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

Site Selection for the Establishment of a Biogas Generation Pilot Complex

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The Climate Technology Centre & Network (CTCN) has provided Technical Assistance through pro-bono support from Ecosian and National Institute of Green Technology (NIGT) to implement the pre-feasibility study for the Organic fertilizer and Anaerobic digestion to produce biofuels technology for Vietnamese agricultural sector.

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1. Background

The United Nations Framework Convention on Climate Change (UNFCCC) was ratified by Vietnam in 1998 and the Kyoto Protocol (KP) in 2002. Ministry of Natural Resources and Environment (MONRE) is the national focal point of the UNFCCC. Furthermore, Vietnam ratified the Paris Agreement on 03 November 2016, where the country committed to take action on climate change for climate adaptation and mitigation.

Subsequently, the country submitted its Intended Nationally Determined Contributions (INDCs) in 2015 and its Nationally Determined Contributions (NDCs) in 2022. Under the measures, Mitigation and Adaptation are the major measures which are closely connected to direct impact from climate action.

Within these measures, Biogas technology has been high on priority as stressed in Vietnam's Technology Needs Assessment (2012), and as stated in Vietnam's updated NDC (2020), 'Collecting and treating millions of tons of organic waste in livestock production to make organic fertilizers', 'Developing biogas to replace coal for cooking in rural areas', and as stated in Vietnam's updated NDC (2022), 'Use of biogas cleaner Raw Materials instead of coal for household cooking in rural areas', 'Development of biogas power', 'Development of using biogas in agriculture sector', 'Measures to reduce methane emissions in sub-sectors of agriculture, especially wet rice farming and management of livestock waste and agricultural by-products' have been put in practice for both mitigation and adaptation purposes.

Vietnam is an agricultural country with about 70% of the population residing in rural areas, and agricultural production accounts for a high proportion of the national economy. In 2022, Vietnam's Ministry of Agricultural and Rural Development (MARD) announced that the agricultural sector recorded a significant growth rate of 3.36%. However, in the case of livestock farms in areas with high population density, it was found that environmental pollution is intensifying due to a lack of management as most livestock breeding farms are small-scale. In particular, the amount of waste generated by the livestock industry is about 73 million tons/year, which is intensifying environmental pollution due to solid waste, liquid waste, dust, noise, and dead livestock and poultry generated by farms.

According to the structure of the livestock industry in Vietnam, pork accounts for 72.6% of meat production by species, and the waste generated by pig farms comes to about 24.38 million tons/year, accounting for 33.4% of the total. However, most pig farms have a small or insufficient land area for waste disposal, and it was found that they suffer difficulties in disposing of waste. About 30% of pig farms separate solid and liquid waste, whereas 60% of them treat it as mixed waste. Among them, 35.5% of pig farms were found to be storing livestock waste because they were unable to treat it, and about 40% were found to be disposing of it untreated without permission.

Active management is required in that the unauthorized discharge of untreated livestock manure can harm the health of local residents by causing water and soil pollution. Livestock waste contains residues of copper (Cu) and zinc (Zn), which are typical pollutants causing heavy metal contamination of soil, specifically zinc oxide (ZnO) is a representative element of heavy metals arising out of pig feed. Unauthorized discharge of elements that affect the environment from livestock farms can cause groundwater pollution and lead to odors.

As the Vietnamese government establishes major policies to expand the livestock market, it is expected that the will to solve problems related to environmental and social problems caused by livestock manure will increase. Through the livestock development strategy 2020-2030 vision 2045, the Vietnamese government has established a plan to increase the commercial production rate of the livestock industry to 70% by 2030 by commercializing small farms. In addition, as the technical regulations for major products produced based on livestock manure are disclosed, the need for securing a market using livestock manure is expected to increase.

Through this project, we plan the construction of a biogas plant and the transfer related technologies to help solve the problem of greenhouse gas reduction and livestock manure management in Vietnam.

2. Current Status

2.1 Overview of the Vietnam Livestock Industry

As of 2021, Vietnam's pig farming sector totals about 2.2 million animals, which accounts for about 3.2%[1] of global pig farming. As Vietnam's livestock industry is large, it is expected that the market for livestock manure and related by-products will be comparatively large compared to the global market.

Table 2.1 Livestock Population in Vietnam (thousand heads)

Year	Buffaloes	Cattle	Pigs	Poultry
2017	2,605.1	6,285.3	29,110.7	407.1
2018	2,486.9	6,325.2	29,830.7	435.9
2019	2,388.8	6,278.0	20,208.3	480.3
2020	2,332.8	6,325.5	22,028.1	512.7
2021*	2,264.7	6,365.3	23,533.4	526.3

** Statistical estimate result*

Source: GSO (2021), Statistical Yearbook of Vietnam

Livestock farming in Vietnam is changing from small-scale livestock farming in rural areas to large-scale corporate livestock farming using various advanced technologies such as smart farms. According to the General Statistics Office of Vietnam's 2016 Rural, agriculture, and fishery census, the number of farms raising more than 200 pigs increased from 1,760 in 2011 to 6,120 in 2016. [2] In addition, to meet the demand for meat in Vietnam, the absolute number of livestock being raised and the number of livestock farms are continuously increasing. Livestock production in Vietnam accounts for about 30% of total agricultural production as of 2017, and FAO's Livestock Production Index, which shows changes in livestock production scale compared to the base years (2014-2016), also recorded a continuous upward trend, reaching 113.13 in 2018. [3]

