Climate Technology Centre and Network (CTCN) Technical Assistance

Technical Assistance (TA) project for the Organic fertilizer and Anaerobic digestion to produce biofuels technology for Vietnamese agricultural sector

Pre-Feasibility Study on the Biogas Generation Plant

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1. Introduction

1.1 Project Background

As climate change is getting worse around the world, countries are suffering from climate change and are trying to overcome it in various ways. Vietnam is one of the countries who have also been suffering from climate change, especially in rural agricultural sector.

As followed by CTCN TA project, this Pre-Feasibility Study (PFS) will identify a project area which is currently suffering from livestock manure and is expected to get worse in the near future due to climate change impacts and develop biogas plant utilization which should be sustainable and climate resilient.

This PFS will focus on developing a portfolio of facilities for a manure biogas project to maximize beneficial livestock manure treatment and utilization for the selected area; review several technology options; identify funding opportunities and coordinate with local stakeholders and other potential stakeholders.

1.2 Objectives

Vietnam has small-scale biogas plants for processing livestock manure, but no large-scale biogas plants. However, there is now demand for the operation of large-scale biogas plants to respond to the expansion of large-scale farms and to make improvements to local environmental issues in Vietnam. Accordingly, a PFS will be conducted on the construction of a large-scale biogas plant for the selected site together with the Ministry of Rural affairs and Development (MARD) as a pilot project.

The purpose of this PFS is to investigate the state of the site, relevant government policies, on-site surveys, technological and economic feasibility analysis, risk assessment, etc. in order to identify the propriety of operating biogas plants in the corresponding area and to identify the necessary biogas plant technologies, profitability of the plant, effects of operating the plant, etc.

The objectives of this project are to develop biogas plant that is sustainable and climate resilient, build the facilities necessary for remove odor and prevent environmental pollution and achieve continuous biogas power generation using livestock manure in the project area. The project development objective is therefore to address Thai Nguyen’s one of critical issues by making Climate Change Adaptation and Mitigation investments with the ultimate aim of improving livestock manure treatment in Vietnam, this will improve the quality of life and economic development in the project.

The prime objective of the PFS is to assist Trong Khoi Company Ltd. to promote the adoption of biogas plant, especially using livestock and agricultural waste in livestock farm that supports by Circular the collection and treatment of animal husbandry waste and agricultural by-project to be used for other purpose. The outputs of this PFS can form a contribution to Trong Khoi Company Ltd who needs to treatment of livestock manure, energy generation, utilization of by-products.

Specific effectiveness are to:

- Power generation through biogas plants
- Increase farmland productivity as a by-product using livestock manure and agricultural waste
- Reducing the burden of livestock manure
- Improve environment and sanitation
- Power generation from Biogas plant
- Develop Business Planning

1.3 The project area

The target site for operating biogas plants of this project is the site where the construction of a large-scale farm area in Thai Nguyen in the northern part of Vietnam is scheduled. As a result of evaluation of the comprehensively considered profitability according to procurement of raw materials and clients compared to other candidate sites (two candidate sites in Thanh Hoa Province), preparation for pursuing the project in the area, and cooperation of the local government, the candidate site in Thai Nguyen was found to be suitable for operating the biogas plant.

2. Current status

2.1 General Information

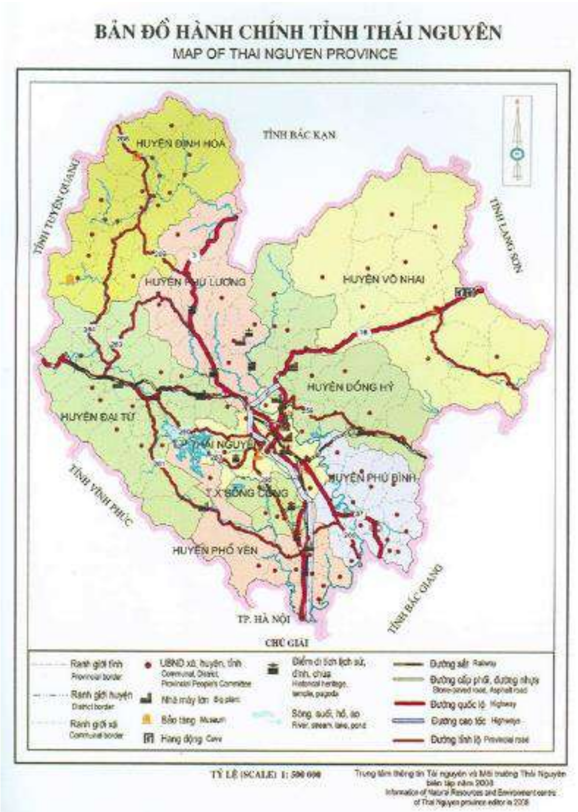
2.1.1 Location of the project site

Thai Nguyen is located on the north side of Hanoi and Identified as one of the regional centers of the northern midland and mountainous provinces. Among the various regions of Thai Nguyen, Dong Hy is a small country place which is one of the districts. Thai Nguyen is subdivided into 9 district level sub-divisions and 178 commune level sub-division. Thai Nguyen is divided into three cities (Thai Nguyen, Pho Yan, Song Con) and 6 districts (Dai Tu, Dinh Hoa, Dong Hy, Phu Binh, Phu Luong, and Vo Nhai), and consists of 178 communes in detail.

Table 2.1 Location of Thai Nguyen

Location	Longitude	Latitude	Altitude(m)
Thai Nguyen	105.83	21.6	36

Figure 2.1. Administrative map of Thai Nguyen Province

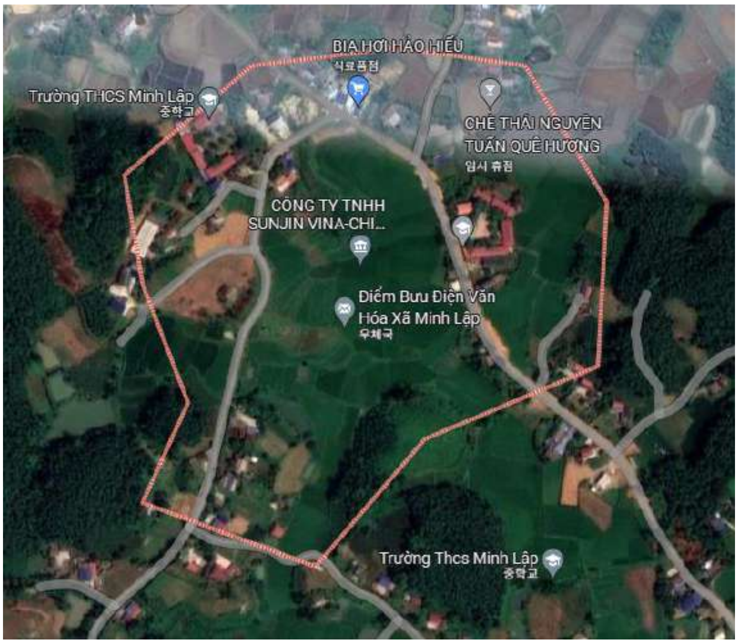


The project site is Minh Lap, Dong Hy district, Thai Nguyen, Minh Lap commune is located in the north of Dong Hy district, about 15km from the center of Thai Nguyen city, the total natural land area of the whole commune is 1,830.19 ha.

Especially project site is surrounded by Binh Ca hamlet (Na Ca village), Minh Ly village (Ao Son), Coffee Village Minh Lap commune, Dong Hy district, Thai Nguyen province. And also, this project site is surrounded by residential area and agricultural area.

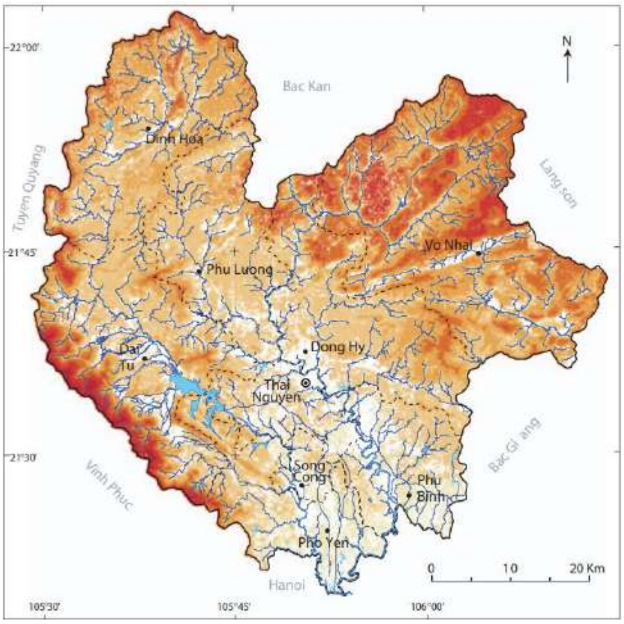
- The East borders on Hao Trung commune
- The West borders on Vo Tranh and Tuc Tranh communes, Phu Luong district
- The south borders on Hoa Thuong and Dong Hy communes
- The North borders on Tan Long commune, Hoa Binh commune, Dong Hy commune

Figure 2.2 Target site



2.1.2 Terrin

Figure 2.3 Topography of Thai Nguyen



Thai Nguyen has many high mountains running in the north-south direction and descending to the south. The structure of the northern mountainous region is mainly strongly weathered rock, forming many small caves and valleys. In the southwest, there is Tam Dao range with the highest peak of 1,590m, steep cliffs and stretching in the direction of Northwest - Southeast. In addition to the above mountain range, there are Ngan Son Mountain ranges starting from Bac Kan running in the northeast, southwest to Vo Nhai and Bac Son mountain ranges running in the northwest and southeast directions. All three mountain ranges of Tam Dao, Ngan Son and Bac Son are high mountain ranges that shield the northeast monsoon.

Minh Lap commune lies within the midland and mountainous area, adorned with numerous hills and mountains spread across its boundaries. The commune is surrounded by high hills and mountains, so there are alternating low-lying areas and mainly concentrated in the same commune center. The commune's topography is generally high to the North, lower to the South - Southeast. The average altitude is from 49.8 to 236.8m above sea level.

The project is located in a mountainous area with favorable conditions and terrain for raising pigs and chickens and planting high-quality fruit trees. The characteristics of the project area are mostly production forest land, the rest is land for perennial crops, land for other annual crops, freshwater aquatic products, rice land and a part of land in rural areas. Currently, in the project area, there are no households living.

2.2 Climate

2.2.1 Climate

The climate of Thai Nguyen is characterized by a favorable mild climate for agricultural and forestry development, which is considered a key parameter for the introduction of biogas plants. The average temperature in the hottest month, June, is 28.6°C, while in the coldest month, January, it is 16°C. The annual sunshine duration ranges from 1,300 hours to 1508.1 hours, with distribution of sunshine hours from June to November. The climate in Thai Nguyen exhibits a clear division between the rainy season, which extends from May to October, and the dry season, which occurs from October to May. The average annual precipitation in 2021 amounted to 1,937.1mm, with the highest rainfall occurring in August and the lowest in January.

Table 2.2 Climate Status

Factor / Year	Temperature(℃)			Precipitation (㎜)	Relative Humidity (%)		Total Sunshine duration (hr)
	Average	Highest	Lowest		Average	Lowest	
2017	24.2	29.3	17.2	2,045.9	81	72	1,278
2018	24.2	29.3	17.1	1,874.6	80	71	1,331
2019	24.7	29.6	17.0	1,889.3	81	75	1,389
2020	24.4	30.5	17.6	1,740.4	79	75	1,326
2021	24.3	30.5	15.7	1,657.9	78	71	1,486
Average	24.4	-	-	1,841.6	79.8	-	1,362

2.2.2 Temperature

Temperature is one of the important parameters in biogas plant for livestock manure treatment processes.

Table 2.3 Monthly Average Temperature (Celsius, °C), 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature	16	17.3	20	23.8	27.2	28.6	28.7	28.2	27.3	24.8	21.2	17.6

2.2.3 Precipitation

Precipitation and annual rainfall days are very important factors in making decisions on biogas plant operation condition. In Thai Nguyen, the average annual precipitation amounts to 1,937.1mm, accompanied by an average of 160 rainy days each year.

Table 2.4 Monthly average precipitation (mm), 2021

month	1	2	3	4	5	6	7	8	9	10	11	12
value	28.0	31.1	60.1	111.5	237.3	306.3	399.4	336.5	227.3	123.2	52.7	24.3

Table 2.5 Number of rain days, 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Rainy days	10.1	12	17.7	16.7	15.1	16.3	18	18.1	13.2	9.8	7.2	6.1

2.2.4 Wind Velocity

Wind velocity is also one of important factors affecting plant corrosion that varies depending on wind speed. In Thai Nguyen, the average annual wind velocity is 1.4m/s which is suitable for construct biogas plant.

Table 2.6 Wind Velocity (m/sec), 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Wind velocity	1.4	4.5	1.4	1.5	1.6	1.4	1.4	1.2	1.2	1.2	1.2	1.3

2.2.5 Relative humidity

Air humidity is one of important factors in determining the capacity of biogas plants. The average annual humidity in Thai Nguyen is 81.6%.

Table 2.7 Air Humidity (%), 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Minimum	63.1	67.0	71.4	70.9	63.7	64.6	65.9	66.2	61.1	58.2	56.2	56.2
Average	79.4	81.4	84.4	85.3	81.8	82.3	83.5	84.7	82.3	79.8	78.0	76.6

2.2.6 Duration of sunshine

Thai Nguyen City's yearly sunshine hours in 2021 are 1,486 hours, and are 1,326 hours in 2020 on average, respectively. So, capacity determination of biogas plant was made based 117.65 hours of sunshine duration on a monthly average basis, as its duration is one of important factors resulting in operational efficiency of a biogas plant.

Table. 2.8 Duration of Sunshine in Thai Nguyen, 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Sunshine duration (Hours)	64.1	44.8	42.2	42.2	78.2	163.4	159.8	182.0	177.4	182.8	161.6	113.3

2.3 Social Condition

2.3.1 Population

The population of Thai Nguyen Province, which is where the site is located, was 1,323,150 in 2021 and it is growing at an annual average of approximately 1.3%. Compared to the average population density of Vietnam in 2021 (297person/km^2), this area has high density (376person/km^2), and it has a high population-to-area compared to other parts of Vietnam.

Table 2.9 Population trend by year in Thai Nguyen

Year	Population			Density (Per km2)
	Total	Male	Female	
2018	1,273,557	623,286	650,271	360
2019	1,290,945	631,071	659,874	366
2020	1,307,871	638,931	668,940	371
2021	1,323,150	646,245	676,90	376

By area, the Dong Hy district where the site is located is the fourth largest area in the region but has a low population with population density of about 218 person/km^2.

Table 2.10 Area, population, and population density in 2021 by district

City/District	Area (km^2)	Population (Person)	Population Density (Person/km^2)
Total	3,521.96	1,323,150	376
Thai Nguyen city	222.12	354,331	1,595
Song Cong city	97.31	72,593	746
Pho Yen town	258.42	197,538	764
Dinh Hoa district	513.77	90,825	177
Vo Nhai district	838.39	69,342	83
Phu Luong district	349.80	104,508	299
Dong Hy district	431.73	94,150	218
Dai Tu district	569.03	176,030	309
Bình Phu Binh district	241.39	163,833	679

2.3.2 Land use

Following land use status, Thai Nguyen focuses on agricultural production, and one of the third percentages is allocated to agricultural activity. Thai Nguyen has wide farmland of about 301,933ha, equivalent to 85.73% of agricultural and forest. Especially, from 2019 to 2021, farmland has decreased by approximately 1,500 Ha, also non-agricultural land increased by 400 Ha based on the purpose of land. For these reasons, Thai Nguyen needs to sense climate change for increasing resilience and confrontation problems on the agricultural side.

Table 2.11 Land use status by purpose in 2019 and 2021

Land use	2019		2021	
	Total (Ha)	Ratio (%)	Total (Ha)	Ratio (%)
1. Farmland	303,555	86.08	301,933	85.73
1.1 Agricultural land	112,048	31.77	109,760	31.16
1.2 Forest	186,648	52.92	187,032	53.10
2. Non-agricultural land	44,445	12.63	47,079	13.37
2.1 Homestead land	12,346	4.06	12,864	13.65
2.2 River and specialized water surface	5,642	1.6	6,254	1.78
3. Unused land	4,664	1.33	3,184	0.9
Total	352,664	100	352,196	100

According to the state of land use, as of 2021, the crop-growing area of Thai Nguyen is approximately 148,727 ha and is categorized into annual crops and perennial industrial crops, with about 75.3% producing annual crops and 24.7% producing perennial crops.

Table 2.12 Farmland Status in Thai Nguyen, 2017~2021

Year	Planted Area of Crops (Ha)	Annual Crops (Ha)			Perennial Crops (Ha)		
		total	Food crops	Annual industrial crops	Total	Perennial industrial crops	Fruit crops
2017	156,552	117,811	88,842	4,828	38,741	21,649	17,054
2018	154,068	116,027	87,885	4,483	38,041	22,027	15,930
2019	152,960	114,998	87,032	4,325	37,962	22,282	15,458
2020	151,562	114,229	85,855	3,960	37,333	22,399	14,680
2021*	148,727	112,066	84,537	3,820	36,661	22,445	13,929

* Statistical expected rate

Of the crops in Thai Nguyen Province, compost and liquid fertilizer produced at the biogas plant can be sprayed on annual crop-growing areas such as for sugarcane, oil-bearing crops, etc. From this perspective, the annual increase of annual crop-growing areas is judged to be an increase of demand for compost and liquid fertilizers produced by the biogas plant. As of 2021, Thai Nguyen Province produces annual crops in 22,456 ha, showing an annual average production site increase rate of 2% over the past five years.

