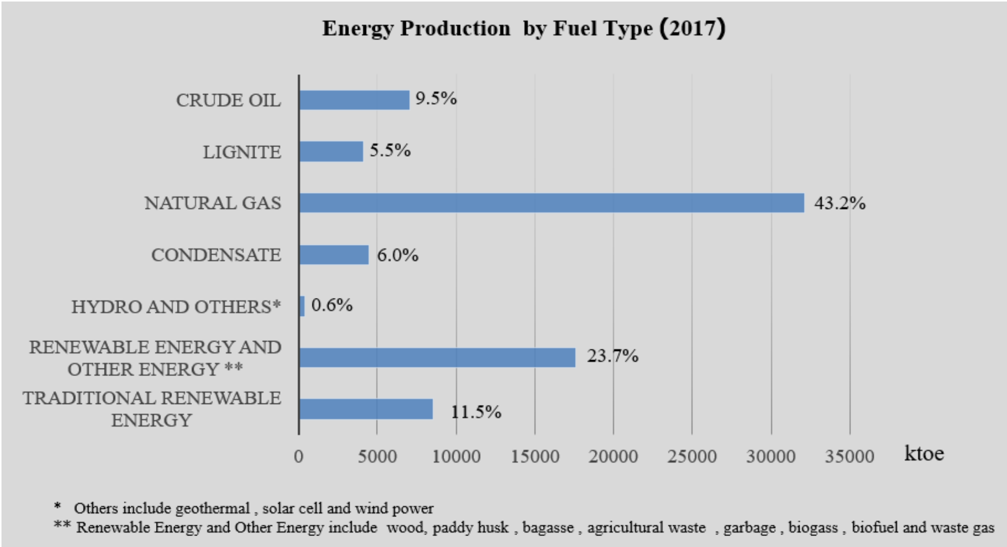

Figure 1.3 Energy production by energy type in 2017

Source: DEDE, 2017a

In 2017, the energy imports made up 78,976 KTOE of energy whereas 99.9% of the total imports were for the commercial production and 0.1% for the traditional renewable energy. In terms of quantity, the commercial import of energy amounted to 78,908 KTOE comprising 45,985; 731; 13,886; 2,725; 13,523; and 2,058 KTOE of crude oil, condensate, coal, petroleum, natural gas, and electricity, respectively.

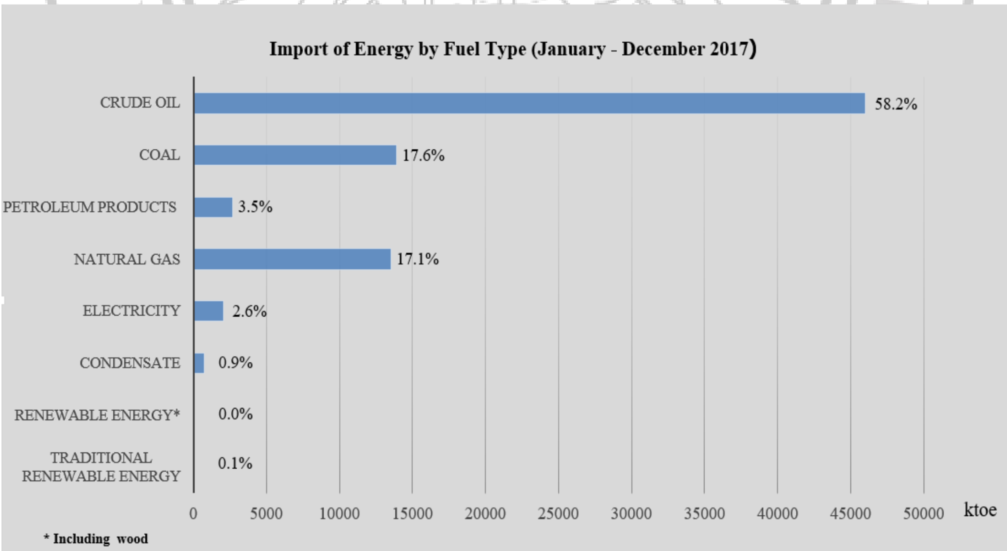

Figure 1.4 Energy imports by energy type in 2017

Source: DEDE, 2017a

After examining Thailand's Energy Situation 2017, it was found that Thailand has a continuous growth of energy demand which was 0.1% from 2016. In terms of domestic energy production, it was found to decrease by 7.1% whereas the energy import increased by 6.1% compared to 2016. The trend suggests a consistent growth of energy import to meet the increasing consumption while domestic production continues to decline. Although Thailand has a policy to promote alternative energy production and energy efficiency pursuant to the 20-year energy conservation plan, 2011-2030 and the energy conservation plan, 2015-2036.Thailand consumed 5.9% more energy compared to 2016 and it continues to import more every year. In addition, the price of imported energy per unit is likely to continuously increase due to the decline of available energy sources and increasing energy scarcity. As a result, Thailand is steering towards an energy crisis, the globally inevitable that is only going to intensify.The increase in energy costs further burdens businesses and increase the cost of living in general. Once this occurs, it will destabilize national energy and economy which further leads to other widespread problems of all sectors.Based on this assumption, renewable energy is an appropriate and essential approach to improve energy security for the households, communities, and country.

The development of renewable energy in Thailand is still limited in many aspects e.g. the community's lack of technological understanding, shortage of skilled and knowledgeable human resources, methods to collect energy-producing raw materials, usage difficulty, changes in lifestyles, and most importantly, the cost-constraints on the investment and installation of energy-production systems. The lack of incentivization to convert to renewable energy, therefore, delays the development in Thailand.

This study aims to investigate the substitution possibility with liquefied petroleum gas (LPG) as it is a product derived from crude-oil extraction in refineries as exhibited in Figure 5 and gas separation in Figure 6. LPG is a colorless and odorless gas mostly used in households and factories.

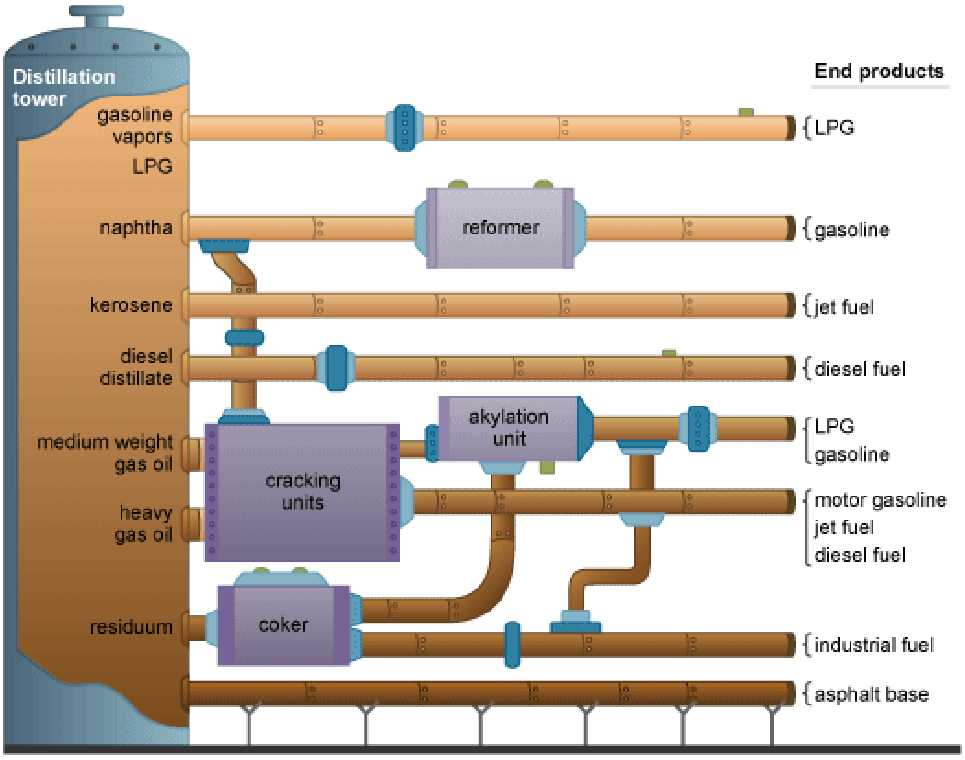

Figure 1.5 The process of oil refining

Source: U.S. Energy Information Administration, 2016

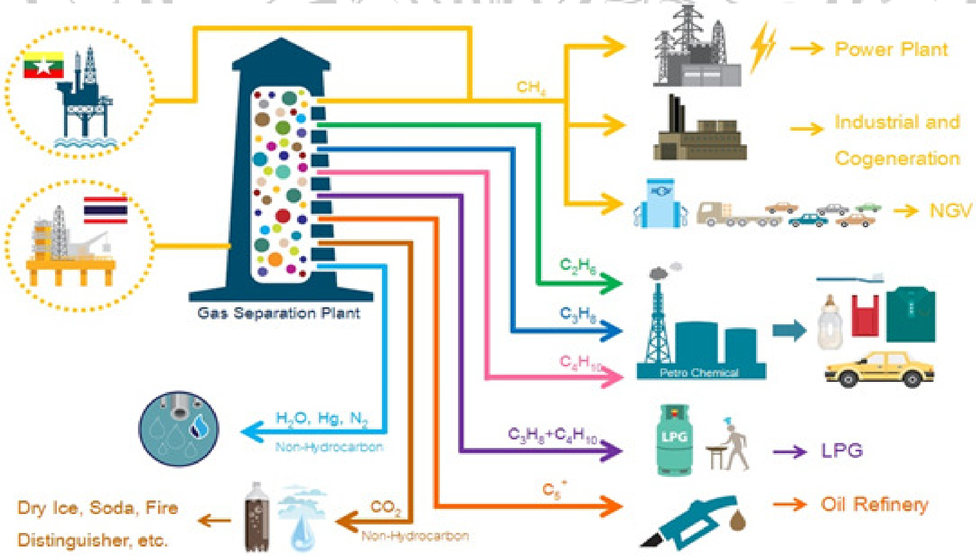

Figure 1.6 The natural gas separation process of a gas-separation plant in Rayong

Source: PPT Distribution service center, 2012

After examining Thailand's Energy Situation 2017, it was found that Thailand produced as high as 43.20% of the energy from natural gas, however, the gas supply continues to deplete every year and will possibly run out in a few years. In addition, it was found that Thailand imported 58.2% of its energy from crude oil and 17.1% from natural gas. The findings indicated an inadequate procurement of natural gas when compared to the demand. Moreover, the crude oil imports were significantly higher than the domestic production constituting an 84.56% ratio. This suggests that Thailand is facing energy insecurity. After examining the situation of LPG in Thailand, it was found that the country has floated the LPG price effective since August 1, 2017. This price float was the first in the history of Thailand following its free trade policy in which the price float shall reflect the actual prices in the global market. The free trade comes without any governmental intervention in retail or wholesale pricing which offers a complete competition freedom to support the future as Thailand will need to import more LPG due to its limited domestic supply. Currently, the price of LPG in the global market is very fluctuating. When compared to neighboring countries, Thai retail prices are still lower in most cases, except for Malaysia, as shown in Figure1.7: A comparison of the LPG retail prices between Thailand and its neighboring countries (September 2017). Variations of energy prices in different countries are due to different tax measures and the collection systems of energy-subsidy funds. In fact, many countries still subsidize the prices.Thailand currently has the subsidy funds for oil and liquefied petroleum gas which are responsible for price subsidies to mitigate the impact on the cost of living that burdens its population.Nonetheless, LPG prices will continue to rise following the pricing mechanism of the global market.

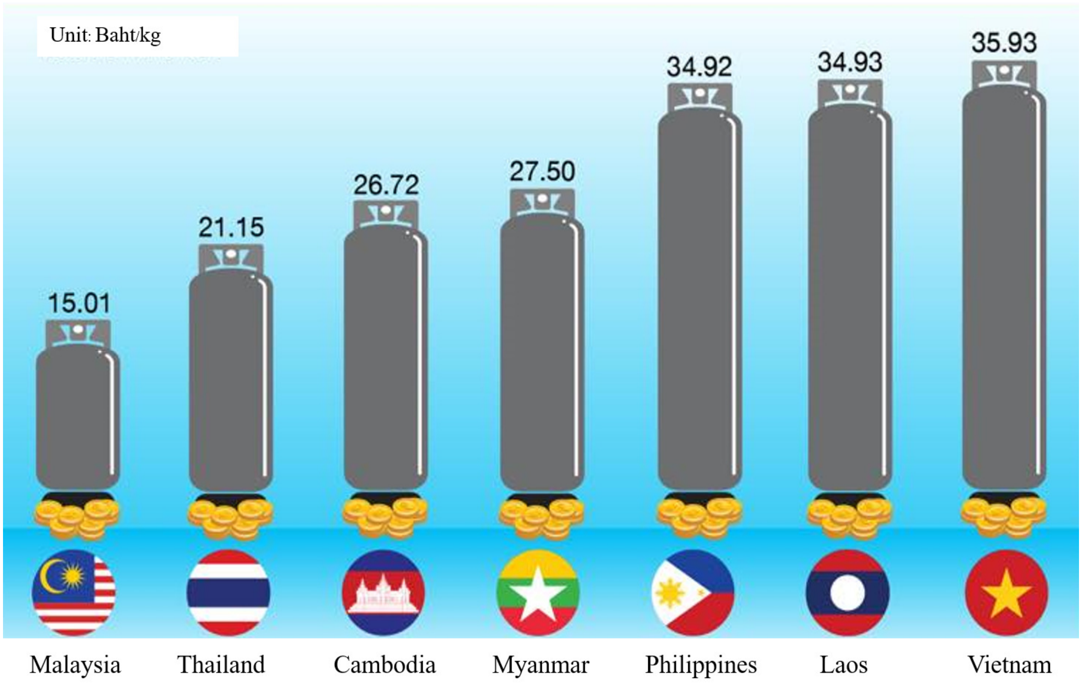

Figure 1.7 A comparison of the LPG retail prices between Thailand and its neighbors (September 2017)

Source: Ministry of energy, 2017

As a result of the socio-economic growth, the agricultural sector expanded at a rate of 2.5% - 3.5%, with an increasing tendency of all product divisions including crop, livestock, fisheries, agricultural services, and forestry. Livestock farms, in particular, grew by 1.2% from 2016. Increased livestock production has caused negative environmental impacts, epidemics, and resistance from the local communities. Most of the problems were due to the lack of standardized systems for animal waste disposal which pollutes the farms and their surrounding environments with disgusting odor. Proper livestock waste management can reduce the environmental impact and social conflict.

Biogas production technology has continuously been developed to improve product quality and production efficiency.In addition, the technology can also reduce and mitigate negative environmental impacts, epidemics, and resistance from the local communities.Biogas production is a technology that ferments animal manure and livestock waste by introducing bacterial anaerobic digestion under appropriate conditions.The produced biogas contains a mixture of methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), and hydrogen sulfide (H_2S) where methane being the main constituent at 60-70% ratio. Methane is a gas with high heating value, however, when it is mixed with a substantial proportion of carbon dioxide, the overall heating value decreases. Pure methane has a heating value as high as 35.64 megajoules per cubic meter while biomass, at a mixture ratio of methane per carbon dioxide being 60%, has a heating value of only 21.6 megajoules per cubic meter.In addition to the reduction of the total heating value, the proportion of carbon dioxide in the biogas also destabilizes the concentration of methane causing incomplete combustion producing unstable flame, smothering the flame, or causing an explosion in the combustion chamber. This lowers the system performance and corrodes the gas pipeline.To mitigate the problems, biogas clean-up and upgrading is required through a reduction of carbon dioxide (CO_2), hydrogen sulfide (H_2S), and moisture in the biogas.The upgraded biogas is called biomethane which is improved equivalently to the quality of LPG. This would also increase the chance for the society to accept alternative-energy technology.

Mae Tha community, Mae On District, Chiang Mai Province is an agricultural community rich of experts with knowledge, local wisdom, and experience, e.g. sustainable agriculture, which has been accumulated through time.It is a community that emphasizes knowledge enhancement and development following the principles of self-reliance of the Sufficiency Economy Philosophy. Being a strong community, the community deserves a potential development on energy where it can opt for a renewable energy source. The study focuses conducted a feasibility analysis on biogas grid development for Mae Tha to encounter negative environmental impacts and epidemics; reduce the social resistance, decrease dependence on fossil energy, and promote a sustainable dependence on renewable energy. Since livestock farms are distributed around the community, a centralized biogas system and household biogas pipeline distribution system are viable for Mae Tha. A biogas grid community development model was emphasized and developed ensuring the network coverage in response to the community demand. The biogas grid is operated in a form of community cooperative where the quality biogas is purchased, sold, and delivered via the gas pipelines, a.k.a. biogas grid, at an affordable pricing suitably with both the economy and operation. This stimulates the community economic activities and strengthens the community-level energy security as it offers a sustainable production and utilization of renewable energy.

Research objectives

1. To evaluate the biogas production potential in Mae Tha community, Mae On District, Chiang Mai

2. To analyze the feasibility of a biogas grid utilization in Mae Tha community

3. To create a biogas grid community development model

Research scope

This study focused on the creation of community development model with biogas grid in Mae Tha community, Mae On District, Chiang Mai. The study involved a survey of the community context; analysis of community potential in utilizing a biogas grid; investigation of the feasibility to establish the biogas grid and a creation of biogas grid community development model. The following details were the research scope:

1. Area Scope

This study on a biogas grid community development model: a case study of Mae Tha community, Mae On District, Chiang Mai Province covered an area of 108 square kilometers comprising seven villages : Ta Mon, Tha Kham, KhoKlang, HuaySai, Pa Not, Don Chai, and Mai Don Chai.

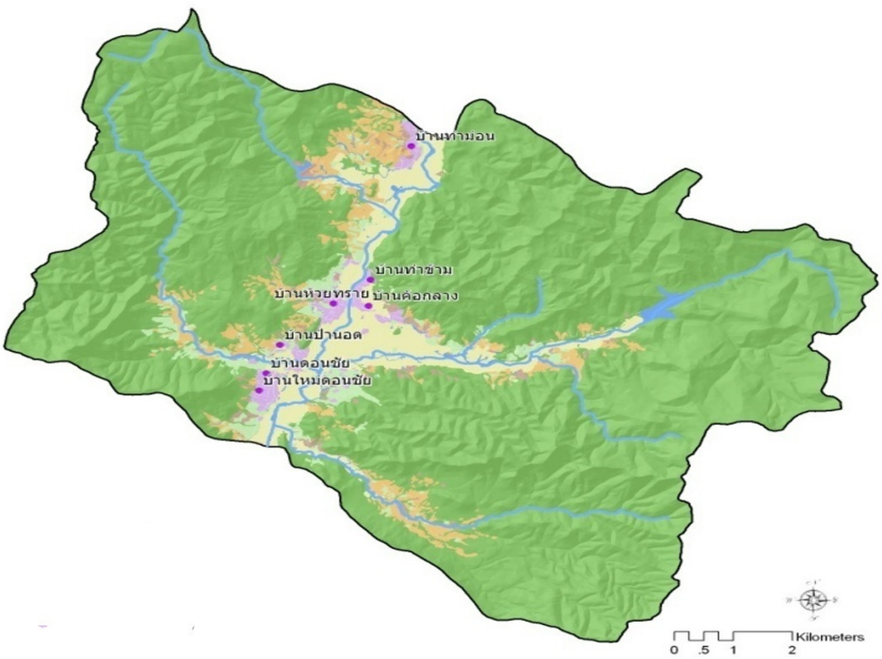

Figure 1.8 The area of Mae Tha community, Mae On District, Chiang Mai Province

2. Population Scope

The population in this study is the 1,500 household members of Mae Tha community, Mae On District, Chiang Mai Province, accounting 100% of the total households in Mae Tha community; 60dairy farms, accounting 100% of the total community dairy farms; 45 beef cattle farms; and23 pig farms.

3. Content Scope

This study employed the following content scopes:

1) Studies of context and energy potential in Mae Tha Community: General community conditions,geography, weather, population data, number of households,occupation data, community energy consumption data (including electricity consumption data,fuel for vehicles, fuel for agriculture, LPG, and firewood), and community's renewable energy potential (e.g. solar energy, hydroenergy, wind energy, energy from waste, bioenergy, and biomass) were examined;

2) Feasibility study for a community biogas project: Three feasibility dimensions were examined including firstly, the technicality analysis that employs the Geographic Information System (GIS) to evaluate and analyze the design of biogas and biogas grid in the community. Biogas Clean-Up and Upgrading technology is used to produce the gas with equivalent quality to LPG; secondly, the economic analysis that determines economic suitability using five indicators including NPV, IRR,BCR, PP, and COE; and thirdly, the operation analysis thatexplores the community's preparedness, biogas technological acceptance, andopinions of all stakeholders within the community;

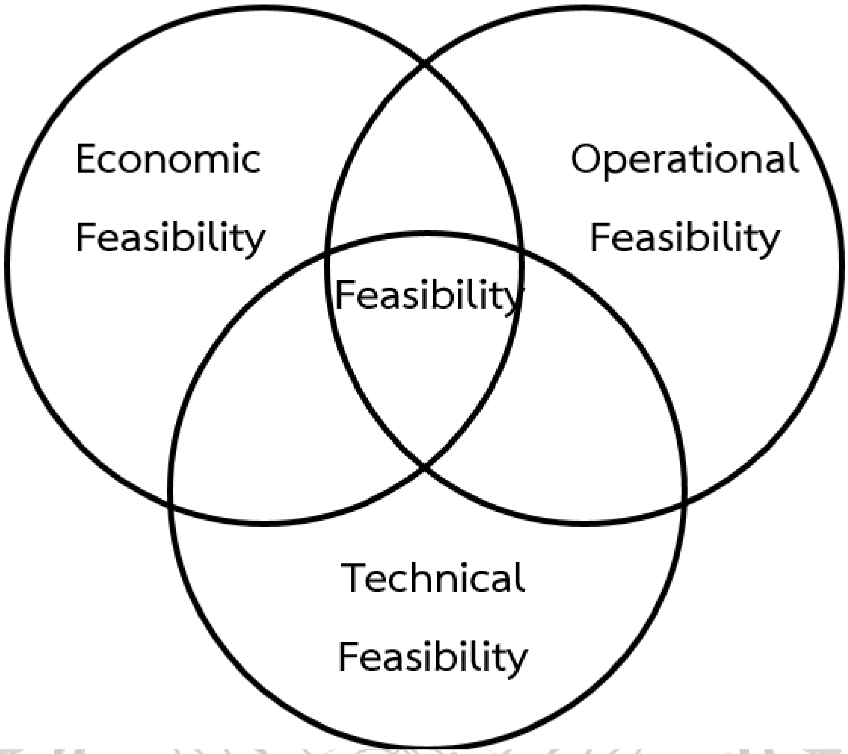

Figure 1.9 The feasibility study of a biogas grid

3) Design and development of a biogas grid community development model: The study sets the trade pricing for biogas that is suitable for both the economy and operation under the model and mechanism of community cooperative.

Definition of terms

1. Biogas Clean-Up and Upgrading refers to a quality development process of the biogas that reduces carbon dioxide (CO_2), hydrogen sulfide (H_2S), and moisture from the biogas until it has an equivalent property to LPG;

2. Biomethane refers to an improved biogas with more methane content than that of the general biogas. Originally, biogas contains approximately 60-65% of methane by volume whereas biomethane comprises 83-90% of methane.

3. Biogas Grid refers to a biogas production system that delivers the product to its users through the gas pipeline;

4. Geographic Information System (GIS) refers to a process of spatial analysis performed by a computer system with an intelligence on geographic locations;

5. Economic Analysis refers to an approach to optimize limited resources for a maximum efficiency through five indicators including NPV, IRR, BCR, PP, and COE. It is to determine project's suitability and cost-effectiveness.

