

STUDY ON THE BIOGAS POTENTIAL FROM PIG FARMS IN VIETNAM**Vo Thi Le Ha¹, Hoang Thi Van¹, Nguyen Thi Thu Hang^{2*}**¹*School of Chemistry and Life Sciences - Hanoi University of Science and Technology*²*TNU - University of Agriculture and Forestry*

ARTICLE INFO	ABSTRACT
Received: 27/9/2023 Revised: 05/01/2024 Published: 03/02/2024	The swine farming has a significant potential for biogas emissions and is a substantial contributor to greenhouse gas emissions within Vietnam's agricultural sector. This study was conducted to determine the total amount of CH ₄ and CO ₂ (eq) released from mature management activities and emission coefficients of CH ₄ and CO ₂ (eq) at different swine farms in Northern, Central and Southern regions, using tier 1 and tier 2 according to IPCC method. The average amounts of CH ₄ were estimated at 1190 ± 330 tons/year (tier 1) and 252 ± 40 tons/year (tier 2) for the present mature management. The total CH ₄ and CO ₂ (eq) were estimated with different scenarios. Both environmental and economic analyses show that swine farms have good greenhouse gas mitigation potential and can earn significant revenue by selling electricity and biofertilizer in the market. The outcome can provide valuable guidelines for policymakers to invest in bioenergy production from farm animal waste.
KEYWORDS Biogas IPCC Swine farm Mature management CO ₂ (eq)	

**NGHIÊN CỨU XÁC ĐỊNH TIỀM NĂNG KHÍ SINH HỌC
TỪ CÁC TRANG TRẠI CHĂN NUÔI LỢN Ở VIỆT NAM****Võ Thị Lê Hà¹, Hoàng Thị Vân¹, Nguyễn Thị Thu Hằng^{2*}**¹*Trường Hóa và Khoa học Sự sống – ĐH Bách Khoa Hà Nội*²*Trường Đại học Nông Lâm – ĐH Thái Nguyên*

THÔNG TIN BÀI BÁO	TÓM TẮT
Ngày nhận bài: 27/9/2023 Ngày hoàn thiện: 05/01/2024 Ngày đăng: 03/02/2024	Ngành chăn nuôi lợn có tiềm năng lớn trong việc phát thải sinh khí sinh học và đóng góp quan trọng vào việc phát thải khí nhà kính trong ngành nông nghiệp tại Việt Nam. Nghiên cứu này đã được thực hiện để xác định tổng lượng CH ₄ và CO ₂ (eq) được phát thải từ các hoạt động quản lý lợn và hệ số phát thải của CH ₄ và CO ₂ (eq) tại các trang trại lợn khác nhau ở miền Bắc, Trung, và Nam, bằng phương pháp IPCC theo tier 1 và tier 2. Lượng trung bình CH ₄ được ước tính là 1190 ± 330 tấn/năm (tier 1) và 252 ± 40 tấn/năm (tier 2) cho quản lý lợn theo kịch bản hiện tại. Tổng lượng CH ₄ và CO ₂ (eq) đã được ước tính với các kịch bản khác nhau. Phân tích khía cạnh môi trường và kinh tế đều cho thấy rằng các trang trại lợn có tiềm năng tốt trong việc giảm phát thải khí nhà kính và có thể thu được doanh thu đáng kể thông qua việc bán điện và phân bón hữu cơ trên thị trường. Kết quả này có thể cung cấp hướng dẫn quý báu cho các nhà quyết định chính trị đầu tư vào sản xuất năng lượng sinh học từ chất thải của động vật trang trại.
TỪ KHÓA Khí biogas IPCC Trang trại lợn Quản lý phân CO ₂ (eq)	

DOI: <https://doi.org/10.34238/tnu-jst.8844>

* Corresponding author. Email: hangtnvn@tuaf.edu.vn

1. Introduction

The environmental impacts of livestock production are attracting increasing attention, especially the emission of greenhouse gases (GHGs). Currently, swine is the most widely consumed meat product in the world, and its production is expected to grow in the next few decades [1]. Currently, swine farming is the most common type of livestock farming in Vietnam. In 2021, there were approximately 13,748 pig farms nationwide, accountings for 57.8% of the total number of farms in the country [2]. The total amount of livestock waste in 2022 reached 81.8 million tons per year, with pig farming accounting for 44.9%, beef cattle for 26.7%, buffalo for 15.3%, poultry for 8.1%, and dairy cattle for 4.9% of the total livestock waste [3]. However, this waste has not been fully treated, causing environmental pollution, and wasting a significant source of biomass.