Table 2.13 Planted area and production of annual crops, 2017~2021

Crops	2017	2018	2019	2020	2021
Area (Ha)					
Sugar-cane	162	166	164	149	114
Tobacco, pipe tobacco	21	26	42	15	17
Oil bearing crops	4.645	4.291	4.113	3.792	3.688
- Groundnut	3.764	3.516	3.383	3.156	3.154
- Soybean tree	805	722	679	576	450
Vegetables, beans of all kinds, flowers	14.854	14.980	15.253	16.085	16.203
- Vegetables	13.555	13.664	13.931	14.730	14.849
- Beans of all kinds	1.176	1.115	1.085	1.104	1.101
- Flowers	123	201	237	251	253
Others annual crops	1.111	1.423	2.180	2.555	2.434
Total	20.793	20.886	21.752	22.596	22.456

* Statistical Estimated Result

Table 2.14 Planted yield of annual corps, 2017~2021

Yield (Quintal/ha)					
Sugar-cane	558,70	552,91	556,77	562,82	566,43
Tobacco, pipe tobacco	21,01	21,03	20,95	22,00	22,35
Oil bearing crops					
- Groundnut	17,29	17,82	17,60	17,80	18,30
- Soybean tree	15,69	16,26	16,29	16,60	16,58
Vegetables, beans of all kinds, flowers					
- Vegetables	17009	172,18	175,55	177,47	180,42
- Beans of all kinds	12,93	13,43	13,64	13,83	14,33
- Flowers	-	-	-	-	-
Others annual crops	-	-	-	-	-

* Statistical Estimated Result

2.3.3 Industry

Vietnam is a country that focuses on agriculture with 43% of its population working in the agricultural industry and where agriculture accounts for a considerable portion of its total GDP. According to the statistics on the number of workers by industry in Thai Nguyen in 2021, about half of the annual average capital created through economic activities in Thai Nguyen is generated from agricultural and related service activities. There are a total of 84 established companies that are active in Thai Nguyen, and most are private farms rather than corporate farms. There has been a recent trend of increasing number of corporate farms. Furthermore, agriculture was found to have the highest industrial productivity per capita in Thai Nguyen. It was approximately 445.9 Bil.VND/year per productive population, or about 27.6 times higher compared to the second highest, which is real estate activity.

Table 2.15 Number of Establishments and workers by industrial groups and provinces, 2021

Industry	Annual average capital (Bill, VND)	Establishment (Unit)	Worker (person)
Total	567,711.3	4,031	189,435
1. Agriculture, forestry, and related service activity	497,605.0	84	1,116
2. Mining and quarrying	4,670.0	56	1,400
3. Manufacturing	399,965.2	815	140,694
4. Electricity, gas, steam, hot water, and air conditioning supply	7,454.2	24	1,471
5. Water supply: sewerage, water management and remediation activities	2,014.6	25	1,480
6. Construction	15,167.5	678	13,824
7. Wholesale and retail trade	51,927.4	1,450	13,440
8. Transportation and storage	5,684.3	271	4,331
9. Accommodation and food service activities	2,237.6	92	839
10. Information and communication	17.4	11	58
11. Financial, banking and insurance activities	1,491.6	14	329
12. Real estate activities	10,929.2	57	676
13. Professional, scientific, and technical activities	934.8	221	2,121
14. Administrative and support service activities	2,379.0	143	5,068
15. Education and training	211.9	52	849

2.3.3.1 Agriculture

Agricultural industry is one of the important economic activities of Thai Nguyen province. In 2021, as against the national figure of 7,592 cooperatives of Agriculture, Forestry and Fishery cooperatives, there are only 83 agriculture cooperatives in the province. Thai Nguyen has more over 301,933 hectare of agricultural land equivalent to 85.73% of natural land in which a part distributed along the streams, scattered by the harsh hydrological.

Table 2.16 Agricultural Industry in Thai Nguyen, 2021

Population in agricultural industry	Agricultural land (Ha)			
	Total	Agricultural production land	Annual Crop land	Corp land
117,681	301,933	109,760	56,142	53,617

Especially, Thai Nguyen is one of the top 5 tea plantations in Vietnam. In 2020, Tea is grown on about 22,399 hectares per year, and production has increased by about 0.9% over the past five years. While the production area of tea—which is a local specialty—had an increase in production and growing area of 3.68% over the past five years, production also grew by 11.58%; thus showing high productivity.

Among the crops produced in Thai Nguyen, paddy, maize, sweet potato, cassava, sugarcane, tobacco, fiber, oil-bearing crops, etc. are crops for which compost & liquid fertilizers produced from the biogas plant can be sprayed. Considering the fact that compost & liquid fertilizers are produced from the biogas plant as a method of increasing the productivity of crops, it is an area with high ease of meeting demand.

Table 2.17 Fruit crops plated area and Production status, 2017~2021

Planted area (Ha)	2017	2018	2019	2020	2021
Coconuts	212	198	205	192	149
Mango	421	433	425	381	338
Orange	2,000	2,246	2,670	2,776	2,656
Banana	1,866	1,868	1,930	1,755	1,709
Longan	1,624	1,835	1,724	1,714	1,652
Litchi	2,950	2,193	1,697	1,421	1,226
Tea	21,649	22,027	22,282	22,399	22,445

Production (Ton)	2017	2018	2019	2020	2021
Coconuts	1,621	1,779	1,882	1,735	1,742
Mango	1,275	1,244	1,341	1,361	1,636
Orange	8,923	12,111	19,276	21,287	20,799
Banana	27,870	26,051	27,206	25,340	24,357
Longan	5,113	6,771	6,525	6,689	9,208
Litchi	11,936	9,314	7,048	5,755	6,166
Tea	224,711	230,903	239,245	244,432	250,732

* Statistical Estimated Result

2.3.3.2 Livestock industry

The field of livestock and poultry breeding has developed stably, and diseases have been basically under controlled. The total production value of the livestock industry in 2022 was estimated at over 506 trillion VND, up 5.5% over 2021. Under these matters, the total value of live pigs in 2022 was estimated at seven million tones, the highest ever. It estimated that the total number of pigs in the country increased by 6.8% compared to the same period in 2021.

Table 2.18 Annual livestock trend in Vietnam (2017~2021)

Number (Thous. heads)	2017	2018	2019	2020	2021*
Buffaloes	2,605.1	2,486.9	2,388.8	2,332.8	2,264.7
Cattles	6,285.3	6,325.2	6,278.0	6,325.5	6,365.3
Pig	29,110.7	29,830.7	20,208.3	22,028.1	23,533.4
Poultry	407.1	435.9	480.3	512.7	526.3

** Statistical estimate result*

Thai Nguyen province is home to a significant population of major livestock species, including buffaloes, cattle, and pigs, with a total count of approximately 509,511 livestock. Pigs take the lead among these livestock species, comprising approximately 77.2% of the overall livestock population. However there has been a notable decline in livestock numbers in recent years due to the outbreak of African swine fever in 2018, leading to widespread slaughtering. However, there are positive projections for the livestock count in 2021, signaling a promising recovery.

Table 2.19 Annual livestock trend in Thai Nguyen (2017~2021)

Number (Thous. heads)	2017	2018	2019	2020	2021*
Buffaloes	57.17	50.95	45.95	44.44	45.04
Cattles	44.18	41.53	42.85	46.27	51.26
Pig	680.99	706.21	429.62	591,81	455.83
Poultry	11.342	13.510	14.303	15.002	4.392

** Statistical estimate result*

As livestock increases, increased livestock wastes and livestock manure are also expected. Thus, continued growth in needs for facilities to handle livestock manure is projected.

2.3.3.3 Fertilizer industry

(1) Definition of fertilizer

According to Article 2 of the Cultivation Act (Law No. 31/2018/QH14), fertilizer refers to a product that has the function of supplying nutrients or improving soil to improve the productivity and quality of crops. Fertilizers are managed in accordance with the Regulations for fertilizer management (Decree No.84/2018/ND-CP) and are classified according to the National Technical Regulations for fertilizers (QCVN No.01-189 /BNNPTNT).

Table 2.20 Fertilizer classification in Vietnam

Classification	Justification
Organic fertilizer	Produced mainly from organic substances and treated through physical or biological process
Inorganic fertilizer/ Chemical fertilizer	produced mainly from inorganic or synthetic organic substances and treated through chemical processes of mineral processing
Biological fertilizer	Produced through biological processes or are natural fertilizer that contain biological substances such as humic acids, fulvic acids, amino acids, or vitamins

(2) Fertilizer business regulation

Fertilizer producers in Vietnam must be issued a "guarantee for fertilizer production" as defined by the Cultivation Act pursuant to the Fertilizer Producer Act. The guarantee for fertilizer production can be issued when enforcing the relevant regulations such as

①construction of suitable equipment for fertilizer production, ②fertilizer quality control system, ③construction of a quality management system according to international standard organizations, ④facilities for separately storing raw materials and finished products, ⑤assigning fertilizer management experts, etc.

Here, fertilizers can be produced using various raw materials; with the recent enforcement of national technology regulations prescribing that livestock wastewater can be used for crops, however, the legal grounds for using fertilizers produced from the biogas plant for crops were established. According to the "National Technological Regulations for Livestock Wastewater Used for Crops," the upper limit of substances was established so that substances of livestock manure can be used as fertilizers. This enables using fertilizers produced from the biogas plant utilizing livestock manure. By prescribing the regulations for the substances of fertilizers produced, profits from organic fertilizers produced in the future are forecast.

(3) Fertilizer market status

While 43% of Vietnam's population work in the agricultural industry, the agricultural production capacity is still less than 1/5 of the total GDP at approximately 12.36%. Therefore, in order to stabilize the agricultural sector and increase production of agricultural goods, there is further growing demand for fertilizers; and with this increased demand, the organic fertilizer market is growing in Vietnam. On average, all land where farming is carried out in Vietnam absorbs over 1 ton of fertilizers (467.7kg per hectare in 2020) annually, and this is higher than the average of other countries (146.4kg per hectare in 2020).

Table 2.21 Industrial product in Viet Nam 2015~2020

Year	2015	2016	2017	2018	2019	2020
Fertilizer consumption	432.27	424.70	457.99	417.44	403.42	467.66

Unit: kg per Ha

In 2016, Vietnam used 11 million tons of compost for the entire year, and use of compost is increasing from the long-term perspective. 90% of the fertilizers used domestically in Vietnam are chemical fertilizers, and production is mostly offset by importing those produced abroad. Annual production of domestic chemical fertilizers is found to be growing in order to satisfy the demand for compost that is growing within Vietnam. The annual amount of chemical fertilizers produced within Vietnam in 2021 was approximately 42.606 billion tons, and the annual average increase over the past five years was found to be about 3.5%.

Table 2.22 Industrial product of in Viet Nam 2015~2021

Industrial product (Thous. tons)	2015	2018	2019	2020	2021*
Chemical fertilizer	3,729.1	4,042.5	3,951.7	4,155.3	4,260.6
NPK fertilizer	3,304.1	3,323.8	3,404.9	3,497.6	3,655.0

** Statistical estimate result*

However, there was high price volatility of import fertilizers due to the increased price volatility of overseas fertilizers, increased production costs in the agricultural sector, etc.; thus raising the economic burdens of farms.

Accordingly, the Vietnamese government seeks to provide policy support programs in order to respond to the expansion and volatility of the fertilizer market.

According to MARD, organic fertilizer consumption—which stood at a mere 280,000 tons (about 2% of the total fertilizer market) in 2015—has been growing at an annual average growth rate of 27% to reach 1.19 million tons (about 10% of the total fertilizer market) in 2021. In addition, while the number of organic fertilizers registered over three years until 2021 grew rapidly at 500%, there has been a trend of decreased use of synthetic fertilizers. In November 2022, MARD established plans to raise the rate of using organic fertilizers by 25% in 2025 as grounds to support the market expansion of organic fertilizers in the country.

Based on such growing market demand and policies for promoting the fertilizer market, it is judged that it will be easier to secure economic feasibility through organic fertilizers produced at the biogas plant.

2.3.4 Traffic

The province has transportation system linking with other provinces as the National highway No. 3, No. 1B, No. 37, Ha Noi-Thai Nguyen Expressway, Thai Nguyen- Bac Kan Expressway, Ha Noi- Thai Nguyen railway, Thai Nguyen- Luu Xa- Kep rail route. In the future, the province will have Ho Chi Minh Road, belt road No.5 of Ha Noi. Most of roads start from the axis along the national highway No.3 running to districts, town and economic zones, mines, and linking to neighboring provinces. In addition, Railway is also convenient for passenger transportation to another province such as Ha Noi, Quan Trieu route and Luu Xa.

With a very convenient location in terms of traffic, 75 km from Hanoi center and 200 km from Hai Phong port. Thai Nguyen is also an intersection point through a system of roads, railways, fan-shaped riverways connecting with provinces and cities, National Highway 3 connecting Hanoi to Bac Kan, Cao Bang and Vietnam.

Such local traffic characteristics will enhance accessibility not only within Thai Nguyen but also from other areas, which can raise the possibility of expanding the scale of the plant as well as management targets. By collecting the livestock manure in nearby areas, it is possible to expand the scale of the biogas plant and increase the sales areas of compost produced using the livestock manure.

Figure 2.5 Road Status in Thai Nguyen

2.4 Water system

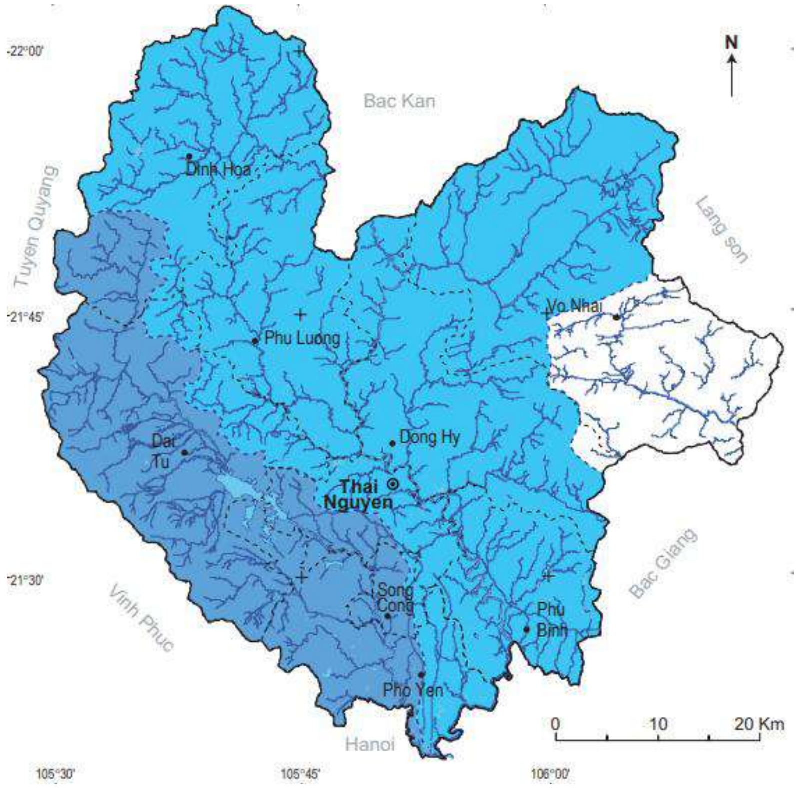
The water resources available in Thai Nguyen mainly includes Cau river and Cong River. The Cau river and the Cong River is a prominent watercourse in the region, flowing through Thai Nguyen Province and its surrounding areas. It holds considerable importance as a water source for various sectors, including agriculture, industry, and domestic use. The river's health and cleanliness are essential for preserving the ecological balance and ensuring the well-being of both humans and wildlife in the area.

Table 2.23 Water system of the main rivers in Thai Nguyen

Name of the River	Location	Length of the river (km)
Cau River	Thai Nguyen	288
Cong River	Thai Nguyen	96

Cau River basin has complex topography with three 3 typical ecological zones (plains, midlands, and high mountains). Cau River basin has the form stretching from North to South, total area is determined to be 6,030km2. The basin has 68 rivers and streams with a length of more than 10km.

Figure 2.6 Water basins of the Cau and Cong Rivers



As of 2021, the number of households receiving sewage through the city's water supply system was 98.5% of the total number of households, indicating that most residents receive water through rivers in proportion to the annual increase in population.

Table 2.24 Water supply status in Thai Nguyen

Year	Population	Percentage of household using Hygienic water	Percentage of urban population provide with clean water by centralized water supply system	Percentage of household using hygienic water (%)
2018	1,273,557	89.90	96.07	91.01
2019	1,290,945	93.01	96.46	93.00
2020	1,307,871	97.70	96.20	95.00
2021	1,323,150	98.50	97.32	95.00

However, the construction of farms, particularly pig farms, can potentially lead to water pollution in the river basins. The management of pig wastewater is of utmost importance to prevent adverse environmental impacts. Without proper waste management practices, the discharge of untreated or poorly treated pig wastewater into the river can contaminate the water, degrading its quality and harming aquatic.

The Minh Lap commune which is project area located is one of the areas affected by retaining water and serving production based on the Cau river. the Cau river flowing along the western and northern boundaries of the Minh Lap commune with an area of 87.66ha. As the project area does not have a water supply system, the project area will use rainwater storage reservoir, Cau river water, groundwater from drilled wells to serve livestock and daily life activities of the whole community. The project will utilize multiple sources of water, including the Cau river, surface water within the project area, and treated wastewater from livestock, all of which meet the quality standards required for national technical regulations on livestock wastewater treatment.