Table 2.2 Number of households raising livestock in Vietnam

Livestock	2011 (Thousands)	2016 (Thousands)	Increase (%)
6 Buffaloes	26.5	43.3	63.4
6 Cattle	92.3	172.4	86.8
20 Pigs	182.7	354.0	93.7
100 Chickens	255.0	360.7	41.5

Source: GSO (2018), Results of the rural, agricultural and fishery census 2016

[1] FAO (2022), Statistical Yearbook World Food and agriculture 2022

[2] GSO (2018), Results of the rural, agricultural and fishery census 2016, p96

[3] FAOSTAT (https://www.fao.org/faostat/en/#data/QI)

Table 2.3 Number of largescale farms in Vietnam

Livestock	2011	2016	Increase (%)
200 Pigs	1,760	6,120	247.7
3,000 chickens	2058	2635	28.0

Source: GSO (2018), Results of the rural, agricultural and fishery census 2016

Pig production is unequally distributed around the country, being concentrated on the Red River Delta in the North and Mekong River Delta in the South, which account for about 40% of the country's population of pigs and about half of its output of pork. Pork production by region is as follows: The Red River Delta is approximately 33%; Northern Midland and Mountainous areas: 13%; North Central and Central Coastal areas: 19%; Central Highlands: 5%; Southeast Region: 12% and Mekong River Delta: 18%.

However, recent increases in the production and supply of livestock products in Vietnam have been very limited. This is because production has decreased due to restrictions on economic activities caused by epidemics among livestock and COVID-19, which have been prevalent in Vietnam since 2019.

In particular, the livestock epidemic lead to the recognition of the problems of the livestock industry structure centered on small farms, the lack of investment in animal feed and fresh distribution industries, which are the part of the overall supply chain, and issues with livestock management due to outdated slaughter technology and insufficient livestock disease systems. For example, the spread of African Swine Fever in Vietnam in early 2019 lead to pork shortages in the consumer market, and led to price increases by the end of the year.

2.2 Overview of Vietnamese Livestock Industry Policy

Analysis shows that the recent growth of the Vietnamese livestock market is due to the Vietnamese government's policies supporting the expansion of the livestock industry. The Ministry of Agricultural and Rural Development (MARD) actively carried out activities such as allocating a portion of the national budget for the Vietnamese livestock industry, supporting the official development and utilization of private investment to actively develop breeds and attract investment in the construction of advanced livestock production models.

- National Law on Animal Husbandry (No.32/2018/QH14)

- The scope of livestock farming includes economic and technical sectors related to activities in the fields of livestock breeding, livestock feed, livestock conditions, livestock product processing and markets.

- More detailed regulations on genetic resource management and environmental protection than the Animal Breeding Act in 2004

- Strengthens the operational requirements of livestock farming facilities by prohibiting the discharge of livestock waste that has not been treated in accordance with the Environmental Protection Act or does not meet the waste collection standards

- Separate human dwellings from pens for livestock, mandating regular sterilization and disinfection of livestock pens and equipment

- Mandates the hygienic quarantine of the collection and treatment of livestock manure, livestock waste, and animal carcasses, in accordance with the relevant laws and regulations regarding veterinary drugs and environmental protection.

- Decision Approving animal husbandry development strategy for 2021-2030 and vision for 2045 (No. 1520/QD-TTg)

- Exploiting potential and strengths of each locality to develop livestock production comprehensively, effectively, sustainably and create jobs, increase income for people, develop the economy in rural areas, rural areas and rural areas while protecting ecological environment, ensuring safety of livestock and poultry diseases and food safety for consumers in the capital.

- The goal of livestock development in the period of 2022-2030, with a vision to 2045, achieving the goals and industrialization, modernization, sustainable development and improving the competitiveness of the livestock industry.

- Within 2022-2030, in 2045, to develop animal husbandry into a modern technical and economic sector and to be industrialized in most of the stages in production of livestock products. Strive to have 80% of livestock products produced in closed and linked chains.

Vietnam recently introduced ‘Guidelines for the Collection and Treatment of Livestock Waste and Agricultural By-Products for Reuse’, a regulatory framework aimed at promoting resource circulation. These guidelines emphasize the proper management of livestock waste and stipulate that it must undergo at least one of the following treatment methods: composting, biological technology, or wastewater treatment.

- Circular Guidelines for the Collection and Treatment of Livestock Waste and Agricultural By-Products for Reuse (No. 12/2021/TT-BNNPTNT)

- Livestock wastewater in household husbandry shall be treated by at least one or a combination of the following methods: Biogas technology, biological ponds, biologicals or other measures used for plants in a manner that minimizes emission of odors and the wastewater does not leak into the surrounding environment.

- Origin livestock wastewater in livestock farms that have been treated in accordance with national technical standards on livestock wastewater may be used for plants or others purposes within the livestock premises. The use of livestock wastewater must minimize emission of odors and prevent the wastewater from leaking into the surrounding environment.

- It is recommended to use biologicals and apply new technological advances to treatment of livestock waste.

Demand for livestock manure treatment facilities, including biogas plants, is expected to increase as policies seek to modernize the livestock industry and simultaneously establish regulations for the treatment and recycling of livestock manure waste treatment.

2.3 Problems with Livestock Farming in Vietnam

The problems of livestock farming in Vietnam are structural problems of the livestock industry and environmental problems caused by its growth.