CHAPTER 2

Literature Review

A study of community development model with biogas grid is based on theories and related research as presented below:

1 Review of concept, theory, and related principle

- Renewable energy policy and plan of Thailand
- Biogas system technology
- Economic evaluation
- Participatory Action Research: PAR

2 Review of related literature

Review of concept, theory, and related principle

1. Renewable energy policy and plan of Thailand

The Ministry of Energy has set the integrated plan for national energy which consisted of three important parts; (1) Energy security: Meeting the people needs of energy consumption corresponded with economic growth rate, population growth rate, urban growth rate, and the proper distribution of fuel; (2) Economy: The cost of energy was properly considered, and it did not intervene in long term economic and social development. Fuel price structure was reformed in order to comply with the cost. The proper tax rate has led to the increase of efficiency of energy consumption in country, and it prevent the extravagant energy consumption, including the enhancement of efficient energy consumption; (3) Ecology: The proportion production of renewable energy in the country and energy from high-efficient technology was increased in order to reduce the effect toward environment and community.

In the integrated plan for national energy, the Ministry of Energy has reviewed 5 major energy plans 2015 - 2036. The productions of national economic and social development plan were a development plans for electricity generating, an energy conservation plan, a renewable and alternative energy development plan, a gas plan, and an oil plan of Thailand. To achieve Alternative Energy Development Plan: AEDP2015, energy production from the existing renewable energy materials within the country was focused to enhance its full capability. The capability of renewable energy production was developed by using proper technology. Moreover, renewable energy was developed for mutual benefit in society and environment of community.

To conduct AEDP2015, the interested persons were allowed to share their opinions in the seminar "The Trend of Energy in Thailand" of the Ministry of Energy on August – September 2014. Also, the opinions and recommendations from focus group seminar on August 2015 were used to support AEDP plan production.

The status of electricity generating from renewable energy

The Ministry of Energy has had the enhancement policy for electricity production from renewable energy since 1989. In accordance with the policy, Electricity Generating Authority of Thailand (EGAT) bought electricity from Small Power Produce (SPP) who generated electrical energy and cogeneration from agricultural residues. Thermal energy residues from production process were applied to generate electricity. Then, it was submitted to transmission system. In doing so, it was an efficient enhancement of electric production and can reduce the amount of investment of government in production and power distribution system.Subsequently, EGAT bought electricity generated by other kinds of renewable energy such as solar energy, biogas, garbage, hydropower, and wind power, from Very Small Power Produce (VSPP) with its maximum electricity of 10 MW. To do so, it will be a chance in remote area to generate electricity, and it can reduce the damage of electrical system. The investment in large-sized power plant construction was minimized in order to distribute electricity by using Adder. However, addition rate and supporting duration were different because it depended on the type of renewable energy. There was an extra electric rate for power plant project of renewable energy in southernmost provinces of Thailand; Yala, Pattani, Narathiwat, and 4 districts in Songkhla. Because of that motivation, the proportion production of electricity generated from renewable energy has increased every year. In 2007, the amount of electricity generated from renewable energy (including off grid power generation) was 4.3 percent in its country. Increasingly, it was 9.87 percent in 2014 (large-sized hydropower was not included).

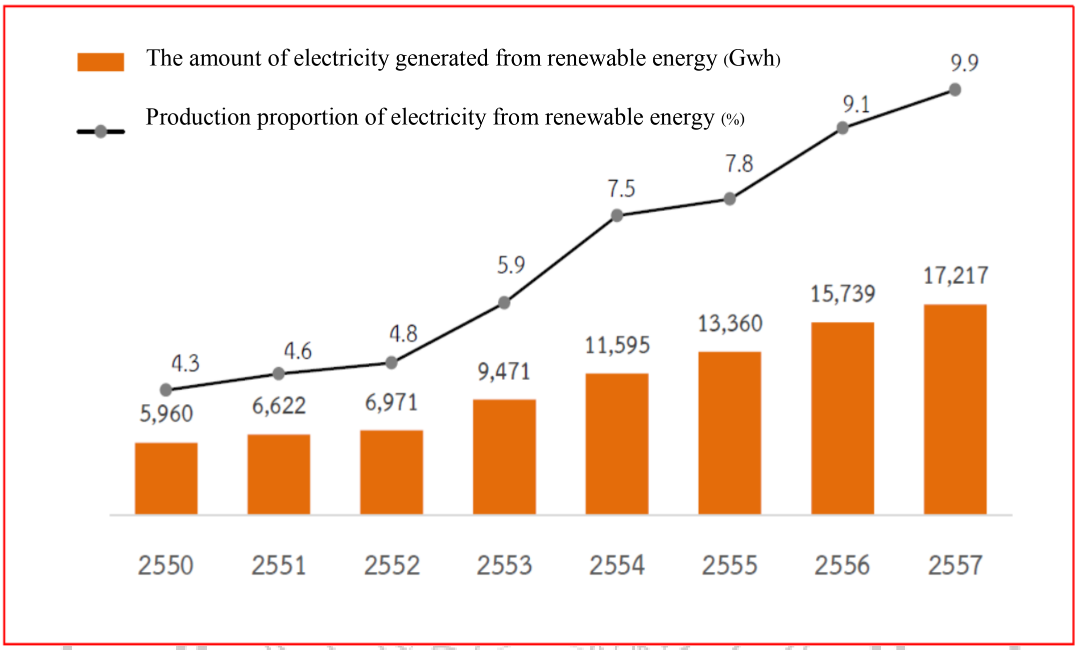

Figure 2.1 Shows the amount of electrical energy generated from renewable energy of Thailand 2007 – 2014

Source: DEDE,2015

The status of thermal production from renewable energy

Renewable energy fuel was applied by major industries to produce thermal. Its major was agricultural industries such as sugar industry, palm oil production industry, tapioca flour industry, lumbering industry, paper industry, rice mill, and rancho. The residues left from production process derived from all of the industries, and it can be used as materials to produce biogas and biomass from wastewater. To do so, it can reduce the overhead from procurement of external fuel. As a result, biomass residues such as bagasse, rice husk, wood scraps, palm fiber, palm kernel shell, and sawdust were widely popular and used as fuel in agricultural industry.

The government policy which promoted electricity production from renewable energy by using cogeneration system was a key tourge investment. Energy production system, biogas production system from dung and wastewater from factory, hot water production and drying from solar energy were enhanced in terms of efficiency. The proportion of renewable energy utilization was increased to reduce the use of fossil fuel. Competitiveness was enhanced because the waste was reused to reduce cost of production and fossil fuel overheads. Moreover, it can promote good health in community around the factory.

Biomass is a renewable energy which dominate in thermal production. In 2014, 89 percent of total renewable energy in thermal production was biomass. Biogas was 9 percent of total renewable energy, and the rest was thermal energy from garbage and solar energy. Thermal energy production from garbage and solar system still needed to be support in order to utilize service and household sector more.

The status of biogas production from renewable energy

For a decade, the Ministry of Energy applied royal initiative of His Majesty the King about renewable energy as a major policy. The energy stability and fundamental renewable energy were promoted in Thailand, especially gasoline and diesel substitution by using biogas which was produced in the country.

The Ministry of Energy has concretely promoted biogas since 2004 in terms of construction permission of biogas factory, increasing biogas station, and public relations to boostpeople's confidence toward biogas. However, biogas utilization was not significantly increased until 2008. From the world energy crisis in 2008, crude oil price was over 150 USD/barrel causing the need of biogas to substitute and to reduce crude oil import. Bio Ethanol utilization was increased from 0.71 million of liters/day to 1.29 million of liters/day, and Biodiesel utilization was increased from 0.80 million of liters/day to 1.40 million of liters/day.Biodiesel utilization was significantly increased in 2011 when the Ministry of Energy added biodiesel in diesel at 3–5 percent, and 7 percent in 2014. However, because crude oil palm which was used to produce biodiesel was a high volatility product within its season, the Ministry of Energy had to reduce the biodiesel adding to diesel in order to be balanced on materials in the country. There were 10 biodiesel production factories in 2014. The total production capacity was 4.96 million of liters/day. Biodiesel was used to substitute total diesel at 1,054.92 million of liters, or 2.89 million of liters/day.

Ethanol utilization was increased by leaps and bounds in 2013 because the Ministry of Energy renounced gasoline (octane 91) utilization which dominated at 40 percent of total gasoline utilization. Because crude oil price in 2013 – 2014 tended to increase, people increasingly utilized gasohol as well as Ethanol. There were 22 Ethanol production factories in 2014. Total production capacity was 5.31 million of liters/day. The total Ethanol utilization was 1,185.50 million of liters or 3.25 million of liters/day.

The target of renewable energy development

Thailand had a supporting and enhancement policy for renewable energy utilization according to Alternative Energy Development Plan (AEDP2015) 2015 – 2036.Renewable energy development plan was a part of energy policy setting, and it needed to be integrated with other energy development plan in order that well working. In AEDP2015, forecast value of final energy consumption was used in accordance with Energy Efficiency Plan: EEP 2015, in case of Energy Intensity achievement at 30 percent in 2036 compared with 2010. After forecast, the final energy consumption in 2036 was 131 million of tons which was equal to crude oil (ktoe). The forecast of net electricity energy consumption of the country from Power Development Plan (PDP2015) in 2036 was 326,119 million of units or 27,789 ktoe. The forecast of thermal energy consumption in 2036 was 68,413 ktoe. Moreover, the forecast of fuel consumption in transportation sector from oil plan in 2036 was 34,798 ktoe. All of these forecasts were used to set the target for increasing renewable energy utilization. The capability of renewable energy source being able to develop was considered in terms of electricity and thermal energy, and biogas fuel under the AEDP2015. It was 30 percent of final energy consumption in 2036.

The strategy for renewable energy development

The Ministry of Energy has set the strategy to promote renewable energy development in 2015 – 2036 as follow;

Strategy 1: the preparation of materials and renewable energy technology

Objective The development of production capacity and material administration by using proper technology

Strategy 1.1 To develop other alternative materials and potential area for renewable energy production

Strategy 1.2 To develop administration format and renewable energy materials for highest efficiency.

Strategy 1.3 To enhance technology development suited for production capability and renewable energy consumption

Strategy 1.4 To improve infrastructure supporting renewable energy utilization

Strategy 2: The increase in production capacity, utilization, and renewable energy market

Objective The advancement of production capacity and needs of renewable energy

Strategy 2.1 To support household and community participating in renewable energy production and consumption

Strategy 2.2 To promote producer and user both domestic and foreign investment in renewable energy

Strategy 2.3 To promote cost reduction and increase efficiency of renewable energy business

Strategy 2.4 To develop renewable energy laws and urgently rectify laws and regulations in order to promote renewable energy development

Strategy 3: Building awareness, and accessing body of knowledge and renewable energy facts.

Objective Building awareness and cognitive knowledge toward the efficiency and sustainability of renewable energy consumption

Strategy 3.1 To develop information system for admiration of renewable energy database.

Strategy 3.2 To publicize information, knowledge, and statistical data of renewable energy

Strategy 3.3 To develop personnel in terms of cognitive knowledge about renewable energy and to build capability of renewable energy utilization both theory and practicality.

Strategy 3.4 To develop system of related renewable energy and to support participation of the system both national and international levels.

To achieve the policy target, the consumption of renewable energy such as electricity energy, thermal energy, and biogas under the AEDP2015 was increased to be 30 percent of final energy consumption in 2036. It was equal to the reduction of fossil fuel at 39,388 ktoe or 590,820 million baht (crude oil price of 1 ktoe= 15 million baht). Equally, greenhouse gas can be reduced from fossil fuel combustion at 140 million tCO2e(DEDE, 2015).

2. Biogas system technology

Biogas is a gas generated via an organic digestion by anaerobic bacteria. The volume of gas depends on substrate, digester temperature, retention time, digester working pressure, fermentation medium pH, and volatile fatty acids components (Dobre, Nicolae, & Matei, 2014). The major components of biogas are as follows:

– Methane: 50-60%

– Carbon dioxide: 25-35%

– Nitrogen: 2-7%

– Hydrogen: 1-5%

– Carbon monoxide: trace

– Hydrogen sulfide: trace

– Others: traces

The biogas energetic value is determined by the methane content. The main factors in the production of biogas have been identified as: 1) Sub layer composition; 2) Temperature inside the digester; 3) Retention time; 4) Working pressure of the digester; 5) Fermentation medium pH; 6) Volatile fatty acids (VFA) (Dobre et al., 2014).

2.1Bacteria used in biogas production

Hydrolytic Bacteria

Hydrolytic bacteria is an anaerobic bacteria that can digest large organic compound into small molecule. For example, it can digest protein, cellulose, lignin and lipid into soluble single molecule of amino acid, glucose, glycerol and fatty acid. Plant containing lignin can be digested harder than animal manure.

Acidogenic Bacteriaoracid foming bacteria

Acidogenic bacteria is a bacteria used for a digession of sugar, amino acid and fatty acid into acetate, carbon dioxide and hydrogen.

Acetogenic bacteria

Acetogenic bacteria can digest volatile organic compound and alcohol into acetate, carbon dioxide and hydrogen. This group of bacteria require low H_2 partial pressure. High H_2 partial pressure can reduce acetate as well as increase propionic acid, butyric and ethanol. Therefore, pH value is decreased that is not suitable for acetogenic bacteria. Then, methanogen bacteria can use hydrogen to decrease H_2 partial pressure.

Methanogenic Bacteria

Methanogenic bacteria can be found in natural river or stomach of ruminant. It can be divided into 2 groups as follows: hydrogenotrophic methanogens and acetotrophic methanogens.

Hydrogenotrophic Methanogens orhydrogen utilizingchemolithotrophs is bacteria that can convert hydrogen and carbon dioxide into methane. The advantage of this bacteria is their ability in decreasing of H_2 partial pressurewhich allows other bacteria operation.

Acetotrophic Methanogens oracetate splitting bacteria is bacteria that can convert acetate into carbon dioxide and methane.

2.2 Biogas digester technologies in Thailand

2.2.1Fixed-dome digester

Fixed-dome digester is typically built of masonry and must be gas-tight. Due to it is constructed under the ground. Therefore, it shields the structure, afford insulation, and affords open space for other uses above ground. A polymer paint was used to seal the digester and water storage tank for gas-tightness. Advantages of fixed-dome digester is its low cost of construction and materials, long life time and there is no moving part in the digester. Disadvantages is there should be a high quality of sealant of digester, the system require high skill of operation technician, and the pressure inside a digester is unstable depends on digester volume (Rowse, 2011).

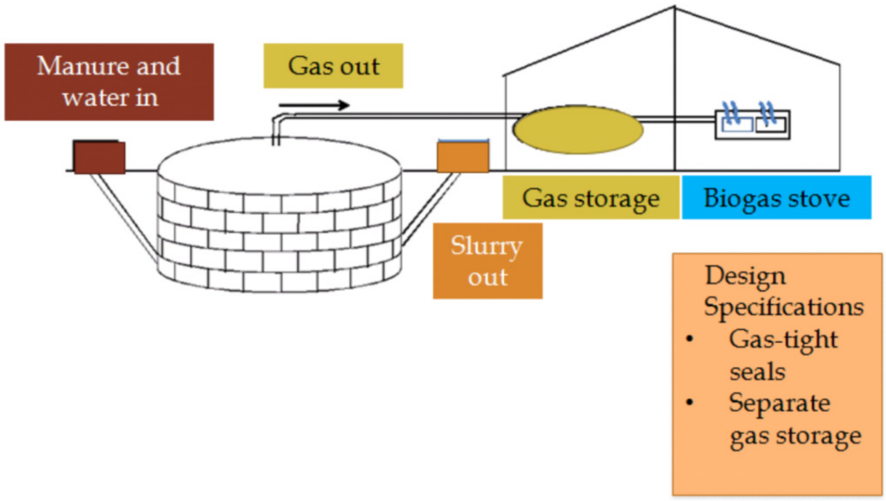

Figure 2.2 Fixed dome digester

Source: Rowse, 2011

2.2.2 Up-Flow Anaerobic Sludge Blanket (UASB) System

The UASB reactor comprises of 2 parts: 1) a three phase separator (gas, solid and liquid) in the upper part of the reactor and 2) a sludge bed in the lower part. The UASB system can be used for large quantity of biogas production under short retention times and at high temperatures due to its high rate anaerobic treatment system. The disadvantages of this system is that slow hydrolysis of entrapped solids especially at low temperatures that decrease performance of the system (Mojiri, Aziz, Zaman, Aziz, & Hamidi, 2012; Seghezzo, Zeeman, van Lier, Hamelers, & Lettinga, 1998).

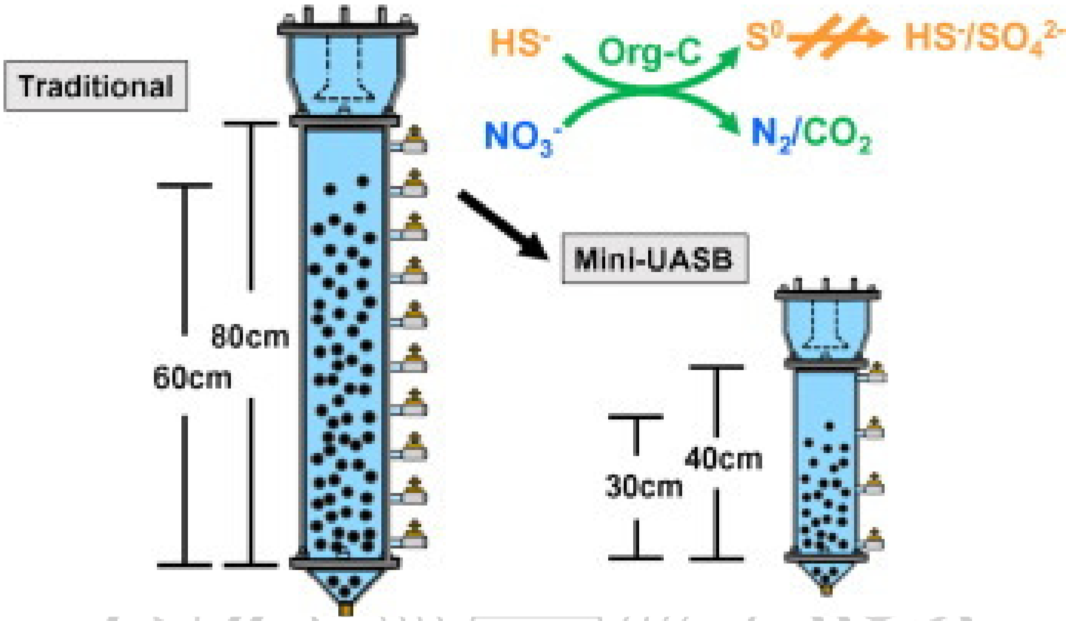

Figure 2.3 Up-Flow Anaerobic Sludge Blanket

Source: Huang et al., 2016

2.2.3 High Suspension Solid-Up-Flow Anaerobic Sludge Blanket (H-UASB)

High Suspension Solid-Up-Flow Anaerobic Sludge Blanket (H-UASB) system is developed from Up-Flow Anaerobic Sludge Blanket (UASB) System. It was created to solve blocking problem of water system by animal manure precipitate. The H-UASB system have buffer tank that can help separate suspendible precipitate from waste water and animal manure. This can minimize suspendible precipitate amount. Then, polyethylene sheet is used to cover digester well and buffer tank in order to collect biogas produced from USAB system.

Figure 2.4 H-UASB (High suspension solid-Up-Flow Anaerobic Sludge Blanket)

Source: DEDE, 2017

2.2.4 Plug Flow Digester

Plug Flow Digester is constructed with concrete material. The digester is long rectangular in shape called "Channel digester". Digester well is placed under ground covered with plastic to keep biogas. Animal manure can be added at a constant rate into the digester. Then it can force other material to move through the digester and be digested. Due to gas storage unit is made of plastic, therefore, pressure increasing unit should be installed in order to use biogas(Chanakya, Reddy, & Modak, 2009).

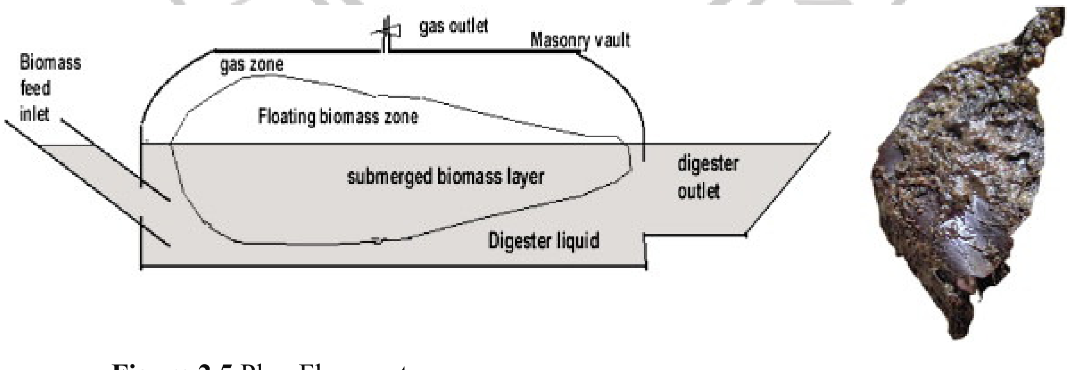

Figure 2.5 Plug Flow system

Source: Chanakya et al.,2009

2.2.5 Covered lagoon system

The covered lagoon system consists of one or more lagoons separated with a solids separator. It covered with plastic sheet called “floating lagoon cover”. Covered lagoon system is developed from plastic gas storage bag of plug flow system. The plastic layer is constructed covering animal manure collecting well (United States Environmental Protection Agency, 2017).

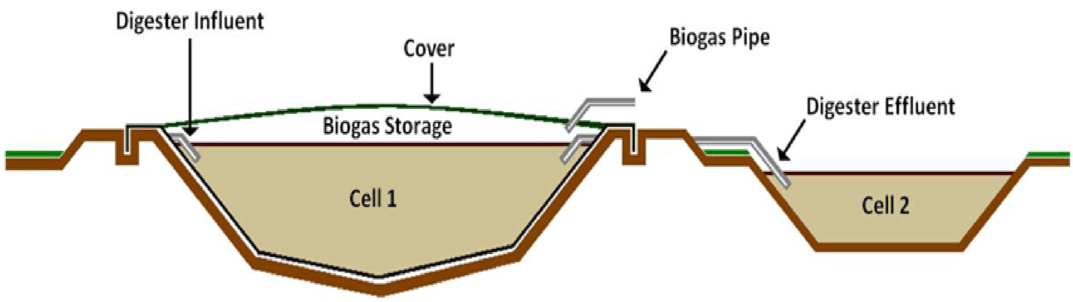

Figure 2.6 Covered lagoon

Source: United States Environmental Protection Agency, 2017

Biogas quality improvement

Biogas is generated through the digestion of animal manure and organic substances by anaerobic bacteria. The produced biogas comprises methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), hydrogen sulfide (H_2S) and other gases. The number of methane should be in the range of 60-70% to be able to be used as fuel gas continuously and stably. The proportion of gases composition in biogas has an effect to biogas heating value. Heating value of methane is high, therefore, the increasing of methane content in biogas results in the increasing of total heating value of biogas. For example, heating value of pure methane is 35.64 MJ/m^3 while heating value of biogas (methane: carbon dioxide = 60:40) is 21.60 MJ/m^3. The increasing of carbon dioxide content can decrease total heating value of biogas and can also discontinue methane content which lead to incomplete combustion, unstable flame, discontinuous flame, and may results in the explosion. These affect to the reduction of system efficiency and the corrosion inside the gas pipeline. Therefore, the improvement of biogas quality should be carried out to solve the problems mentioned above.The improved or upgraded biogas called “biomethane”.

The improvement of biogas quality will help in decreasing of carbon dioxide content which will result in high quality of biogas.

In order to improve biogas quality, carbon dioxide will be separated and trapped. It can be done using various kinds of technique as follows:

1. Water scrubbing technique

Water scrubbing is a carbon dioxide separation technique that using water scrubber packed in a column. This packed scrubber can increase the contact between gas and water. Therefore, this system is suitable for the decrease of acid gases such as carbon dioxide and hydrogen sulfide. Biogas produced from the digester will be flowed trough the packed scrubber in the column opposite to the flow of water. The carbon dioxide gas contacted with water will be dissolved in the water. Therefore, methane portion in biomethane will increase (Islamiyah, Soehartanto, Hantoro, & Abdurrahman, 2015).