2.5 Manure treatment facilities

Vietnam is an agricultural country and about 70% of the population live in rural areas. Therefore, agricultural production plays a crucial part in the national economy, and there has been a huge increase in the scale of the livestock industry recently. Due to the growth of industries, livestock farms with high population densities were found to have severe environmental pollution. Multiple livestock farms are operated as small livestock ranches, and it was found that there are difficulties in managing wastes generated by livestock farms. The major environmental pollutants from livestock farms were found to be solid wastes, wastewater, dust, noise, dead livestock and fowl, burying, etc. and an investigation found that pollution is worsening every year due to wastes.

The quantity of livestock manure generated in Vietnam has continuously increased from 2017 to 2019. In 2019, the Vietnamese livestock industry produced about 86.92 million tons of livestock manure, or 2.62 million tons more compared to 2018. In terms of livestock species, the amount of wastes produced per pig was smaller compared to cows and buffaloes, but there were approximately 2,493 million heads in 2019; thus accounting for about 20.9% of all livestock manure wastes generated. The Pig farming waste concentrated mainly in lowlands and populated areas and causes the greatest pollution compared to other animal farming species.

Table 2.25 Current situation of solid waste generation from livestock in Viet Nam

Animals	Solid wastes (kg/head/ day)	2017		2018		2019	
		Population (Mil. Head)	Solid waste (mil. Tons)	Population (Mil. Head)	Solid waste (mil. Tons)	Population (Mil. Head)	Solid waste (mil. Tons)
Cow	10	5.66	20.64	5.80	21.17	5.96	21.76
Buffalo	15	2.49	13.64	2.43	13.28	2.35	12.87
Pig	2	27.41	20.01	27.40	20.00	24.93	18.20
Poultry	0.2	385.50	28.14	408.97	29.85	467.00	34.09
Total	-	-	82.43	-	84.30	-	86.92

However, currently, there is no expansion of livestock manure treatment facilities in Vietnam to deal with the amount of livestock manure generated. Following Vietnam National Environmental report in 2014, 1,700 farms have wastewater treatment system, which is 7.2% of total livestock industry. And, about 36% of livestock manure is discharged directly into the environment (16% from concentrated animal husbandry facilities, 40% from farming households, of which 32% of farms and 47% of households do not have any environmental treatment measures) and more than 60% of the waste is treated but most of them are treated without the permitted standards. And the reason that pig manure in slurry form which is not easily collected. About 80% of the manure is generated by smallholder farms, and the reminder comes from commercial farms. smallholder farms account for the largest share of buffalo farms (98.8%), but also a high percentage of cattle (89.4%), pig (75.0%), and poultry farms (71.8%).

The processing method of livestock manure treatment facilities operating in Vietnam mostly used biogasification through landfill methods. With the waste-to-energy policy of the government and issues of the livestock manure treatment method, etc. highlighted recently, however, the biogas utilization method through anaerobic digestion was found to be used more commonly as a new treatment alternative. As following the table, livestock manure management in Vietnam has been selected effluent management in multiple provinces. In Ha Noi, usually most of manure treated within biogas, approximately 91.5% of livestock manure treated with Biogas plant. But, In Bac Giang, which has the one of the largest livestock industries, only 25% percent of manure treated with Biogas plant.

Table 2.26 Livestock manure management status in Vietnam

Effluent Management	Province (Unit: %)			
	Hung Yen	Ha Noi	Thai Binh	Bac Giang
Biogas	47.6	91.5	30	25
Compost	9.5	6.4	37	29
Used for plant	38.1	23.4	-	-
Directly discharge into environment	28.6	4.3	14.0	0
Discharge to fish ponds	52.4	17.0	-	-
Collection for sale	28.6	34.0	-	-
Stored	-	-	8	14

Following the research about livestock waste management in Vietnam, Pig manure treated market has not developed caused that not widely used for fertilizer. The price of pig manure is low, which go up to approximately 1,000-3,000 VND (approximately 0.13 USD) for a bag of 20 kg. (T. Thi Dan et al., 2004)

In the case of Thai Nguyen Province where the site is located, over 670 livestock farms are mixed in together with residential areas as of 2013. Environmental protection facilities were not constructed according to the sewage and waste treatment standards for the numerous livestock ranches due to shortage of land, and this resulted in environmental pollution that affects the life of residents in the area. In 2013, only 10% of livestock farms in operation carried out environmental impact assessments and environmental protection duties, and 6 farms paid environmental fees for wastewater, but the collected amount was found to be very low. The livestock manure treatment effects and stability of treatment of livestock farms in Thai Nguyen were found to be relatively low, and operating facilities to make improvements to environmental pollution was deemed necessary.

2.6 Electricity supply condition

With the ongoing development of the industry, Vietnam has experienced a significant increase in its average annual power consumption growth rate, reaching approximately 9.7% between 2010 and 2020. In 2020, the country's power consumption soared to 214.3 TWh, creating a demand for the continuous expansion of facility capacity in response to the growing market usage. The percentage of households supplied with power, increasing from 2.5% in 1975 up to 99.53% in 2019. In rural areas alone, the percentage of rural households using electricity as 2020 reached 99.26%, consequently only about 0.74% of rural households have not had access to electricity.

Installed capacity in 2019 is 55,107MW, it follows hydropower 36.81%, Coal fired 35.83%, and gas-fired & oil-fired 16.07%. The annual power production of Vietnam in 2019 was 2,311kWh, which was an 8.85% increase compared to the previous year; electric power in 2019 was 208.4 billion kWh, representing an 8.87% increase compared to the previous year.

Table 2.27 Installed capacity by fuel types in Viet Nam

Power Source	2019		2020	
	MW	%	MW	%
Hydropower	20,283	36.81	20,774	29.98
Coal fired	19,744	35.83	21,554	31.10
Gas fired + oil fired	8,857	16.07	8,858	12.78
Wind	369	0.67	518	0.75
Solar	4,669	8.47	8,871	12.80
Rooftop solar	320	0.58	7,785	11.23
Biomass	293	0.53	365	0.53
Imported	572	1.04	572	0.83
Total	55,107	100	69.297	100

Source: Annual Report 2021, EVN Vietnam Electricity

There has been a growing need for carbon neutrality of electric power generation sources recently, and Vietnam established plans to increase the ratio of renewable energy generation to 30.9%~39.2% by 2030 through its 8th power development plan. Plans to reduce greenhouse gas emissions were established to accelerate the conversion into renewable energy, targeting reduction of 204 million and 254 million tons by 2030 and 27 million and 31 million tons by 2050. With the establishment of policies for reducing greenhouse gases and expansion of renewable energy in the long term, the feed-in-tariff (FIT) program is in place to support the active entry of foreign capital to generate renewable energy as a tool for expanding renewable energy generation. As a measure to promote the expansion of solar power, wind power, biomass, and waste energy when selling electricity within the electric power market in Vietnam, FiT of about 7.08-10.05 cents USD/kwh for electric power produced using renewable energy is being applied in order to defend against the low electricity costs.

3. Government plan of Climate change

3.1 Climate Change

Vietnam updated its nationally determined contributions for reducing greenhouse gas emissions in 2022, committing to a 15.8% reduction in greenhouse gas or 43.5% if it receives international assistance by 2030 relative to business as usual (BAU). As stated in NDC, Reducing Biogas relates to using biogas instead of coal for household cooking in rural areas, using biogas power, and development of using biogas. And measure to reduce methane emissions in sub-sectors of agriculture, especially management of livestock waste and agricultural by-products are those carried out for the implementation of Vietnam's statement at COP 26 to reduce methane emission by 30% from 2020 levels by 2030.

From '2030 to 2050, National Adaptation Plans' promote outcomes of the 2021-2030 period, continue to improve the capacity for adaptation to climate change of humans, infrastructure facilities and national system in order to protect and improve the quality of life and so on. It implements suitable livestock industry model for climate change adaptation, and present a capacity building plan for agricultural, forest and fisher sector by connecting energy production and livestock industry.

Following these plans, the Ministry of Agriculture and Rural Development planned an Implementation plan of the Paris Agreement on climate change for the period of 2021-2030. It treated reducing home gas emissions through livestock waste management by strengthening public applications of advanced technology towards bio-secure animal husbandry and environmental protection. The implementation of an integrated approach involving the treatment of biogas generated from pig waste on a farm, along with the adoption of water-saving pig farming techniques, has led to the development of a system for producing organic fertilizers.

3.2 Vietnam National Priority and Relevant Plans

The Vietnamese government has set a target to achieve 4 to 5 percent industry growth per year until 2025, and 3 to 4 percent growth from 2026 to 2030. To reach this goal, Vietnam's livestock industry is beginning to shift away from small-scale household farming to modern, large-scale industrial processing. Furthermore, Vietnam concern that using livestock manure for expansion of economic value within circulation of resources.

Vietnam categorized livestock manure as organic wastes and announced enforcement rules on the organic waste treatment method for livestock farms. This aims at minimizing the environmental pollution generated in the livestock waste and agricultural industry byproduct collection and treatment method. Therefore, livestock wastes generated at farms are required to undergo biogasification, biopond operation, or other biological treatment method that can minimize odors. Based on this, policy directions that can minimize environmental pollution caused by illegally discharged livestock manure as well as for utilizing livestock manure were established.

When operating biogas plants as a method for treating livestock manure, electricity and compost are generated as byproducts. The key policies of the Vietnamese government regarding electric power and compost can be examined accordingly.

The Vietnamese government aims at expanding renewable energy out of its national power production, and this was included in the national power generation plans. According to the 8th power development plan of the Vietnamese state-owned power corporation in 2023, coal power development—which accounts for 40% of total electric power production—will be phased out, and plans to expand renewable energy to 39GW by 2030 were also established. In addition, it is implementing the Feed-in-Tariff for renewable energy as a policy to promote the expansion of the renewable energy market. In Vietnam, the price of electricity is about 0.00 cents USD/kw, and profits are judged to be low compared to facility investments. Therefore, as a promotion policy for expanding sustainable energy development, fixed electric power sales pricing policies were implemented to improve profitability, and renewable energy electricity is sold at 8.45 cents USD/kw on average. However, it does not include the electric power produced through biogas within the renewable energy prescribed as covered by the policy. As it was analyzed that needs for electricity produced through the biogas plant will increase from the perspective of expanding waste-to-energy and renewable energy in the future, more of such policies are expected.

In addition, there are also high levels of policy interest from the Vietnamese government on organic compost produced from the biogas plant. A key industrial sector of Vietnam is agriculture, and chemical fertilizers are actively used to increase the productivity of the agricultural sector. To developing the production and use of organic products, the industry will develop a model for the use of organic fertilizer, using economical, balanced, and effective fertilizer in key national crop group. Nonetheless, the fertilizer market in Vietnam depends heavily on imported chemical fertilizers. Thus, Vietnam is supporting the growth of the fertilizer industry by expanding the domestic production of chemical fertilizers and providing and supporting the grounds for expanding the use of organic fertilizers. The Ministry of Agriculture and Rural Development aims to have local production using 25% organic fertilizers in 2025. (Increasing amount of qualified production by 1.25 times, equivalent to 5 million tons per year.) Regarding this, operating biogas plants is congruent with Vietnam's aims of waste-to-resource and expansion of domestic production policies as organic compost can be produced using livestock manure.

4. Field Investigation

4.1 Information of project

This project will construct new farms, and operating four pig farms and two chicken farms on a site spanning 300 ha is planned. Plans involve raising 9,600 breeding pigs, 80,000 pigs, and 640,000 chickens. Therefore, it is a project site requiring the operation of facilities that can treat wastewater including livestock wastewater generated during the operation of the livestock farms. The expected daily wastewater generated from the livestock work of this project site is about 250 tons/day, and it was found that livestock manure biogas treatment and composting methods are being considered in the project development stage. That is because this project site plans to engage in agricultural activities as well to include pomelo, oranges, bananas, etc. on parts of the site in addition to livestock.

The target site was investigated for operating biogas plants; based on this, feasibility studies were performed for the implementation of appropriate technologies and to secure their economic feasibility.

Table 4.1 Information of project area

Parameter	Value	Unit	Remarks
(1) Farm site	300	ha	
- (Use) Livestock industry	120	ha	
- (Use) Agricultural industry	180	ha	Cultivated corps : Pomelo, Orange, Banana, etc
(2) Scale of livestock industry			
- Pig heads	89,600	Unit	
- Chicken heads	640,000	Unit	
(3) Daily generated waste water	250	ton/day	

4.2 Soil investigation

4.2.1 Purpose

The purpose of this survey is to ascertain and thoroughly examine the makeup and soil attributes of the layers present across the designated area. This data is vital for ensuring a sound foundation for design and cost-effective planning. Additionally, it serves to preempt any issues that might arise when cultivating food in the chosen location.

4.2.2 Scope

The location for biogas plant is Minh Lap, Dong Hy, Thai Nguyen, Vietnam.

Table 4.1. Location of project site

In order to select the site for this investigation, the project sector ground plan drafted in the past was referred to in order to plan the drilling site, and on-site investigations were conducted for the final selection of the site suitable for investigation according to the on-site conditions.

Table 4.2 Soil investigation location

Sample	Location		Specification
	X	Y	
1	105047'26.8''	21041'30.1''	At the stream flowing into the Cau River, after the wastewater receiving point from the project area is about 100m downstream, about 100m southwest of the project
2	105048'03.6''	21041'49.8''	At the location along the stream flowing into the Cau River, after the receiving point of wastewater from the project area downstream, 150m north of the project
3	105047'21.9''	21041'21.9''	Soil at the discharge point area of the wastewater treatment system

4.2.3 Result

A total of three soil surveys were conducted to identify the stratum distribution status and characteristics for this project area, and the results of the study showed that the state of the soil of each region was at a level suitable for 'the national technological standards for forests.'

Table 4.3 Results of measurement and analysis of soil quality

Target name	Unit	Result			National Technology standard
		Sample 1	Sample 2	Sample 3	
Zn	mg/kg	50.54	50.2	47.38	200
As	mg/kg	13,617	16,087	22.33	20
CD	mg/kg	<1.5	<1.5	<1.5	3
Pb	mg/kg	38.88	39.113	29.35	100
Cu	mg/kg	27.63	21.26	30.24	150

4.3 Characteristic of livestock waste

4.3.1 Purpose

Operating the biogas plant effectively requires investigations on the livestock manure state procured by the biogas plant. As highly concentrated organic matter must be included in livestock manure to produce biogas efficiently, stable supply of raw materials with high concentrations of organic matter is essential. Thus, analysis on whether livestock manure in Vietnam possesses a certain level of organic matter to produce biogas through state investigations is mandatory.

4.3.2 Characteristics of livestock manure

As a limitation, the state of livestock manure of Vietnam has differences in the process of managing the livestock manure from the farm, rather than regional differences. Livestock manure discharged by livestock facilities has different states depending on the state of the livestock breeding facility, scale of the livestock breeding facility, and amount of fluids used. In particular, there are huge differences in the concentration of wastewater depending on various environmental conditions such as livestock manure, drinking water, cleaning water, feed residue, etc. Therefore, there can be large differences per farm in the treatment process of livestock manure. Considering the shortage of livestock manure treatment facilities in Vietnam and the characteristics of the livestock industry that is mainly composed of small livestock facilities, however, similar state is predicted since the livestock manure management methods of farms are similar.

Thus, for this project, the state of livestock manure was analyzed based on data on the livestock manure state of areas similar to Thai Nguyen, which is the target site for this project.

Table 4.4 Characteristics of piggeries wastewater in Vietnam

Site (Unit : mg/L)		pH	TSS	BOD_5	COD	TN	TP
Vietnam (2021) *		7.86 (±0.44)	162.7 (±133.3)	240.9 (±313.7)	505.3 (±706.9)	126.7 (±259.7)	28.9 (±24)
Gia Lam (2015)		7.2	615	2,817	5,210	-	-
Binh Phuoc (2022)		8.36	980	1,560	3,025	123.0	37.1
Korea	Feces	-	254,257	68,187	63,146	8,518	2,152
	Urine	-	553	4,543	3,793	4,606	148
	Average	-	43,562	13,182	12,066	3,025	418
QCVN 62/BTNMT **		5.5-9.0	150	300	100	150	-
QCVN 01-195:2022/BNNPTNT ***		5.5-9.0	-	-	-	-	-

Phuoc areas had a difference in the quantity of livestock manure for analyzing the state of livestock manure, but the state of livestock manure was found to have similar tendencies. However, the livestock manure parameters of the major regions of Vietnam were found to have exceeded the technological regulations for livestock wastewater. The regulation standards were exceeded in the TSS, COD, BOD, and TS items, and discharge of the livestock manure to the external environment without treatment is subject to administrative sanctions based on the relevant laws. Thus, it is evident that the operation of facilities for treating livestock manure is mandatory for Vietnam's pig-raising facilities by considering the livestock manure characteristics.

In Vietnam, there are many cases wherein cleaning water is used in large amounts for cleaning livestock manure at livestock farms because of the burdens of high-concentration wastewater treatment. The concentration was found to be low compared to the state of Korea's livestock manure handled by Korean companies transferring the technology, and the pollution load is also low due to livestock manure. Therefore, in reviewing the biogasification facilities using livestock manure, it is necessary to reduce the use of cleaning water of digesters and biogas facilities and modernize operation methods to reduce the amount of inflow of livestock manure. Considering the fact that technological obstacles can be reduced by making improvements to pig farms, it is necessary to consider the current situations when planning for the facilities.