Structural problems in the livestock industry include livestock management, and the main problems are the structure of the livestock industry being centered on small-scale farms, a lack of investment in animal feed and fresh distribution, which are adjacent industries in the livestock production chain, outdated slaughter technology and insufficient livestock disease systems. In order to solve these problems, the need for management of livestock facilities such as conversion to large-scale pig farming livestock facilities, prevention of the spread of infectious diseases through implementation of livestock management systems, hygiene management and bio-security, and livestock manure treatment facilities is becoming increasingly important.

In addition, as the population of Vietnam increases by 1.03% per year, the demand for livestock products, especially pigs and poultry, has increased rapidly, resulting in serious environmental problems such as wastewater discharge, air pollution and soil pollution.

In pig farming, about 70-90% of nitrogen, minerals (Potassium, magnesium, and others), and heavy metals contained in the feed are reportedly excreted into the environment. These substances are concentrated in farm effluents. In these matters, the discharge of untreated livestock manure can cause water, soil, and air pollution.

Table 2.4 Types of pollution caused by livestock waste

Types	Pollution
Water pollution	Organic matters, pathogens, and chemical residues from discharged manure follow natural water flows and go into local canals and rivers, and some of these penetrate deeply in to ground water.
Soil pollution	As livestock wastes from farms, which are disposed on agricultural land without a suitable nutrient management plan, result in overfertilization of the soil, toxic runoff, and the leaching of contaminants.
Air pollution	The decomposition of livestock wastes generates CO_2, NH_3, CH_4, H_2S, bacteria, endotoxins, volatile organic compounds, odorous substances, and fine particles

Source: World Bank Group (2014), An overview of agricultural pollution in Vietnam: The Livestock Sector

Currently, the number of large farms operated by companies is gradually increasing in accordance with efforts to introduce a large-scale livestock farming industry and systematic livestock management system to Vietnam. To reduce environmental pollution caused by livestock farming, the importance of eco-friendly facilities such as biogas plants that can be installed at large-scale farms is also increasing. However, for reasons such as 1) low electricity prices maintained by the state, 2) the technical complexity and expense of constructing medium- and large-scale biogas digesters, 3) limitations of gas purification technology and the high cost of high-quality generators, the introduction of large-scale biogas plants has not been implemented so far.

It is necessary to review the feasibility of introducing large-scale biogas facilities to Vietnam, and to conduct a pilot project to evaluate the feasibility of expanding the supply of biogas facilities in the future. So, in this project, a pilot project to introduce a biogas plant suitable for large-scale farming in Vietnam was discussed with MARD.

2.4 Overview of Biogas Plants in Vietnam

Biogas plants in Vietnam have developed around small-scale bio-digesters for home use that qualify for government subsidies. The cumulative number of domestic biogas digesters installed by 2021 was 295,345, with 5,961 being newly installed in 2020, and 5,000 in 2021.[4] The most popular size is $6m^3$. The most common technologies[5] are Brick made KT digesters and Composite digesters. Based on the SVN support project, 100% of installations

4 SVN (2021) 'BIO-DIGESTER INSTALLATIONS IN SELECTED COUNTRIES'

5 SVN-Vietnam 'Household biodigesters in Vietnam SNV-Vietnam building a sector for 20 years'

in 2010 were Brick made KT digesters, but by 2020, 82% of all bio-digesters were technically advanced Composite digesters.

The huge distribution of bio digesters improved access to a clean, renewable, and reliable source of energy for more than 790,000 rural households across 55 provinces and cities of Vietnam. The biogas plants installed reduced emissions by 800,000 tons of CO_2 equivalent per year.[6]

Small-scale bio-digester support fund donors include Sterilisatie Vereeniging Nederland (SVN), an aid organization in the Netherlands, Asia Development Bank (ADB), World Bank (WB), and Japan International Cooperation Agency (JICA) and as of 2020, SVN stood the highest with 62.6% of the total.

SVN's Vietnam biogas program, which makes up the biggest share, started in 2006 with the MARD in Vietnam. The goal of this project is to develop a commercially viable biogas sector by providing subsidies and technology to biogas project operators. Key activities includes:

- Training biogas masons on the construction of various designs of brick dome-shaped domestic bio-digesters
- Training government technicians on biogas technology. The trained technicians play an important role in communicating the benefits of biogas technology, supporting enterprises in identifying suitable households and providing them with extension services on the use of bio-slurry
- Advocating the benefits of biogas technology via mass media
- Quality control by government technicians to ensure the construction meets quality standards
- Research and development, including research on the use of bio-slurry, new uses for the biogas other than cooking and lighting

Currently, 8,500 medium and large-scale pig farms appear to have biogas digesters, but most of the demand for biogas is for cooking, and the remaining biogas is not converted into electricity but is released into the air[7] and thus the introduction of plants for large-scale farms is needed.

Vietnam's large-scale biogas plant facilities include a biogas plant operated by Greeco Farm in Bac Lieu Province in Southern Vietnam. The plant utilizes HDPE technology, and the farm's two electric generators are run by biogas for about 10 hours per day with a capacity of

6 https://www.snv.org/project/vietnam-biogas-programme

7 https://www.snv.org/project/scaling-bioenergy-commercial-farms-vietnam

300KWh, providing enough electricity for the 15 members of the farm and many shrimp raising farms in the region.

Until now, the Vietnamese biogas plant market has developed mainly with small-scale digesters that qualify for installation subsidies. As there have been technical problems with large-scale plants and no government subsidies for the electricity produced by them.

If a feed-in tariff for electricity can be agreed and technical problems can be resolved, it is expected that the growth potential of the large-scale biogas plant market will be high.