2. Pressure swing absorption (PSA) technique

Pressure swing absorption technique is used for carbon dioxide separation by changing pressure inside the separation column. Impurity gases will be absorbed on porous solid material packed in a column according to the different of pressure. It is an efficient technique for the removal of carbon dioxide and other impurity gases to obtain high qulity of biomethane (Ko, Siriwardane, & Biegler, 2005).

3. Amine absorption technique

Amine absorption process is a technique that use amine solution to separate biogas. Amine is worldwide used in an industrial factory that produce large amount of carbon dioxide. It is also used in the petroleum separation (Huertas, Giraldo, & Izquierdo, 2011).

4. Membrane separation technique

Membrane separation technique is used to separate carbon dioxide by selective membrane. In the process, biogas is fed through one site of membrane which pressure is controlled as P1. Carbon dioxide and other gases in biogas will be flowed through membrane into opposite side of membrane which pressure P2. P1 and P2 are set to be different in order to perfectly separate carbon dioxide and methane. Biogas quality improvement or biogas upgrading techniques comparison can be listed as Table 2.1.

Table 2.1 Comparison of biogas upgrading techniques

System Characteristic	Biogas upgrading techniques			
	Pressure swing absorption (PSA)	**Water scrubbing**	**Amine absorption**	**Membrane separation**
Absorption characteristic	Surface absorption	Physical absorption	Chemical absorption	Membrane absorption
Cleaning system	Require	Not Require	Require	Require
Pressure (bar)	4-7	4-7	Atmosphere	16-40
Methane loss (%)	3-10	1-2	<0.1	ND
Maximum methane yield (%)	>96	>97	>99	90-94
Energy usage (kWh/Nm^3)	0.25	<0.25	<0.15	ND
System Temperature (^oC)	Room Temp	Room Temp	100	Room Temp
Chemical regeneration	Yes	Yes	Yes	-
Energy required for absorber regeneration	Moderate	Moderate	High	No

Source: Energy Research and Development Institute – Nakornping, 2015

Biomethane gas grid standard

For biogas grid construction, the components and materials should be provided corresponding to gas transmission and distribution piping systems standard: ASME B31.8 (American Society of Mechanical Engineers [ASME], 2016) and biomethane gas grid standard developed by Energy Research and Development Institute – Nakornping (2017).

1. Materials used in gas transmission and distribution piping systems

For the construction of biomethane grid, biogas pipeline and related components should be a liquid, pressure and chemical resistant material. Materials used in gas transmission and distribution piping systems are listed in Table 2.2.

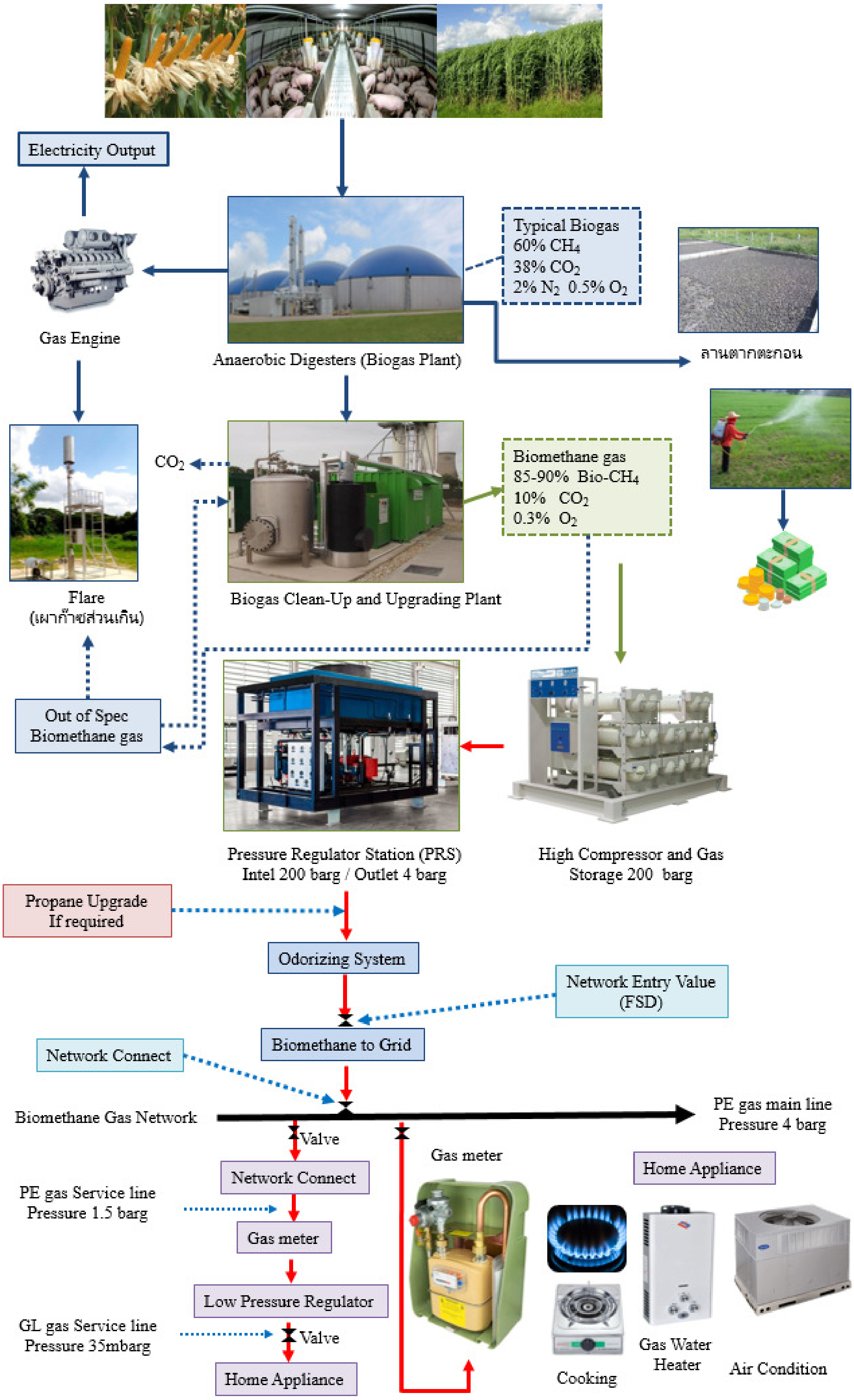

Figure 2.7 Process of Biomethane gas pipeline

Source: Energy Research and Development Institute – Nakornping, 2015

Table 2.2 Materials used in gas transmission and distribution piping systems

Materials	**Type**	**Standard**
Iron Pipe	- Line Pipe	API5L or equivalent
	- Welded and Seamless Pipe	ASTM A53 or equivalent
	- Seamless Pipe	ASTM A106 or equivalent
	- Electric-Fusion (Arc)-Welded Pipe	ASTM A134 or equivalent (Size NPS 16 and Over)
	- Electric-Resistance-Welded Pipe	ASTM A135 or equivalent (Size NPS 4 and Over)
	- Electric-Fusion (Arc)-Welded Pipe	ASTM A139or equivalent
	- Seamless and Welded Pipe	ASTM A333 or equivalent
	- Metal-Arc-Welded Pipe	ASTM A381 or equivalent
	- Electric-Fusion-Welded Pipe	ASTM A671 or equivalent (for Atmospheric and Lower Temperatures)
	- Electric-Fusion-Welded Pipe	ASTM A672 or equivalent (for High-Pressure Service at Moderate Temperatures)
Ductile iron pipe	Ductile iron pipe	ANSI A21.52 or equivalent
Thermoplastics	Thermoplastics components used in pipeline	ASTM D 2513 or equivalent
Reinforced Epoxy Resin	Reinforced epoxy resin components used in pipeline	ASTM D 2517 or equivalent

Source: Energy Research and Development Institute – Nakornping,2017

2. Tools used in gas transmission and distribution piping systems

Tools used in gas transmission and distribution piping systems should be a liquid, pressure and chemical resistant material according to standards mentioned in Table 2.3.

Table 2.3Tools used in gas transmission and distribution piping systems

Tools	Standard
Small Manually Operated Metallic Gas Valves	ANSI B16.33 or equivalent
Steel Valves	ANSI B16.34 or equivalent
Large Manually Operated Gas Valves Manually Operated Thermoplastic Gas Shut Offs and Valves	ANSI B16.38 or equivalent ANSI/ASME B16.40 or equivalent
Pipeline Valves	API 6A or equivalent
Cast Iron Gate Valves	MSS SP-70 or equivalent
Cast Iron Plug Valves Threaded Valves	MSS SP-78 or equivalent ANSI B1.20.1 or API 5L or API 6Aor equivalent
Flange Alloy Steel Bolts	ANSI B16 or equivalent ASTM A 193 or ASTM A 320 or ASTM A 354 or equivalent
Thermoplastic Fittings	ASTM D 2513 or equivalent
Reinforced Thermosetting Plastic Fittings	ASTM D 2517 or equivalent

Source: Energy Research and Development Institute – Nakornping, 2017

3. General requirement for biogas pipeline construction and installation

Underground pipeline distance

For biogas pipeline construction and installation, underground pipeline distance should be at least 300 mm from other underground structure apart from system. This distance is suitable for maintenance and it can prevent damage and danger happened from other nearby structure. In the case of distance between pipeline and other structure is less than 300 mm, there should be a regulation for damage protection of biogas pipeline (Energy Research and Development Institute –Nakornping, 2017).

Pipeline installation

1) In pipeline installation process, there should be a regulation for damage protection of biogas pipeline from water corrosion, flood, landslide and other disaster which can affect to the movement or overweight load.

2) After land trenching and biogas pipeline installation, landfill covering should be done to strengthen pipeline structure. This process will help to protect the damaging of pipe and coating material layer on pipe surface. Landfill covering should be done by order of soil layer as same as the layer prior trenching. If there is plenty of rock and rough soilat the installation place, rock must be separated prior to landfill covering step.

3) Biogas pipeline installed above ground level should be protected from traffic accident and others by installing pipe away from traffic road or installing blocking layer to prevent biogas pipe from motor vehicle crashing. Moreover, after landfill covering, there should be a labelling of pipeline notification placed close to pipeline as much as possible including 2 of the following points.

- Each intersection of community road or railroad
- Anywhere else that require pipeline labelling in order to prevent or reduce damage

The labelling of pipeline notification sign should express a clear letter that is easy to read. The wording used in notification sign must contain wording of "warning", "beware", or "dangerous" following with wording of "biogas pipeline". The letters size must be at least 25 mm tall. It must include responsible organization name and contact telephone number (Energy Research and Development Institute – Nakornping, 2017).

Plastic pipeline installation

Due to plastic is considered to be a non-ultraviolet resistant material. It can be deteriorated by sunlight that can cause a risk of gas leakage. Therefore, plastic pipe should be installed underground. By using of plastic pipe on ground, lifetime of plastic pipe will be shorter than indicated by factory certification or less than 2 years (Energy Research and Development Institute – Nakornping, 2017).

Gas flow meter and tools used in user's area

1) In order to utilize biogas energy, household user have to installed pipe from the main biogas grid pipeline to their house or user area. Biogas pipe within user area can be both metal or plastic pipe. The metal pipe can be piped on ground or wall depends on suitably. The plastic pipe is not recommended to be piped on ground. It should be piped underground (Energy Research and Development Institute – Nakornping, 2017).

2) Connection of biogas pipe from the biogas grid to user area must install switching valve above pressure adjustment (regulators) unit or gas flow meter. Switching valve must be installed in an open area outside building that can be accessed easily. The switching valve must be made of gas flow corrosion resistance, biogas contamination chemical resistance, and switching resistance material.

3) Gas flow meter and regulator must be installed in the open area that is safe and easy to access.

3. Economic evaluation

Economic feasibility of biogas system was analyzed to study the economic feasibility in details. Cost – Benefits analysis was to study financial benefit and cost from biogas system by classification required. Financial functions were used to analyze and calculate the cost and benefits. The methods were showed as follows;

Remuneration was an important factor, so the instruments were used to analyze economic feasibility of biogas system. The remuneration was divided into two parts.

1) Tangible Benefit is a benefit that can be valued as money. For example, biogas development being able to increase the amount of gas can increase the benefits like money as well as cost reduction in biogas system.

2) Intangible Benefit is a benefit that is not money, and it cannot be valued as money or it is hard to do so such as building good image of community by using biogas all over the village.

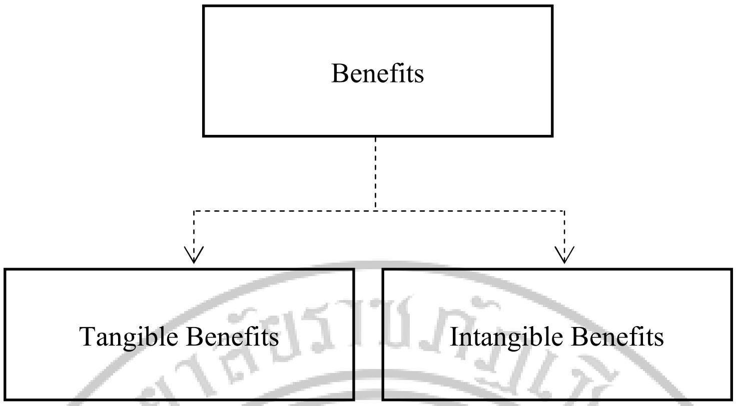

Figure 2.8 Remuneration of biogas system

Cost considerations were divided into two types; tangible cost and intangible cost.

1) Tangible cost is a cost that can be valued as money such as construction cost of biogas pond, cost of biogas pipeline, and operation cost.

2) Intangible cost is a cost that cannot be valued as money. The characteristic of tangible and intangible costs was also divided into 2 types. One Time Cost is a cost that is calculated at the beginning project of biogas system such as construction cost of biogas pond and cost of biogas pipeline. Recurring Cost is a cost that occur during the operation such as water supply from corral cleaning, wage, and maintenance cost. Apart from one time and recurring costs, its cost can also be divided into 2 types; Fixed Cost is a cost that does not depend on usability such as water supply cost from corral cleaning and wage.Variable Cost is a cost that is changeable in accordance with usability such as maintenance cost of biogas production process.

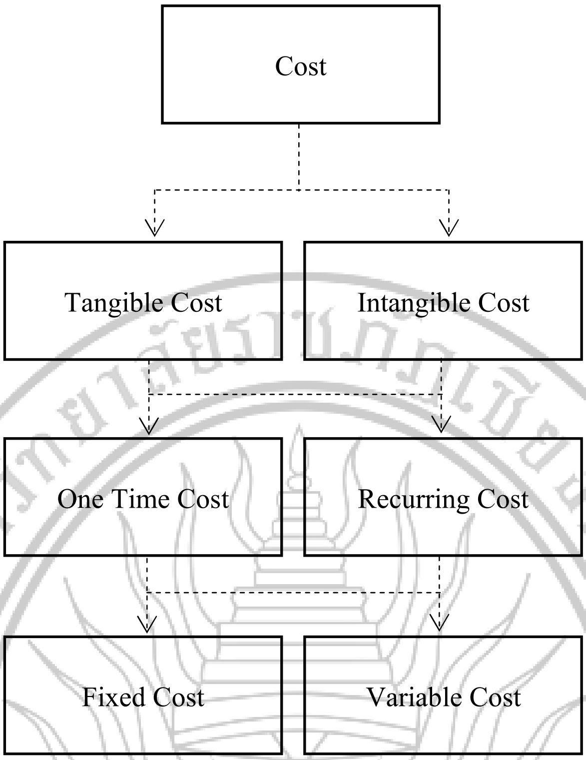

Figure 2.9 Cost consideration of biogas system

To analyze net benefit considered the cost and benefit from biogas system. The cost and benefit was compared to analyze net benefit. The five instruments which were used to assess net benefit were presented below.

1. Net Present Value (NPV)
2. Internal Rate of Return (IRR)
3. Benefit/Cost Ratio (BCR)
4. Payback Period (PP)
5. Cost of Energy (COE)

Net benefit acquired from biogas system of the community was evaluated, it was presented in details as follow;

1. Net Present Value (NPV)

Net Present Value is a present value of net benefit flow. It indicated that how much net benefit acquire from the project. Although, investment project has already finished, benefit still occurred during the economic duration of the project. By the way, the construction cost occurred, especially in the investment period.The operation costs – fixed and maintenance, and investment in equipment to replace the old one – occurred throughout economic calendar of the project. It can be calculated from the formula below(Deng & Hägg, 2010; McAfee, 2005; Paturska, Repele, & Bazbauers, 2015; Sgroi, Foderà, Trapani, Tudisca, & Testa, 2015; Tsagarakis & Papadogiannis, 2006).

$$NPV = PVB\text{-}PVC = \sum_{t=1}^{n} \frac{(B_t\text{-}C_t)}{(1+r)^t} \quad (1)$$

Where

B_t	:	Value of benefit from the project in the t year
C_t	:	Cost value from the project in the t year
r	:	Discount rate
t	:	Project period (1,2,...,n)
n	:	Project age or year ended of the project

Net Present Value method was conducted to find the difference between PVB and PVC, and it can indicate that "whether or not the project will be worth investing". In other words, if NPV value was higher than 0, the project was economically worthwhile and acceptable. But if NPV value was lower than 0, the project was not acceptable. If NPV value of the project was equal to 0, no matter it should be invested in or not, it did not affect economic system anyhow(Deng & Hägg, 2010; McAfee, 2005; Paturska et al., 2015; Sgroi et al., 2015; Tsagarakis & Papadogiannis, 2006).

2. Internal Rate of Return (IRR)

Internal Rate of Return is a return rate in investment or discount rate, and it has led to the equivalence between present value of total return and present value of total overheads. In other words, the IRR is a discount rate. As a result, the value of net present cash acquired from the return of investment was equally zero. IRR value is r value causing NPV = 0, as presented below(Deng & Hägg, 2010; McAfee, 2005; Paturska et al., 2015; Sgroi et al., 2015; Tsagarakis & Papadogiannis, 2006).

$$\text{IRR} = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} = 0 \tag{2}$$

To consider how interesting and worthy of the project is, IRR value should be high and higher than discount rate or opportunity cost in the project analysis. There should be the process of NPV and IRR value finding in order to consider how to use capital effectively and how much net return gain(Deng & Hägg, 2010; McAfee, 2005; Tsagarakis & Papadogiannis, 2006).

3. Benefit/Cost Ratio (BCR)

Benefit/Cost Ratio is a comparative analysis between PVB and PVC. If BCR value was higher than 1, the project gave worthy return. But if the BCR value was lower than 1, the return from project was not worth investing. It can be calculated from the formula below(Deng & Hägg, 2010; McAfee, 2005; Tsagarakis & Papadogiannis, 2006).

$$\text{BCR} = \frac{\text{PVB}}{\text{PVC}} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}} \tag{3}$$

BCR value can be used to measure the worthiness but unable to select or prioritize the project because the BCR measure the worthiness in terms of ratio (how much return was paid from a unit of investment). Anyhow project size did not affect ratio value. The project which present value of benefit was higher than present value of cost was an acceptable project. In other words, the project was acceptable only if BCR value was higher than 1(Deng & Hägg, 2010; McAfee, 2005; Tsagarakis & Papadogiannis, 2006).

4. Payback Period (PP)

Payback Period is an estimation of profit margin or return of investment which is equal to initial investment. Payback Period was analyzed yearly, but the acquired result was integral number. The PP was easily calculated by using the formula below(McAfee, 2005; Paturska et al., 2015; Sgroi et al., 2015).

Payback Period= cost of investment / average total return per year (4)

5. Cost of Energy (COE)

Cost of Energy was conducted to evaluate energy price of the production system, including investment cost, and operation and maintenance. Annual net overheads in production process (cost) was evaluated by comparing with total unit of energy generated during project period. It can be calculated from the formula below(McAfee, 2005; Paturska et al., 2015; Sgroi et al., 2015).

$$COE = \frac{\sum_{n=0}^{N}\left[C_n/(1+i)^n\right]+TIC}{\sum_{n=1}^{N}\left[Enet\right]} \tag{5}$$

Where

C_n : Project cost in the n year

I : Discount rate

N : Total number of year in the project period

Enet : Unit of energy generated in the n year

TIC : Initial investment

6. Project Sensitivity Analysis

Project sensitivity analysis was to test conclusion stability derived from the analysis based on probability range, discretion about numerals, and hypothesis used in that analysis. The replacement of assumption or new numeral differed from the past in specific levels, or assumption or existing numerals in budget estimation needed to be tested and calculated again. Then, how different of analysis result from the previous one was considered. In case, the analysis result did not differ from the original one, or slightly differ in the non-impact level of practical if the project still be worthy. Benefit and cost of project have changed into bad direction or sometimes slightly good result. The risk might cause the reduction of project's benefit at 5 percent, or the cost might increase roughly 5 percent. Method or procedure of this analysis was uncertainly determined. For common variables, if the value was changed, it has led to the change of projects such as production capacity, the amount of utilization, estimated useful life, price of the products, and asset price - in case it has come to the end of life.

7. Participatory Action Research: PAR

Participatory action research (PAR) is a research methodology that help to promote people participation as people organization pattern. This people organization happened from PAR will be able to work effectively on the strength organization structure and action. PAR methodology can increase people ability by information system. Awareness of information data will help people to be able to analyze and solve problems in order develop community. Therefore, there should be research training for local people to generate local community researcher (Baum, MacDougall, & Smith, 2006; Kindon, Pain, & Kesby, 2008; McIntyre, 2007; Whyte, 1991).

PAR technique is similar to participant observation in anthropology. The researchers have to live in community and participate community activities. The research study focuses on local community study as a community member. Local people behavior will be specified by physical environment, economic, social and politics. Interviews and observation will be mainly used as research tools to obtain in-depth information. Anthropology knowledge will also be applied to develop the research(Baum et al., 2006; Kindon et al., 2008; McIntyre, 2007; Whyte, 1991).

The important keys of PAR are community management and people involvement. Therefore, community management and people involvement are included in research process. The aim is to encourage the utilization of people and community resources in local community development as people organization. There are an outsource researchers play a role as organization manager who help to promote research training for local community people. They are also responsible for community decision guideline and promoting of participation and involvement of local people to play a role through the process of PAR methodology. The outsource researcher can help to coordinate and educate academic knowledge and various kinds of research techniques(Baum et al., 2006; Kindon et al., 2008; McIntyre, 2007; Whyte, 1991).

Participatory action research consists of 5 research phases that is the methodology combined with community organization and problem base learning as follows (Boonchieng, 2015):

1. Pre-research Phase

1.1 Community selection and assessment

1.2 Integration of researcher and local community

1.3 Basic community data survey

1.4Participatory action research concept propagation for community

2. Research Phase

2.1 Problem analysis associating with community people

2.2 Local community researcher training

2.3 Analysis of problem risk in participatory action research and generation of alternative solution

2.4 Research methodology design and data collection

2.5 Data analysis

2.6 Information presentation for community meeting venue

3. Planning Phase

3.1 Community planning staff training

3.2 Project or activity generation

3.3 Possibility of work plan study

3.4Project budget and funding agency finding

3.5 Planning of project follow up and project evaluation

4. Implementation Phase

4.1 Working group member selection

4.2 Working group training

5. Monitoring and Evaluation Phase

The important keys of the participatory action research are monitoring and evaluation process. Therefore, there should be a local evaluator team set up in order to monitor and evaluate project operation. Prior to the evaluation process, the training workshop about are monitoring and evaluation process and related techniques should be provided to local evaluators. Local evaluator team have to monitor project working group continuously. The monitoring indicators including work plan, time frame, objective achievement. The monitoring and evaluation team will collect the information and assessment results for the village meeting in order to acknowledge and provide additional comments. This process will show a local people the results of the joint efforts of all parties to help solve the problems of the community (Boonchieng, 2015).

Participatory action research (PAR) is a technique that emphasizes community participation in finding and analyzing of community problem. Then, they can analyze and do a problem solving plan to reduce or eliminate community problem. This method and its process are beneficial to community collaboration and researchers. PAR is the suitable technique that is required participation from all parties (Baum et al., 2006; Boonchieng, 2015; Kindon et al., 2008; McIntyre, 2007; Whyte, 1991).