5. Technology Feasibility

With the growing need to treat livestock manure generated annually due to the activation of Vietnam's livestock industry, there is also a growing need to implement biogas plant technologies. Thus, this study seeks to analyze the technological feasibility of newly establishing biogas plant facilities using anaerobic digestion to treat livestock manure within Vietnam. The key processes of biogas plants will be examined, and technologies suitable for Vietnam's market—which is in the initial stage of forming large-scale biogas plant markets—will be drawn up considering the climate conditions, local operation capacities, etc. In addition, the necessary biogas plant capacity will be deduced based on the quantity of daily livestock manure of pig farms in Thai Nguyen, which is the target site of the project, to present finally the model for large-scale biogas plants suitable for Vietnam's current situations while being cost-effective as well.

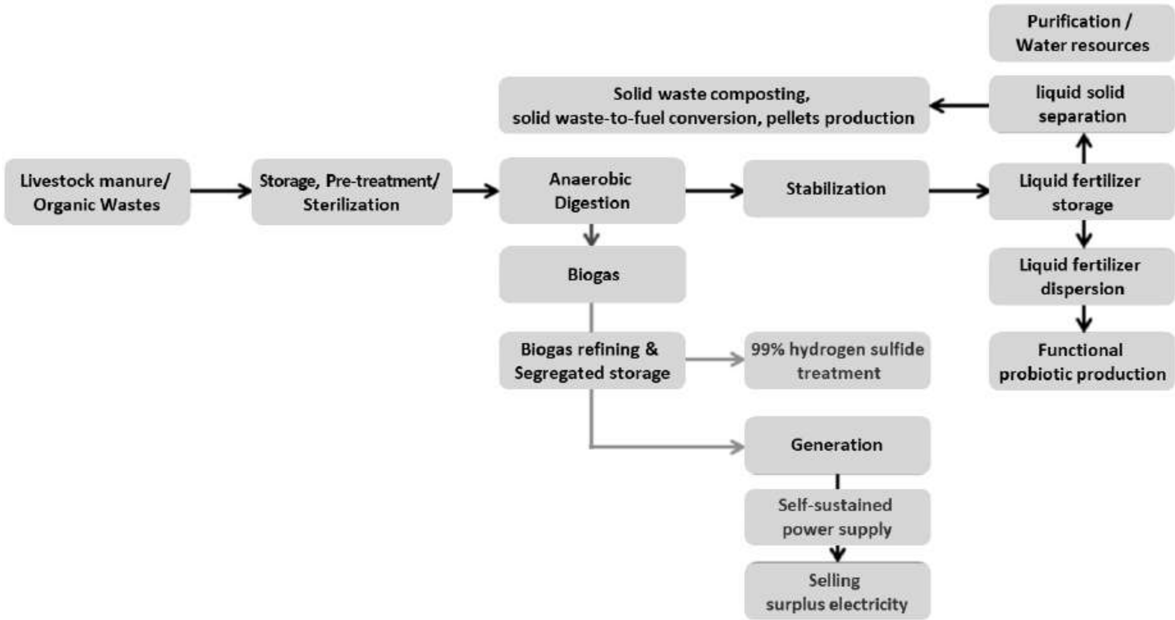
5.1 Treatment of livestock manure

This facility intends to utilize anaerobic digestion systems to treat livestock manure, generate electric power using biogas generation plants, and produce organic compost and liquid fertilizers through composting.

The anaerobic digestion facility considered for this project is the most advanced treatment method among livestock manure treatment methods and is a very useful method not only for generating electric power through methane gas but also in terms of using wastewater through livestock manure. Biogas produced through anaerobic digestion can produce electric energy and heat energy, and since green hydrogen can be produced through natural gas substitution or improved quality of methane gas, it is a method that is expected to see advancement in energy generation. From the perspective of operating equipment, this is judged to be a facility with high energy effectiveness. Furthermore, the biogasification process using livestock manure has high additional productivity of the equipment through resource circulation resulting from the composting of livestock manure. From the aspect of operating equipment, the key production process of biogas plants can minimize damages suffered by local residents resulting from bad odor as it has less odor compared to livestock manure treatment methods of burying, etc., which were used in Vietnam in the past, through anaerobic digestion. Such features of biogas plants can enhance their technological acceptability to local residents, and it is judged that operation will be easy through the cooperation of stakeholders.

The key process of the livestock manure biogas facility considered in this project is divided into pre-treatment, anaerobic digestion, biogas refining and generation, and compost & liquid fertilizer manufacturing processes. The technological considerations per process and technological feasibility of this project will be analyzed based on this.

Figure 5.1 Livestock Manure to Energy Process and Compost & Liquid Fertilizer Production and Utilization Concept Chart



5.2 Receiving and Pre-treating Livestock Manure

Receiving and pre-treating livestock manure include the series of processes of bringing and measuring livestock manure, removing inflow impurities, and making flux adjustments, and the receiving method can be categorized into bringing in using vehicles or flowing in through manure collection pipes. Anaerobic digestion facilities will be installed in large-scale farms for this project, so pipes will be connected between the farm and plant to bring in the livestock manure. When additionally bringing in nearby livestock manure using vehicles, however, it is necessary to secure the route for the collection vehicle and install a separate entry. Measurement facilities are also needed to check the amount received. The received livestock manure will pass through an inflow impurity treatment device and get sent to a storage tank, and it will then be injected at constant quantities into the anaerobic digester to undergo anaerobic digestion.

5.2.1 Receiving

Livestock manure reception and measuring are the process of bringing in livestock manure via pumps or pipes with measurement performed to bring the received livestock manure into the biogas plant. During the inflow of manure via pipes, clogging of pipes, odors due to leaks, etc. must be considered. As a solution for this, this project can consider multiple closing methods to solve the odor issue, installing cleaning water nozzles in areas where there are concerns of clogging or installing flanges. Likewise, if it is difficult to install inflow pipes or when receiving livestock manure additionally from nearby livestock farms, reception via collection vehicles can also be considered.

5.2.2 Anaerobic Digestion Pre-treatment

When receiving livestock manure, high quantities of inflow impurities, sediments, or suspended sediments can also flow in, necessitating the removal of the impurities included within the livestock manure through pre-treatment processes. Moreover, in order to improve the efficiency of anaerobic digestion facilities through the pre-treatment process, the concentration of inflowing raw water must be evenly maintained. Thus, in this project, the installation of apparatus for treating adulteration and fine impurity removal device considering the mitigation of loads for the anaerobic digester and future utilization conditions was planned. It was designed to remove stably the residue of suspended sediments to stabilize the succeeding processes, while also enabling pipes and pumps, etc. to operate smoothly.

5.2.3 Storage Facility

Storage tanks (flux adjustment tank) are facilities for the adjustment to constant state of inflowing water that can be uneven before flowing into the anaerobic digester and to ensure measured supply into the anaerobic digester. It allows stable supply of livestock manure whose foreign particles have been removed through the storage facility into the anaerobic storage tank, and enables homogenizing sludge that will be supplied to the anaerobic digester. In this project, the facility capacity will be secured to store inflowing amounts for more than 3 days in order to ensure sufficient retention time within the storage tank for the appropriate operation of the anaerobic digester.

5.3 Anaerobic Digestion Facility

5.3.1 System Description

Anaerobic digestion is a process of converting over 90% of the inflow into gas such as CH_4 using microorganisms in zero-oxygen state. This is suitable for treating highly concentrated organic wastewater as it generates less sludge compared to other wastewater treatment processes and uses relatively less energy compared to aerobic digestion processes, so it is a more economical process.

The anaerobic digestion process uses microorganisms to go through the hydrolysis stage, acidogenesis stage, and methanogenesis stage to be turned into biogas. Each stage decomposes organic matter using microorganisms, so an optimal environment must be maintained for the growth of microorganisms. Thus, in order to maintain an optimal environment, its necessary to predict gas generation according to the characteristics of livestock manure to establish the anaerobic digestion facility.

Biogas production differences depending on facilities, but considering that it increases by around 20-25% (average 23%) compared to the standard state based on volume, the biogasification design facilities of the methane gas generation rate took into consideration the maximum amount (0.30~0.48m3 CH_4/kgVS) considering the instantaneous load rate change. When operating the anaerobic digestion biogas facility in Vietnam in the future following this feasibility study, it will be necessary to calculate and apply the appropriate value through BMP tests according to the organic load of livestock manure.

5.3.2 Anaerobic Digester

1) Categorization by digestion temperature

Anaerobic digester are divided into mesophilic digestion that uses mid-temperature anaerobic microorganisms that grow at 35~37℃ and thermophilic digestion that uses high-temperature anaerobic microorganisms that grow at 50~55℃.

The temperature of anaerobic digestion is crucial in terms of process stability and efficiency. In particular, methanogenic bacteria has slower hydrolysis and growth speed compared to acidogenesis and it is relatively sensitive to temperature; hence the importance of maintaining appropriate temperature during process operation. Mesophilic digestion is known to be stable for methanogenesis and operation. Thermophilic digestion exhibits better efficiency in liquid solid separation compared to mesophilic, but advanced operation technologies are needed for the stable operation of thermophilic anaerobic digestion, and it also has the weakness of rising costs due to additional energy consumption to maintain temperature.

Table 5.3. Categorization of methods according to digestion temperature

Category	Thermophilic digestion	Mesophilic digestion
Temperature	50 ~ 55℃	35 ~ 37℃
Strengths	● Faster reaction rate for shortened treating time ● Requires small site for installing digester ● Increased biogas generation ● Kills pathogenic bacteria ● Increases dewaterability of sludge	● Relatively easy to operate ● Easy to adjust pH ● Good stability against shock loads ● Small energy required for heating, thus costing less for operations

In this project, it is judged that applying the mesophilic digestion method—which consumes less energy and whose operation is easy—is feasible. The northern part of Vietnam has a four-season climate; thus requires heating depending on the season. It is easy to adjust the pH with mesophilic digestion and it has good stability against shock loads, making it relatively easier to operate. Therefore, it is judged that it would be more appropriate to select the digestion method that can be implemented stably in Vietnam as it has insufficient experience in operating digester.

2) Categorization by digestion method

Anaerobic digestion decomposes organic matter that accounts for more than 80% (for solid matter) of organic wastes through the stages of hydrolysis, acidification, and methanization and generates sludge and biogas as the final byproduct.

Anaerobic digester are categorized into single-phase method that uses one reaction tank and double-phase method that uses two reaction tanks. In the single-phase method, digestion sludge, liquid, and gas get generated and react in a single digester. On the other hand, for double-phase digestion methods, hydrolysis and acidification reaction occurs through acidogenesis bacteria in the first-stage digester, and the high-concentration acidogenesis created through this creates and reacts methane smoothly through methanogenesis bacteria in the second-stage digester.

Figure 5.2 Categorization by digestion method

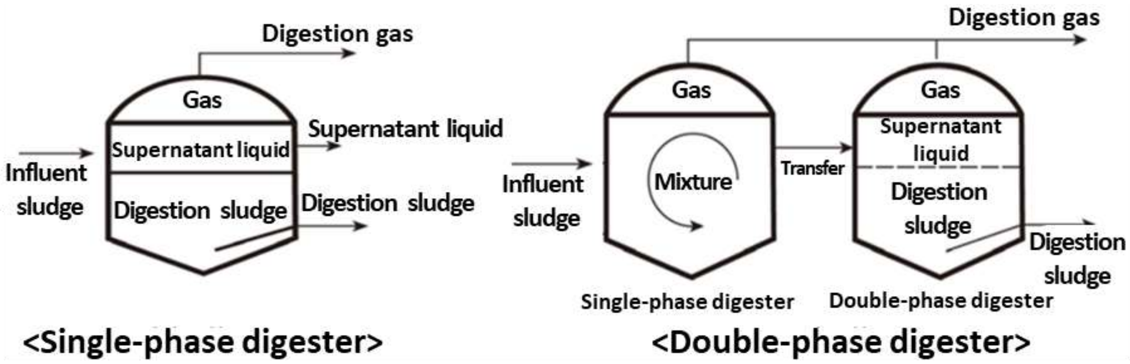


Table 5.4 Method categorization by digestion method

Category	Single phase digestion	Double phase digestion
Overview	Acid and methane fermentation occurs simultaneously in a single reaction tank	Acid and methane femernation occurs in separate reaction tanks
Strengths	● Faster reaction rate for shortened treating time ● Can select wet or dry type and medium or high temperatures ● Simple structure and easy to operate ● Small area needed for installing digester	● High ability to react to shock load ● Low impact on methane digestion process through accumulation of acidogenesis generated in the single stage ● Possible to optimize environmental conditions suitable for each stage
Weaknesses	● Weak against shock load ● Difficult to adjust the pH, making it hard to meet optimal conditions for the reaction process of each stage ● May be difficult to operate normally when accumulating acidogenesis generated in the acid fermentation process	● Relatively longer treating period ● High installation costs ● Requires operational skills ● Requires larger site area for installation

It was judged that using single-phase digestion that utilizes a single reaction tank is feasible for this project. Single-phase digestion is cheaper to install and the structure is simple; hence the faster reaction tank speed, easy operation, and higher performance suitability.

3) Review of mixing device

Mixers are devices that improve digestion efficiency by preventing wastes from being deposited at the bottom of the digester while maintaining sludge in the digester at even states. If an appropriate mixer is not installed and mixing is not performed appropriately, it can result in reduced gas generation, worsened treated water quality, reduced pH, and other problems that decrease digestion efficiency.

When selecting the type of mixer, a high-efficiency mixer should be applied to suppress the formation of scum layers resulting from the high concentration of protein and fat substances within the livestock manure. It is also necessary to apply a mixer for improving the movement of biomass containing highly concentrated solids and the mixing efficiency. When selecting the mixer, it should be a suitable model that does not overload the mixing effect and easy to operate and maintain, with high mixing efficiency.

Mixing methods are divided into the two main categories of gas mixing and mechanical mixing methods. The gas mixing method pressurizes parts of the gas generated in the digester with a gas compressor and sends it back to the digester. It consumes more power compared to mechanical mixing methods and requires higher manpower and costs for maintenance, while also generating secondary pollutants (waste oil) and having the weakness of having low mixing intensity. Therefore, the submersible mixing method—which has high mixing efficiency and low energy consumption—was reviewed for this project.

Table 5.5 Mixer type

Category	Submersible mixer	Compression type agitator	
		Propeller type	Paddle type
Structural Characteristics	Installed on one side of the tank that uses the propulsion force of a propeller-type impeller to create swirls throughout the digester to mix inside the digester	A vertical impeller is attached to a flat board for wide-ranging use, and placing the impeller at an angle can change the flow	Uses the principle of changing the flow from the axial flow within the tank by placing the impeller at an angle
Strengths	● Outstanding mixing efficiency	● Simple structure and easy to	● Easy to maintain the drive part

	● Simple structure with few malfunctions ● Low maintenance costs. ● Can adjust height according to changing water level within the tank	maintain the drive part ● No limitations in the number of rotations	● Simple structure and easy to handle ● Simple production
Weaknesses	● Concerns of some dead space depending on the installation location and angle	● Drive part on land causing noise during operation ● When installing a rectangular tank, requires many units to be installed ● Difficult to manufacture propeller	● Drive part on land causing noise during operation ● When installing a rectangular tank, requires many units to be installed ● If wing speed is adjusted incorrectly, there is a possibility of blind spots of flow

Among the mechanical mixing methods, submersible mixers have outstanding mixing efficiency and simple structure causing few malfunctions, while also costing less for maintenance; even in the case of malfunctions, it is easy to inspect and repair above water, so it is judged to be easy to operate and appropriate for use in Vietnam.

5.3.3 Sludge dehydration facility

Digestion sludge dehydration refers to facilities that reduce water content through dehydration, and it is easy to produce and handle compost & liquid fertilizer through liquid solid separation and is a means of increasing work efficiency.

Methods for dehydrating sludge include mechanical dehydration that uses a machine and natural drying that uses natural energy such as sunlight or wind, etc. Natural drying is suitable for drying digestion sludge and is an economical method in terms of power costs, but there are limitations according to site conditions such as facility area and surrounding environment. Mechanical dehydration facilities cost more in terms of maintenance to dry sludge but requires less space, making it suitable for places where it is difficult to secure a sufficient site area. At this time, the selection of mechanical hydration methods should be decided considering construction costs, maintenance costs, scale of treating facilities, site conditions, final disposition method of sludge, etc.

As this project considers production of compost & liquid fertilizer in the future, mechanical dehydration using centrifugal dehydrators—which are effective for drying sludge—was considered.

Table 5.6 Comparison of dehydration method

Category	Centrifugal dehydrator	Multi-disc dehydrator	Belt press
Overview	liquid solid separation using centrifugal force of the rotating part Secondary compression dehydration by internal screw for solids	Compression dehydration by internal screw and back pressure plate for solids	Operates continuously Compressed through two sheets of follicules to separate effluent and dehydration cake
Features	● Does not require a pump in the middle, thus reducing power costs ● Closed structure, thus reducing noise and deodorizing ● High-speed centrifugation, thus having outstanding dehydration efficiency	● High power used ● Closed structure for easier deodorizing ● Complicated structure making maintenance difficult	● High power used ● Difficult to deodorize ● Complicated composition making maintenance difficult

As this project considers production of compost & liquid fertilizer in the future, mechanical dehydration using centrifugal dehydrators—which are effective for drying sludge—was considered. In addition, the solids and filtrate dehydrated during operation will be used as compost and liquid fertilizer, respectively, so it is necessary to limit the use of chemicals during dehydration. Therefore, as centrifugal dehydrators have excellent dehydrating performance and they can dehydrate without adding chemicals, its performance is judged to be suitable.