3. Development of Criteria for Site Selection

3.1 Considerations for introducing biogas plant

It is important to establish criteria to select an appropriate site for introducing a pilot biogas plant in Vietnam. Key evaluation factors for introducing a biogas plant suitable for local characteristics were derived by benchmarking similar cases that promoted the commercialization of biogas.

In the case of Republic of Korea, where the state leads the introduction of a biogas plants, the following evaluation factors for a biogas plant project were established to promote a 'facility for recycling livestock manure'.

Table 3.1 Evaluation categories for the introduction of biogas plants in Korea

Category	Evaluation Factor
Appropriateness of Business Plan	(1) Business Conditions for (Site, Supply of Raw Materials, Secure Land to Spray Fertilizer on etc.) (2) Facility Plan (3) Operational Management (4) Economic Feasibility
Competency of Project Leader	(1) Financial Soundness (2) Ability to Procure Financing (3) Track Record (4) Quality Control
Local Government Support	(1) Basic Plan (2) Ability to Solve Problems (3) Implementation Inspection (4) General Status (Amount of livestock manure generated, Status of treatment facilities) (5) Odor Management Plan and Activities

Source: 'Format for Business Plan for Recycling of Livestock Manure', Ministry of Agriculture, Food and Rural Affairs, Korea

Biogas plants in Korea are classified by appropriateness of business plan, competency of project leader, and local government support, and evaluation indicators for regarding the introduction of plants have been established for each item. By redefining the above evaluation items according to the following criteria, the biogas plant introduction evaluation criteria were established based on the profitability and ease of implementation of the project.

Table 3.2 Redefinition of Evaluation Criteria

Project Profitability	Project Ease
A. Securing Raw Materials	C. Level of Readiness
B. Securing Customers	D. Local Government Cooperation

In order to ensure the project is profitable, it is necessary to determine whether or not it is possible to secure raw materials and customers, and to identify obstacles to the project, the degree of readiness of candidate sites and cooperation of local governments should be evaluated.

3.2 Criteria for site selection

1) Project Profitability

To implement a biogas plant, it is necessary to consider profitability based on ease of securing raw inputs (livestock manure), and ease of securing demand for outputs.

(1) Securing Raw Materials

In order to evaluate the possible profit of biogas plant, it is necessary to assess the conditions of the proposed business site, with a focus on raw materials. In order to evaluate candidate sites, it is necessary to determine whether or not a site for the plant has been is secured, as well as the number of livestock (pigs) being raised nearby that will secure livestock manure that can be utilized, and the estimated amount of wastewater generated per day by the livestock.

The planned farm site and number of livestock will depend on the planned size of the project, and in the case of livestock wastewater, the amount is calculated according to the number of livestock kept and this amount is used to determine whether sufficient raw materials can be secured.

(2) Securing Customers

Since whether or not there is a subsidy for operating a biogas plant and whether there are customers for the electricity and compost and liquid fertilizer generated by the plant are linked to whether or not the business is profitable, it is necessary to determine demand for the product. A qualitative evaluation is conducted on whether a cooperative relationship has been established with nearby farms to sell compost and liquid fertilizer and whether it is considering connecting to the power grid to sell the electricity that the business plan proposes will be generated.

2) Project Ease

To implement a biogas plant requires consideration of the readiness to implement the business plan, and cooperation from the government on proceeding with the project.

(3) Readiness of the Target Area to Implement the Project

The readiness to implement the project is a key matter to be considered when establishing a business model for operating a plant and for defining the interests of livestock and biogas plant, and it is possible to identify obstacles to the success of the project.

It is necessary to evaluate whether detailed plans for the biogas plant project and its future operation have been established. The overall farm development investment type and track record, the expected construction period, construction-related permits required and progress, and planned facility investment amount are identified to evaluate the degree of readiness to implement the project.

(4) Local Government Support

In order to construct plant, cooperation with the local government is absolutely essential, and it is necessary to evaluate whether local government will assist in securing whatever permits are needed during the development as well as cooperating once the project is operating. A qualitative evaluation should be conducted on whether or not to build cooperative relationships with local government for the development of large-scale farms and biogas plants as well as current levels of cooperation.

Table 3.3 Evaluation Criteria and Definition of Subcategories

Evaluation Criteria		**Title**	**Unit**
Profitability	1) Securing Natural Resources	Agricultural Site Area	Ha
		Number of Pigs	Unit
		Amount of Wastewater Generated Daily	Ton
	2) Securing Customers	Intention to Connect to the Electricity Grid	Yes or No
		Intention to Use Compost and Liquid Fertilizer	Yes or No
Ease	3) Project Readiness	Investment Type	Investment Type and Track Record the Investment Company
		Expected Construction Period for Piggery	Construction Start Date, Period and Status
		Planned Level of Investment	Level of Investment
	4) Government Support	Status of Construction Permits	Status of Permitting
		Cooperation with Government	Qualitative

4. Preliminary site selection

4.1 Stakeholder discussion

Since this TA project involves the Vietnamese agricultural sector and livestock manure, Kick-off meeting were held about selecting the target site with the Department of Livestock Production within the Ministry of Agriculture and Rural Development(MARD), the leading ministry in Vietnam's agricultural sector.