Swine farming waste is considered as a source of input material for many bioenergy production cycles, including biogas production, which is one of the three highest bioenergy production capacities in the country (including pig farms, cassava starch processing industry, and organic waste). Biogas from pig farming mainly consists of methane gas, which is known as a combustible gas that can be converted into electricity. Biogas from pig farming can be converted into sustainable fuel, with approximately 0.6 to 0.8 m³ of biogas equivalent to 1 kWh of electricity through anaerobic digestion [5]. There is a high potential for development of biogas systems in swine farms in Cambodia, which can produce the electricity capacity of 127,700 kWh/year [6]. Bioenergy potential in Vietnam could be expected to reach about 1,400 MW by 2035 [7]. However, as of 2022, only about 41.8% of livestock facilities in the country have invested in livestock waste treatment by anaerobic digestion with or without biogas recovery [8]. Several studies have been conducted to assess greenhouse gas emissions at pig farms in Vietnam [9], [10]. However, studies on assessing the bioenergy potential from pig farms are relatively limited. Therefore, the pig farming industry in Vietnam is wasting a significant amount of potential bioenergy from pig farming waste, which needs to explore in this study.

As one of the livestock sectors generating the largest amount of waste in the country including organic solid waste, wastewater, air emissions, the pig farming industry needs to comply with National Technical Regulation on the Effluent of Livestock according to QCVN 62:2021/BTNMT, as well as the guidelines for livestock waste treatment stipulated in Law on animal husbandry in 2018 and Law on Environmental Protection in 2020. Biogas production, a form of bioenergy, through anaerobic digestion at pig farms is the most optimal solution for addressing waste issues as well as effectively utilizing the potential of bioenergy.

In addition, countries around the world are striving towards sustainable development goals and a series of commitments made at the COP26 conference in 2021, aiming at reducing greenhouse gas emissions and addressing global climate change. Vietnam strongly committed to achieving "NetZero" emissions by 2050 and reducing 30% of methane emissions by 2030 [11]. This commitment serves as a driving force for the pig farming industry to effectively manage livestock waste. Therefore, to recognize the urgent and practical issues as mentioned, this study is conducted to estimate and identify the bioenergy potential at pig farms in Vietnam based on different scenarios towards sustainable development goals and the NetZero commitment.

2. Methodology

2.1. Objective of research

The study was carried out to investigate and assess the status of pig farming and waste management in 97 small and medium-sized pig farms across 11 provinces in Vietnam from April 2022 to July 2022. The farms were distributed across the North (57 farms), the Central (27 farms), and the South (12 farms) regions, presented in Fig. 1. Methodology of the

Intergovernmental Panel on Change (IPCC) is used to calculate the amount of biogas generated based on scenarios developed from livestock production and pig waste management.



Fig. 1. Map for distribution of investigated pig farms in Vietnam

2.2. Calculation method

Methodology of the Intergovernmental Panel on Change (IPCC) is used to calculate the amount of biogas generated from anaerobic digestion from enteric fermentation and manure management in tier 1 and tier 2 [12]. However, the swine has relatively lower methane emissions, because much less methane-producing fermentation takes place in their digestive systems. So, methane emission was only calculated from manure management in scope of this study.

CH₄ emission for manure management was estimated as following:

$$E_{(CH_4)} = EF \times N \quad (1)$$

$$EF_{CH_4} = VS_T \times 365 \times [B_o \times 0,67 \text{kg/m}^3 \times \frac{MCF}{100} \times MS] \quad (2)$$

$$VS_t = [GE_T \times (1-DE\%) + (UE \times GE_T)] \times (1 - \frac{ASH\%}{18,45}) \quad (3)$$

where parameters are explained in Table 1.