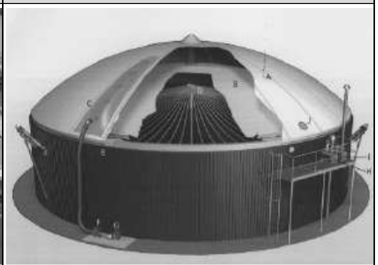
5.4 Pre-treatment and Use of Biogas

5.4.1 Biogas Storage Facility

Biogas storage tanks are facilities for storing biogas generated from the anaerobic digester for a certain period of time and must be designed to have low risk of incidents due to gas leaks, must be economically feasible, and must be a model that is suitable for the installation space.

Biogas storage methods include atmospheric storage method, high-pressure storage method (CNG), and adsorption storage method (ANG), and biogas mostly uses constant-pressure storage methods in production facilities. The atmospheric storage method can be divided into wet tank storage where gas is detained in a roof tank filled with water, double-membrane method that detains gas in the inner membrane of two membranes made of resin, method of placing resin balloon inside a steel tank, and method of placing a rubber cover on top of the fermentation tank.

Table 5.8 Comparision of Biogas strage type

Category	Double membrane method	Resin balloon method inside a steel tank	Rubber roof method on the top of the digester (integrated type)
Schematic diagram			
Features	Representative method for storage of dry constant-pressure gas, uses a membrane with PVC coating on polyethylene fiber Stores biogas inside the inner membrane and blows air into the space of the outer and inner membranes using a pressurizing fan to adjust the biogas pressure, while	As a method for storing dry atmospheric storage method, this is a type that stores a resin balloon such as polyethylene inside a steel tank Air is blown into the internal balloon and around the steel tank using a pressurizing fan to maintain the biogas pressure of the balloon at nearly constant levels	Normally used by biogas plants of individual farms for treating livestock manure Air is blown into the narrow space in the double rubber roof using a pressurizing fan to maintain the shape of the outer rubber roof, while maintaining biogas pressure at almost constant levels Integrated type that costs

	maintaining the shape of the outer membrane as a half-circle The outer membrane maintains a shape with resistance to maintain constant biogas pressure.	Cost competitive compared to the double membrane	less and requires smaller installation space

In this project, the digester integration method that requires less installation space and less costs for installation with the digester upper rubber roof method was considered.

5.4.2 Dehumidification Facility

Dehumidification facilities mitigate vapors in gas. Gas with no water vapor is called dry gas, and the method of making dry gas from gas with moisture is called dehumidification.

Biogas dehumidification technologies are crucial as they determine the equipment load in the desulfurization process or methane separation process. Too much moisture can shorten the life of desulfurizing catalysts, resulting in higher operation costs, and moisture in the methane separation process can also interfere with physical adsorption; thus reducing the methane separation efficiency.

Digestion gas dehumidification facilities can be categorized into cooling, adsorption dehumidification, and absorption dehumidification.

Cooling is a method of maintaining the surface temperature of the cooling coil at lower than the dew point when wet gas in the air is passed through the cooling coil to condensate moisture in the passing gas on the cooling coil surface. Gas that passes through the cooling coil is stripped of moisture as the temperature is lowered.

Adsorption dehumidification is similar to absorption dehumidification as the former adsorbs moisture with the adsorption material, but has the advantage of the adsorption material being regenerated. Silica gel, molecular sieves, and alumina gel are commonly used as adsorption materials. Adsorption materials gradually become saturated as they adsorb moisture, so they must be regularly regenerated to remove the adsorbed moisture. Adsorption dryers normally consist of two pressure containers that simultaneously perform moisture removal of compressed air and regeneration of adsorption material.

Absorption dehumidification uses liquid (LiCl solution) absorption materials to perform gas cooling, dehumidification, cleaning, and disinfection simultaneously, and it is characterized by the fact that very stable dehumidification is carried out due to the nature of the absorption solution.

Table 5.9 Categorization by dehumidification method

Category	Overview	Features
Colling	Cools gas temperature to 1~ 5℃ through the heat exchanger to remove moisture	● Can treat high quantities of moisture ● For biogas, when used alone, suitable for thermal power generation processes Cannot be used as a process alone in processes for enhancing quality
Adsorption Method	Adsorbs moisture using adsorption materials such as active carbon, consists of two reactors to take turns in adsorption/detachment processes	● Can remove moisture at under dew point -60 ● Commonly applied in processes for improving quality of biogas
Absorption Method	Moisture is absorbed and removed by absorption materials such as glycol and when regenerating the absorption material, it is regenerated by applying heat of over 200℃	● High energy consumption Low applied performance
Compressed Cooling Method	Equipment installed on the rear of wet desulfurizing equipment during the process of using methane gas by anaerobic digestion to remove the moisture included in biogas	● As temperature rises, high effects when used together with cooling ● High power usage ● Suitable for small-scale plants

Cooling was considered in this project as it can treat high quantities of moisture, it is highly effective, and it enables the stable operation of facilities; thus making management easy. During the actual design, however, the selection of a system that is cheaper and easier to maintain on-site should be considered.

5.4.3 Desulfurization Facilities

Biogas in vapor saturated state and in addition to methane (CH4) and carbon dioxide (CO2), also includes significant amounts of hydrogen sulfide (H2S). Since hydrogen sulfide and vapor contained in biogas can be combined to form sulfuric acid that can corrode facilities that use biogas in the rear part, siloxane and hydrogen sulfide must be removed in the forward part of the biogas generation facility. Therefore, it is necessary to construct facilities for removing hydrogen sulfide using desulfurizing facilities. Desulfurizing methods can be categorized into dry desulfurization, wet desulfurization, and bio desulfurization according to the desulfurization materials and operation methods.

The dry desulfurization method removes hydrogen sulfide through chemical reaction with iron desulfurizers or physical adsorption; it does not require wastewater treatment unlike wet desulfurization, and operating facilities is also easy. For dry desulfurization methods, appropriate desulfurizing agents according to the type of digestion gas and sulfur type must be used; when used for hydrogen sulfide, iron desulfurization agents such as iron oxide (Fe2O3) must be used.

Wet desulfurization is a method that dissolves hydrogen sulfide using water or alkali chemicals, showing relatively constant removal rates. (About 60% when using water and 85~99% when using alkali chemicals) However, it requires equipment management as constant concentrations of chemicals must be maintained.

Bio desulfurization usually uses the interaction of microorganism activities, and its construction cost is relatively high and operation conditions are a bit difficult. However, maintenance is easy compared to other methods, it can be used semi-permanently, and it uses less chemicals and incur lower auxiliary costs, making it economically more advantageous.

Table 5.10 Comparison of desulfurization methods

Category	Dry desulfurization	Wet desulfurization	Bio desulfurization
Basic principles	Removal by adsorption with desulfurizing agent (iron oxide)	Treatment by absorption scrubbing with scrubbing water	Oxidizing action by sulfur oxidizing bacteria
Method	Produce ferric oxide in the form of pallet for use in the adsorption tower	Use the property of dissolving 1㎥ of water and 2.8㎥ of hydrogen	Install desulfurization tower to oxidize carrier microorganisms or oxidize through bacteria

		sulfide under 20℃ 1 atmospheric pressure (Use alkali chemicals)	proliferation in the fermenting tank or gas holder wall
Elimination rate	Over 95%	About 60% when only using water 85~99% when adding alkali chemicals	76~85%
Strengths	● Low initial investment costs ● Relatively easy to install in small scales	● Low maintenance cost ● Constant removal rate (CO_2 partial resumption and CH_4 concentration)	● Low maintenance cost ● Use semi-permanently
Weaknesses	● Expenses slightly high due to replacement period of desulfurization agents ● Wastes generated when replacing desulfurization agents	● High initial investment costs ● Possibility of generating hydrogen sulfide when treating waste waters	● Low desulfurization effect ● Air must be slightly blown in, thus having risk factors during operation

In this project, dry desulfurization—whose equipment operation is relatively easier and whose operation is very convenient—was considered. Dry desulfurization is convenient for operations as stable desulfurization can be maintained by replacing the desulfurization agents, and it can mitigate risk elements for operations in Vietnam.

5.4.4 Odor Treatment Facilities

Odor treatment facilities must be considered in order to eliminate various odors generated from anaerobic digestion facilities to improve the work environment in the treatment center and to prevent complaints and discomfort of local residents. When selecting the deodorizing facility, an economical method must be selected considering various aspects such as treated air volume, source type, odorous material type and quantity, volatility of generated smell, deodorizing goal, surrounding environmental situation, ease of maintenance, etc.

Table 5.11 Comparison of odor treatment facilities

Category	Chemical scrubbing	Bio filter method (Microorganism filtration)	Active carbon adsorption	Combustion oxidization
Principle	Absorbs odorous materials with chemical solution (acid, alkali) to absorb and neutralize chemically	Microorganisms in the filter absorb and adsorb odorous materials to decompose by oxidation	Adsorb odorous substance with active carbon or silica gel	Burn odorous material to eliminate
Odorous material subject to elimination	Acid rubbing: ammonia and amine Alkali rubbing: hydrogen sulfide Mercaptan, fatty acid, etc.	Effective against organic compound odors Effective for removing everyday odors such as sewage treatment centers	Different by adsorption material Effective against all substances that cause odors through the combination of adsorption materials (adhesive active carbon + neutral active carbon)	Ignition point of most odorous materials are within the temperature range of 200℃ ~ 800℃ and is effective for all materials that cause odors
Characteristics	● Effective against odors with certain substances ● Not appropriate for compound odors ● Can remove mist and dust	● Effective for medium- to high-concentration and compound odors ● Uses microorganisms, so there is no	● Effective against low-concentration odors ● Relatively low initial investment costs ● High	● Excellent deodorizing effect ● Reacts to oxygen to generate carbon dioxide, nitrogen, and sulfurous acid

	simultaneously ● Causes waste water ● Relatively many auxiliary facilities such as chemical dilution retention tanks, etc. ● High initial investment costs and maintenance costs	secondary contamination ● Difficult to culture microorganisms, tight operation not possible ● Relatively high initial facility investment cost	maintenance cost due to regular replacement active carbons ● Due to the characteristics of absorption-type active carbons, weak in environments with high humidity	gas ● Appropriate for small amounts of high concentration due to high operation costs ● In the case of catalytic oxidization method, increased installation cost and operation costs due to the use of catalysts

This project considered the active carbon adsorption method, which has relatively lower initial investment costs. As it can be effective for low concentration odors according to the type of adsorption material, however, change of the chemical scrubbing can be considered by taking into account the intensity and type of odor. This can be determined according to the odors generated locally through this feasibility study.

5.4.5 Generation Facility

Energy that can be produced using biogas can be divided into heat, generation, gas that substitutes city gas, green hydrogen production, etc. In this project, generation facilities will be operated to use power within the area and to sell surplus power, and waste heat generated from the generation facilities will be used for heating the digester and for heating water.

When installing biogas generation facilities, the pressure of the supplied equipment such as ventilators, etc. must be maintained stably so that biogas can be supplied sufficiently to the generator. When composing the generation equipment using digestion gas, the type of generator is determined by the amount of gas generated. At this time, the micro gas turbine usually uses small generators (25~300 kW), and general gas engines commonly use generation capacities of 0.05~1.3MW.

Table 5.12 Features of generation equipment using biogas

Category	Gas engine	Gas turbine	Fuel cell
Output range (kW)	8~5,000	300~100,000	50~10,000
Generation efficiency (%)	28~40	20~35	36~50
Total heat efficiency (%)	80~90	75~80	80~90
Heat rate	App. 1.5	2~3	-
Fuel	Biogas, LPG	Biogas, kerosene (diesel)	Biogas, kerosene
Minimum methane content (%)	40	40	60
Engine price	Low	Medium	Large
Maintenance cost	Low	Large	Large
Noise and vibration	Large	Medium	Low
Strengths	● Clean exhaust gas and easy to recover heat ● Easy maintenance	● Compact equipment and does not require coolant ● Low noise and vibration	● High generation efficiency ● Low noise and vibration

Weaknesses	● High noise and vibration ● High equipment costs	● Low generation efficiency	● High equipment cost

Gas engine methods can be considered in this project for sufficient power generation. The purity of methane generated in this biogas is about 70%, so it generates biogas that allows sufficient generation; considering its high generation efficiency, the facility is judged to have high economic feasibility. Maintenance is easy compared to other methods and maintenance cost is low, so it is assessed to be suitable for local use.

5.5 Production and Utilization of By-products

Livestock manure is fertilizer containing high amounts of nitrogen, etc., and treating it appropriately enables producing high-quality organic fertilizers to substitute chemical fertilizers. By using the anaerobic digestion facilities, it is possible to maximize the methane generation of livestock manure to produce renewable energy (electricity, heat), and the CO_2 generated in this process can be used for greenhouses, etc., while compost and liquid fertilizers are returned to farmland, etc., which will not only reduce greenhouse gases but also increase economic value.

5.5.1 Composting Facility

Composting is generally the process of decomposing and stabilizing organic materials with microorganisms. The final substance must not wield a negative impact on the environment, and it must be possible to use on the soil. The organisms included in organic fertilizers are completely decomposed by microorganisms and transformed into carbon dioxide, water, and minerals.

When biogas facilities are activated, dehydration cakes are generated, and this can be used as resources for making compost. The organic fertilizer produced in biogasification facilities include sufficient organisms so it can improve the agricultural productivity of nearby farms, and financial resources can be obtained for operating the biogas facility by selling the produced compost. This project considered operating composting facilities in order to operate biogas facilities and secure economic feasibility.

5.5.2 Liquid Fertilizer Production Facility

Liquid fertilizers aerate or mix anaerobic digestion liquids to supply oxygen to digestion liquids, and it is the process of decomposing organisms into aerobic microorganisms. Aerobic liquid fertilization facilities biologically decompose and stabilize organisms or odorous substances. The anaerobic digestion liquid generated in the biogas plant can be used immediately as liquid fertilizer under aerobic conditions or after storing in liquid fertilizer storage facilities. In order to utilize the anaerobic liquid fertilizers generated in biogas facilities, this project considered the implementation of aerobic liquid fertilization facilities and also took into account the following important operation plans to produce liquid fertilizers: In order to ensure that there are no problems in using liquid fertilizers in aerobic conditions, plans to set up ventilation facilities to draw in sufficient air during operation (for every $1m^3$ of liquid fertilizer tank valid capacity, 0.03 m^3 air/minute or higher) were established including plans for 24-hour operations. Plans were also made to install highly efficient oxygen organs to raise the oxygen delivery efficiency to reduce the capacity of ventilators and reduce power costs.

5.6 Determination of Design

In this feasibility study, two or more standard technologies applied to the entire process ranging from receiving facilities, pre-treatment facilities, anaerobic digestion, biogas refining and generation, and compost & liquid fertilizer manufacturing processes were compared and reviewed, and the optimal plan for the conditions in Vietnam was deduced.

As a result, it was decided to link with farms, have an anaerobic digester format, secure sludge dehydration facilities, secure generation for using the generated biogas, and have composting and liquid fertilizer production facilities for the operation of the biogas plant. This plan deduced the specializations and strengths of each process technology and took into full consideration Vietnam's climate conditions, operation conditions, market status, etc., so it is judged to have been designed appropriately. During the actual feasibility study, however, it is necessary to take into account the fact that the selections may change depending on the conditions for pursuing the project. Based on the technologies above, the biogas plant capacity designed for this project is as follows:

Table 5.13 Design of Biogas plant capacity

Parameter	Unit	Value	Remarks
Input			
(1) Livestock manure	100	ton/day	
Biogas production through anaerobic digestion process			
(2) Produced biogas	3,000	m^3/day	Methane purity 70 %
(3) Electricity	3.1	Mw/day	Operating 330 day/year
By-product			
(4) Liquid Organic Fertilizer	95	ton/day	
(5) Organic Fertilizer	6,750	kg/day	

***Backup Factor for biogas plant inefficiency**

The amount of biogas produced from the biogas plant can differ according to the characteristics of the received livestock manure materials (organic concentration, etc.) and stability of manure supply. In the event that raw materials with low concentration are received or livestock manure cannot be supplied stably due to infectious diseases, etc., the biogas plant may have to stop operations or it may have reduced efficiency. Considering the fact that such factors can affect not only power generation but also stable byproduct production, management on the supply side is crucial.

5.7 Reduction of greenhouse gas emission

5.7.1 CDM Methodology

The basis for logically selecting quantitative reduction quantities through the project and for verifying the reduction in detail must be provided. Calculation of greenhouse gas reduction for biogas plants using livestock manure in this project can be made by utilizing the CDM methodology approved by the UNFCCC.

(1) Selection of Methodology

Calculate reduced emissions based on AMS-III.D. Methane recovery in animal manure management systems among the UNFCCC CDM methodology.

Table 5.14 CDM Methodology AMS-III.D.

Methodology	Methane Recovery in animal manure management systems
Condition	**(1) Methodology applicable conditions** • The livestock population in the farm is managed under confined conditions. • Manure or the streams obtained after treatment are not discharged into natural water resources (e.g. river or estuaries). • The annual average temperature of baseline site where anaerobic manure treatment facility is located is higher than 5°C. • In the baseline scenario the retention time of manure waste in the anaerobic treatment system is greater than one month, and if anaerobic lagoons are used in the baseline, their depths are at least 1 m. • No methane recovery and destruction by flaring or combustion for gainful use takes place in the baseline scenario. **(2) Project activity conditions** • The residual waste from the animal manure management system shall be handled aerobically. In the case of soil application, proper conditions and procedures (not resulting in methane emissions) must be ensured. • Technical measures shall be used (including a flare for exigencies) to ensure that all biogas produced by the digester is used or flared. • The storage time of the manure after removal from the animal barns, including transportation, should not exceed 45 days before being fed into the anaerobic digester.