[Stakeholder] Department of Livestock Production, Ministry of Agriculture and Rural Development (DLP, MARD)

- Date: 14. December. 2022
- Venue: Meeting room, MARD
- Participants: (DLP, MARD) Duong Tat Thang, Quynh Hoa

Left and Right: Kick-off meeting at the head office of the Department of Livestock Husbandry, Ministry of Agriculture and Rural Development, Hanoi

When it came to securing raw materials, the MARD DLP proposed to prioritize areas based on i) the distance between farms, ii) the number of livestock, and iii) the prevention of contamination from livestock manure was a priority. In particular, it was suggested that the pilot project should be promoted in an area where large-scale livestock farms are being newly built and where prevention of environmental pollution caused by livestock manure needs to be implemented.

In addition, through this discussion, in the process of selecting the target site, it was confirmed that governmental support would be needed in operating the biogas plant. In particular, DLP's Director Mr. Thang mentioned that when introducing a biogas plant, it would be important to establish a cooperative relationship with local stakeholders, and extensive discussions would be needed on the necessity of the biogas plant and the benefits.

Therefore, in order to consider the relevant issues when selecting the target site, the expected benefits from the introduction of biogas at the target site were replaced with economic profits, and revenue from securing customers was applied as an additional criterion for target site selection.

Table 4.1 Expected Profitability with Customers Secured

Evaluation Criteria	Title	Unit
2) Securing Customers	Expected Electricity Produced	Mw/year
	Expected Sales Revenue from Electricity	USD/year
	Expected Compost Produced	Ton/year
	Expected Sales Revenue from Compost	USD/year
	Expected Liquid Fertilizer Produced	Ton/year
	Expected Sales Revenue from Liquid Fertilizer	USD/year
* Assuming processing 100 tons of livestock manure generates 6.4Mw/day of electricity * Assuming revenue of 0.09 USD/kwh for electricity * Assuming wastewater procedure results in output of 5% compost, 95% liquid fertilizer * Assumes revenue of 50 USD/Ton for compost, 6 USD/Ton for liquid fertilizer		

4.2 Candidate Site selection

In order to select candidate sites for target site selection, MARD DLP first selected three candidate sites, and conducted literature reviews and field visits to collect information on the commercialization potential and willingness to introduce biogas plants.

- [Candidate site 1] Thanh Hoa (Thanh Hóa) Province
- [Candidate site 2] Thanh Hoa (Thanh Hóa) Province
- [Candidate site 3] Thai Nguyen (Thái Nguyên) Province

5. Target Site Selection

5.1 Candidate site field visits

Information on the candidate sites was collected, and site surveys were conducted to confirm their suitability for constructing a biogas plant. MARD DLP participated in the field surveys, and with their cooperation we heard from local government officials and livestock farm stakeholders about the local situation, their business plans, and their willingness to introduce a biogas plant.


Left and Right : Interview with Local stakeholders (Thanh Hoa Province, Thai Nguyen Province)

[Candidate Site 1] Thanh Hoa Province Candidate 1


Left: Observation of candidate site 1
Right: Panoramic view of the candidate site 1

The farm planned for candidate site 1 has an area of 300Ha, and is expected to raise about 60,000 pigs, and generate 200 tons of wastewater. Total production at the target site would be about 4,672 Mw/year of electricity, 3,650 tons/year of compost, and 69,350 tons/year of

liquid fertilizer. However, one of the results of the field survey was that it might be difficult to sell the electricity because it will not be connected to the external power grid.

If the electricity generated at the target site is used as on-site electricity, the expected revenue for Candidate 1 from operating the plant is 1,109,080 USD/year per year according to the following calculation.

Table 5.1 Annual Revenue of Candidate 1

Parameter	Value	Unit	Remark
Total Revenue from Sale of By-products	**1,109,080**	**USD/year**	**[=1+2+3]**
1. Annual Revenue from Electricity			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Electricity Produced per Day Assuming Input of 100 tons	6.4	Mw/day	
(3) Annual Electricity Output	4,672	Mw/year	[=(1)/100x(2)x365]
(4) Unit Price of Electricity	0.09	USD/kWh	
Total	420,480	USD/year	[=(3)x(4)*1000]
2. Annual Revenue from Compost			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Compost per 100 tons	5	%	
(3) Annual Production of Compost	3,650	Ton/year	[=(1)x(2)x365]
(4) Unit Price of Compost	50	USD/ton	
Total	182,500	USD/year	[=(3)x(4)]
3. Annual Revenue from Liquid Fertilizer			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Liquid Fertilizer	95	%	
(3) Annual Production of Liquid Fertilizer	69,350	Ton/year	[=(1)x(2)x365]
(4) Unit Price of Liquid Fertilizer	6	USD/ton	
Total	416,100	USD/year	[=(3)x(4)]

In addition, the owner company that owns the farm has a high interest in investing to the livestock farm business, and is reported to be willing to invest in a livestock manure treatment plant for the site as well as a large-scale farm to develop a livestock manure treatment model that can be applied in other regions. In particular, given that the partner company of the pig farm is a large company with stable funds, there is a high possibility of expanding the business.

The farm was planned to be constructed over a period of 68 months from January 2023, and the environmental impact assessment, master plan, and construction permits were all completed confirming that local government was being cooperative.

[Candidate Site 2] Thanh Hoa Province Candidate 2


Left and Right: A panoramic view of the candidate site 2

Although the planned area of the farm at candidate site 2 was not confirmed, it is planned to raise 30,000 pigs there with an additional 17,000 pigs being raised at farms within a 4 km radius. Approximately 100 tons of livestock manure wastewater is generated per day from the total of 47,000 animals at the site.