Review of related literature

Jianguo et al. (2005) conducted the research of siting analysis of farm-based centralized anaerobic digester systems for distributed generation using geology information system (GIS). Land-suitability evaluation was studied using GIS model for the assessment of potential energy systems as well as an anaerobic digester coupled with a power generator. The experimental design was model developing with the integration of environmental restriction, economic factors and social limitations in order to evaluate the appropriate site for system construction and installation. In order to determine factors that affecting to the selection of system installation site, the analytic hierarchy process (AHP) method was used. The obtained model was then applied to Tompkins County, New York as a case study for a practical demonstration site. The most appropriate site for distributed bio-energy systems using dairy manure was classified using a siting suitability map. From the integration of spatial data and non-spatial information from GIS based model, it was found that the model was suitable for the development of bio-energy. In addition, the model can be adapted for assessing other biomass resources.

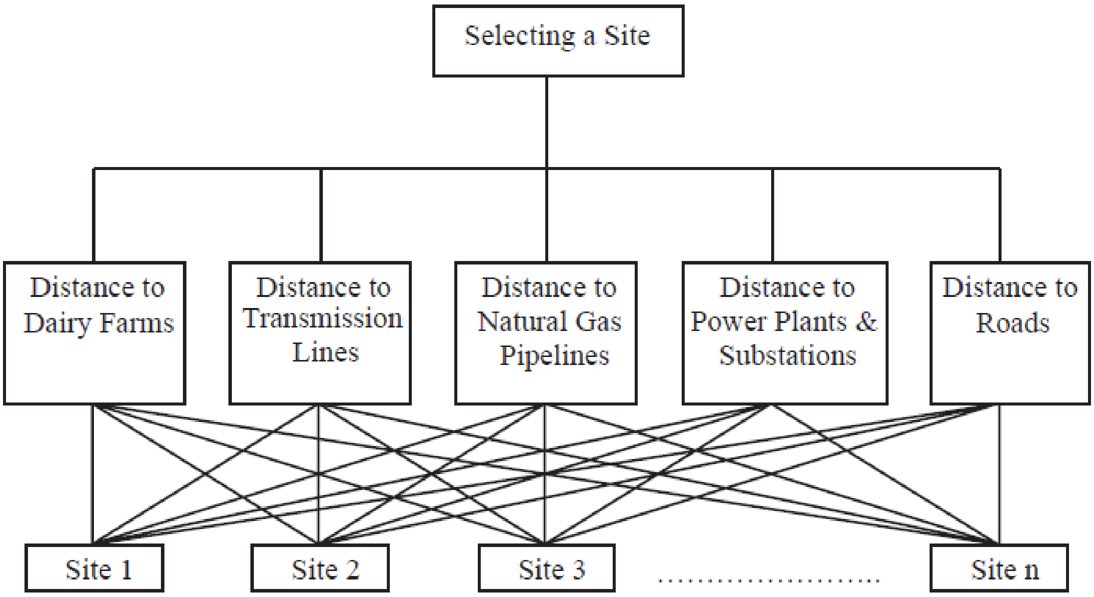

Figure 2.10 Structure of hierarchy for AHP

Source: Jianguo et al., 2005

Bioteau et al. (2012) conducted the research of a GIS-based approach for adjusting the improvement of collective biogas plants. A research project is devoted to the application of such spatial methodologies in local community. In this study, case study of a local scale community in the “Pays de Fougres” was selected. It was a rural area of 1000 km, contains 82,000 inhabitants, located in the northeast of Brittany, France. The total potential energy of livestock farming dung, agricultural waste, food industrial waste, garden waste from, sewage sludge from wastewater treatment process and food wastes from educational institution cafeterias and hospitals were found to be24 802, 10 369, 1 395, 268, 141 and 62 toe respectively, totalizing 37,037 toe. Bio-energy resources from agricultural activities such as crop residues and livestock farming manure was found to be 95% of the total energy potential. Bio-energy potential could be used to substitute 11of the total energy consumed from households.Even this percentage in substitution is look like small, but it could differentiate an important awareness in order to help in implementation of the renewable energy commitments in France. First of all, as shown in Figure 2.11, a bio-resource mapping was created using a specific calculation technique for each bio-material. Maximum distance was considered to be relative to the energy potential of each bio-material. The sum of the energy potential was calculated as a derived layer. Then, sensitive areas such as distances from housing and wetlands were recognized as inhibited areas that there should not be the biogas plant construction as labelled the buffer zones in constraint map. Suitability map was finally created in GIS pattern using the data obtaining from energy potential and constraint map. The GIS technique was also used to determine actual transportation route and reasonable route to bio-material for biogas production. Therefore, this research could be used to confirmed that GIS technique is an important instrument to evaluate biogas potential in community with the accurate location to estimate bio resource, sensitive area for system construction, suitable biogas grid and their most benefit transportation.

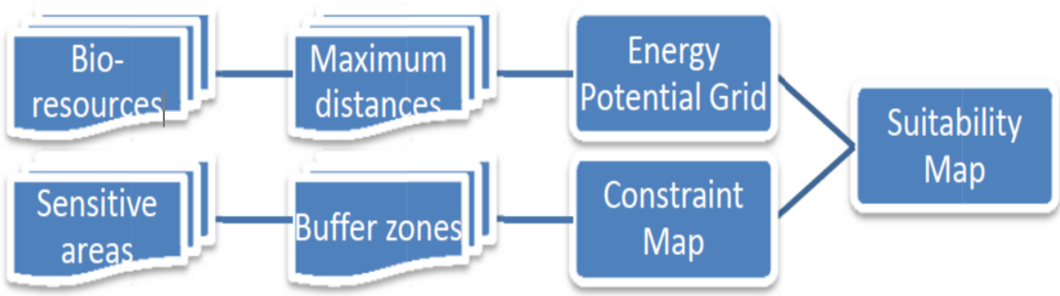

Figure 2.11 Flow diagram describing the successive steps of the geographical free algorithm

Source: Bioteau et al., 2012

In Kujawsko-Pomorskie Voivodeship, Poland, there was also a research in the assessment of potential of livestock manure and crop residue for biogas production by Sliz-Szkliniarz,& Vogt(2012). The research was carried outusing GIS technique. The selection of Kujawsko-PomorskieVoivodeship was due to the construction of biogas plant in Poland was identified to be under legal regulations. The extension of potential livestock manure and crop residue for biogas production stimuluses the requirement for the evaluation of various kinds of geo graphicaland environmental constraints along with economical and technical issues. It confirmed that biogas plant construction and development was socio-economically and ecologically considered. In this research, both spatial and non-spatial data were combined to the GIS model to support the analysis of appropriatelocations for biogas plant construction. The major bio substrate was livestock manure, such as pig and cattle, and co-substrates such as crop silage.Moreover, the economic analysis as cost and benefit was also evaluated together with technical analysis to determine how much biogas feedstock could cost to make investments viable as well as to evaluate the economic factors or value which can encourage the biogas development, production and utilization. The techno-economic evaluation was studied for the integration of heat and power generation and bio-methane injection into the biogas grid. The operation steps of this research is shown in Figure 2.12.

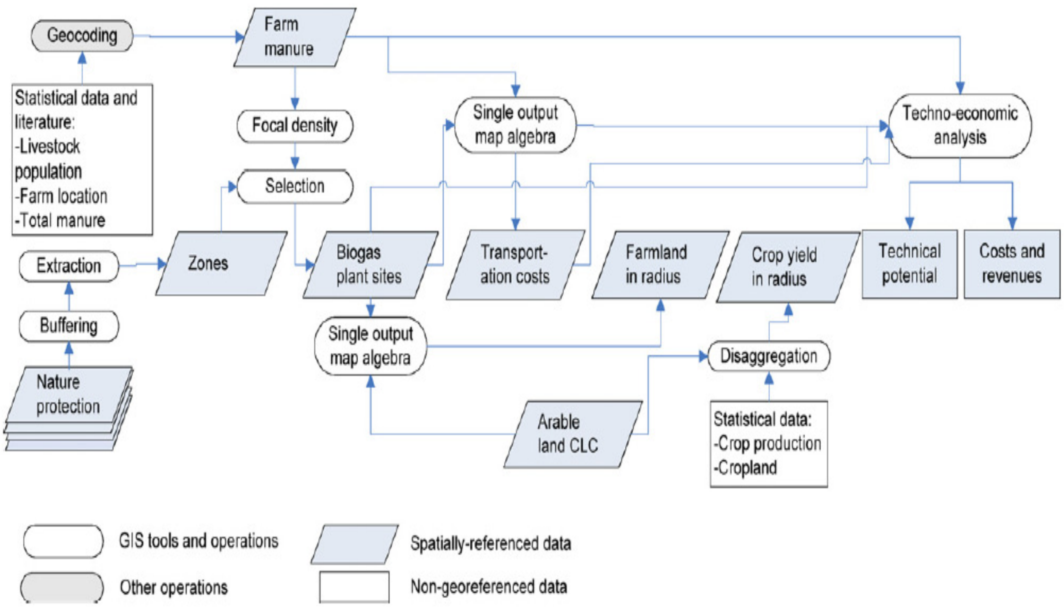

Figure 2.12 Flow diagram describing operation steps of the method.

Source: Sliz-Szkliniarz et al., 2012

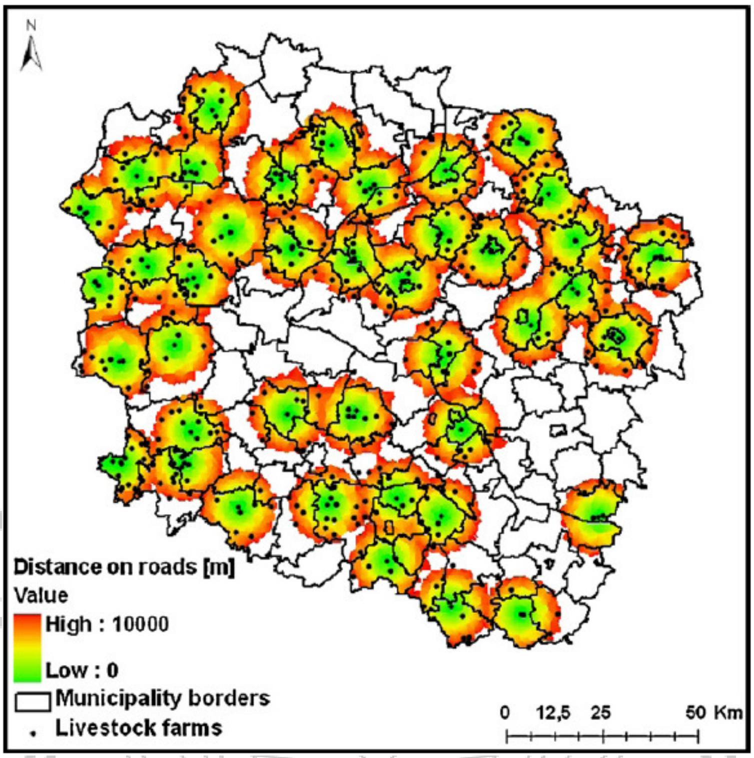

Figure 2.13 Selected livestock farms in a distance of 10km on roads from potential

Source: Sliz-Szkliniarz et al., 2012

Biomethane is produced by the quality improvement of biogas to obtain high percentage of methane more than 95% that the quality is equivalent to LPG. It is an interesting energy source due to it can be produced by the purification of biogas. The biogas quality improvement is called biogas upgrading. Molino et al.(2013)conducted the research of biogas upgrading via membrane process by modelling of pilot plant scale and the end uses for the grid injection.This research presented the techno economical factors for the upgrading technique, staring from biogas until the production of bio-methane. In order to improve the quality of biogas to obtain bio-methane, it is required to eliminate sulfur compounds, water, carbon dioxide, oxygen, metals, and halogenated organic molecules. The upgraded biogas called bio-methane can be used for bio-methane grid and transportation to households and industry. On the other hand, it can be applied in CNG-vehicles usage.

Petersson (2015)stated that the composition in biogas was not only methane, carbon dioxide and water. It may also comprise with other chemical substances called impurities that could cause a serious damage to biogas pipeline through the biogas injection to grid and households utilization. The impurities in biogas could cause corrosion and mechanical wear as well as it could release some poison gases. Therefore, it was required to remove these impurities by using various kinds of technique. The effects that different impurities may occur when biogas is used and techniques to decrease their concentrations.From the biogas technology study, the researchers have concentrated on enhancing the biogas quality into bio-methane which have high purity and high methane contents before transporting biogas togrid and households.As a result of the biogas quality upgrading, the gas contains high methane with low impurities which it's quality is equivalent to LPG. Therefore, the consumers could believe in biogas quality that have high security in use. On the other hand, biogas quality upgrading technique utilization will strongly cause the expensive cost of technology. Hence, the economic analysis should be one of the most important key to evaluate the possibility of high quality biogas plant construction.

Economic analysis of biogas production was also studied by Himmawan, Rachapradit, and Rachapradit (2017). Biogas production system used for economic evaluation in this study was PVC bag biogas digester using animal manure as biogas feedstock. Economic analysis in this study was the calculation of cost-benefit by using PVC bag biogas digester with animal manure as biogas feedstock to replace LPG usage of household in Phitsanulok, Thailand. In order to obtain insights data about initial investment costs, financial benefits and maintenance expenses experienced to the PVC biogas bag digester users were carried out by in-depth interviews.The researchers found that biogas generated from PVC biogas bag digester could entirely substitute 100% of LPG using, for household with 4 members, 3meal cooking daily and having livestock farming. The economic analysis found that there were THB 6,292 NPV, 25.41% IRR and 2.67 years payback period.In addition, changes in LPG price sensitivity investigation exhibited that the NPV of the project remains positive value until LPG price drops more than 20. The researchers proposed that PVC biogas bag digester is an economical way for biogas production in households as well as concrete example of renewable energy and eco-friendly.

In order to construct biogas plant as well as other renewable energy, economic analysis should be concerned especially in the term of worthiness. Assawtangsathean (2017)studied the worthiness of investment in renewable energy in Thailand. The researcher found that the cost structure among all types of renewable energy was similar. Nevertheless, when investment return was concerned, biogas was better than the other renewable energy based on payback period of 3-4 years of calculation.The researcher also found that the worthiness of the renewable energy investment should be concerned not only the investment of low costs of infrastructure and high profitability, but also the overall economic worthiness, environment and community, and society.Finally, costs in technology, materials, land, buildings, electrical bills and consultancy were found to be the key factors affecting the worthiness of the investment in renewable energy in Thailand with statistical significance at 0.05 level.

Kongpann (2014)conducted the research of economic and social return on biogas investment system from swine farms. Case study in this research was Tambon Tam, Chai Badan District, Lopburi. Study on economic and social return of biogas investment system from pig farm in the case study was applied by the concept of evaluation. The results of the research can be concluded that. This project is worthiness in the investment. The return of investment of 333,264 and 259,564 baht in the first year, and second year, respectively.The return to descending order was: 1) The farming area produced higher yield per hectare from biological fertilizer usage. Bio-fertilizer could also be sold and could help to decrease chemical fertilizer cost. 2) The production of biogas could decrease LPG cost in households.3) It could provide job and employment in community. 4)Greenhouse gases could be decreased as well as environmental friendly.

The total cost of investment in the research reported by Kongpann (2014) was 416,400 Baht, consisting of construction cost is gas tank, gas pipeline, gas furnace and gas pressure station, Total cost for management fees was 31,200 Baht per year including fertilizer fee and utilization of public utilities.The direct and indirect returns were found to be worthiness the investment. Internal Rate of Return (IRR) is 32.61%. The payback period was found to be not exceed 22months. The net present value (NPV) was found to be1,067,030 Baht and the cost per effectiveness (C/E ratio of 19,553 Baht/tonCO_2eq). The results of this research would be the basis for the analysis of the efficiency of renewable energy investment in the public sector or social enterprise. Based on a study of biogas economics research, biogas technology is worthiness investing in both social and economic aspects. By the way, it was also depended on the cost and raw materials. Analyze the economics of indicators. Indicators are NPV BCR IRR PP and COE.

Siladech et al. (2012)conducted the research the development guidelines for local energy operation in MahaSarakham Provinces.The objectives of this research were to study means to develop local energy in MahaSarakham Provinces. The implementation of this quantitative research was through data collection was by was by means of the CIPP Model application. The study on assessment of the project operation in planning the local energy in MahaSarakham Province There were two aspects of data collection; semi-structured interview-inquiry of data from 10 officials of the Energy office and Prather Tambon Administration Organization (TAO), Nadoon District, MahaSarakham; a questionnaire-collection of data from a sample group of 100 participating people in the project. The Research Results: The local energy project operation were found that the strategic development plan on energy was clear and compatible with community development. but local people did not understand problems and situations of energy much. Besides, there were limitations of budget, personnel and specific was not suitable because of being designated by the annual budget planning, Some procedure did not really make local people understand and aware of energy importance; it did not cause much interest, either The limited budget could not promote technology to meet community's needs; besides, complexity of technology prevented inspiration from learning and experimenting with innovations.

Phoochinda (2102) conducted the research on sustainable energy planning of the community in Thailand. Community energy planning is a policy laid down by the Thai government with the main purpose of increasing the use of alternative energy, such as renewable energy. In Thailand, the success of community energy planning was found to be at a moderate level, as it results in the reduction of energy expenses, self-production of energy for consumption in the community, more prudent use of energy, and the setup of energy study centers. However, there are some problems and obstacles in community energy planning including lack of continuation in energy management because support is provided only during the initial phases with a view to promoting the community's self-support; not enough importance given to community energy planning at the policy level; lack of awareness of the importance of community energy planning on the part of the leaders and people in the community; lack of appropriate support with funds and resources; and failure to adjust community energy planning to suit the community's context. The ten processes in community energy planning, as proposed by the government, can be used as guidelines in the future. Prior to that, however, it is advisable that the community's actual needs be analyzed, as well as available resources, capacity for the management of energy self- production, and appropriate means to save energy. Also important is data collection of the results of community energy planning so that the community can be informed.

Thanarak et al. (2017) reported the factors affecting biogas usage of restaurants in Phitsanulok Municipality.The factors were consisted of biogas production system knowledge, the willingness of the businesspersons, the government funding and the energy user awareness. Population and samples were 21 barbecue and hotpot buffet restaurants time in Phitsanulok municipality. Krejcie & Morgan method was used in population sampling. Data collection was done in December 2015. Multiple regression analysis was used to analyze the obtained data. A research tool used in this study was questionnaire contained 39 questions. Statistical analysis showed that government support was revealed a greater capability to forecast the biogas utilization concerning the biogas of restaurants at 2.76 percent at a .05 significance level.

As compared to associated research, the community energy development model found that planning in community energy of Thailand was medium effective. As a result of the absence of actions continuousness and there was no concerning about the significance of community energy planning development as well as the budget limitation for community energy development support and resources. Moreover, the result confirmed that government support in biogas system production affected to the biogas installation in restaurants. The development method and pattern of community development by renewable energy will focus on production method and technique. In order to support the development and the utilization of biogas production, community should be a part of the development process and research. Therefore, participatory research and community decisions were found to be a key factor that could help to succeed in community energy development through the support of both technology and financial from the government sector.

CHAPTER 3

Research Methodology

A study of community development model with biogas grid in Mae Tha community consisting of the evaluation of potential in biogas production in the community, analysis of the feasibility of technical projects, economics, and community development models through biogas grids.The details are as follows: To achieve the objective of the research, the research work operation was split into 3 parts as follows:

Part 1: The evaluation of the potential of the community in generating biogas grid by studying the context and survey the livestock farming data of Mae Tha community, Mae On District, Chiang Mai, as shown in Figure 3.1.

Part 2: The analysis of the feasibility of the community biogas grid in 3 aspects including the analysis of the technical, economic and operational possibility, as shown in Figure 3.2.

Part 3: The community development by biogas grid by analyzing the data from the context of the community, using of energy, potential of community energy and analysis of the possibility of the project on technique, economy and operation to specify and create the format of specifying buying-selling rate of biogas with the suitability on the economy and operation by administration in the format of community cooperative, as shown in Figure 3.3.