Scope	• scope 13 (Waste handling and disposal) • This methodology covers project activities involving the replacement or modification of anaerobic animal manure management systems in livestock farms to achieve methane recovery and destruction by flaring/combustion or gainful use of the recovered methane. It also covers treatment of manure collected from several farms in a centralized plant.
Baseline	• The situation where, in the absence of the project activity, animal manure is left to decay anaerobically within the project boundary and methane is emitted to the atmosphere.

(2) Baseline Calculation Assumption

As the livestock farm is currently in the design stage, there are limitations in that details aside from plant plans cannot be identified in detail for the baseline scenario, and therefore, the livestock manure storage period and future technical measures were assumed for calculation.

- In the baseline scenario, the manure storage period was assumed as more than 1 month.
- It was assumed that technical measures were established for using or flaring all produced gases.
- In the case of project activities, it was assumed that livestock manure is brought into the digestion plant within 45 days including the transport time.

Table 5.15 Baseline assumption

No	CDM AMS-III.D. conditions	Project activity conditions
1	The livestock population in the farm is managed under confined conditions	The annual average heads of livestock at farms will be maintained at 185,900 heads.
2	Manure or the streams obtained after treatment are not discharged into natural water resources(e.g. river or estuaries).	Maure and wastewater remaining after treatment will all be used as liquid fertilizer or compost.
3	The annual average temperature of baseline site where anaerobic manure treatment facility is located is higher than 5°C.	The annual average climate of Thai Nguyen is 24 degrees Celsius, thus satisfying the temperature conditions of the anaerobic treatment plant site.
4	In the baseline scenario the retention time of manure waste in the anaerobic treatment system is greater than one month, and if anaerobic lagoons are used in the baseline, their depths are at least 1	The livestock manure storage period in the baseline scenario will be established in plans of less than 1 month (assumed)

	meter.	
5	No methane recovery and destruction by flaring or combustion for gainful use takes place in the baseline scenario.	As there are no biogasification plants in the baseline scenario, methane collection due to flaring and combustion does not occur
6	The residual waste from the animal manure management system shall be handled aerobically. In the case of soil application, proper conditions and procedures (not resulting in methane emissions) must be ensured.	Remaining wastes of the livestock manure management system will be turned into compost & liquid fertilizer according to the standards set forth by Vietnam's "fertilizer quality standards" and "livestock wastewater management regulations for crops"
7	Technical measures shall be used (including a flare for exigencies) to ensure that all biogas produced by the digester is used or flared.	Technical measures will be established in order to use all produced biogas as heat or power generation or to monitor whether it is flared (assumed)
8	The storage time of the manure after removal from the animal barns, including transportation, should not exceed 45 days before being fed into the anaerobic digester.	Plans will be set up so that the storage period of manure does not exceed 45 days prior to being brought into the digestion plant (assumed)

The project activity also meets all the applicability conditions set forth in the methodology, as described below:

- Livestock head restriction conditions at the farm
- Conditions for treating byproduct wastes generated from biogasification
- Annual climate conditions of the region where the livestock manure treatment plant will be located
- Minimum manure retention period condition of the livestock manure treatment system in the baseline scenario
- Conditions on methane recovery generated in the baseline scenario
- Conditions on compliance with remaining waste handling regulations of the livestock manure management system
- Conditions on monitoring measures to prevent leaks of the produced biogas
- Maximum storage conditions for the manure storage period before being brought into the anaerobic digestion treatment plant

Other project preconditions for applying in the reduction equation are as follows.

- Only swine for livestock type
- 1 livestock manure treatment system

As all activities of the project satisfy the methodology applicable conditions and project activity conditions indicated in the methodology, AMS-III.D version 21.0 was applied for calculating reductions.

5.7.2 Emission reduction

(1) Baseline emissions

It was calculated using the manure quantity that decomposes anaerobically during the baseline period, and the methane annual emissions that occur in the livestock volatile solids based on average annual heads of livestock were calculated. The baseline of this project was set at 13,725 livestock heads at an annual average at the farm, and that the rate of manure managed by each system is 100%.

Baseline emissions (BE_y) = GWP_{CH4} * D_{CH4} * Ufb * MCF_j * $B_{0,LT}$ * $N_{LT,y}$ * $VS_{LT,y}$ * $MS\%_{BL,j}$

Table 5.16 Baseline Emissions

Parameter	Value	Unit	Remarks
GWP_{CH4}	21	t CO_2e/t CH_4	
D_{CH4}	0.00066	t/m^3	
Ufb	0.94		
MCF_j	0.79		
$B_{0,LT}$	0.29	m^3CH_4/kg_dm	
$N_{LT,y}$	13,725	n	
$VS_{LT,y}$	109.5	kg-dm/animal/year	
$MS\%_{Bl,j}$	100	%	
BEy	4,485.8	tCO_2e	

(2) Project activity emissions

Biogas leaks, flaring and combustion, emissions caused by fossil fuels or electricity used while activating the plant, emissions occurring during transportation, and methane emissions occurring due to storing manure during the project operation period was calculated. When pursuing this project, the emissions due to physical leaks of biogas was calculated at 880.2tCO_2e, and the emissions due to fossil fuels and electricity used while activating the plant was calculated at approximately 1,013tCO_2e.

Project activity emissions (PEy) = PEPL,y + PEflare,y + PEpower,y + PEtransp,y + PEstorage,y

Table 5.17 Project activity emissions

Parameter	Value	Unit	Remarks
PEPL,y	880.2	t CO_2e	
PEflare,y	0	t CO_2e	
PEpower,y	1,013	t CO_2e	
PETransp,y	0	t CO_2e	
PEstorage,y	0	t CO_2e	
PEy	1,893.04	t CO_2e	

(3) Emission reduction

Greenhouse gas reductions applied in this methodology was calculated as follows, and it was assumed that there would be no leaks due to pursing the project while calculating reductions.

Table 5.18 Emission reduction

Parameter	Value	Unit	Remarks
$ER_{y,ex\ post}$	2,592.8	t CO_2e	
$BE_{y,ex\ post}$	4,485.8	t CO_2e	
$PE_{y,ex\ post}$	1,893.0	t CO_2e	
MD_y	0	t CO_2e	
$PE_{power,y,ex\ post}$	-	t CO_2e	

The baseline emissions due to methane generated from livestock manure, project emissions due to implementation of the biogas plant, and greenhouse gas emissions from this project were calculated as follows.

Table 5.19 Yearly emission reduction

Period	Baseline emission	Project activity emission	Leakage	Emission reductions
Y	4,485.8	1,893.04	-	1,893.0
Y+1	4,485.8	1,893.04	-	1,893.0
Y+2	4,485.8	1,893.04	-	1,893.0
Y+3	4,485.8	1,893.04	-	1,893.0
Y+4	4,485.8	1,893.04	-	1,893.0
Y+5	4,485.8	1,893.04	-	1,893.0
Y+6	4,485.8	1,893.04	-	1,893.0
Y+7	4,485.8	1,893.04	-	1,893.0
Y+8	4,485.8	1,893.04	-	1,893.0
Y+9	4,485.8	1,893.04	-	1,893.0
Y+10	4,485.8	1,893.04	-	1,893.0
Y+11	4,485.8	1,893.04	-	1,893.0
Y+12	4,485.8	1,893.04	-	1,893.0
Y+13	4,485.8	1,893.04	-	1,893.0
Y+14	4,485.8	1,893.04	-	1,893.0
Total Estimated Emission Reduction	67,287.0	28,395.6	-	28,395.0

5.7 Demand and localizations

In order to assess whether the capacity of the equipment is appropriate based on the technological review of each of the processes above, when considering the supply of livestock manure of the corresponding livestock farms, demand for the produced electricity, etc., assessments were made on whether the capacity of the equipment to be operated is appropriate. Analysis was conducted on the expected demand centering on electric power and compost & liquid fertilizer, as well as whether it can be applied locally.

5.7.1 Forecasting demands

5.7.1.1 Electricity

The direct electric power demand expected from this project is the electric power demand for facilities in farms and electric power demand for operating the biogas plant, and potential electric power demand can be defined as the electric power demand within Thai Nguyen City as the target area of this project. In the case of direct power demand, electric power can be used immediately by connecting the electric power generator and the facility using the power in the area. In the case of potential electric power demand, it can be sold to the outside if grounds for sales in the national power grid are established.

For direct demand, the expected electric power volume for operating the biogas plant is 842,055kw/year, and the power generated through the operation of the plant can be used for self-power generation or reused. In addition, the expected power consumption is 6,829,000kw/year for operating facilities such as pig farms installed in farms, butchery and processing facilities, storage facilities, and worker convenience facilities; when using the power generated by the plant, parts of the electric power to be purchased externally can be substituted.

In the future, if the amount of electric power produced increases with the expansion of the biogas plant and exceeds the amount used within the plant, it can be sold to the local grid in Thai Nguyen City. As of 2021, 1,323,150 people live in Thai Nguyen; according to the average power usage per person in Vietnam, the daily usage is about 2,169kw/person, and the daily power consumption of Thai Nguyen can be computed as approximately 2,869,912,350kw/day. If legal grounds that allow selling the power to the grid used in the city are established, there is a high possibility of power sales and distribution based on the fact that it has a high ratio of renewable energy among the electric power supplied in the city.

Table 5.20 Expected demand of electricity

Demand	Parameter	Value	Unit	Remarks
Direct demand	(1) On-farm demand	6,829,200	kw/year	Except biogas plant
	(2) Biogas Plant demand	842,055	kw/year	
	Total	7,671,255	kw/year	[=(1)+(2)]
Potential demand	(3) Thai Nguyen population	1,323,150	Person	
	(4) Electricity per capita	2,169	kw/person/day	
	Total	2,869,912,350	kw/city/day	[=(3)X(4)]

5.7.1.2 Fertilizer

The compost and liquid fertilizer produced in the biogas plant include nutrients equivalent to those of chemical fertilizers. Organic fertilizer contains a variety of organic acids, peptides, and rich nutrients including nitrogen, phosphorus, and potassium. Not only provide comprehensive nutrition for crops, also with long fertilizer effect, which can Increase and update the soil organic matter and promote microbial breeding, improve soil physical and chemical properties and biological activity.

Organic compost and liquid fertilizer can be produced through the biogas plant using anaerobic digestion, which is considered for this project. Organic compost and liquid fertilizer can be sold outside through commercialization or by distributing to the local region. In the case of liquid fertilizer with high mass, however, as it is necessary to have a cultivation ground large enough to receive the liquid fertilizer in the area near the plant, it is important to secure demand.

Compost produced using biogas can be utilized in paddy, maize, sweet potato, cassava, sugarcane, tobacco, fiber, oil-bearing crops, vegetables, beans, flowers, and peanuts, which are mostly annual crops. A wide range of crops are produced in Thai Nguyen; in particular, considering the fact there is large-scale tea farming, procuring demand is expected to be easy.

The farm considered in this project has plans for cultivating crops annually on 180.7ha, and there is demand for compost produced by the biogas plant for spraying on said farmland. When spraying compost in said farm according to the amount of compost sprayed in Vietnam, it is judged that 53,667.9kg/year can be consumed. Moreover, in the area of Thai Nguyen, the areas where annual crops and perennial crops are produced span approximately 148,727ha

(46.38% of the total area of Thai Nguyen) as of 2021; therefore, it is judged that there will be a high possibility of selling compost & liquid fertilizers to nearby farms.

If compost produced by the biogas plant in this project is used, direct demand is expected to be 53,667.9 kg/year according to the average compost distribution quantity of Vietnam (297kg/ha/year) at said farm, and the expected indirect potential demand is expected to be about 44,171,919kg/year.

Table 5.21 Expected demand of Fertilizer

Demand	Parameter	Value	Unit	Remarks
Direct demand	(1) On-farm cultivation area	108.7	ha	
	(2) Fertilizer dosage per area	297	kg/ha/year	
	Expected fertilizer demand	53,667.9	kg/year	[=(1)X(2)]
Potential demand	(3) Target crop plantation area	148,727	ha	2021 in Thai Nguyen
	(4) Fertilizer dosage per area	297	kg/ha/year	Organic fertilizer applicability in Vietnam
	Expected fertilizer demand	44,171,919	kg/year	[=(1)X(2)]

5.7.2 Local applicability

5.7.2.1 Electricity

Implementing electric power generation technologies in the rural areas of Vietnam can help solve problems through the use of self-generated electricity and by reducing the costs of operating agricultural and livestock businesses. As of 2020, the rate of rural families using electric power in Vietnam is about 99.26%, showing stable supply of power. Power consumption in Vietnam is growing annually, and consumption activities of not only households but also rural area production activities were found to be increasing. For example, if the electric power rate of pig farms in Vietnam is 1,000 heads, it was found to cost about 5,000,000VND/month, or approximately 5,000kw/month. Based on this, it is assessed to be a significant technology for procuring economic feasibility as it can construct an eco-friendly self-power generation system that can respond to the demand for electric power considering the costs incurred for production activities.

However, the current challenge is that the government has not allowed biogas electricity to be connected to the national grid, leading to an inability to consume the electricity generated from biogas. As the importance of treating livestock manure and need for generating biogas increase within Vietnam, however, MARD is reportedly preparing policies that will allow the power generated from biogas to be sold on the grid. Therefore, the groundwork for securing profitability in the future is expected to be provided.

From the perspective of capacity, the farm of the target site has electric power demand of 7,671.6 Mw/year. Since the electric power produced through this project is 1,023 Mw/year, it is expected to meet about 13.3% of the electric power capacity needed by the farm. This is a reduction in use of electric power generated from operating the farm, so it is expected to create profits.

5.7.2.2 Fertilizer

According to Vietnam's Ministry of Agriculture and Rural Development, chemical fertilizers are used heavily in Vietnam to improve agricultural productivity. However, excessive use of chemical fertilizers can cause eutrophication of the soil and increase fertilizer costs; thus lowering the profitability of other agricultural industries. As such, policy goals to use organic compost as a substitute for chemical fertilizers were established in Vietnam, and organic fertilizers produced through the biogas plant can be utilized as a plan for activating this. The organic compost and liquid fertilizer produced by the biogas plant can serve as a supplier of nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sodium, etc. that are needed for the growth of crops, so they can have high value as an alternative to chemical fertilizers. Accordingly, there is a high possibility of utilizing the organic compost and liquid fertilizer produced through this project, and demand is also expected to be met appropriately as there are many crop production sites at nearby farms.

Moreover, the farm as the target site possesses agricultural activity sites spanning 180.7ha, so this corporation is expected to use approximately 53,667.9kg/year. Thus, it is expected to use about 0.02% of compost among the compost produced from the biogas plant annually in terms of biogas plant capacity. Considerations can be made to sell compost not used by farms to nearby farms in Thai Nguyen; hence the need to build cooperative relationships with farms to sell the compost & liquid fertilizers. By operating the biogas plant through agreements with local stakeholders, and if there are sufficient discussions on the social benefits that can be obtained by operating the plant, the cooperation of farmers can be obtained on the use of compost & liquid fertilizers.

6. Economic Feasibility

6.1 Estimation of project cost

6.1.1 Direct Project Cost Estimates

The direct project cost estimates are based on cost estimation provided by a local company and technical experts and include an allowance for contingencies.

Table 6.1 Direct Project Cost

Classification	Direct Project Cost (USD)	Remarks
EPC	3,190,200	
Construction Cost	1,351,740	
Total	4,541,940	

6.1.2 Indirect Project Cost Estimates

Indirect cost estimates are based on cost estimation provided by a local company and technical experts and include an allowance for contingencies.

Table 6.2 Indirect Project Cost

Classification	Indirect Project Cost (USD)	Remarks
Design & construction supervision cost	234,000	
Test operation cost and others	113,100	
Total	347,100	

6.1.3 O&M Cost Estimates

O&M cost estimates are based on cost estimation provided by a local company and technical experts and include an allowance for contingencies.

Table 6.3 O&M Cost Estimates

Classification	O&M Cost (USD)	Remarks
Wages	25,161.8	
Chemical costs	9,964.5	
Maintenance and repair costs	48,890.4	
Testing and analysis costs	7,078.5	
Water costs	7,055.1	
General management cost	7,548.6	
Total	124,013.76	

6.1.4 Total Project Cost Estimates

Total Project Cost are as follows.

Table 6.4 Total Project Cost Estimates

Classification	Project Cost (USD)	Remarks
Direct Project Cost	4,541,940	
Indirect Project Cost	347,100	
Total	4,889,040	

6.2 Estimation of Benefits

6.2.1 Project Assumptions

In This Pre-feasibility study, a social discount rate was assumed to be 8.5%. because Vietnamese company has a roll of project owner, Vietnamese company is able to have loan and in-kind contribution as financing instrument to contribute funds to this project. The Economic feasibility analysis has been made based on this loan only project on the assumption that loans would be available to construct biogas plant for the implementation of the projects. Loans were applied for the entire construction cost and an annual interest rate of 8.5% was applied for even repayment of principal and remaining principal to calculate the interest on the loan. Considering the propriety of the operation of the biogas plant and contract period according to scope of loan, the repayment period and economic calculation period was set at 15 years.

This project has been evaluated based on the following assumptions:

It was assumed that profits from this project occurred through sales of each byproduct. Byproducts from this product are electric power, organic solid compost, and liquid fertilizer. Production of each byproduct was calculated by assuming that the biogas plant with livestock manure treatment capacities of 100 tons/day is operated as planned. In result, plans to produce organic solid compost of 2,463,750 kg/year, liquid fertilizer of 34,675 ton/year, electric power of 1,023 Mw/year annually were established.