Total production at the target site would be about 3,373.6 Mw per year of electricity, 2,920 tons per year of compost, and 55,480 tons per year of liquid fertilizer, thus it will be possible to monetize it by selling by-products. There are a number of farms in the vicinity that could consume compost and liquid fertilizer, and since there is a plan to connect the farm to the power grid, there is a strong possibility of selling by-products. Accordingly, the expected revenue for candidate 2 when a plant is added is 815,264 USD per year as shown by the following calculation.

Table 5.2 Annual Revenue of Candidate 2

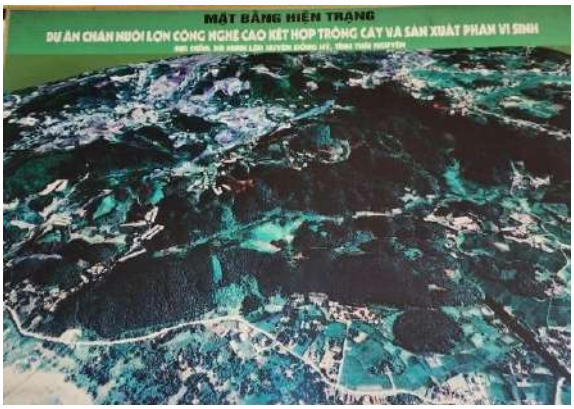
Parameter	Value	Unit	Remark
Total Revenue from Sale of By-products	**815,264**	**USD/year**	**[=1+2+3]**
1. Annual Revenue from Electricity			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Electricity Produced per Day Assuming Input of 100 tons	6.4	Mw/day	
(3) Annual Electricity Output	3,373.6	Mw/year	[=(1)/100x(2)x365]
(4) Unit Price of Electricity	0.09	USD/kWh	
Total	336,384	USD/year	[=(3)x(4)*1000]

2. Annual Revenue from Compost			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Compost per 100 tons	5	%	
(3) Annual Production of Compost	2,920	Ton/year	[=(1)x(2)x365]
(4) Unit Price of Compost	50	USD/ton	
Total	146,000	USD/year	[=(3)x(4)]
3. Annual Revenue from Liquid Fertilizer			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Liquid Fertilizer	95	%	
(3) Annual Production of Liquid Fertilizer	55,480	Ton/year	[=(1)x(2)x365]]
(4) Unit Price of Liquid Fertilizer	6	USD/ton	
Total	332,880	USD/year	[=(3)x(4)]

Stakeholders in this region are aware of the need to treat livestock manure following a wastewater treatment problem at a nearby farm, which raises 100,000 pigs, and have been considering the introduction of a biogas plant for to treat livestock manure right from the beginning of the farm development. However, it was determined that the timing for introducing a biogas plant through this project was not appropriate, as construction on the farm is already in progress.

The farm has completed the environmental impact assessment (EIA) and received construction permits, but has not established a master plan for wastewater treatment as part of its facility operation. So, it would need persuading about introducing a biogas plant as a measure of waste treatment.

[Candidate Site 3] Thai Nguyen Province Candidate 3



Left: A panorama Thai Nguyen Candidate Site plan
Right: Thai Nguyen Candidate Site, head office of stakeholder

The farm planned for candidate site 3 has an area of 300Ha, and is expected to raise about 89,600 pigs, and generate 250 tons of wastewater. [8] Total production at the target site would be about 5,840 Mw per year of electricity, 4,563 tons per year of compost, and 86,688 tons per year of liquid fertilizer. The farm owner promoting this project not only owns a pig farm, but also has nearby farmland for crop production. So they plans to use the compost and liquid fertilizer produced in the biogas plant on their farm as well as sell it to nearby farms, it means that this project evaluated as having a high likelihood of being profitable.

Accordingly, the expected revenue for Candidate 3 when a plant is added is 1,273,850 USD per year as shown by the following calculation.

Table 5.3 Annual Revenue of Candidate 3

Parameter	Value	Unit	Remark
Total Revenue from Sale of By-products	**1,273,850**	**USD/year**	**[=1+2+3]**
1. Annual Revenue from Electricity			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Electricity Produced per Day Assuming Input of 100 tons	6.4	Mw/day	
(3) Annual Electricity Output	5,840	Mw/year	[=(1)/100x(2)x365]
(4) Unit Price of Electricity	0.09	USD/kWh	
Total	525,600	USD/year	[=(3)x(4)*1000]
2. Annual Revenue from Compost			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Compost per 100 tons	5	%	
(3) Annual Production of Compost	4,563	Ton/year	[=(1)x(2)x365]
(4) Unit Price of Compost	50	USD/ton	
Total	228,125	USD/year	[=(3)x(4)]
3. Annual Revenue from Liquid Fertilizer			
(1) Wastewater Generated per Day	200	Ton/day	
(2) Percentage Converted to Liquid Fertilizer	95	%	
(3) Annual Production of Liquid Fertilizer	86,688	Ton/year	[=(1)x(2)x365]
(4) Unit Price of Liquid Fertilizer	6	USD/ton	
Total	520,125	USD/year	[=(3)x(4)]

[8] According to the EIA, the project will generate up to 2000 tons of wastewater a day, but we have amended the amount of livestock manure to 250 tons to match the number of pigs.

The farm owner is a company that has experience running large-scale livestock farms in Dong Nai Province (100 Ha) and Nghe An Province (500 Ha), and is aware of the need for treating livestock manure on large-scale livestock farms.

In addition, it is analyzed that this project is capable of operating stably and securing livestock manure having confirmed investment in the project by a large conglomerate.