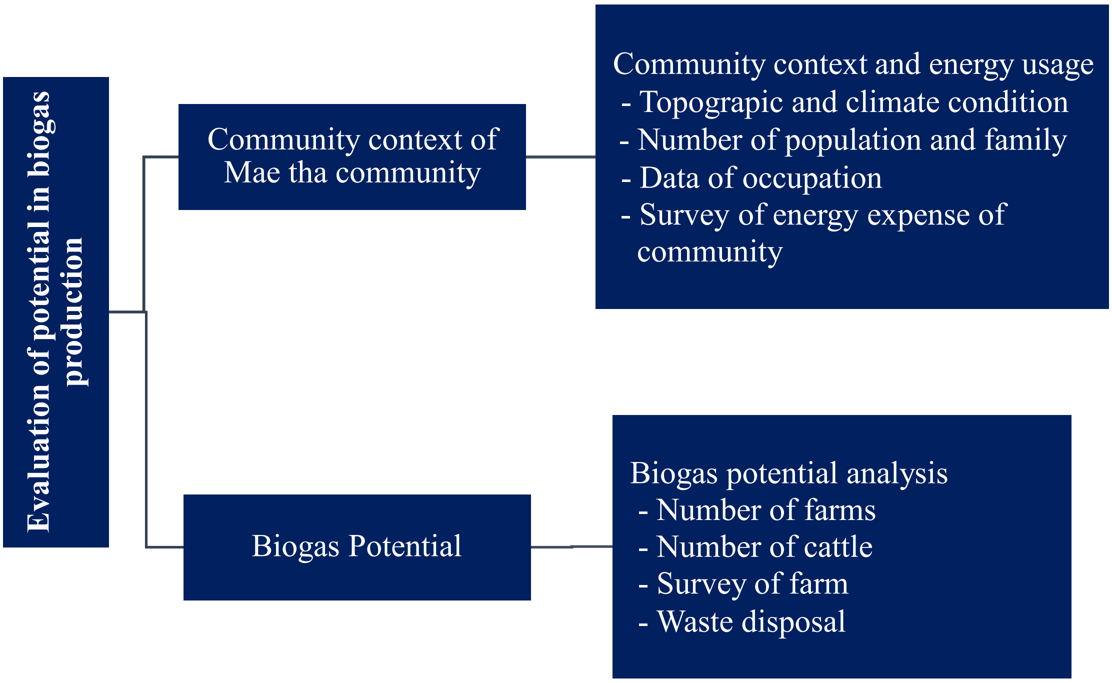

Figure 3.1 Potential assessment guideline of community power

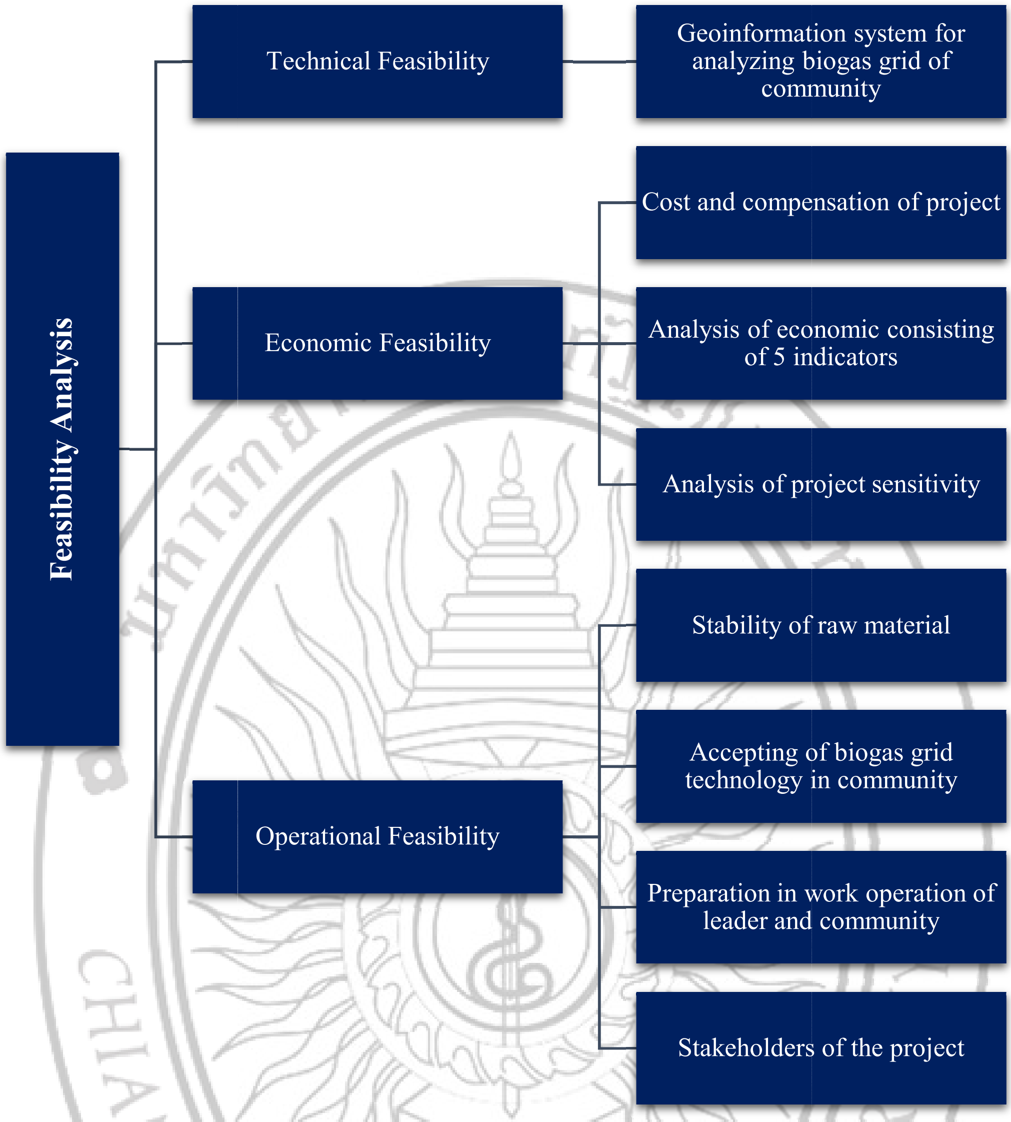

Figure 3.2 The guideline to analyze the possibility of biogas grid

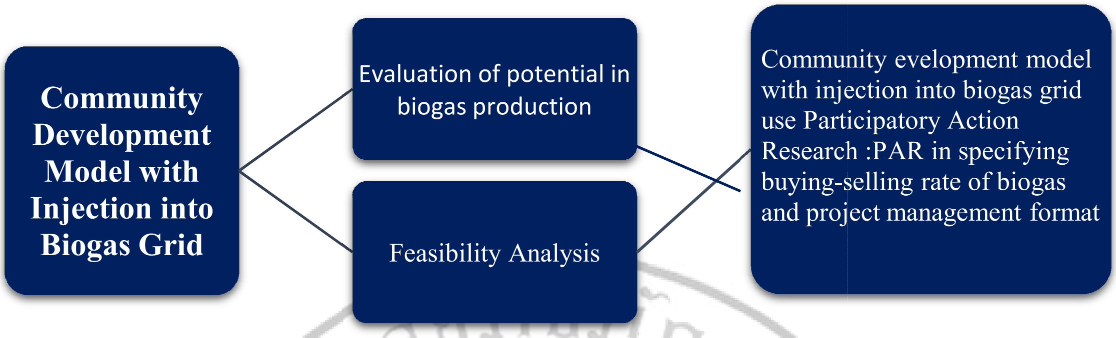

Figure 3.3 Guideline of specifying and creating the format of developing community by biogas grid

Population and sample group

Population and the sample group used in the research were divided into 3 parts as follows.

Part 1: Survey of the community context and using of energy from the households in Mae Tha community, Mae On District, Chiang Mai for 1,500 households which can specify the sample group for 100% of all the families.

Part 2: Survey and analysis of the potential from producing biogas from livestock farms(dairy cattle farm, beef cattle farm and pig farm) in Mae Tha community, Mae On district, Chiang Mai in the number of 128 farms which can specify the sample group for 100 of all the cattle farm.

Part 3: The analysis of people with interested in the project from the business operator selling LPG gas, cattle farm owner and people in Mae Tha community , Mae On district, Chiang Mai by using In-Depth Interview of business operators selling LPG which could specify the sample group from purposing sampling for7villages and 1 person for each village. The in-Depth Interview of dairy cattle farm can specify the sample group from purposing sampling for 7 villages and 3 people for village and using Questionnaire with people in the community for 4,860 people which can specify the sample group by using the table of Krejcie & Morgan specified to have the ratio of the interested characteristics of people in the rate of 0.5 and the acceptable error is 5% and the conviction rate was 95% by having the sample group of 357 people.

The tools and method in collecting the data

This research had the objective to study the community context of using energy and evaluate the energy potential of community which will use Primary Data and Secondary Data to select the suitable technology in using and developing community and then analyze the possibility of using the technology of biogas grid with the community to specify and create the format of community development by biogas grid by having the details, tools and method in collecting the data as follows.

The tools used in collecting the data

The tools used in collecting this research work was divided into 3 parts consisting of part 1, the tools used in collecting the data was community context and using of energy. Part 2 was the tools used in collecting the data of evaluating energy potential of the community. Part 3 the tool used in the analysis of the possibility of the community biogas grid and the part 4 the tools used in analyzing the format of developing community by biogas grid which had the details as follows.

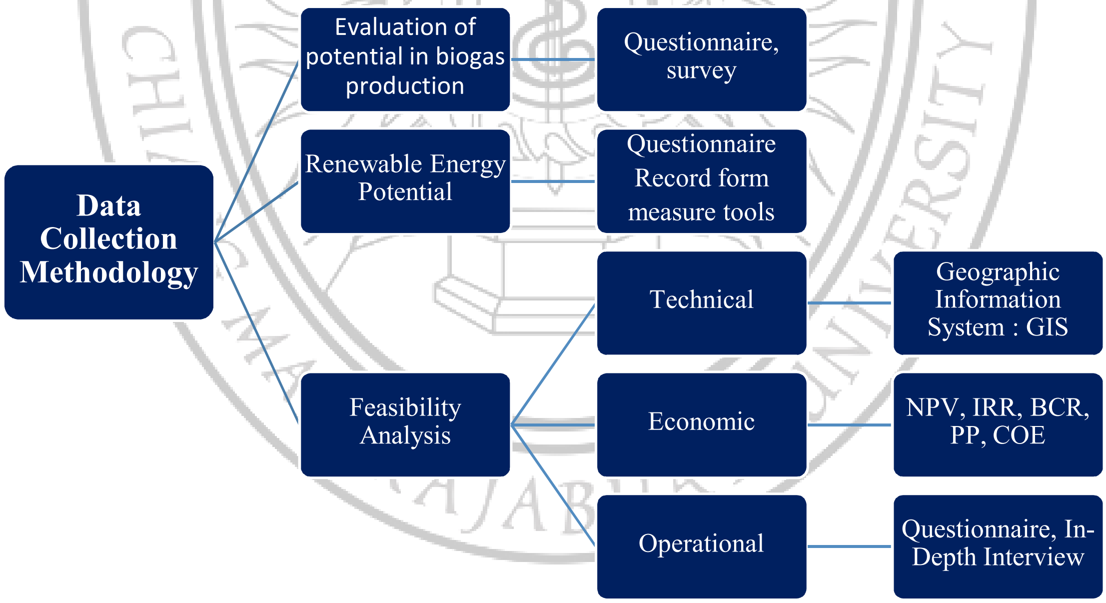

Figure 3.4 The tools used in collecting the data

Part 1: The tools used in collecting the community context data and using of energy which the data were collected by using questionnaire in the appendix A to question people in the community for 1,500 households which was 100% of the amount of all the households.

1) General information of the questionnaire respondents

2) The data on using energy (electricity cost, fuel cost, LPG cost and firewood)

3) The data for garbage amount and garbage selection

4) Knowledge and understanding on alternative energy

Part 2: The tools used to collect data for assessing the potential of biogas systems in the community was done using the questionnaire Record form And GPS coordinates, as Appendix B, to evaluate and analyze the potential of biogas production in the community. Tools used in analyzing the possibility of community biogas grid, analyzing the possibility of community biogas grid by using Geographic Information System : (GIS) in analyzing the technical suitability of biogas project technique by using 5 economic indicators consisting of NPV, IRR, BCR, PP and COE and analyze the sensitivity of the project in analyzing the suitability analysis on economics of the biogas grid by using In-Depth Interview and using the questionnaire in the appendix C in analyzing the suitability on the operation of biogas grid.

Part 3: The tools used in analyzing the format of developing community by biogas grid by Participatory Action Research (PAR) as the process emphasizing on the participation of the community in the study to find the case, problems of community to join hands analyzing, planning the correction of problem of community.

Data analysis

1. Analysis of biogas potential in the community

Analysis of the context data of community and using of energy community context analysis secondary data were used to study the general condition of the Mae Tha community using content analysis and analysis of energy consumption from electricity, oil, LPG and firewood from the energy consumption questionnaire. By means of average. And the sum of the energy consumption data. To analyze the amount and value of community energy.

Analysis of the community biogas potential Community Biogas Potential Analysis 128 farms, beef cattle and pigs accounted for 100% of total farms. The analysis of the number of livestock is shown in Table 3.1. Type and number of animals suitable for the biogas production system.

Table 3.1 Type and number of animals suitable for producing biogas production system

Type	Pond level (cubic meter)			
	30	**50**	**100**	**1,000**
Dairy cattle (number)	17	28	56	560
Beef cattle (number)	31	52	104	1,040
Pig (number)	140	230	460	4,600

Source: NSTDA, 2002

2. Analysis of the feasibility of the biogas grid

2.1 Analysis of the Technical Feasibility

Analysis of the Technical Feasibility of community biogas grid, the research had survey the data of cattle farm by using questionnaire, data record form and Global Positioning System (GPS) by using the survey of dairy cattle farm, beef farm and pig farm in the number of 128 farms which are in the rate of 100% of all the cattle farm by surveying the type and number of the cattle , characteristics of raising, droppings disposal method, selling method, height from sea level and collection of the coordinate of cattle farm, analysis of the technical feasibility of biogas grid with the details as follows.

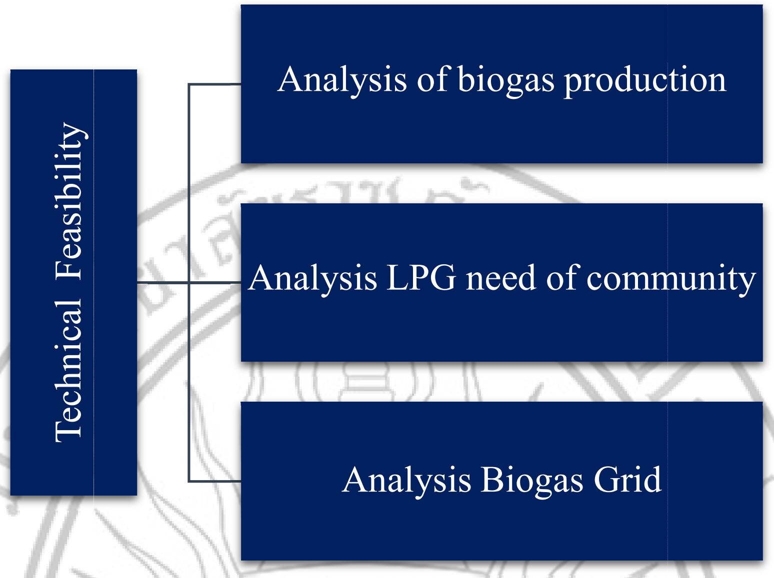

Figure 3.5 Guideline of the analysis of the technical feasibility

Analysis of the quantify of biogas that can be produced depended on the number of animals by analyzing from the number of cattle. Nowadays the biogas production system technology in various formats had been improved and developed from the government and private sector inside and outside the country regarding the efficiency, quality, safety and price etc so that the biogas production system has stability and could be more acceptable. This would create use of alternative biogas production system instead of LPG widely.

The analysis of the amount of biogas happened can be calculated from the size of biogas tank. The amount of biogas happening per day was 50% of the estimate of the size of biogas which in this research the research focused on using biogas with quality close to LPG by having Biogas Clean-up and Upgrading System to be Bio-methane by carbon dioxide disposal system (CO_2), Hydrogen sulfide (H_2S) and the humidity from biogas which would cause the loss of biogas around 50% of the amount of bio-methane which can replace LPG around 85% (1 kilogram Bio-methane = 0.85 kilogram LPG)

Analysis of the need to use LPG of Mae Tha community by analyzing from the energy use questionnaire from gathering data from questionnaire for 1,500 families which were 100% of all the families by analyzing from the total amount of how to use LPG gas per day in each family.

Analysis of biogas grid was an analysis of the amount and size of biogas production system that was suitable for the need to use of community and suitable on the area along with analysis of the grid of biogas pipe by using Geographic information system (GIS) to analyze the technical feasibility of biogas grid which the topographical information technology system was the working process on Spatial Data by computer system used in specifying the data and information technology relating to the area position, the data and map in GIS was information technology system in the format of data table and the database relating to special data. As for the application to use the topological in analyzing the biogas grid of the community by importing the data in the position of cattle farm to analyze the suitable area in distributing biogas to each family in the community for 1,500 families.

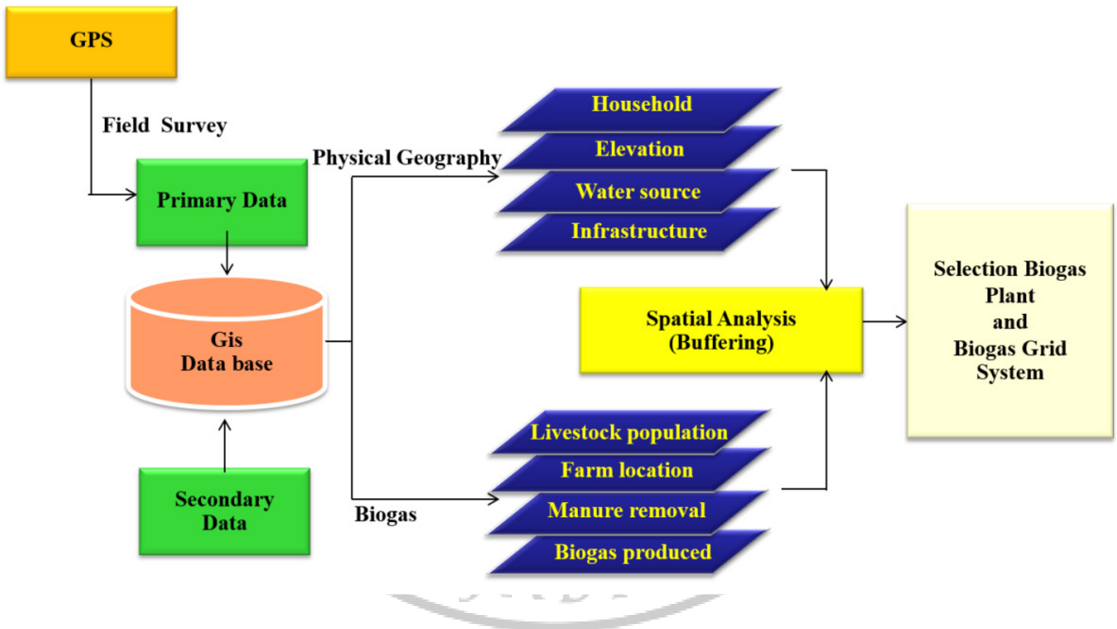

Figure 3.6 Guideline of how to analyze biogas grid by GIS

2.2 Analysis of the economic feasibility

Analysis of the economic feasibility of Biogas Grid grid by analyzing the cost-benefit of biogas grid by splitting the cost into 2 types which are Fixed Cost and Variable

Cost. The main Fixed Cost consists of Biogas Plant production system construction budget and Biogas Clean-Up and Upgrading Plant and biogas Grid to families including buying-selling meter of biogas and analyzing the Variable Cost from context data of community along with the work operation and management of biogas grid in the format of community cooperative which was the cost varied according to usage. Then make Benefit Analysis of biogas grid from selling biogas to Biogas Grid for 1,500 families. The project compensation will be consistent with the biogas tank, produced biogas quantity and the rate of buying and selling biogas making the project to be suitable and worth the economy.

Analyzing the Economic Analysis which the analysis indicator of the economic effect and project decision have 5 indicators as follows.

- Net Present Value : NPV
- Internal Rate of Return : IRR
- Benefit/Cost Ratio : BCR
- Payback period : PP
- Energy cost per kilogram comparing to LPG (Cost of Energy : COE)

The details of the economic analysis and project decision was as follows.

1) The analysis and decision to invest in the project by analyzing from Net present Value : NPV which was to calculate the difference between current cost of the expected compensation in the future according to the required minimum compensation rate or the Cost of capital, the decision making to accept the project depends on the positive cash current which shows that the compensation from investment was higher than the required rate of return or more than Cost of capital.

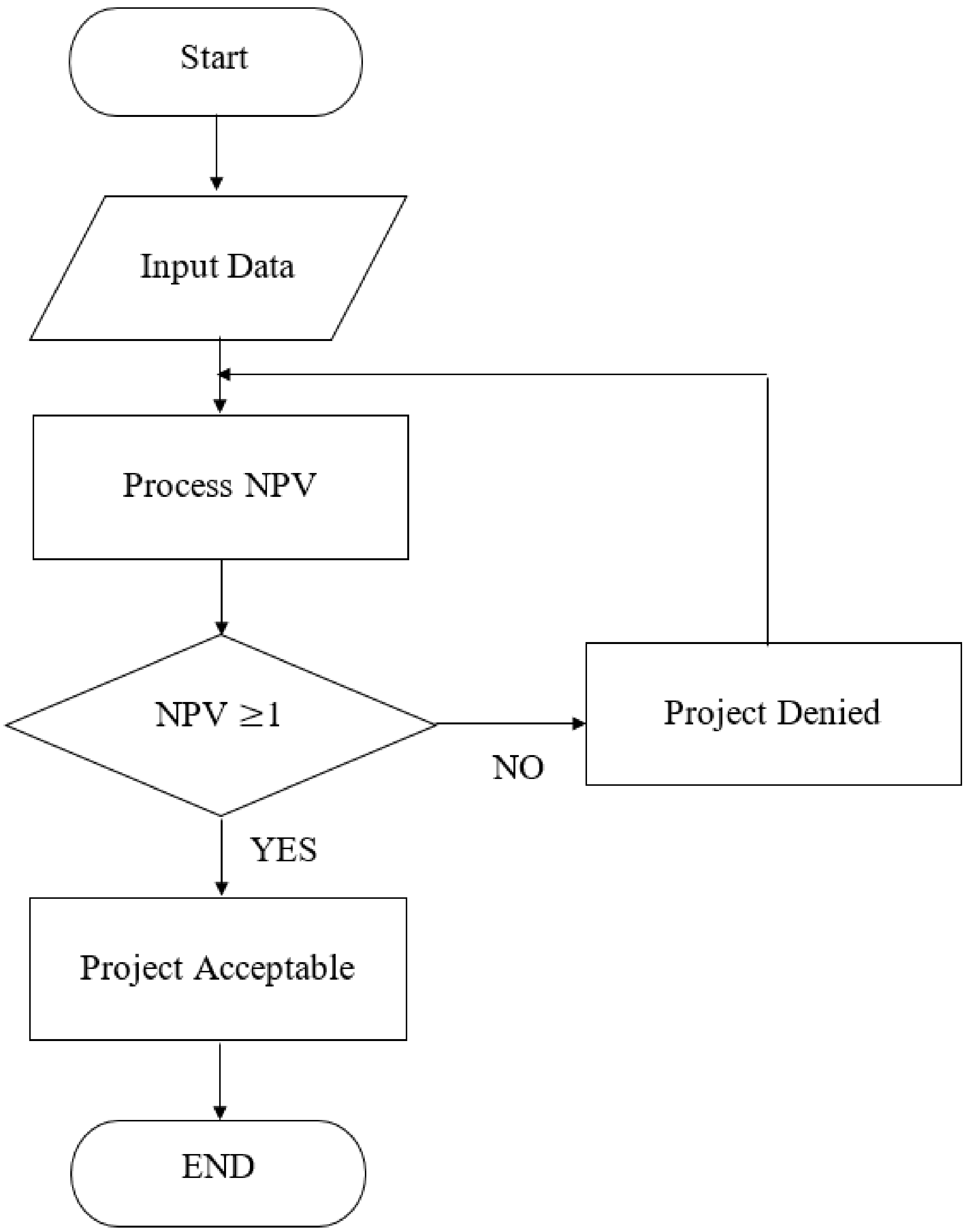

Figure 3.7 The analysis and decision-making of the Net Present Value Indicator

2) Analysis and decision-making to invest in the project by analyzing from Internal Rate of Return: IRR which was the calculation to find the compensation result received from the investment in the project. This compensation rate will be the rate making Net Present Value to be 0 or the compensation received from the first investment. When knowing

compensation rate from the investment to accept the project when the compensation rate from investment was higher than Required rate of return or more than cost of capital.

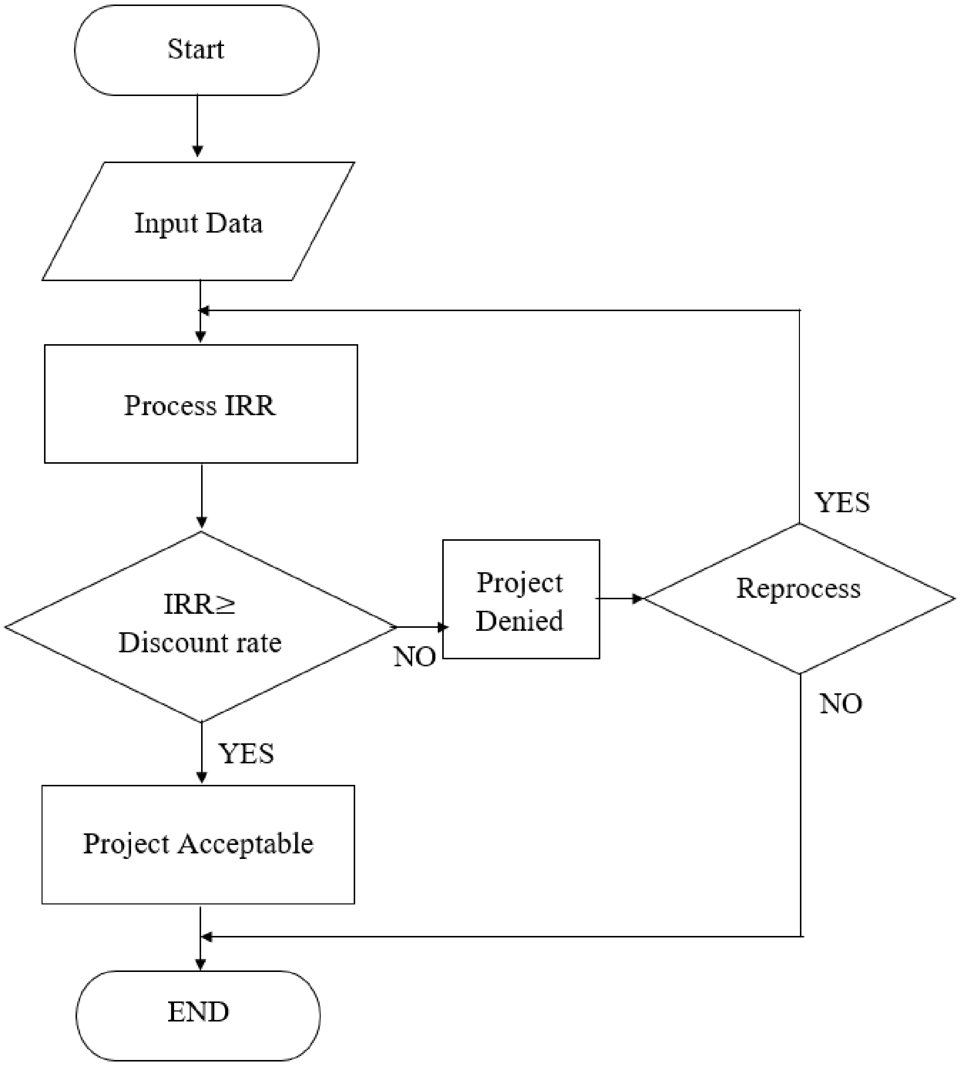

Figure 3.8 Analysis and decision of Internal Rate of Return

3) Analysis and decision making to invest in the project by analyzing from Benefit-Cost Ratio (BCR) which was the difference of value calculation of the benefit with the value of the expense which was the compensation rate per cost. The decision-making to accept the project depended on the benefit per positive cost which shows that the compensation from that investment was higher than the Cost of Capital.