In addition, in order to identify that byproducts regularly produce the technically planned quantity and to identify the economic feasibility of the produced byproducts, the unit price for Vietnam was estimated. Electricity was estimated with the FiT predicted price for renewable energy of the Vietnam Electricity Corporation and the price of compost and liquid fertilizer based on the substance of byproducts according to Vietnam's compost market status and price of similar products.

Table 6.5 The Assumptions for estimation of benefits

No	Assumptions	Unit	Value	Remark
Rate				
1	Social discount rate	8.5	%	
Biogas plant Production Capacity				
2	Electricity	3.1	Mw/day	
3	Organic Liquid Fertilizer	95	ton/day	
4	Organic Solid Fertilizer	6,750	kg/day	
A)	Electricity generation capacity			
	Daily production capacity	3.1	Mw/day	
	Monthly production capacity	93	Mw/month	
	Annual production capacity	1,023.0	Mw/year	Operating 330 day/year
B)	Fertilizer production capacity			
	Daily production capacity	6,750	kg/day	
	Monthly production capacity	209,250	kg/month	
	Annual production capacity	2,463,750	kg/year	
C)	Liquid fertilizer production capacity			
	Daily production capacity	95	ton/day	
	Monthly production capacity	2,850	ton/month	
	Annual production capacity	34,675	ton/year	
D)	Emission reduction			
	Annual emission reduction	2,593	tCO_2eq/year	

6.2.2 Annual revenue from selling electricity

The electric power produced through the biogas plant in this project is approximately 1,023Mw/year, and plans were established to sell the electricity to the state-run Vietnam Electricity Corporation (EVN) by connecting with the outside grid as renewable energy.

When selling electric power within Vietnam's electric power market, pursuant to the 2023 renewable energy policies, Feed-in Tariff (FiT) was established for biomass and waste energy prescribed by government agencies that have the authority to decide tariffs on energy projects, as well as tariffs that can be applied on existing renewable energy projects for the EVN's sales price. There is no legal basis to sell electric power produced from biogas plants as of yet, but considerations were made in case that produced from the biogas plant may be sold to national electric power in the future. Therefore, the price was calculated by reflecting the average price of FiT of renewable energy currently being applied, and in result, the FiT electric power price for that produced by the biogas plant was estimated at 8.45/kWh.

Table 6.6 The tariff for renewable energy projects in Vietnam

No	Generation Sources	Technology	Applicable duration (years)	Applicable tariff (US cents)	Applicable regulations
1	Wind power	Onshore wind farms	20	8.5/kWh	Decision 24
		Offshore wind farms	20	9.8/kWh	
2	Solar power (Grid-connected ground generation)	COD occurred before Jun 30, 2019	20	9.35/kWh	Decision 11, Decision 13
		COD occurred after Jun 30, 2019	20	7.09/kWh	
3	Biomass	Co-generation (Combined heat-power)	20	7.03/kWh	Decision 24
		Electricity Production	20	8.47/kWh	
4	Waste to energy	Direct burning	20	10.05/kWh	Decision 31
		Landfill for gas production	20	7.28/kWh	
Average tariff of renewable energy				8.45/kWh	

Thus, in order to calculate the annual profits from selling electric power produced annually from this biogas plant, FiT price was applied to the electric power of the biogas that could be predicted for calculation. Based on the 1,023Mw/year produced annually from the biogas plant, when applying electric power prices of 8.45 cent USD/kWh, the economic benefit obtained through electric power annually is expected to be about 86,444 USD/year.

Table 6.7 Expected annual revenue of Electricity

Parameter	Value	Unit	Remarks
Electricity generation capacity			
(1) Daily generation capacity	3.1	Mw/day	
(2) Monthly generation capacity	96.1	Mw/month	
(3) Annual generation capacity	1,023.0	Mw/year	Operating 330day/year
Expected Tariff for biogas electricity	8.45	Cent USD/kwh	
Total annual revenue	86,444	USD/year	[=(3)X1000X8.45/100]

6.2.3 Annual revenue from selling organic fertilizer

Organic composts produced through this biogas plant are solid compost and liquid fertilizer. When injecting about 100 tons of livestock manure, the amount of organic compost and liqudi fertilizer produced through the biogas plant are approximately 2,463,750 kg/year and 34,675 ton/year, respectively, and when selling the produced organic compost to nearby farms, it was analyzed that profits could be made.

Table 6.8 Expected annual revenue of organic fertilizer

Parameter	Value	Unit	Remarks
A) Production Capacity for Organic solid fertilizer			
(1) Daily generation capacity	6,750	kg/day	
(2) Monthly generation capacity	209,250	kg/month	
(3) Annual generation capacity	2,463,750	kg/year	
B) Production Capacity for Organic liquid fertilizer			
(4) Daily generation capacity	95	ton/day	
(5) Monthly generation capacity	2,945	ton/month	
(6) Annual generation capacity	34,675	ton/year	
C) Estimated market price			
(7) Estimated market price of Organic solid fertilizer	0.03	USD/kg	
(8) Estimated market price of Organic liquid fertilizer	7.18	USD/ton	
D) Annual revenue of organic solid fertilizer	61,594	USD/year	[=(3)X(7)]
E) Annual revenue of organic liquid fertilizer	248,967	USD/year	[=(6)X(8)]
Total annual revenue	310,560	USD/year	[=D+E]

6.2.3.1 Characteristics of organic fertilizer

The value of livestock manure-based fertilizer produced from this biogas plant contains a balance of various nutrients that can supply a range of nutrients to crops, and compost has slow action and liquid fertilizers are nearly equivalent straight fertilizers as chemical fertilizers, and can therefore be used as alternatives to chemical fertilizers. However, it was analyzed that the inclusion ratio of organisms is low compared to chemical fertilizers that are most commonly used in Vietnam. Compound fertilizers that account for most of Vietnam's fertilizer market contain the three major fertilizer elements of nitrogen (N), phosphorous (P), and potassium oxide (K2O), and it is called NPK fertilizer. A 20kg bag of the compound fertilizer NPK that is commonly used contains nitrogen (N) 21% (4.2kg), phosphorous (P) 17% (3.4kg), and potassium oxide (K2O) 17% (3.4kg) for about 55% (11kg). On the other hand, in the case of compost produced through biogas plants, it corresponds to about 2-3% compared to NPK. Therefore, in order to apply compound fertilizers to have the same effect in the same area, it will require about 25 times more of liquid fertilizers.

6.2.3.2 Estimation of real cost of organic fertilizer

In this economic feasibility study, the feasible price for solid compost and liquid fertilizer was deduced based on the price of compost sold at local markets, components of fertilizer, and willingness to pay among Vietnamese fertilizer market consumers to find the price of organic solid compost and liquid fertilizer prices produced through the biogas plant.

As sales of solid compost is active in the Vietnamese fertilizer market, it is important to present affordable prices in terms of price. Therefore, as of 2022, the estimated fertilizer sales price for the Vietnamese market in proportion to the NPK content of organic fertilizers and compound fertilizers was calculated for the lowest price among chemical fertilizers imported and distributed in Vietnam. Compared to chemical fertilizers generally distributed in the Vietnamese market, the organic content of organic fertilizers produced through the biogas plant is approximately 3.6%, and the price of fertilizer was calculated at the price corresponding to about 3.6% of the market sales price. In result, the analyzed compost price for sale in Vietnam was about 0.03 USD/kg.

Table 6.9 Estimated cost of organic fertilizer

Parameter	Value	Unit	Remarks
NPK Content			
(1) NPK fertilizer	55	%	
(2) Organic fertilizer	2	%	
Estimated price of fertilizer			
(3) Average NPK fertilizer price	16,400	VND/kg	Lowest price as of 2022
(4) Estimated Organic fertilizer price	596	VND/kg	[=(2)/(1)X(3)]
	0.03	USD/kg	USD/VND=0.00006
	30	USD/ton	

For liquid fertilizers, the price was computed based on research data on the purchase intent of liquid fertilizer produced using livestock manure within Vietnam. The research results indicate that farmers who consider the use of liquid fertilizers as safe are more likely to pay for liquid organic fertilizers. The average willingness to pay for liquid organic fertilizer of farmers in Mekong delta is about 169,000 VND/ton, which is higher the willingness to pay in Da Nang for liquid organic fertilizer (94,800 VND/ton). Based on the presumption that the liquid fertilizer market will be activated through the establishment of government policies that promote the use of organic fertilizer, as well as inflation, it was estimated that it can be sold at a price of 169,000 VND/ton (7.18 USD/ton).

6.2.4 Tangible benefits

The tangible beneficiaries are economic benefits for the residents of Thai Nguyen and surrounding areas who buy organic fertilizer and renewable energy-based electricity of biogas plant. Organic fertilizer supplied through this project at a lower price than a current price of organic fertilizer, so consumers can purchase fertilizer for enhancing their agricultural productivity at a lower price. Assuming that each household and farmer purchase fertilizer about 297kg/ha, and each hector can be used with maximized with their productivity.

And also, the amount of electricity is set 1,131.5 Mw/year to sale can be used as a Renewable energy. The electricity generated by the biogas plant can be sold on-farm or to the external grid. As the on-farm expected demand of electricity is about 7,671.3Mw/year, it could be suitable for electricity consumption as a renewable energy. And, when expanding the number of biogas plants and selling them outside of farms, the benefits may be granted to citizens of Thai Nguyen. The expected demand of electricity of Thai Nguyen is 2,869,912 Mw/city per day. It calculated with assumption that 1,323,150 individuals purchase electricity for 2.169Mw/person/day. As following the number of expected demands, it will add the indirect beneficiaries of biogas plant.

Therefore, it can be estimated that all Thai Nguyen citizen can be indirect beneficiaries through this project. This business model is expected to help make this project replicable because positive awareness of biogas plant through anaerobic plant will increase in the vicinity of area.

Table 6.10 Economical beneficiaries

Parameter	Value	Unit	Remarks
Estimated consumed electricity on-farm			
(1) Farm for Pigs	6,829.2	Mw/year	
(2) Biogas plant	842.1	Mw/year	
Total	7,671.3	Mw/year	[=(1)+(2)]
Estimated consumed electricity in Thai Nguyen			
(1) Thai Nguyen population	1,323,150	Individuals	
(2) Electricity consumption per capita	2.169	Mw/person/day	
Total	2,869,912	Mw/city/day	[=(1)X(2)]
Estimated Fertilizer demand in Thai Nguyen			
(1) Target Crop plantation area	148,727	Ha	
(2) Fertilizer dosage per ha	297	Kg/ha/year	
Total	2,869,912	Kg/city/day	[=(1)X(2)]

6.2.5 Intangible benefits

This project has 3 types of indirect benefits that are intangible: society, economy, and environment. It is envisaged that this project will give rise to indirect benefits to society, health and environment that are intangible.

In this pre-feasibility study, it is envisaged that intangible benefits from this project would include environmental and social benefits. In terms of environment, The project targets residents in Thai Nguyen with climate change upgrade infrastructure support. It is predicted that through this project, they will be able to be provided clean and safe water from contaminated groundwater due to livestock manure treatment. In addition, the number of direct beneficiaries is expected to increase further, as the population migrating to Thai Nguyen caused by this project’s success is not included in the current population projections.

By introducing biogas plants, indirectly adaptability to climate change is improved in terms of water quality management. And also, it is possible to prevent water pollution by livestock manure in the city.

In social benefit, it is expected that there will be no impact on the water system that supplies drinking water to the city, which will indirectly benefit the entire population of Thai Nguyen city. With an annual average growth rate of 1.3%, the population of Thai Nguyen city is projected to reach 1,323,150 individuals.

In economy, it is an effective livestock manure treatment facility, and economic benefits can be obtained by activating the by-product market due to treatment costs for environmental pollution caused by untreated livestock manure and livestock manure treatment. Revitalization of the local economy can be achieved through economic activities that are shifted to product production corresponding to the market mechanism according to job creation and product production for manpower for the operation of livestock manure treatment facilities.

Table 6.11 Intangible benefits of project

Category	Intangible benefits
Environmental benefits	- Prevention of water and soil pollution
Social benefits	- Reduce social costs by preventing water and soil pollution - Reducing health problems such as infectious diseases caused by pollution
Economy benefits	- job creation for residents

	- Revitalize market mechanisms by production (electricity and organic fertilizer market)

6.3 Economic Feasibility Analysis

All costs and benefits are calculated at constant prices as estimated market price. Benefit generation period assumed to be 15 years after investment completion for about 15 years.

The social discount rate is 8.5% suggested by the state of bank Vietnam, but 8.5% is applied ager 15 years of benefit generation and is conservative calculation under financially stable status.

6.3.1 Result of economic feasibility analysis

The results of economic feasibility analysis are as follows.

Table 6.12 Result of economic feasibility analysis

Analysis	Values
Net Present Cost (USD)	8,207,076
Net Present Benefit (USD)	3,296,813
Net Present Value (NPV) (USD)	-4,910,262
Benefit/Cost ratio (B/C ratio)	0.4
Internal rate of return (IRR) (%)	-18.90%

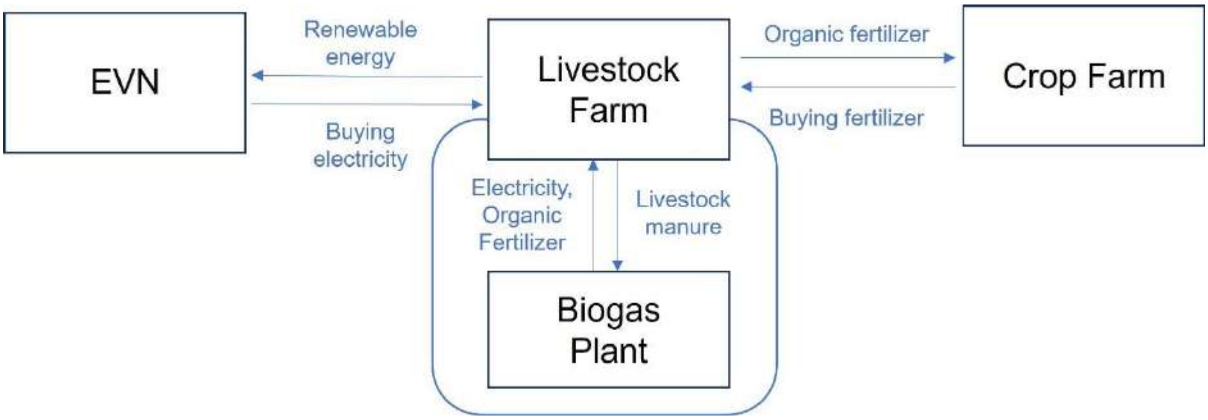
This biogas plant has high EPC price for initial implementation, and it was analyzed that it has a business structure in which it is difficult to collect the investment principal and make profits within 15 years of operation. The economic feasibility of minus structures can be improved through low-interest loans or free subsidies. It is necessary to improve the economic feasibility through funding proposals with more detailed plans through this feasibility study.

7. Draft plan of pilot complex

The draft plan was established from the perspective of matters to be considered and project structurization when implementing the biogas plant pilot complex of this target site.

The relationships and roles of each entity of the biogas plant project are as follows.

Figure 7.1 Biogas plant revenue structure



When producing the biogas plant at a livestock farm, it is possible to use the generated livestock manure in the biogas plant to produce renewable energy-based electric power and organic compost and liquid fertilizers. Based on such products, organic compost can be sold to nearby farms and renewable energy electricity can be sold to the Vietnam Electricity Corporation (EVN) using the power grid.

Companies jointly invested by stakeholders or operated by livestock farms can make investments for independent operations can be an option for the business model of this project. First, upon conducting technical capacity building so that local companies that entered an MOU through this TA Project can conduct operations in this project, the plant operation plans were designed so that it can be operated by local livestock companies.

In addition, considering the fact that improvements can be made when business investments are supported from outside as shown as the results according to the above economic analysis, a process for supporting the support project is needed for investment funding. According to the preliminary feasibility economic analysis, it was analyzed that it is not feasible to implement biogas plants, but it was judged that the project can be pursued if accompanied by support from outside funding or the Vietnamese government for plant implementation. It is anticipated that the costs for this feasibility study and plant implementation can be used for the feasibility study support funds for technology transfers or support funds for developing the project as an international reduction project.

The schedule for implementing this biogas plant established the main feasibility study and plant construction schedule considering the time that the local livestock farm will complete construction. Construction of local livestock farms began in the first half of 2023, and over one year is expected for the construction schedule from completing the livestock farm until its operation. Therefore, more detailed feasibility research will be carried out through the main feasibility study within the schedule expected until operation of the livestock farm to carry out investigations for implementing the biogas plant, and plant construction and pilot operations are scheduled. The expected main feasibility schedule is about one year, and the biogas plant implementation schedule is expected to be about two years.

8. Impact Assessment

The assessment of the project's impact on the environment is carried out according to the project construction and operation stages. The impact assessment is specified for each impact source, each affected object, and at the same time proposes appropriate measures and works to protect the environment, ensuring to meet the requirements of environmental protection. field for each impact was assessed.

To evaluate the project in detail, in the environmental impact assessment report, the assessment is carried out as below:

The project construction phase includes assessment of impacts of land occupation, migration, resettlement, assessment of site clearance, and transportation of raw materials, construction project submissions. The project phase into operation includes activities that generate emissions, wastewater, and solid waste during project operation and incidents and risks that may occur during project activities.

From the evaluations in the two phases of project operation as above, the Investor will propose appropriate measures and works to protect the environment in order to minimize the impacts and impacts on the soil, water, air, solid waste, as well as impacts on social environment.