Moreover, when planning the project, consideration was given to facility investment for a biogas plant, such as wastewater treatment facilities, biogas facilities, power generation facilities, and liquid fertilizer utilization, and active consideration for economic utilization through investment in this project was also undertaken.

It was noted that the environmental impact assessment and necessary construction permits have been obtained, and a project execution plan has been established with the goal of starting construction in late 2023. In addition, when visiting candidate site, research team receive the intention to cooperate in promoting future projects of the Animal Husbandry, Veterinary and Fisheries sub-department in Thai Nguyen Province's intention to cooperate in future projects. As they promised to sign a letter of intents(LOI) soon, it makes easy to make a cooperation with local government.

Table 5.4 Candidate site Characteristics

Characteristics		Candidate site 1	Candidate site 2	Candidate site 3
		Thanh Hoa	Thanh Hoa	Thai Nguyen
1) Securing Raw Materials	Farming Area	300 Ha	-	300 Ha
	Number of Pigs	60,000	30,000 (Within 4km) 17,000	89,600
	Daily Wastewater	200 tons	160 tons	250 tons
2) Securing Customers Revenue (KRW/Day)	Grid Connection	No	Yes	Yes
	Sell Compost and Liquid Fertilizer	Yes	Yes	Yes
	Revenue from Electricity	Electricity Output: 4,672 Mw/year Electricity Revenue: 420,480 USD/year (If connected to the grid)	Electricity Output: 3,736.6 Mw/year Electricity Revenue: 336,384 USD/year	Electricity Output: 5,840 Mw/year Electricity Revenue: 525,600 USD/year
	Revenue from Compost	Compost Output: 3,650 Ton/year Compost Revenue: 182,500 USD/year	Compost Output: 2,920 Ton/year Compost Revenue: 146,000 USD/year	Compost Output: 4,563 Ton/year Compost Revenue: 228,125USD/year
	Revenue from Liquid Fertilizer	Liquid Fertilizer Output: 69,350 Ton/year Liquid Fertilizer Revenue: 416,100 USD/year	Liquid Fertilizer Output: 55,480 Ton/year Liquid Fertilizer Revenue: 520,125 USD/year	Liquid Fertilizer Output: 86,688 Ton/year Liquid Fertilizer Revenue: 520,125 USD/year
3) Readiness	Form of Investment	- Farm Owner (Owner Company) has high interest in investing this business model - Partner Company of a Thai Livestock Conglomerate - Possible to spread the livestock manure treatment model to other regions	- A problem with wastewater treatment occurred in a 100,000 pig farm in the surrounding area, so an investment is being planned for livestock manure treatment in the form of a joint stock company	- The investment company has experience operating a 100Ha, 25 billion USD business in Dong Nai province and a 500Ha, 60 million USD business in Nghe An province - A Conglomerate related to livestock has confirmed investment, and it is a business site with high interest in bio-security - The planned project period is 50 years
	Piggery Construction Period	Expected to take 69 months from January, 2023	Construction in Progress	Break Ground at end of 2023
	Planned Level of Facility Investment	Pig Farm Wastewater Treatment Facility (Recycled as agricultural water) Biogas Facility	Pig Farm Wastewater Treatment Facility Biogas Facility	Pig Farm Wastewater Treatment Facility Biogas Facility Generate part of electricity itself Use liquid fertilizer on its own farm
4) Local Government Support	Construction Permitting Status	1. Environmental Impact Assessment complete 2. Master Plan of farm complete 3. Construction Permitting complete	1. Environmental Impact Assessment complete 2. Construction Permitting Complete	1. Environmental Impact Assessment complete 2. Construction Permitting Complete
	Local Government Cooperation	-	-	Secured promise from local government to sign an LOI regarding the project

5.2 Evaluation and Selection of Candidate Site

1) Evaluation Method

Based on the comparison table above, the current status of each indicator was quantified and given a score, and the results were recalculated through comparison and quantitative evaluation of each target area. The characteristics of the candidate sites were evaluated from the perspective of profitability and ease of project promotion by weighting them as follows.

(1) Securing raw materials: In order to understand the ease of securing raw materials for biogas plants, relative evaluation was given by assigning a higher score as the number of pigs raised and amount of wastewater generated per day increased.

(2) Expected profitability: Relative evaluation of the expected economic benefits arising when customers are secured based on the amount of electricity, compost, and liquid fertilizer produced by the biogas plant.

(3) Project readiness: Relative evaluation based on the whether a biogas plant plan was included as part of the business plan for each target area, the appropriateness of the project, the construction period and project period.

(4) Local government support: Relative evaluation based on policies for the management of the livestock industry promoted by local government, expansion of fertilizer use to improve agricultural productivity, and current status of cooperation for new farm permits, and whether there are any obstacles to promoting the project.