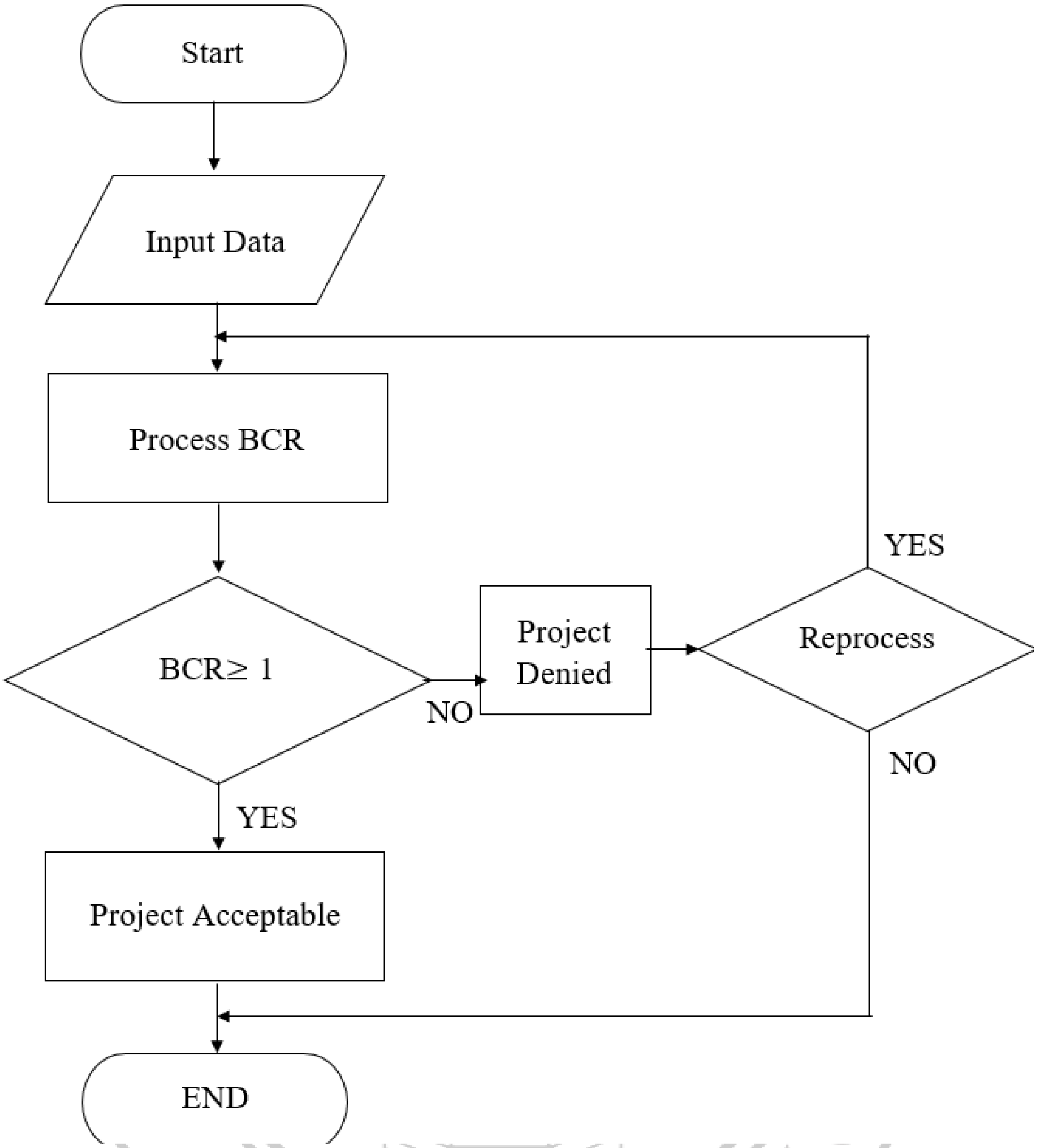

Figure 3.9 Analysis and decision-making of Benefit-Cost Ratio indicator

4) Analysis and decision-making of project investment by analyzing from Payback Period (PP) to consider the investment period so that the net cash receiver able received from the investment is worth with the invested cost, the decision-making to accept the project depending on the break-even point period. If the break-even point period is short, the project would worth the investment.

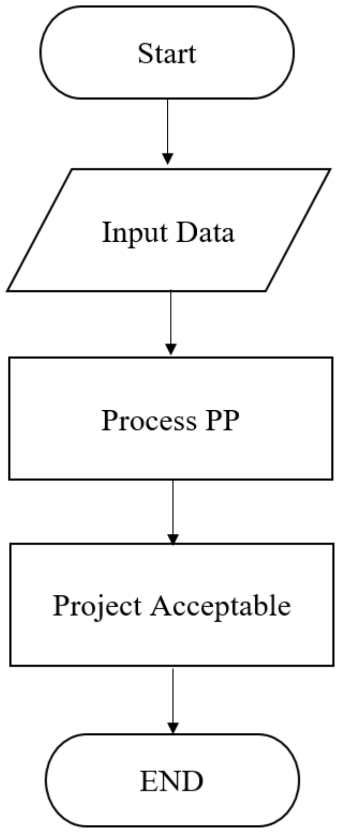

Figure 3.10 Analysis and decision-making of the Payback period indicator

5) Analysis of the energy cost per kilogram comparing with LPG (Cost of Energy : COE)

Energy cost per kilogram comparing with LPG gas by evaluating the energy cost of energy production system included in the investment cost, the operation and maintenance cost which was the evaluation of all yearly accumulated expense used in the production (cost) comparing with the kilogram of all LPG gas that the system can produced for the entire project operation period.

Analysis of the Project Sensitivity Analysis, the research focused on analyzing the Fixed Cost change that caused suitability of the operation to buy and to sell biogas via community pipe grid. From the study of the LPG situation after LPG inflation for free trade to reflect the actual world market. There would be not retailing and wholesaling price control in perfect competition to support the future that Thailand would import more LPG from the restriction of the production source in the country that would be reduced. Nowadays, the LPG gas price in the world market would be very fluctuating comparing with the neighbor countries. The retailing price of Thailand was lower than almost every country except for Malaysia. The different energy price in each country was from tax policy and the fund collection system or different energy price promotion. Many countries still have price promotion but nowadays Thailand has fixed liquid petroleum gas fund to reduce the impact to people living cost and in the future the price of LPG will be increased continuously because there was a lack of fossil energy which would was more violent. Therefore, in order to support the dependence on alternative fuel of the government community there must be the support on alternative fuel. This was because alternative energy system technology was expensive and so there was not worthiness in the investment. Therefore, the researcher had the concept in analyzing the sensitivity of the project in 5 cases to analyze the price to buy-sell biogas with economic and operation suitability with the details as follows.

Scenario 1: When the government sector promotes in the investment of the community biogas grid 100% of the investment budget (only in the biogas production system, improvement of the biogas quality and community biogas grid)

Scenario 2: When the government sector promoted the investment budget of community biogas grid for 70% of the investment budget (only the biogas production system, improvement of biogas quality and community biogas grid)

Scenario 3: when the government sector supported the investment budget of community biogas grid for 50% of the investment budget (only the cost for biogas production system, improvement of biogas quality and community biogas grid)

Scenario 4: when the government sector supported the investment budget of the community biogas grid for 30% of the investment budget (only the biogas production system cost, improvement of biogas quality and community biogas grid)

Scenario 5: Analysis of the investment budget of the biogas that make the buying and selling price of biogas comparable to LPG in the rate of 28 baht per kilogram so that it would be consistent with the buying-selling price of LPG today by increasing the buying-selling price for 5 per cent per year.

2.3 Analysis of Operational Feasibility

Analysis of the operational feasibility by analyzing the preparation in the work operation of the leader and community analyzed from Secondary Data from gathering the data of community and from observation including the interview to receive the data of the preparation in the project operation, analysis of the acceptance of community biogas grid technology by using the questionnaire which was the analysis of the acceptance of biogas grid technology and to know the motivation in choosing technology and adjustment of the behavior to use labor from using LPG to use biogas. The stability of the raw material was analyzed from Secondary Data from gathering community data and from observation including interview to analyze the stability of the raw material source in producing biogas and analysis of people with interest in the community by analyzing from the questionnaire and in-depth interview form. The target group was business operator selling LPG, owner of cattle farm and people in Mae Tha community in order to analyze the possibility in the operation of the project of community biogas of Mae Tha community.

3. Analysis of the model of community development by biogas grid

The analysis of the community development by biogas grid by Participatory Action Research (PAR) was the process with the participation of the community in analyzing and decision-making in choosing technology with suitability with the community potential. The analysis of the format of community development by biogas grid was the study of community context, using of energy and study of potential on alternative energy with community. When receiving the potential with suitability in community operation, the project technical, economic and operational feasibility was analyzed order to know the project operation guideline to analyze the format of community development by biogas grid by Participatory Action Research (PAR) by operating with the community along with returning research work to community to confirm the correct and suitable research result in using with the community of Mae Tha community, Mae On district, Chiang Mai.

CHAPTER 4

Results and Discussions

A study of community development model with biogas grid in Mae Tha community consisting of the evaluation of potential in biogas production in the community, analysis of the feasibility of technical projects, economics, and community development models through biogas grids. The details are as follows:

Results

1.Analysis of biogas potential in the community

1.1 Analysis of Mae Tha community energy expense

From the analysis of the questionnaire, energy expense data of Mae Tha community in February 2014 was carried out consisting of electricity, vehicles fuel, agricultural fuel, and LPG payment. The total questionnaires of 1,093 were analyzed as shown in Table 4.1.

Table 4.1 Energy expense of Mae Tha community in February 2014

Village No.	Energy Expense			
	Electricity (Baht/month/ household)	Vehicles Fuel (Baht/month/ household)	Agricultural Fuel (Baht/month/ household)	LPG (day/ 15 kg)
1	257.59	2,115.77	1,656.78	87.15
2	326.34	1,244.58	757.66	103.39
3	286.98	1,017.98	932.81	129.14
4	336.21	2,333.56	646.92	79.16
5	415.45	1,741.67	1,142.37	83.72

Table 4.1 Energy expense of Mae Tha community in February 2014 (Continued)

Village No.	Energy Expense			
	Electricity (Baht/month/ household)	Vehicles Fuel (Baht/month/ household)	Agricultural Fuel (Baht/month/ household)	LPG (day/ 15 kg)
6	325.71	939.13	1,105.36	81.51
7	405.48	1,654.96	686.51	67.81
Average	**336.25**	**1,578.24**	**989.77**	**90.27**

Analysis of electricity consumption data obtained from the questionnaire showed that the electricity cost was 340 baht per month per household. The data of vehicle fuel consumption showed that the average fuel expense for vehicles was 1,578.24 baht per month per household with the total vehicle fuel usage in Mae Tha of 28,080,000 baht per year. The analysis of agricultural oil use data from the questionnaire showed that the average price of oil for agriculture was 990 baht per household. Mae Tha community spent 989.77 Baht for agricultural fuel per month. A survey of LPG usage showed that 15 kilograms of LPG was used for an average of 90 days per household (0.2 kg/day/household) equivalent to 300 kg/day/community. The price of 15 kilograms LPG was 420 baht. LPG usage in Mae Tha community is found to be 2,520,000 baht per year. Estimated energy expenditure of Mae Tha community was about 48 million baht per year.

1.2 Analysis of livestock farms information

From the study, the area survey having potential in producing renewable energy has shown that Mae Tha community is the farming community. It has numerous livestock farming including dairy cattle, beef cattle and pig farming. The researchers analyzed the biogas potentially produced from these farms, as shown in Table 1, the number of livestock farms and the capability of biogas production in Mae Tha community. From the biogas potential survey, there were 128 livestock farms in Mae Tha community, consisting of 60 dairy cattle farms, 45 beef cattle farms and 23 pig farms. The number of dairy cattle, beef cattle, and pig was found to be 1,865, 807, and 2,480, respectively. From the study, biogas potentially produced from these farms was calculated, as shown in Table 4, biogas potential in Mae-Tha sub-district. The results showed that, biogas could be produced from the existing manure of dairy cattle, beef cattle, and pig with the total biogas volume of 1,500, 350, and 250 m^3/day equivalent to 690, 161, and 115 kg of Liquid petroleum gas (LPG).

The results showed that there was a large number of livestock farms in Mae Tha community. In the future, number of farms trends upward.The major effect of animal manure from livestock farming to community is environmental pollution and health hazard. Therefore, utilization of animal manure for biogas production is the great solution for Mae Tha community.

Table 4.2 The number of livestock farms and the capability of biogas production in Mae Tha community

Livestock Farms	No. (farms)	No. (animals)	Biogas tank size* (M^3)	Biogas produced* (M^3/day)	LPG equivalent* (kg/day)
Dairy cattle	60	1,865	3,000	1,500	690
Beef cattle	45	807	700	350	161
Pig	23	2,480	500	250	115
Total	**128**	**5,152**	**4,200**	**2,100**	**966**

*Calculation based on National Science and Technology Development Agency (2001)

In order to select type of livestock manure to produce biogas, farm characteristics and manure collecting expedient were evaluated. The study found that most of pig farm in Mae Tha community were constructed on wet ground which were inconvenience for manure collecting. As well as beef cattle farms in Mae Tha community were no boundary farm that were not capable for manure collecting too. The area survey of dairy cattle farming to characterize the farming pattern and collect the farming coordinates had revealed that the farming pattern was half-sheltered half-free-range in designated area.The total farming area of dairy cattle was 113 Rais, in which encompassing 60 dairy cattle farms, 1,865 dairy cattle, and 10 dung tanks. Altogether, the available dung could be used in biogas grid system with the size of 3,000 m^3.

The biogas volume will be 1,500 m^3/day or equivalent to LPG of 690 kg/day. From this information, therefore, Ma Tha Sub-district community was capable of running biogas grid for the community size of 1,500 households. From the evaluation of dairy cattle manure potential in biogas production and LPG usage in Mae Tha community, the results showed that Mae Tha community has the potential to produce biogas more than LPG requirement in community. Therefore, biogas production from dairy cattle farms is suitable for Mae Tha community.

2. Analysis of the feasibility of the biogas grid

2.1 Analysis of the Technical Feasibility

The geographic coordinates collection and GIS analysis of all farms to evaluate the potential of the biogas grid installation has shown that the milk cattle farms are located around the community setting area. The housing setting are condensed within the nearby area, with the population of 1,500 households within the radius of 5 km. In order to design and designate the installation location of the biogas system, the technical possibility was analyzed for biogas grid utilization in Mae Tha community. Also, from report on development of biogas grid standard and the utilization potential of local biogas grid in community and/or industry area, we have found that the suitable size of the biomethane pipeline system should be in the radius of 5 km, where the households are condensed within this proximity. The biogas system should produce more than 2,000 m^3 of biogas to meet the criteria of the suitability set by Energy Research and Development Institute – Nakornping Chiang Mai University [ERDI-CMU] (2016).

Our study has shown that the distribution pattern of housing in Ma Tha Sub-district was along the community main road and was condensed within the same area, in the radius of no more than 5 km. This finding indicates that Ma Tha Sub-district is a suitable community for biogas grid utilization. One possible approach in biogas system design to allow sufficient amount for the community usage of 1,500 households is to designate one area with the biogas well size of 3,000 m^3 and with radius of utilization for 5 km. The spot of the biogas plant is shown in Figure 4.1

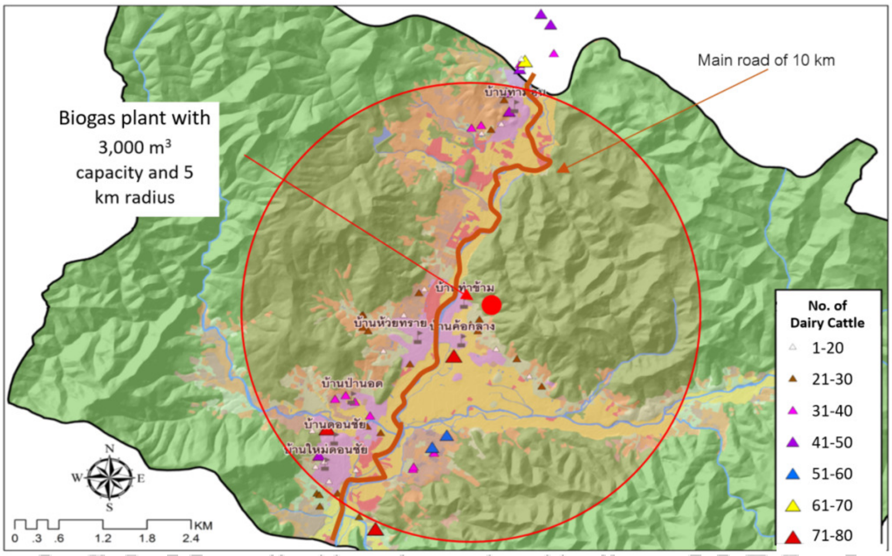

Figure 4.1 Milk cattle farm coordinates in Mae Tha community and proposed designated area for community biogas well

2.2 Analysis of the economic feasibility

The economical possibility was performed with the details as followings:

1) Investment Cost Analysis

The investment cost analysis of the community biogas grid with the size of 3,000 m^3, for 1,500 households was divided to be fixed cost analysis, i.e. the cost able to evaluate to money value without any change from usage, and variable cost, i.e. the cost able to change due to usage. The details of analysis are shown in Table 2.

2) Benefit analysis

Benefit analysis of biogas grid for the project period of 20 years has demonstrated the return of investment from the biogas selling to the community with the biogas size of 3,000 m^3 and production capability of 1,500 m^3 to be 750 kg/day of biomethane after quality improvement process or to be equivalent to 637.50 kg/day of LPG or about 600 kg/day (Energy Research and Development Institute – Nakornping Chiang Mai University [ERDI-CMU]. 2015).

3) Economic analysis

Economic analysis of biogas grid in the case area of Mae Tha community, Mae On District, Chiang Mai, has the requirements as followings:

- Biogas grid system of 3,000 m^3 for delivering biogas to the community member of 1,500 households.

- The biogas production yield, equivalent to 600 kg of LPG.

- Given discount rate (r) to be 7% (average Minimum loan rate of Bank of Thailand was 6.95%) (Bank of Thailand. 2017).

- Project duration was 20 years.

- Investment cost of the community was 100%.

Economic Analysis has given the results of 5 indicators: NPV, IRR, BCR, PP and COE as shown in Table 4.3

Table 4.3 Investment cost for biogas grid size of 3,000 m^3 for 1,500 households

Items	Cost (THB)
Fixed cost	
1) Biogas well, size 3,000 m^3	15,000,000**
2) Biogas quality improvement system, size 1,000 m^3/day	14,000,000**
3) Biogas pipelines, for 1,500 households	24,000,000**
4) Dung carriage truck, size 4,000 Liters, 1 truck	480,000
5) Labor cost for dung well, 50 well, 3,000 THB each	150,000
Total fixed cost	**53,630,000**
Variable Cost	
1) Yearly maintenance (THB/year)	200,000
2) Gasoline (THB/year) (Increase 2%/year)	180,000
3) Personnel (Increase 3%/year)	
- Executive, 1 person (THB/month)	18,000
- Finance officer, 1 person (THB/month)	15,000
- Technical officer, 1 person (THB/month)	15,000
- Mechanic, 1 person (THB/month)	15,000
- Truck driver, 1 person (THB/month)	8,000

** Cost of biogas well, biogas quality improvement system, and biogas pipelines were calculated according to biogas grid system developed by Energy Research and Development Institute – Nakornping, Chiang Mai University (ERDI-CMU. 2015)

Table 4.4 Economic analysis of biogas grid

Indicators	Results
Net Present Value: NPV (THB)	44,477,329
Benefit/Cost Ratio: BCR	1.67
Internal Rate of Return: IRR (%)	7.00
Payback period: PP (year)	9
Cost of energy: COE (THB/kg LPG equiv.)	17.21

From the estimation of investment cost and return of investment under the requirements mentioned above, the sale rate of biogas equivalent to LPG was given to be 32.17 THB/kg and increase rate of 5% per year.

Project sensitivity analysis

From the economic analysis of the community biogas grid, we have found that if the community invested for 100%, it would have to sell biogas equivalent to LPG in the price no less than 32.17 THB/kg, and with the increasing sale rate of 5% per year. Given the situation of the current market price of LPG, which is 28 THB/kg, the LPG price seems to increase according to the market mechanism in the world. The sensitivity analysis of the community biogas grid recognizes the importance of the constantly increased sale rate of LPG and the problem of energy shortage in the future. Therefore, the government sector should have a policy in supporting and empowering the utilization of renewable energy in the community. It could be a partial subsidy, and the author propose the following models:

Scenario 1: when the government sector support fixed cost for 100% (only biogas grid system and not the management cost)

Scenario 2: when the government sector support fixed cost for 70% (only biogas grid system and not the management cost)

Scenario 3: when the government sector support fixed cost for 50% (only biogas grid system and not the management cost)

Scenario 4: when the government sector support fixed cost for 30% (only biogas grid system and not the management cost)

Scenario 5: Analysis of the investment budget of the biogas that make the buying and selling price of biogas comparable to LPG in the rate of 28 baht per kilogram so that it would be consistent with the buying-selling price of LPG today by increasing the buying-selling price for 5 per cent per year.

Table 4.5 Economic analysis of biogas grid when the government sector supports the budget for 100, 70, 50 and 30%

Indicators	Project sensitivity analysis			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
NPV (THB)	1,369,942	14,286,325	22,892,658	31,498,990
BCR	1.10	1.50	1.58	1.63
IRR (%)	7.00	7.00	7.00	7.00
PP (year)	1.00	7.00	8.00	9.00
COE (THB/kg LPG equiv.)	4.93	8.62	11.07	13.53

From the estimation of investment cost and return of investment under the condition of Scenario 1, 2, 3, and 4, given BCR > 1 and IRR > 7%, the results showed that the community have to assign the buying-selling rate of the biogas equivalent to LPG to be no less than 4.25, 12.62, 18.20, and 23.78 THB/kg, and increase 5% per year.

Table 4.6 Analysis of investment costs that cause biogas trading 28 Baht per kilogram (LPG equiv.)

Indicators	Scenario 5
Net Present Value: NPV (THB)	38,024,210
Benefit/Cost Ratio: BCR	1.65
Internal Rate of Return: IRR (%)	7.00
Payback period: PP (year)	8.50
Cost of energy: COE (THB/kg LPG equiv.)	15.38

Currently the retail price of LPG with the tank size of 15 kg is 420 baht (28 baht / kg). Based on the economics analysis of the biogas grid, it was found that if the community invest 100% of biogas grid system construction they will not be able to sell biogas cheaper than present LPG price in the market. This could affect to the biogas grid utilization in Thailand. From economic analysis mentioned in scenario 1-4, the results showed that different investment budgets will have a direct impact on the price of biogas. Therefore, the researcher assumed that if the community would like to sell biogas at 28 THB/kg LPG equiv., there should be a support from government at least 15% of fixed cost. In addition, government should provide interest-free loans 75 - 80% for 10 years. The rest of 5-10% should be obtained from community in order to encourage local people participation in community development.