8.1 Criteria of impact assessment

The project impact can be categorized as impact resulting from activities that occur in the biogas plant implementation process. Identifying impact will contain reviewing whether this project can be executed in accordance with Thai Nguyen's requirement of environment, industry and safety, Vietnamese Environmental Law, Etc.

Impact assessment in this study aimed at making broad-ranged predictions per impact item for the environmental impact that this project can have, and the analysis level was conducted based on the project plans that can be established in the preliminary feasibility study stage.

Evaluation items for those that are expected to impact the environment when constructing the livestock manure biogasification plant and composting equipment according to the execution of this project are as follows.

Table 8.1 Criteria of impact assessment

Impact category	Sub-category	Activity
Environmental impact assessment	Soil	Soil movement due to construction
	Biodiversity	Change of plant and animal life due to construction
Social impact assessment	Air	Dust scattering caused by construction
	Water	Increases suspended sediments in nearby rivers during construction
	Soil	Soil pollution due to activation of construction equipment
	Noise	Noise and vibration impact due to activation of equipment during construction

8.2 Project activity

The project activity of this project can be defined as the biogas plant construction process, and it can be described with household migration, local people’s livelihood, ground clearance, transporting construction materials, operation equipment and machines, etc.

Table 8.2 biogas plant construction activity and impact

Activity	Impact
Migration, resettlement	- In the project area, there are no households living, so the process of migration and resettlement is not too complicated because it does not affect the residence and daily life of the people.
The issue of people's livelihood, local employment, and economic development	- At present, the project area is a part of forest land that is rarely cultivated by households due to low economic efficiency. Therefore, the project's operation will not affect people's livelihood much.
Ground clearance activities	- After the implementation of the compensation agreement, the site clearance activities are mainly carried out in the process of collecting the amount of vegetation cover and plants in the area where the construction of houses and livestock will be carried out. - In this process, dust, noise, exhaust gases from levelling machinery are generated. - Issues of security and order arise due to the concentration of a large number of constructions workers.

	- Generation of domestic solid waste, construction solid waste and hazardous solid waste. - Generation of domestic wastewater, surface runoff due to loss of vegetation cover, surface runoff when it rains will be larger than normal.
The process of transporting construction materials	- Dust generation from transportation, loading and unloading of materials and construction process
Operation of equipment and machines	- Generation of exhaust gas and noise from the operation of construction machinery and means of transport.
Sources not related to waste	- Impact sources not related to waste such as noise, vibration, landslides, incidents, and risks occurring during basic construction

8.3 impact assessment

8.3.1 Soil

To facilitate the construction of the biogas plant, land reclamation activities are essential. However, this process engages pollution through several mechanisms, including vegetation removal, waste-rock manipulation during land reclamation, and the application of non-degradable natural pollutants through spraying. Notably, the organic matter within the waste-rock exacerbates soil compaction, erosion, and degradation caused by rainwater runoff. Furthermore, synthetic organic materials introduce long-term soil contamination due to their persistent, non-biodegradable characteristics.

And also, the primary environmental pollutants in this project are solid waste and scattered construction materials. Additionally, the soil environment is also impacted by pollutants present in the air and wastewater. After rainfall, airborne pollutants and contaminants from wastewater infiltrate the soil, leading to soil degradation and transformation.

To prevent soil pollution at the construction site, a comprehensive waste management approach will be implemented. All generated waste, including waste grease, paint residue, asphalt, and rags, will be meticulously collected and stored within dedicated containers located in the project area. These containers are specifically designed to prevent spills and ensure 100% containment, mitigating the risk of soil contamination. The accumulated waste will be consolidated and contracted with a specialized unit responsible for both collection and treatment. This unit will also handle any hazardous waste resulting from the previous project. By diligently following these practices, the project aims to maintain a clean and controlled environment, preventing any potential spills or leakage from reaching the soil.

8.3.2 Water

During the construction process of the project's work items, water pollution originates from various sources, including domestic wastewater from construction activities and rainwater overflows across the entire construction site. This typically happens during the rainy season, spanning from June to October each year. Additionally, pollution caused by stormwater runoff is minimal and not a significant concern. The main sources of water pollution during the construction phase are rainwater overflow and domestic wastewater, characterized by suspended solids and various organic compounds such as BOD, COD, nitrogen compounds, phosphorus, and Coliform bacteria.

Rainwater runoff is the main source of impacts on the quality of the surrounding surface water environment due to the presence of many suspended sediments, soil, sand, garbage, grease, etc. on the surface and pollutants in the environment. During the construction, the influence of stormwater runoff is quite large because the amount of waste and dust discharged into the environment is high, making the overflowing rainwater more polluted. The toxicity level is not high because the pollutant composition is mainly inorganic. However, if rainwater overflow is not well controlled, it will have a negative impact on the surface water of the project area, especially affecting the water quality and the irrigation system in the project area. The duration and extent of the impact depends on many factors, including seasonal factor. In the rainy season, the concentration of wastewater will be diluted but the pollutants in the wastewater will be carried away by the rainwater. In this season, the rainfall can be 3-4 times higher than in the dry season, so the amount of rainwater runoff also increases 3-4 times.

The surface water environment in the project area, particularly the drainage system, is the primary object directly impacted. If not treated before being discharged into the environment, it will be a source of water and soil pollution.

In order to mitigate water pollution at the construction site, the following measures will be implemented. After leveling the areas, the ground will undergo compaction using a roller, in compliance with construction regulations. This process aims to minimize the transport of soil and rocks during rainwater overflow, effectively reducing pollution of nearby surface water bodies. Additionally, drainage ditches will be excavated around the leveled areas, capitalizing on the natural topography to guide rainwater overflow through a trench system. This design will help direct the water to temporary settling pits located near the inter-commune roads. Once in the settling pits, sedimentation will occur, allowing particles to settle at the bottom. The clarified water will then be directed to a biological pond, promoting further purification and minimizing the potential for water pollution.

8.3.3 Air

The source of waste during the construction process, the sources of air pollution usually occur during the construction shipping issues. The source of air pollution caused by loading and unloading activity, leveling the ground, transporting construction materials, the process burning fuel of machines operating can make a dust, noise, and toxic gas (SO_x, CO, NO_x, etc.)

Dust generated from stages such as transportation of construction materials, machinery and equipment, leveling ground, construction of other ancillary works. During this period, dust is generated by loading and unloading activities, leveling, and leveling to create ground for the construction of auxiliary works in service of mining. Based on the emission coefficient of the amount of dust generated in the stages according to WHO documents, for every 1 ton of soil and rock excavated on site, out 0.17 kg of dust. Dust generated during the construction process can easily diffuse, causing air pollution in nearby areas.

To minimize air pollution, it is necessary to prevent the generation and spread of dust during the construction process. To reduce dust, vehicles involved in material transportation during construction and production must strictly adhere to general traffic regulations. They should be equipped with canvas covers to securely enclose the crates and prevent the dropping of soil, rocks, and materials, thus minimizing the emission of dust into the environment. And also, dust dispersion will be addressed by watering the surface of the project area during the leveling phase to create a moist ground. The transportation routes within the project area will also be regularly moistened using a sprinkler system, with water being sprayed four times a day. While this approach may not eliminate dust particles, it effectively minimizes their dispersion, contributing to the reduction of air pollution in the vicinity.

8.3.4 Bio-diversity/Ecosystem

Near to the project area lies a network of in-field ditches and small streams that directly receive wastewater from the project. As a result, the project's impact on the aquatic ecosystem of these inland water bodies is inevitable. During the site preparation for mining, erosion and sedimentation may occur, further exacerbating the situation. The impacts on the aquatic ecosystems primarily stem from water pollution caused by the project's wastewater, which includes high levels of suspended matter hindering light penetration and an abundance of organic matter reducing oxygen solubility in the water. This pollution disrupts the water environment, negatively affecting the survival of various aquatic species and diminishing the self-cleaning capacity of the water. Since most ecosystems are highly sensitive to environmental changes, water pollution can bring about significant alterations in aquatic ecosystems, particularly during the rainy season. Therefore, the investor must implement effective management and treatment measures in the rainy season to ensure that pollutants do not adversely impact the surface water in the area.

The project's most substantial impact on biodiversity is the destruction of vegetation, along with the associated biota such as plant biomass, individual plants, and plant species. The extent of destruction varies, with some areas completely devastated within the project's construction site, while surrounding areas experience adverse effects on growth and development due to waste generated by project activities. Consequently, the project implementation results in the loss of terrestrial vegetation and affects animal species, leading to a degradation of biodiversity. However, it is important to note that the terrestrial ecosystem in the project area, as well as the water ecosystem, is relatively impoverished, and there are no endemic wildlife species. Therefore, the negative impacts of the development process on biological resources in the project area are not significant.

9. General Conclusion and Policy Proposal

9.1 General Conclusion

In summation, this feasibility study report centers on the implementation of an anaerobic digestion biogas plant in conjunction with a newly established pig farm situated in Thai Nguyen Province. The examination underscores Vietnam's burgeoning livestock sector, wherein the agricultural domain assumes a substantial role in the nation's economy. Within Southeast Asia, Vietnam holds particular prominence in pig farming. The considerable methane output stemming from livestock manure within this industry necessitates prudent management due to its detrimental environmental impact when irresponsibly discharged. As Vietnam increasingly recognizes the significance of livestock manure management, the consideration of a biogas plant as a means of proper treatment and resource circularity has gained traction. This project thus undertakes a feasibility study to introduce a biogas pilot complex.

The envisaged biogas plant, designed as a pilot endeavor, boasts the capability to process 100 tons of livestock manure daily. This process yields 3.1MW of electricity, 5 tons of organic compost, and 95 tons of liquid fertilizer. The biogas plant is strategically formulated to maximize biogas production efficacy through the implementation of an anaerobic digestion process. A comprehensive feasibility study has been conducted to facilitate the transfer of relevant technologies. Findings from the technical feasibility assessment emphasize the imperative of tailoring the operational methodology of each facility within the biogas power generation process, factoring in localized resource utilization, climatic conditions, and human expertise. The preliminary technical viability evaluation provides a foundational understanding that necessitates further intricate analysis.

Furthermore, the economic viability evaluation of the project reveals an initial substantial indebtedness due to elevated Engineering, Procurement, and Construction (EPC) costs. The subsequent 15-year economic analysis indicates challenges in offsetting this debt through anticipated profits over the facility's operational span. Consequently, the study underscores the necessity of recalibrating project investment costs through avenues such as government support for livestock manure or external funding.

Regarding the establishment of the pilot biogas plant, the study engages in discussions encompassing technology and requisite policies through a Capacity Building program, with the aim of empowering local enterprises to competently manage the biogas plant, as documented in Deliverable 4.

The impending introduction of a pilot biogas plant in Vietnam heralds potential benefits, including the mitigation of environmental pollution induced by livestock manure and the reduction of greenhouse gas emissions through the utilization of biogas-generated electricity, thereby engendering a positive impact on climate change. This endeavor assumes significance owing to its prospective role in fostering sustainable practices and aligning with broader environmental goals.

9.2 Policy Proposal

9.2.1 Recognize Needs for Project

In order to obtain cooperation from stakeholders for the implementation of the biogas plant, mutual understanding on the justification and suitability of the project are needed. Consent and understanding on the need for climate change response by rural areas are needed, and the need for treating livestock manure wastes must be shared by the government. Therefore, the difficulties of treating wastes by livestock plant within Vietnam for rural areas were analyzed through this TA project, and the need for treating wastes of livestock facilities was discussed with the Vietnamese government and local stakeholders.

The Vietnamese government recognizes the need to prevent environmental pollution resulting from livestock manure as well as the need to reduce greenhouse gases for the sake of global climate change response. Accordingly, regulations on handling livestock manure are being strengthened, and policy support measures are being developed such as carrying out renewable energy electric power FiT for supporting renewable energy businesses. In addition, targets were established for reducing the use of chemical fertilizers, which is a main cause of soil pollution, and increasing use of organic fertilizers to draw up plans for preventing environmental pollution. Items meeting the needs of the government were discussed from the perspective of preventing environmental pollution, reducing methane greenhouse gas emissions, developing clean energy, and promoting the user of organic compost by treating livestock manure through the biogas plant by utilizing livestock manure.

Companies operating large-scale livestock farms are facing difficulties due to increased demands to reduce greenhouse gas emissions and prevent environmental pollution due to the growing global ESG, demands for implementing problem-solving plans for wastes, as well as stronger legal regulations by the government. Discussions were held on not only the roles of waste treatment plants when implementing biogas plants, but also the potential profits such as reduced greenhouse gas emissions during discharge, electric power that can be obtained by operating the plant, and from the perspective of using organic compost & liquid fertilizers.

Based on such needs as above, it is expected that the effects will be even greater by developing a biogas plant business structure tailored to the situation of Vietnam.

9.2.2 Improvement Economic feasibility of Project

It was found that a business model structure that improved economic feasibility is needed to pursue this project. Upon making economic analysis for this project, the investment cost and profit expected from this project is about -4,910,262USD for net present value and the total benefit/cost ratio is 0.40, showing that it is a business structure that is has negative cost-benefit. The EPC cost considered for implementing the biogas plant is about 80% of the total cost, and it was found that EPC cost accounted for a large portion of the total cost.

However, in order to treat large amounts of livestock manure and implement technologies suitable for the local situation, sufficient investments must be made in EPC, and therefore, support for investment activities is needed. Thus, necessary matters for stable improvement of economic feasibility in this TA Project process were discussed with local stakeholders.

Currently, the Vietnamese government has made laws on treating livestock manure, and the biogas plant was presented as an item to respond to this. However, from the perspective that the livestock market of Vietnam is growing in size, additional support policies will be needed based on the fact that large-scale EPC is needed. Therefore, improving the profit structure of the plant can be proposed by supporting EPC investment subsidies and through the tipping fee program for treating manure once operations begin at the time of implementing the project through subsidy policies.

(1) Support for Equipment Subsidies for Implementing Biogas Plants

Early procurement of large-scale funds are needed to implement the biogas plant. This acts as an entry barrier for implementing biogas plants, and it can have a negative impact on the profit structure for the long-term operation of the project. This is whey subsidy support policies considering the appropriateness of operating the respective equipment is needed.

The burden for early capital investment can be mitigated by paying grants for EPC equipment for the implementation of the biogas plant. Of the net cost including the initial EPC costs and operation expenses for 15 years of this project, EPC costs account for about 80%. The interest cost for loans for the EPC cost accounts for about 40% of the net cost when the interest rate is 8.5%. Considering the fact that it is difficult to implement plants due to the high initial costs among the net cost, appropriate grant rates were calculated for implementing biogas plants.

Table 9.1 Project Profitability Assessment per Grant Ratio

No	Grant ratio (%)	NPV(USD)	B/C	IRR(%)	ROI(%)
1	50	-1,374,547	0.71	-8.65	-3.3
2	55	-776,524	0.81	-5.74	8.21
3	60	-667,404	0.83	-4.96	11.59
4	65	-558,285	0.86	-4.17	15.17
5	70	39,739	1	0	31.88

The appropriate grant support ratio for implementing EPC for the biogas plant in this project is about 70%, and the project feasibility can be improved at the time when the B/C ratio turns to 1 within the project period (15 years).

(2) Tipping fees for treating livestock manure

It is difficult to offset the operation costs generated from operating the biogas plant with the produced byproducts. The organic compost & liquid fertilizer produced from the biogas plant and electric power market price are set a bit low. However, it is expected that the market price will increase due to the government's policies for reducing the use of chemical fertilizers and for expanding renewable energy, but it was found that it will be difficult to offset cost and profitability of the project because of the large gap. Therefore, it is possible to improve profitability of biogas plant operation with policies of levying treatment costs for livestock manure on farms based on the concept of manure collection fees or consigned treatment fees.

But in order to operate the tipping fee system, it is necessary for farms to recognize the issues with livestock manure and have the intent to make payments to resolve this. Also, a collection system is needed for collecting manure, and based on the assumption that a stable support system will be put in place for the operation of the biogas plant, it is necessary to develop systemized support policies to improve awareness and jointly solve the problem. For example, support measures such as tipping fees can be developed to allow operation of joint biogas plants by multiple small farms, instead of large-scale corporate farms, and to improve profitability.

In the case of this project, when providing support for operation costs to secure economic feasibility, it is necessary to provide support for manure collection fees, or tipping fees, at approximately 7.5 USD per ton. Through a local stakeholder of this project, the appropriate tipping fee was collected for the manure collection fee that can be applied in Vietnam based on the prices of other countries that can be benchmarked. In the case of other countries that apply tipping fees, companies that handle wastes for treating livestock manure receive about 15.5-31 USD/ton according to the livestock waste of livestock farms in the stage of collecting livestock manure that will be placed in the biogas plant. Accordingly, tipping fees can improve profitability as biogas plant businesses can perceive it as profits from handling wastes, while simultaneously having the advantage of having farms recognize the need for handling livestock wastes and thereby mitigate environmental pollution. As this will operate in a method where farms will have to bear the costs for livestock manure compared to the EPC cost supported a single time for biogas plant businesses, social consensus will be required.

When tipping fee is supported at about 7.5 USD per ton, the burden of the business can be reduced by improving the B/C ratio per grant ratio and by improving IRR. Furthermore, as the ratio of supported grants were temporarily reduced, it was analyzed that the overall burden for policy support will be decreased.

Table 9.2 Project Feasibility Evaluation when Operating the Tipping Fee System

No	Grant ratio (%)	NPV (USD)	B/C	IRR (%)	ROI (%)
1	50	898,737	1.19	4.79	63.38
2	55	1,252,309	1.29	7.26	75.06
3	60	1,605,881	1.41	10.27	88.53
4	65	1,959,452	1.54	14.02	104.25
5	70	2,313,024	1.71	18.91	122.82