Table 1. Parameters in the calculation equation

E (CH ₄)	CH ₄ emissions from manure management [Kg CH ₄ /year]	References
EF _{CH₄}	Emission factor for pig, kg CH ₄ / head.year; EF = 7 kg (CH ₄ /head.year)	[12]
N	The number of head of swine	Questionnaires
VS(T)	Daily volatile solid excreted for manure, kg dry matter/ day	Questionnaires
365	Basis for calculating annual VS production, days/year	
Bo	Maximum methane producing capacity for manure produced, m ³ CH ₄ /kg VS (0.29 m ³ CH ₄ /kg VS for Asian countries)	[12]
MCF	Methane conversion factors for each manure management system (%)	[12]
MS	Fraction of manure handled using manure management	Questionnaires
GE	Gross energy intake, MJ/day	Questionnaires
DE%	Digestibility of the feed in percent (75-85%)	[12]
UEGE	Urinary energy is expressed as fraction of GE. (0.02GE)	[12]
ASH	The ash content of manure calculated as a fraction of the dry matter feed intake	[12]

3. Results and discussion

3.1. The waste management status at swine farms

The study was conducted onsite surveys at 96 swine farms in three regions of the North, Central, and South in 2022. Farms with a scale of 500-1000 animals accounted for 23%, farms with a scale of 1000-5000 animals accounted for about 57%, and the remaining was 20% of farms with a scale of over 5000 animals. Among the 96 surveyed swine farms, the scale of swine farms varied among the regions. Farms with a scale of 1000-5000 animals accounted for the majority in the North, while farms with a scale of 500-1000 animals were mainly concentrated in the Central region, and farms with a scale of over 5000 animals were mainly distributed in the South.

Waste management from swine farming activities, focusing on manure, wastewater, and biogas management, was also comprehensively investigated at 96 farms in three regions. The survey results showed that, there were currently two manure management methods including direct discharge of the manure into the anaerobic digester (with or without biogas recovery) and separation of manure before discharging it into the biogas pit (without biogas recovery). Manure management methods varied among the farms in three regions, which may be the reason for the demand on fertilizer usage, awareness and scale of swine farms. Specifically, many farms directly discharged the manure into the anaerobic digester, which accounted for 60% total investigated farms in the North and 89% in the Central region, respectively. In contrast, in the Southern region, farm owners prioritized the separation of manure before discharging into the anaerobic digester, accounting for 67% of total investigated swine farms in this region.

In livestock wastewater context, it is fact that, all wastewater flows were discharged into the anaerobic digesters along with manure in the farms. Then, these flows from almost all farms were discharged into the settling tank (accounting for 75-96% of total farms), while very few farms could treat these flows to meet QCVN 62:2021/BTNMT (Column B). The treated wastewater was used for irrigation and aquaculture purposes, recycled back to the livestock system, and discharged directly into the environment depending on the specific uses. It is important to underline that there are differences in the management of treated wastewater among the farms in the three regions. However, there are similarities in the management of treated wastewater in the northern and central regions. Specifically, 82% of farms in the north regions and 67% of farms in the central regions discharge treated wastewater into the environment, whereas the rest reused these flows for irrigation or fish farming purposes. In contrast, all wastewater after treatment was reused for irrigation, fish farming, and other purposes, which was observed in all farms in the South. This difference was likely attributed to the scarcity of fresh water due to saltwater intrusion and high demand for water in the region.

In biogas management aspect, biogas (CH_4) was generated from farms managed under three methods including flaring, direct release into the environment, and using for power generators. Among the biogas management methods, direct biogas disposal into the environment is the most common, accounting for 68% of farms in the North, 89% of farms in the Central and 50% of farms in the South region. This is also the most concerning environmental pollution matter as it increases the greenhouse effect. Additionally, biogas has the potential to be converted into electricity, which can save energy use and contribute to sustainable development goals. However, despite the great potential for biogas production and use for power generator, the number of farms using biogas for this purpose is relatively limited in certain regions. Specifically, only 23% of farms in the North and 33% of farms in the South use biogas to power generators for household purposes. All farms used electricity and had relatively high demand for it. According to questionnaires, the total electricity consumption at pig farms in the North, Central, and South regions was 850,000 kWh/month, 627,000 kWh/month, and 684,120 kWh/month, respectively. Therefore, if biogas is not used to produce electricity, it will be a great waste and contribute to environmental pollution, which needs to be properly addressed.