2.3 Analysis of Operational Feasibility

Stability of raw material

The results showed that Mae Tha Community is an agricultural community consisting of 80% of farmers. Surveying and interview with dairy cattle farmers found that the Mae Thong community now has 60 dairy cattle farms. The raw milk is sent to the raw milk collector plant located nearby the community. From the community development plan of Mae Tha community, it was found that the Mae Tha community is likely to expand and increase the number of dairy farms because there is a definite milk collector factory, local farmaers are experienced in dairy farming, and there is enough raw material for dairy farming. The community has also set up a livestock framing area for farm owners who want to expand their farms and new farm owners in the area of the community in order to reduce the environmental pollution. Moreover, old dairy cattle trading is not sold in bulk style. They will be sold individually. Therefore, there will be high stability of dairy cattle manure as raw material for biogas production in Mae Tha community. Also, there is a group member of dairy cattle farms owners to share an idea and operational direction of dairy farming.

Accepting biogas project technology of community

From the study of an acceptance in the biogas grid technology of Mae Tha Community, 357 local people were surveyed. The results showed that the factors that affect the acceptance and incentive for biogas grid technology selection were the reduction of the environmental problems from livestock farming, budget support from the government sector, cheaper biogas prices, the quality of biogas that is compatible with LPG, and stability of biogas.

Preparation in work operation of leader and community

Mae Tha community have plenty of local knowledge and knowledge from the experience gained in the community, such as resource management, knowledge management, forest fire management, wilderness care, forest management rules, irrigation system management, local community management experiences, sustainable agriculture, sustainable agriculture management concepts, sustainable farming techniques, and appropriate farming model.These knowledge bases are important to the improvement of the community sufficiency roadmap and the development of Mae Tha Community, which emphasizes the process of enhancing the knowledge and development of the Mae Tha community's ideas towards self-reliance according to sufficiency economy philosophy. Consequently, the operation of the community was focused to improve the existing activities in Mae Tha community. In order to support the sufficiency community, the local people were encouraged to do self-analysis, community analysis, knowledge and experience creation based on the concept of sufficiency economy, income reducing and income generation for sufficiency households volunteer. In Mae Tha community, Mae On, Chiang Mai, the community leaders have been very interested in and focus on renewable energy. Most of the leaders in the area have a lot of knowledge about renewable energy and the community has a committee on renewable energy in the community. They are able to study the potential and operation of community energy. The community can also update the community energy database to utilize in developing of community energy plan according to the community energy potential. Community leaders have been meeting and publicizing energy consumption in the community as well as renewable energy to help local people to realize in energy conservation and the use of agricultural waste products to convert into energy via various kinds of process. These groups have the strength and potential to push the community energy utilization.

Stakeholders of the project

There were 3 groups of stakeholders in this research, namely community members, farm owners and LPG business owners. The survey of 357 Community members was sampled by Krejcie & Morgan method. In-depth Interview of 21 farm owners and 7 LPG business owners were selected by proposing sampling.

For the evaluation of local people in the biogas grid model acceptance using questionnaire, the total number of 4,860 people in the community which can specify the sample group by using the table of Krejcie & Morgan specified to have the ratio of the interested characteristics of people in the rate of 0.5 and the acceptable error was 5% and the conviction rate was 95% by having the sample group of 357 people.

From the study of factors influencing the accepting biogas project technology of community, it was found that the most important factor was environmental pollution reduction (76%). The second was government support (62%), the third was Lower price of biogas compared to LPG (61%), the fourth was stability (56%), and the last was quality (35%). In addition, 77.45% of people in the community were found to accept the use good quality of biogas grid that cheaper than LPG. Finally, 64% of people in community were agree with biogas grid model.

The results showed that 7.45% of people in the community had a demand for high quality biogas which was cheaper than LPG, does not use 4.90% and not sure. 17.65%. For the utilization of biogas with high quality and more expensive than LPG, the community thinks that 21.57% is use, 54.90% is not use, and 23.53% is not sure. Therefore, the price is an important factor in the acceptance of community gas network technology. Moreover, it was found that people in Mae Tha community thought that alternative energy was useful 81.21%, 2.98% thought that it was useless and 15.81% had no comment.

From the farm owners in-depth interview, the results revealed that biogas grid development model for Mae Tha community had high impact to make their income by the creation of group member to sell fertilizer produced from the obtained by product of biogas digestion. Even it could not replace the lost of income in selling dairy cattle manure, it could help to reduced environmental pollution released from farming area.

From the LPG business owners in-depth interview, the results showed that biogas grid development model will affect to the reducing of their income. By the way, 50% of LPG business owners agreed well to develop biogas grid model in order to reduce pollution and also to support renewable energy utilization in the community. While 50% of LPG business owners were not sure if they have to agree with biogas grid utilization. Therefore, there should be a workshop to educate people in community to understand in detail about biogas as well as others renewable energy technology.

The results from 3 groups of stakeholders could be found that most of them agreed with community development model with biogas grid. Incidentally, there was a few people hesitated in biogas grid due to they were lack of technology confidence.

3. Analysis of the model of community development by biogas grid

For the analysis of community development model with renewable energy, The first step is to study the context of the community, power consumption, explore the potential of community in production of renewable energy. The study should be carried out by the researcher together with local people. After data collection and conclusion, the researcher should return the research finding to the community in order to confirm valid survey data is to be able to evaluate the potential of renewable energy that is appropriate to the community. The second step, when the suitable renewable energy potential for community involvement was selected, feasibility of the technology using the technical evaluation process, feasibility of economics and the implementation will be studied. The third step is to create a model for community development, community involvement, and the return of information to the community.

In cooperative community model, in addition to the cooperative members, there are 5 main personnel, including financial manager, academician, technicians and truck drivers. To manage the biogas grid, it is starting from the process of transporting dairy cattle manure from the dairy farm to the biogas plant by filling in the daily routine. After biogas production process, the produced gas will be flow through biogas upgrading unit to improve gas quality into bio methane to which has high quality comparable to LPG and transported along the gas pipeline of the community. Meters are installed in every household for bill payment calculation. The management of the biogas grid will be carried out as community cooperative which results in the economic revolutions within the community. The sludge produced after biogas production will be used to be fertilizer for use and sell both within the community and outside the community. By joining together of the dairy farm owners can manage the sales of fertilizers. Based on the analysis and research, the model of community development through the biogas grid is shown in Figure 4.2.

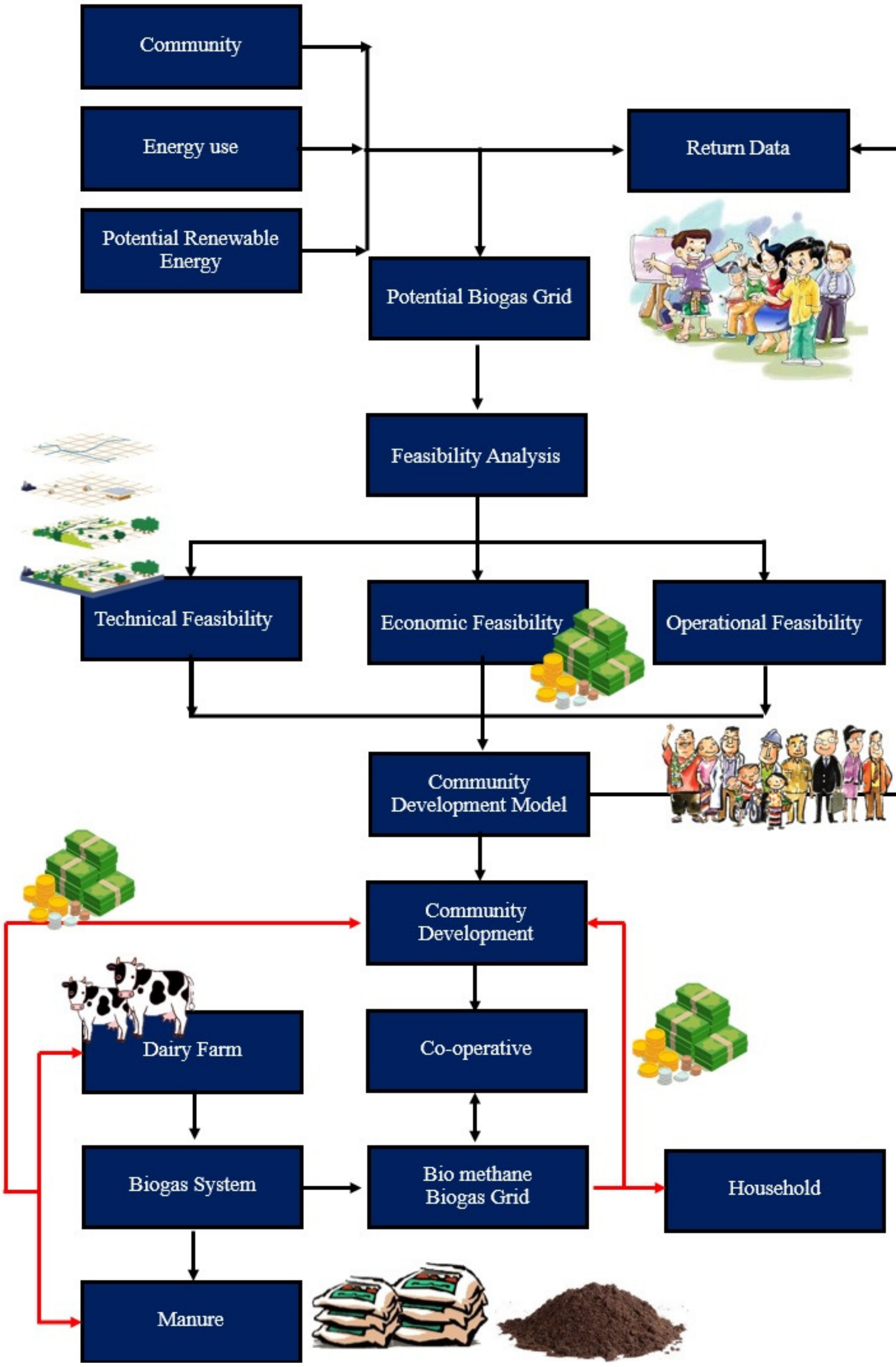

Figure 4.2 Community Development Model with Biogas Grid

Discussions

The objective of this study is to study the model of biogas grid to develop local community. This research conducts in both quantitative and qualitative by divided into 3 parts. The first part is the evaluation of the renewable energy efficiency in community. The second part is the possibility analysis of biogas grid by analyzing the appropriate in technique, economics, and operation. The third part is the creation of biogas grid form in developing local community.

The result of the study and evaluation of the renewable energy efficiency in local community was found that the Mae Ta district which is the agricultural community that has 1,500 households. The total ranches are 128 farm including dairy farm, beef cattle farm, and pig farm. The total animal is 5,152 animals which can produce the biogas 2,100 cubic meters per day and can be compared as liquefied petroleum gas 996 kg. per day. Thus, the renewable efficiency in Mae Ta district is suitable for producing biogas.

The result of possibility analysis of biogas grid by analyzing the appropriate technique was found that Mae Ta district has the potential on producing biogas from feces of dairy cows sized 3,000 cubic meters. According to the possibility analysis, the Geographical Information System (GIS) was used to analyze the biogas grid of community for 1,500 households in the radius which is less than 5 km. and the nearby ranches so that it is proper to conduct in the part of techniques

The result of possibility analysis of biogas grid by analyzing the appropriate economics was found the government section should support the investment budget which is not less than 15% to make the trade on biogas in the same as liquefied petroleum gas (LPG) in 28 baht per kilogram under the LPG price rate in the market. This will cause the cost-effectiveness in the field of economics.

The result of possibility analysis of bio gas network by analyzing the appropriate operation in community was found that Mae Ta district is the strong and available community to conduct the project and then also establish Mae Ta Yung Yeen Agricultural Corp. Ltd to develop the community in sustainable agriculture, the form of agricultural appropriation, the increased income and decreased the expenses. This is the significant basic that will reach to the development of Mae Ta community which emphasizes the supportive process in learning and developing the idea under the sufficiency economy philosophy. From analyzing the survey about the biogas grid system in Mae Ta district, the community is agreed with renewable energy system because it can make the benefits to community in 81.21% if bring the biogas grid system into community. The people in community agree on 84.46% and the people need the support from government on investment budget and experts on 84.64%. Therefore, Mae Ta communication is the strong and available community in conducting part.

The analysis and the creation of developing form of biogas in community will conduct by using the pattern and protocol of cooperative to reduce expenses and increase income and also create the economy cycle in community. Moreover, it also reduces the pollution problems and accident from delivering the LPG. It reinforces the energy security in community level.

CHAPTER 5

Conclusion and Suggestion

Conclusion

The possibility of biogas grid utilization in Mae Tha community, Mae On District, Chiang Mai, Thailand, is suitable both technically and economically. The study used GIS to analyze the location of the biogas grid and the finding was in agreement with the study of Kamching (2017). The model is the installation of the centralized biogas system with the size of 3,000 m^3 and equipped with gas quality improvement system to yield biomethane, which is the most resemble to LPG. The pipeline radius is no more than 5 km for 1,500 households. The economic analysis suggests that if given the community investment for 100%, the biogas selling price will be more than the LPG market price. Therefore, to initiate the community to increase energy usage from biogas, the government sector should support the investment cost of no less than 15% of the fixed cost. The government should support the budget for studying the strategy to decrease the cost of biogas well, the standard of the quality improvement system for biogas, and the pipeline. These factors and also the promotion of the market competition will allow the government sector to use less budget in supporting the biogas grid. In addition, our result is in agreement with the finding of Tanarak (2017) that the supportive factors from the government sector in producing biogas affected the decision making of the people in choosing the biogas for household commodity. Using renewable energy like biogas in this case study, in the aspect of energy strategy, will therefore strengthen the energy security and decrease the energy crisis of the country.

Suggestion

1) There should be the study of biogas grid system management to sustain the operation

2) There should be the study of the community stakeholders, e.g. the biogas users, the farm owners, and the LPG retailers.

3) There should be the study of the biogas management when the biogas is not enough or over supplied in the community.

REFERENCES

Ali, G., Nitivattananon, V., Abbas, S., & Sabir, M. (2012). Green waste to biogas: Renewable energy possibilities for Thailand's green markets. *Renewable and Sustainable Energy Reviews, 16*(7), 5423-5429.

American Society of Mechanical Engineers [ASME]. (2016). *Gas Transmission and Distribution Piping Systems: B31.8*. Retrieved from https://www.asme.org/products/codes-standards/b318-2016-gas-transmission-distribution-piping

BaČekoviĆ, I., & Østergaard, P. A. (2018). Local smart energy systems and cross-system integration. *Energy, 151*, 812-825.

Bank of Thailand. (2017). Deposit Rates for Individuals of Commercial Banks. Retrived from https://www.bot.or.th/english/statistics/_layouts/ application/interest_rate/in_rate.aspx

Baum, F., MacDougall, C., & Smith, D. (2006). Participatory action research. *Journal of Epidemiology & Community Health, 60*(10), 854-857.

Bioteau, T., Boret, F., Tretyakov, O., Béline, F., Balynska, M., & Girault, R. (2012). *A GIS-based approach for optimizing the development of collective biogas plants.* Paper presented at the Global assessment for organic resources and waste management, Orbit 2012.

Boonchieng, W. (2015). *Participatory Action Research*. Retrieved from http://www.crc.ac.th/2015/pdf/5.1.5-8-Par.pdf.

Cai, Y., Huang, G., Tan, Q., & Yang, Z. (2009). Planning of community-scale renewable energy management systems in a mixed stochastic and fuzzy environment. *Renewable Energy, 34*(7), 1833-1847.

Chanakya, H. N., Reddy, B. V. V., & Modak, J. (2009). Biomethanation of herbaceous biomass residues using 3-zone plug flow like digesters – A case study from India. *Renewable Energy, 34*(2), 416-420. doi:https://doi.org/10.1016/j.renene.2008.05.003

Deng, L., & Hägg, M.-B. (2010). Techno-economic evaluation of biogas upgrading process using CO2 facilitated transport membrane. *International Journal of Greenhouse Gas Control, 4*(4), 638-646. doi:https://doi.org/10.1016/j.ijggc.2009.12.013

Denis, G. S., & Parker, P. (2009). Community energy planning in Canada : The role of renewable energy. *Renewable and Sustainable Energy Reviews, 13*(8), 2088-2095.

Department of Alternative Energy Development and Efficiency [DEDE]. (2017a). Thailand's Energy Situation January - December 2017. Retrieved from http://www.dede.go.th/ewt_news.php?nid=47140&filename=index.

Department of Alternative Energy Development and Efficiency [DEDE]. (2017b). *Biogas production from animal manure*. Retrieved from http://webkc.dede.go.th/testmax/node/188

Dobre, P., Nicolae, F., & Matei, F. (2014). Main factors affecting biogas production-an overview. *Romanian Biotechnological Letters, 19*(3), 9283-9286.

Energy Research and Development Institute-Nakornping. (2015). *Biogas upgrading for biomethane production*. Chiang Mai University.

Energy Research and Development Institute-Nakornping. (2017). *Biomethane gas grid standard*. Retrieved from http://erdi.cmu.ac.th/file/BiogasGridStandard.pdf

Gebrezgabher, S. A., Meuwissen, M. P., Prins, B. A., & Lansink, A. G. O. (2010). Economic analysis of anaerobic digestion—A case of Green power biogas plant in The Netherlands. *NJAS-Wageningen Journal of Life Sciences, 57*(2), 109-115.

Gwavuya, S., Abele, S., Barfuss, I., Zeller, M., & Müller, J. (2012). Household energy economics in rural Ethiopia: A cost-benefit analysis of biogas energy. *Renewable Energy, 48*, 202-209.

Huang, C., Li, Z.-l., Chen, F., Liu, Q., Zhao, Y.-k., Gao, L.-f., . . . Wang, A.-j. (2016). Efficient regulation of elemental sulfur recovery through optimizing working height of upflow anaerobic sludge blanket reactor during denitrifying sulfide removal process. *Bioresource Technology, 200*, 1019-1023. doi:https://doi.org/10.1016/j.biortech.2015.09.109

Huertas, J., Giraldo, N., & Izquierdo, S. (2011). Removal of H2S and CO2 from Biogas by Amine Absorption. In *Mass Transfer in Chemical Engineering Processes*: InTech.

Islamiyah, M., Soehartanto, T., Hantoro, R., & Abdurrahman, A. (2015). Water scrubbing for removal of CO2 (carbon dioxide) and H2S (hydrogen sulfide) in biogas from manure. *KnE Energy & Physics, 2*(2), 126-131.

Jank, R. (2017). Annex 51: Case studies and guidelines for energy efficient communities. *Energy and Buildings, 154*, 529-537.

Kindon, S., Pain, R., & Kesby, M. (2008). Participatory action research. In *International encyclopaedia of human geography.* (pp. 90-95) : Elsevier.

Ko, D., Siriwardane, R., & Biegler, L. T. (2005). Optimization of Pressure Swing Adsorption and Fractionated Vacuum Pressure Swing Adsorption Processes for CO2 Capture. *Industrial & Engineering Chemistry Research, 44*(21), 8084-8094. doi:10.1021/ie050012z

Ma, J., Scott, N. R., DeGloria, S. D., & Lembo, A. J. (2005). Siting analysis of farm-based centralized anaerobic digester systems for distributed generation using GIS. *Biomass and Bioenergy, 28*(6), 591-600.

McAfee, R. P. (2005). *Introduction to economic analysis.* California: California Institute of Technology.

McIntyre, A. (2007). *Participatory action research* (Vol. 52). London: Sage Publications.

Mendes, G., Ioakimidis, C., & Ferrão, P. (2011). On the planning and analysis of Integrated Community Energy Systems: A review and survey of available tools. *Renewable and Sustainable Energy Reviews, 15*(9), 4836-4854.

Ministry of energy. (2017). *A comparison of the LPG retail prices between Thailand and its neighbors.* Retrieved from https://gnews.apps.go.th/news?news=6354

Mojiri, A., Aziz, H. A., Zaman, N., Aziz, S. Q., & Hamidi, A. (2012). *A Review on Anaerobic Digestion, Bio-reactor and Nitrogen Removal from Wastewater and Landfill Leachate by Bio-reactor*. *Advances in Environmental Biology*, *6*(7), 2143-2150.

Molino, A., Migliori, M., Ding, Y., Bikson, B., Giordano, G., & Braccio, G. (2013). Biogas upgrading via membrane process: modelling of pilot plant scale and the end uses for the grid injection. *Fuel, 107*, 585-592.

Murphy, J., & McCarthy, K. (2005). The optimal production of biogas for use as a transport fuel in Ireland. *Renewable Energy, 30*(14), 2111-2127.

Paturska, A., Repele, M., & Bazbauers, G. (2015). Economic Assessment of Biomethane Supply System based on Natural Gas Infrastructure. *Energy Procedia, 72*, 71-78. doi:https://doi.org/10.1016/j.egypro.2015.06.011

PPT Distribution service center. (2012). *Natural Gas Application*. Retrieved from https://dscng.pttplc.com/(S(ypgi00wa1sjrbwrcpff152ds))/Knowledge/Knowledge-inside?p=Natural_Gas_Application

Rasheed, R., Khan, N., Yasar, A., Su, Y., & Tabinda, A. B. (2016). Design and cost-benefit analysis of a novel anaerobic industrial bioenergy plant in Pakistan. *Renewable Energy, 90*, 242-247.

Rowse, L. E. (2011). *Design of small scale anaerobic digesters for application in rural developing countries* (Doctoral dissertation).University of South Florida.

Sawin, J., & Flavin, C. (2006). National policy instruments: Policy lessons for the advancement & diffusion of renewable energy technologies around the world. *Renewable Energy. A Global Review of Technologies, Policies and Markets*.

Sawin, J. L. (2004). National Policy Instruments-Policy Lessons for the Advancement & Diffusion of Renewable Energy Technologies Around the World. *Oil, Gas & Energy Law Journal (OGEL)*, *2*(2).

Seghezzo, L., Zeeman, G., van Lier, J. B., Hamelers, H. V. M., & Lettinga, G. (1998). A review: The anaerobic treatment of sewage in UASB and EGSB reactors. *Bioresource Technology, 65*(3), 175-190. doi:https://doi.org/10.1016/S0960-8524(98)00046-7

Sgroi, F., Foderà, M., Trapani, A. M. D., Tudisca, S., & Testa, R. (2015). Economic evaluation of biogas plant size utilizing giant reed. *Renewable and Sustainable Energy Reviews, 49*, 403-409. doi:https://doi.org/10.1016/j.rser.2015.04.142

Sliz-Szkliniarz, B., & Vogt, J. (2012). A GIS-based approach for evaluating the potential of biogas production from livestock manure and crops at a regional scale: A case study for the Kujawsko-Pomorskie Voivodeship. *Renewable and Sustainable Energy Reviews, 16*(1), 752-763.

Tsagarakis, K. P., & Papadogiannis, C. (2006). Technical and economic evaluation of the biogas utilization for energy production at Iraklio Municipality, Greece. *Energy Conversion and Management, 47*(7), 844-857. doi:https://doi.org/10.1016/j.enconman.2005.06.017

United States Environmental Protection Agency. (2017). *AgSTAR: Biogas Recovery in the Agriculture Sector*. Retrieved from https://www.epa.gov/agstar

United States Energy Information Administration [EIA]. (2016).*Refining Crude Oil*. Retrieved from https://www.eia.gov/energyexplained/index.php?page=oil_refining

Whyte, W. F. E. (1991). *Participatory action research*. London : Sage Publications, Inc.

Yiridoe, E. K., Gordon, R., & Brown, B. B. (2009). Nonmarket cobenefits and economic feasibility of on-farm biogas energy production. *Energy policy, 37*(3), 1170-1179.

APPENDICES

APPENDIX A

Questionnaire

Evaluationof Renewable energy potential in Mae Tha community, Mae On District, Chiangmai, Thailand

Project objective **To survey of renewable energy potentialinMae Tha community.**

Description of questionnaire

1.This questionnaire was used to study and survey of renewable energy potential inMae Tha community

2. The data of this questionnaire is used to interpreted for study of renewable energy potential in Mae Tha community. It will not affect to any assessor.