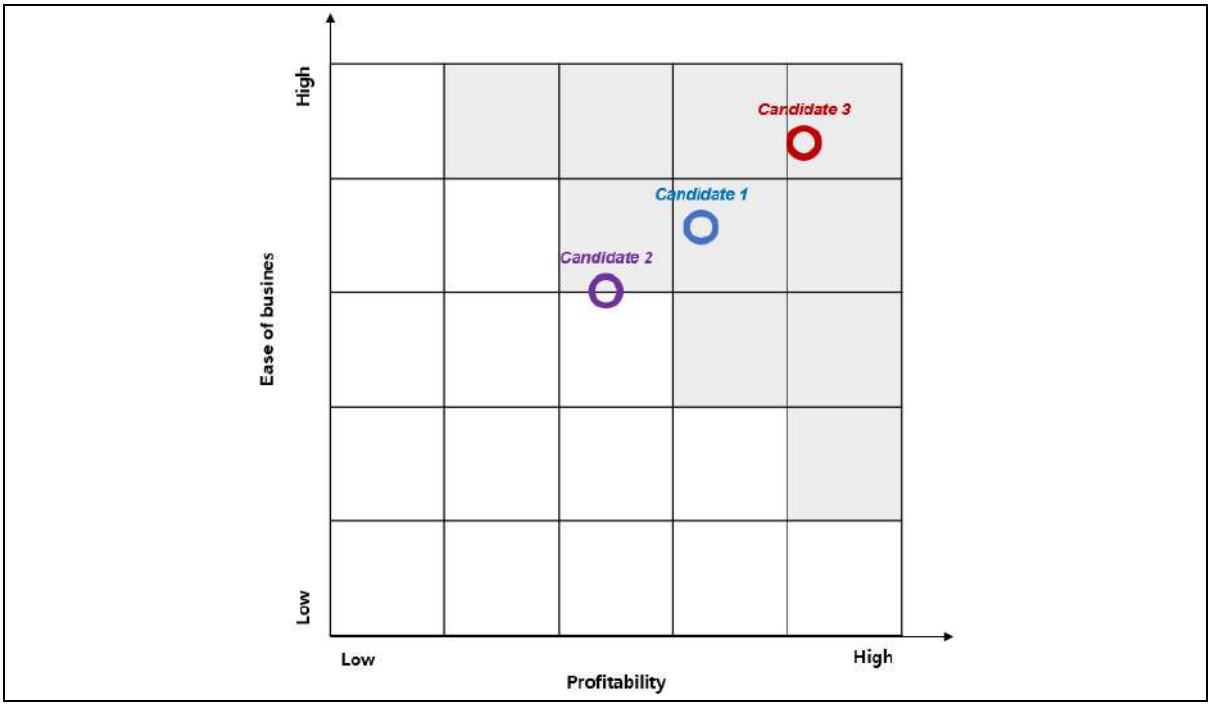
2) Evaluation Results

The results of the evaluation criteria above are set out in table and chart form below.

Table 5.5 Result of Candidate site evaluation

Evaluation			Candidate 1	Candidate 2	Candidate 3
Profitability	(1) Possibility of Securing Raw Materials	Site Size	7	5	7
		Daily Wastewater	6	4	8
	(2) Profitability	Electricity Revenue	7	5	9
		Compost Revenue	6	4	8
		Liquid Fertilizer Revenue	7	5	9
	Sub-total		33	23	41
Ease	(3) Readiness	Appropriateness of Investment Form	7	5	8
		Appropriateness of Development Period	6	4	8
		Level of Investment	7	7	10
	(4) Local Government Support	Construction Permit Status	9	7	7
		Government Cooperation	7	7	10
	Sub-total		36	30	43
Total			69	53	84

Figure 5.1 Result of Candidate site evaluation



**Blue: Candidate 1, Purple: Candidate 2, Red: Candidate 3*

In terms of quantitative scores, Candidate 3 has about 89,600 animals producing raw materials, and the amount of wastewater generated per day is expected to be about 250 tons, generating 5,840 Mw/year of electricity and is thus evaluated as the top candidate in terms of achieving the greatest revenue. On the other hand, when comparing Candidates 1

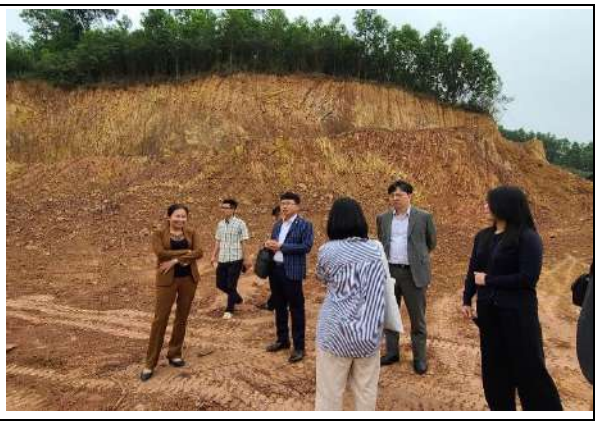
and 2, which are expected to generate a similar level of wastewater, Candidate 1 has a higher expected number of livestock and waste than Candidate 2, but has a relatively low profitability index because external sales of power are impossible due to difficulty in connecting to the power grid.

In addition, from the viewpoint of ease of promoting the project, a high evaluation was given if the farm project investment type, project suitability, and facility plan were highly conducive to the biogas plant preliminary feasibility study and the expected period for the main project. In the case of Candidates 1 and 2, construction of the farm has either started or will start imminently in 2023 and thus with the need to perform a feasibility study there would likely be a discrepancy in the operational start date of the farm and the biogas plant and thus was evaluated with a low score in terms of readiness. On the other hand, in the case of Candidate 3, the local government showed a willingness to provide cooperation, and it was evaluated that the ease of project implementation was higher than other candidate sites given that the period for introducing the plant was more suitable.

Overall, Candidate 3 site was evaluated as being the most suitable target for building the plant because it will be easier to establish a business monetization model through for the biogas plant and cooperation with local stakeholders, including local government, is judged to be easier.

Annex A: Gallery

Left-Right : Field Trip in Thanh Hoa Province



Left-Right : Field Trip in Thai Nguyen Province