Thank you very much for your kind cooperation.

Part 1 Please complete the following personal Information.

1. Name............................ Surname.. Tel:......................................

Address.............. Village No.......... Mae Tha community, Mae On District, Chiangmai

2. Number of people in your family .... persons (Count in real stay)

3. Occupation of people in your family

❑ Agricultural/ farmer............. persons ❑ Retail / Business owner .... persons

❑ Student .... persons ❑ Government Officer / Employees.......... persons

❑ Other.................... persons

*Remark : Do not fillin part 3 if you are not agricultural/ farmer.

Part2 Information about energy consumption

1. Average of electricity expense per month................................... Bath.

2. Fuel expense (For transportation) Average per month .... Bath.

(For agriculture) Average per month .... Bath.

3. 1 tank of LPG gas (standard 15kg/tank) can use for .... day

4. Coal / Firewood

❑Do not use

❑Coal/ Firewood is used for combustion approximately...... kg per month.

Part 3 Survay of household waste discharge

1. Household waste classification (wet/dry)

❑ Yes ❑No

2. Amount of household wet waste (waste from food)

❑less than 1kg ❑1-3kg ❑4-6 kg

❑7-9 kg ❑more than 10 kg

3. Amount of household dry waste (drinking water bottle, plastic bags, paper)

❑less than 1kg ❑1-3kg ❑4-6 kg

❑7-9 kg ❑more than 10 kg

Part 4 Understanding of renewable energy

Description Renewable energy was refer tonatural energy which unlimited to used, such as biomass energy, waste energy, water energy, wind energy and solar energy.

---

1. In your opinion, do you need more information about renewable energy?

❑ Enough ❑not enough

2. In your opinion, you know about information of renewable energy?

❑high ❑moderate ❑low

3. Please order the type of renewable energy which your know as 1-7 (1 is well know, 7 is never know)

.................Biomass energy

.................Waste energy

.................Water energy

.................Wind energy

.................Solar energy

.................Other ....

4. Do you used renewable energy?

❑No

❑Yes (You can select more than one answer)

❑Biomass energy

❑Waste energy

❑Water energy

❑Wind energy

❑Solar energy

❑Other..

5. Do you think that renewable energy is benefit for community?

❑Yes

❑No Because ....

❑Other..

6. If this community establish/ use the renewable energy. Do you agree?

❑Yes

❑NoBecause ....

❑Other..

7. If this community apply renewable energy or use energy saving devices

What is the effect on you?

❑Nothing

❑Energy expense change

❑Daily life changes

❑Community environment change

❑Behevior of energy consumtion change

❑Other..

8.If this community establish/ use the renewable energy. Do you need government sector support?

❑Yes

❑No Because ....

❑Other..

9.Do you know about energy conservation and energy saving?

☐high ☐moderate ☐low

10. Other suggestion

....

....

....

....

....

....

....

....

APPENDIX B

Survey Form

Evaluation of biogas potential in Mae Tha community, Mae On District, Chiang Mai, Thailand

---

<u>Personal information</u>

Name..................................Surname...Tel..

Address No...................Moo......Mae Tha community, Mae On District, Chiang Mai, Thailand

<u>Type and amount of animal</u>

1. Dairy cattle...................(animal No.)

Farming type

❑Free❑Limited area only in farm ❑Other..

Manure disposing..

2. Beef cattle...................(animal No.)

Farming type

❑Free❑Limited area only in farm ❑Other..

Manure disposing..

3. Pig...................(animal No.)

Farming type

❑Free❑Limited area only in farm ❑Other..

Manure disposing..

4. Farm location...

5. Farm highness above sea level..

APPENDIX C

Interview of stakeholder who have responsibility to Community Biogas Grid

This interview was the part of Ph. D. thesis and wascreated by graduate student of Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University. It was used to interview stakeholder who have responsibility to Community Biogas Grid in Mae Tha community, Mae On District, Chiangmai, Thailand

There are 3 parts of interview as follows:

Part 1- Personal information

Part 2- Interview information of stakeholder who have responsibility to community biogas grid

Part 3- Interview information of stakeholder who have responsibility to community development by biogas grid model.

Community biogas grid refers to the improved biogas system with high quality equivalent to LPG. The gas was delivered by gas pipeline and gas consumption was monitored by gas meter which was installed every household.

Development of community biogas grid model refers to a biogas system using dairy cattle manure as raw material which can produced 3,000 m^3 of biogas. The dairy cattlemanure was added every day. The community cooperative was established to manage and charge the biogas expenses for use to develop the community.

Stakeholder refers to people who have positive/negative,direct/indirecteffect from community biogas grid

Thank you very much for your cooperation.

Part 1 Personal Information.

Desciption : Please check ✓ in ❑ which match your information.

1. Sex

❑male ❑ female

2. Age

❑ less than 20 years ❑ 20 – 30 years ❑31 – 40 years ❑ 41 – 50 years

❑more than 51 years

3. Education

❑ High School/lower ❑Diploma ❑Bachalor ❑Graduate

4. Occupation

❑ Goverment officer❑Employee

❑ Business owner ❑Farmer ❑Student ❑ Other . . . .

Part 2 Interview of stakeholder who have responsibility to community biogas grid

1. Do you think that your community has an environmental pollution effect from livestock farming

❑Very high ❑High ❑Low ❑Very low ❑N/A

2. Do you know about information of biogas system?

❑Very high ❑High ❑Low ❑Very low ❑N/A

3. Do you know that your community has a potential in utilization of community biogas grid?

❑Yes ❑No ❑Not sure

4. Please order the factors affecting to the community biogas grid selection as 1-5(1 is the most affect, 5is the less affect)

.... Biogas quality equivalent to LPG

.... Lower price of biogas compared to LPG

.... Government support

.... Stability

.... Environmental pollution reduction

5. Would you like to use biogas from community grid which is more expensive compared to LPG?

❑Yes ❑No ❑Not sure

6. Would you like to use biogas from community grid which is cheaper than LPG?

❑Yes ❑No ❑Not sure

Part 3 Stakeholder of community biogas grid opinion

What do you think about community development model by biogas grid from this research?

❑Agree ❑Not agree ❑Not sure

Reason

....

....

....

In-depthInterview

Community Biogas Grid in Mae Tha community, Mae On District, Chiang Mai, Thailand

Stakeholder: Dairy cattle farm owner

1. Sex ❑ Male ❑ Female
2. Age ....years
3. Occupation ....
4. Status ....
5. Farm address ....

....

6. Number of dairy cattle ....

8. Income from manure selling...............................Bath/month

7. From our study, the result showed that the potential of community biogas grid in your community which produced by cattle manure is capable to apply in all households. Income from biogasselling will be manage by the community cooperative. Do you agree with this model?

❑ agree ❑ not agree ❑ not sure

Suggestion/Resson

....

....

....

....

....

8. If we need to use cow manure from your farm to produce biogas, is there any affect to income of your manure selling?

❑seriously ❑most ❑low ❑verylow ❑noteffect

Suggestion/Resson

....

....

....

....

....

....

....

9. If we can solve manure income loss by selling the biogas sludge, what do you think about this idea?

❑It is possible ❑It is impossible ❑Not sure

Suggestion/Resson

....

....

....

....

....

....

....

10. Do you agree with community development model by biogas grid through direct bio gas selling to all household by gas Pipeline?

❑ agree ❑ not agree ❑ not sure

Suggestion/Resson

....

....

....

....

....

....

....

In-depthInterview

Community Biogas Grid in Mae Tha community, Mae On District, Chiang Mai, Thailand

Stakeholder : LPG business owner

1. Sex ❑ Male ❑ Female
2. Age ....
3. Education ....
4. Business location ....

....

5. LPG sold (estimation).....................................tank/month

6. From the community potential evaluation, Mae Tha community is capable to construct community biogas grid. What do you think about biogas grid model that is the utilization of high quality biogas for all households as a community cooperative?

❑Agree ❑Not agree ❑Not sure

Suggestion/Resson

....

....

....

....

....

....

....

7. Is there any effect from the reducing of your income from selling LPG?

❑Very high ❑High ❑Low ❑Very low ❑No effect

Suggestion/Resson

....

....

....

....

....

....

....

8. Do you agree with community development model by biogas grid?

❑Agree ❑Not agree ❑Not sure

Suggestion/Resson

....

....

....

....

....

....

....

APPENDIX D

Economic Analysis

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	53,630,000		53,630,000		53,630,000.00	-	- 53,630,000.00	
1		1,052,500	1,052,500	7,045,230	983,644.86	6,584,327.10	5,600,682.24	6,584,327.10
2		1,069,550	1,069,550	7,397,492	934,186.39	6,461,255.57	5,527,069.18	13,045,582.67
3		1,086,941	1,086,941	7,767,366	887,267.63	6,340,484.44	5,453,216.81	19,386,067.11
4		1,104,680	1,104,680	8,155,734	842,754.95	6,221,970.71	5,379,215.76	25,608,037.82
5		1,122,773	1,122,773	8,563,521	800,521.93	6,105,672.19	5,305,150.26	31,713,710.01
6		1,141,229	1,141,229	8,991,697	760,448.99	5,991,547.48	5,231,098.48	37,705,257.48
7		1,160,053	1,160,053	9,441,282	722,422.99	5,879,555.93	5,157,132.94	43,584,813.42
8		1,179,255	1,179,255	9,913,346	686,336.87	5,769,657.69	5,083,320.82	49,354,471.11
9		1,198,840	1,198,840	10,409,013	652,089.32	5,661,813.62	5,009,724.30	55,016,284.73
10		1,218,816	1,218,816	10,929,464	619,584.46	5,555,985.33	4,936,400.87	
11		1,239,193	1,239,193	11,475,937	588,731.55	5,452,135.14	4,863,403.59	
12		1,259,977	1,259,977	12,049,734	559,444.68	5,350,226.07	4,790,781.39	
13		1,281,176	1,281,176	12,652,221	531,642.55	5,250,221.85	4,718,579.30	
14		1,302,800	1,302,800	13,284,832	505,248.17	5,152,086.86	4,646,838.69	
15		1,324,856	1,324,856	13,949,074	480,188.66	5,055,786.17	4,575,597.51	
16		1,347,353	1,347,353	14,646,527	456,394.99	4,961,285.49	4,504,890.50	
17		1,370,300	1,370,300	15,378,854	433,801.83	4,868,551.18	4,434,749.36	
18		1,393,706	1,393,706	16,147,796	412,347.26	4,777,550.23	4,365,202.97	
19		1,417,580	1,417,580	16,955,186	391,972.66	4,688,250.22	4,296,277.56	
20		1,441,932	1,441,932	17,802,945	372,622.51	4,600,619.38	4,227,996.87	
Total		20,713,508	78,343,508	232,957,252	66,251,653.24	110,728,982.65	44,477,329.41	

Scenario 1 when the government sector promotes in the investment of the community biogas grid 100% of the investment budget (only in the biogas production system, improvement of the biogas quality and community biogas grid)

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	630,000		630,000		630,000.00	-	- 630,000.00	
1		1,052,500	1,052,500	930,312	983,644.86	869,450.47	- 114,194.39	869,450.47
2		1,069,550	1,069,550	976,828	934,186.39	853,199.06	- 80,987.34	
3		1,086,941	1,086,941	1,025,669	887,267.63	837,251.41	- 50,016.22	
4		1,104,680	1,104,680	1,076,952	842,754.95	821,601.85	- 21,153.09	
5		1,122,773	1,122,773	1,130,800	800,521.93	806,244.81	5,722.88	
6		1,141,229	1,141,229	1,187,340	760,448.99	791,174.81	30,725.82	
7		1,160,053	1,160,053	1,246,707	722,422.99	776,386.50	53,963.50	
8		1,179,255	1,179,255	1,309,042	686,336.87	761,874.60	75,537.73	
9		1,198,840	1,198,840	1,374,495	652,089.32	747,633.95	95,544.63	
10		1,218,816	1,218,816	1,443,219	619,584.46	733,659.49	114,075.03	
11		1,239,193	1,239,193	1,515,380	588,731.55	719,946.23	131,214.68	
12		1,259,977	1,259,977	1,591,149	559,444.68	706,489.29	147,044.61	
13		1,281,176	1,281,176	1,670,707	531,642.55	693,283.88	161,641.33	
14		1,302,800	1,302,800	1,754,242	505,248.17	680,325.30	175,077.14	
15		1,324,856	1,324,856	1,841,954	480,188.66	667,608.94	187,420.29	
16		1,347,353	1,347,353	1,934,052	456,394.99	655,130.27	198,735.27	
17		1,370,300	1,370,300	2,030,754	433,801.83	642,884.84	209,083.02	
18		1,393,706	1,393,706	2,132,292	412,347.26	630,868.30	218,521.05	
19		1,417,580	1,417,580	2,238,907	391,972.66	619,076.37	227,103.71	
20		1,441,932	1,441,932	2,350,852	372,622.51	607,504.85	234,882.35	
Total		20,713,508	25,343,508	30,761,654	13,251,653.24	14,621,595.22	1,369,941.98	

Scenario 2 When the government sector promoted the investment budget of community biogas grid for 70% of the investment budget (only the biogas production system, improvement of biogas quality and community biogas grid)

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	16,530,000		16,530,000		16,530,000.00	-	- 16,530,000.00	
1		1,052,500	1,052,500	2,763,780	983,644.86	2,582,971.96	1,599,327.10	2,582,971.96
2		1,069,550	1,069,550	2,901,969	934,186.39	2,534,692.11	1,600,505.72	5,117,664.08
3		1,086,941	1,086,941	3,047,067	887,267.63	2,487,314.69	1,600,047.06	7,604,978.77
4		1,104,680	1,104,680	3,199,421	842,754.95	2,440,822.83	1,598,067.88	10,045,801.59
5		1,122,773	1,122,773	3,359,392	800,521.93	2,395,199.97	1,594,678.04	12,441,001.56
6		1,141,229	1,141,229	3,527,361	760,448.99	2,350,429.88	1,589,980.88	14,791,431.44
7		1,160,053	1,160,053	3,703,730	722,422.99	2,306,496.61	1,584,073.61	17,097,928.05
8		1,179,255	1,179,255	3,888,916	686,336.87	2,263,384.52	1,577,047.65	
9		1,198,840	1,198,840	4,083,362	652,089.32	2,221,078.27	1,568,988.95	
10		1,218,816	1,218,816	4,287,530	619,584.46	2,179,562.79	1,559,978.33	
11		1,239,193	1,239,193	4,501,906	588,731.55	2,138,823.30	1,550,091.75	
12		1,259,977	1,259,977	4,727,002	559,444.68	2,098,845.29	1,539,400.61	
13		1,281,176	1,281,176	4,963,352	531,642.55	2,059,614.54	1,527,971.99	
14		1,302,800	1,302,800	5,211,519	505,248.17	2,021,117.07	1,515,868.90	
15		1,324,856	1,324,856	5,472,095	480,188.66	1,983,339.18	1,503,150.53	
16		1,347,353	1,347,353	5,745,700	456,394.99	1,946,267.42	1,489,872.43	
17		1,370,300	1,370,300	6,032,985	433,801.83	1,909,888.59	1,476,086.76	
18		1,393,706	1,393,706	6,334,634	412,347.26	1,874,189.74	1,461,842.48	
19		1,417,580	1,417,580	6,651,366	391,972.66	1,839,158.15	1,447,185.49	
20		1,441,932	1,441,932	6,983,934	372,622.51	1,804,781.37	1,432,158.86	
Total		20,713,508	41,243,508	91,387,023	29,151,653.24	43,437,978.27	14,286,325.03	

Scenario 3 when the government sector supported the investment budget of community biogas grid for 50% of the investment budget (only the cost for biogas production system, improvement of biogas quality and community biogas grid)

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	27,130,000		27,130,000		27,130,000.00	-	-27,130,000.00	
1		1,052,500	1,052,500	3,985,800	983,644.86	3,725,046.73	2,741,401.87	3,725,046.73
2		1,069,550	1,069,550	4,185,090	934,186.39	3,655,419.69	2,721,233.30	7,380,466.42
3		1,086,941	1,086,941	4,394,345	887,267.63	3,587,094.09	2,699,826.46	10,967,560.50
4		1,104,680	1,104,680	4,614,062	842,754.95	3,520,045.60	2,677,290.65	14,487,606.10
5		1,122,773	1,122,773	4,844,765	800,521.93	3,454,250.35	2,653,728.42	17,941,856.45
6		1,141,229	1,141,229	5,087,003	760,448.99	3,389,684.93	2,629,235.93	21,331,541.38
7		1,160,053	1,160,053	5,341,353	722,422.99	3,326,326.33	2,603,903.34	24,657,867.71
8		1,179,255	1,179,255	5,608,421	686,336.87	3,264,152.01	2,577,815.13	27,922,019.71
9		1,198,840	1,198,840	5,888,842	652,089.32	3,203,139.82	2,551,050.50	31,125,159.53
10		1,218,816	1,218,816	6,183,284	619,584.46	3,143,268.05	2,523,683.58	
11		1,239,193	1,239,193	6,492,448	588,731.55	3,084,515.37	2,495,783.83	
12		1,259,977	1,259,977	6,817,071	559,444.68	3,026,860.88	2,467,416.20	
13		1,281,176	1,281,176	7,157,924	531,642.55	2,970,284.04	2,438,641.50	
14		1,302,800	1,302,800	7,515,820	505,248.17	2,914,764.71	2,409,516.55	
15		1,324,856	1,324,856	7,891,611	480,188.66	2,860,283.13	2,380,094.47	
16		1,347,353	1,347,353	8,286,192	456,394.99	2,806,819.89	2,350,424.90	
17		1,370,300	1,370,300	8,700,502	433,801.83	2,754,355.97	2,320,554.14	
18		1,393,706	1,393,706	9,135,527	412,347.26	2,702,872.68	2,290,525.42	
19		1,417,580	1,417,580	9,592,303	391,972.66	2,652,351.70	2,260,379.03	
20		1,441,932	1,441,932	10,071,918	372,622.51	2,602,775.03	2,230,152.52	
Total		20,713,508	51,843,508	131,794,280	39,751,653.24	62,644,310.98	22,892,657.74	

Scenario 4 when the government sector supported the investment budget of the community biogas grid for 30% of the investment budget (only the biogas production system cost, improvement of biogas quality and community biogas grid)

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	37,730,000		37,730,000		37,730,000.00	-	- 37,730,000.00	
1		1,052,500	1,052,500	5,207,820	983,644.86	4,867,121.50	3,883,476.64	4,867,121.50
2		1,069,550	1,069,550	5,468,211	934,186.39	4,776,147.26	3,841,960.87	9,643,268.76
3		1,086,941	1,086,941	5,741,622	887,267.63	4,686,873.48	3,799,605.85	14,330,142.24
4		1,104,680	1,104,680	6,028,703	842,754.95	4,599,268.37	3,756,513.42	18,929,410.61
5		1,122,773	1,122,773	6,330,138	800,521.93	4,513,300.74	3,712,778.81	23,442,711.34
6		1,141,229	1,141,229	6,646,645	760,448.99	4,428,939.97	3,668,490.98	27,871,651.32
7		1,160,053	1,160,053	6,978,977	722,422.99	4,346,156.05	3,623,733.06	32,217,807.37
8		1,179,255	1,179,255	7,327,926	686,336.87	4,264,919.49	3,578,582.61	36,482,726.86
9		1,198,840	1,198,840	7,694,322	652,089.32	4,185,201.37	3,533,112.04	40,667,928.22
10		1,218,816	1,218,816	8,079,038	619,584.46	4,106,973.30	3,487,388.84	
11		1,239,193	1,239,193	8,482,990	588,731.55	4,030,207.45	3,441,475.90	
12		1,259,977	1,259,977	8,907,140	559,444.68	3,954,876.47	3,395,431.79	
13		1,281,176	1,281,176	9,352,496	531,642.55	3,880,953.54	3,349,311.00	
14		1,302,800	1,302,800	9,820,121	505,248.17	3,808,412.36	3,303,164.19	
15		1,324,856	1,324,856	10,311,127	480,188.66	3,737,227.08	3,257,038.42	
16		1,347,353	1,347,353	10,826,684	456,394.99	3,667,372.37	3,210,977.37	
17		1,370,300	1,370,300	11,368,018	433,801.83	3,598,823.35	3,165,021.52	
18		1,393,706	1,393,706	11,936,419	412,347.26	3,531,555.62	3,119,208.36	
19		1,417,580	1,417,580	12,533,240	391,972.66	3,465,545.24	3,073,572.58	
20		1,441,932	1,441,932	13,159,902	372,622.51	3,400,768.69	3,028,146.18	
Total		20,713,508	62,443,508	172,201,537	50,351,653.24	81,850,643.69	31,498,990.45	

Scenario 5 Analysis of the investment budget of the biogas that make the buying and selling price of biogas comparable to LPG in the rate of 28 baht per kilogram so that it would be consistent with the buying-selling price of LPG today by increasing the buying-selling price for 5 per cent per year.

Year	Fixed	Variable Cost	Cost	Benefit	PVC	PVB	NPV	PP
0	45,730,000		45,730,000		45,730,000.00	-	- 45,730,000.00	
1		1,052,500	1,052,500	6,132,000	983,644.86	5,730,841.12	4,747,196.26	5,730,841.12
2		1,069,550	1,069,550	6,438,600	934,186.39	5,623,722.60	4,689,536.20	11,354,563.72
3		1,086,941	1,086,941	6,760,530	887,267.63	5,518,606.29	4,631,338.66	16,873,170.00
4		1,104,680	1,104,680	7,098,557	842,754.95	5,415,454.77	4,572,699.82	22,288,624.77
5		1,122,773	1,122,773	7,453,484	800,521.93	5,314,231.31	4,513,709.38	27,602,856.08
6		1,141,229	1,141,229	7,826,159	760,448.99	5,214,899.89	4,454,450.89	32,817,755.97
7		1,160,053	1,160,053	8,217,466	722,422.99	5,117,425.12	4,395,002.13	37,935,181.09
8		1,179,255	1,179,255	8,628,340	686,336.87	5,021,772.32	4,335,435.44	42,956,953.41
9		1,198,840	1,198,840	9,059,757	652,089.32	4,927,907.41	4,275,818.09	47,884,860.82
10		1,218,816	1,218,816	9,512,745	619,584.46	4,835,796.99	4,216,212.53	
11		1,239,193	1,239,193	9,988,382	588,731.55	4,745,408.27	4,156,676.72	
12		1,259,977	1,259,977	10,487,801	559,444.68	4,656,709.05	4,097,264.37	
13		1,281,176	1,281,176	11,012,191	531,642.55	4,569,667.75	4,038,025.21	
14		1,302,800	1,302,800	11,562,801	505,248.17	4,484,253.40	3,979,005.24	
15		1,324,856	1,324,856	12,140,941	480,188.66	4,400,435.58	3,920,246.93	
16		1,347,353	1,347,353	12,747,988	456,394.99	4,318,184.45	3,861,789.46	
17		1,370,300	1,370,300	13,385,387	433,801.83	4,237,470.72	3,803,668.89	
18		1,393,706	1,393,706	14,054,656	412,347.26	4,158,265.66	3,745,918.40	
19		1,417,580	1,417,580	14,757,389	391,972.66	4,080,541.07	3,688,568.41	
20		1,441,932	1,441,932	15,495,259	372,622.51	4,004,269.28	3,631,646.77	
Total		20,713,508	70,443,508	202,760,431	58,351,653.24	96,375,863.05	38,024,209.81	

CURRICULUM VITAE

Personal Profile : Ms. Phoosita Chaisombat

Date of Birth : 29 July 1986 (32)

Education and certification

- Master of Science, Renewable Energy, 2012
  Narasuan University, Phitsanulok, Thailand.
- Bachelor of Science, Applied Physics , 2009
  Narasuan University, Phitsanulok, Thailand.

WORK EXPERIENCE

1. Managing Director of B. N. Solar Power Co.,Ltd 2014 - Present
2. Managing Director of ASP ASIA SUN POWER Co.,Ltd 2017 - Present