3.2. Estimation of CH_4 and CO_2 (eq) emission from swine farm in different tier

Table 2 presents total methane and CO_2 (eq) emissions derived from mature management at the investigated swine farms in three regions using tier 1 and tier 2. The amount of CH_4 and CO_2 (eq) emitted from the manure management process at pig farms vary by region, and these estimated results differs between two calculation methods (tier 1 and tier 2). The Tier 1 approach is one of the simplest and most common approaches for estimating CH_4 and GHG emissions, and it focuses on species populations and emission factors, which are specific to the examined animal species, regardless of age and/or production, mature management. Meanwhile, Tier 2 methodology considers various parameters related to animal husbandry, such as animal feed supply and mature performance, in addition to herd structure and animal numbers, allowing for a more precise approach. Specifically, the number of pigs on farms varies from 142,000 to 224,400, resulting in corresponding CH_4 emissions ranging from 994 to 1571 tons per year, and CO_2 (eq) emissions ranging from 20,874 to 32,987 tons per year if the tier 1 was applied. In case of applying tier 2, CH_4 emissions vary from 201 to 279 tons per year, and CO_2 emissions vary from 4225 to 5869 tons per year. The estimated amounts of CH_4 and GHG in pig farms in tier 2 had tendency to be lower than those in tier 1. CH_4 emission factors varied from 1.9 to 3.7 kg CH_4 /head.year, which was in range of those reported in swine farms in Lam Dong [9] and were significantly lower than those reported in swine farms in Da Nang [10]. These emission factors fall within the default emission factor range that the IPCC has provided for the Asian region (2-7 kg CH_4 /head.year).

Table 2. Results of CH_4 and CO_2 (eq) emissions from mature management using Tier 1 and Tier 2

Region	Animal Category	Pig population	Tier 1		Tier 2	
			CH ₄ (ton/year)	CO _{2eq} (ton/year)	CH ₄ (ton/year)	CO _{2eq} (ton/year)
North						
	Market swine	110,800	664.8	13960.8	210.7	4424.5
	Sow	5,170	31.02	651.42	24.5	515.4
	piglet	51,700	310.2	6514.2	16.6	348.2
Central						
	Market swine	61,700	431.9	9069.9	187.0	3926.1
	Sow	7,300	51.1	1073.1	55.2	1159.6
	piglet	73,000	511	10731	37.3	783.5
South						
	Market swine	71,500	500.5	10510.5	111.0	2330.4
	Sow	13,900	97.3	2043.3	53.9	1131.0
	piglet	139,000	973	20433.0	36.4	764.1

In addition, these results are consistent with the study of Konstantina et al. (2020), who reported that tier 2 emissions estimations were notably lower compared to those of Tier 1 in pig farms in some European countries due to lower emission factors [13]. In addition, it is underlined that the amount of CH_4 and CO_2 (eq) emitted from pig farms in the southern region is highest when applying tier 1, while farms in the central region will emit the highest amount of these gases if using the tier 2 method. A different manure management system and/or feed supply could have contributed to this difference in calculation between two methods.

3.3. Estimation of CH_4 emission from swine farm in different scenarios

The Livestock Law issued in 2018 requires the livestock farms to treat wastewater from livestock production activities for meeting environmental standards (discharge levels A or B level according to QCVN 62-2016 /BTNMT) and to treat waste-gases from livestock production activities to comply with the National Ambient air quality standards. These requirements have been considered as the challenges and motivations for pig farms (1) to equip waste treatment systems in which biogas is captured; (2) separate mature to reduce the load for the wastewater

treatment system and it also generates additional income for the farms from selling solid manure as substrate for organic fertilizer production.

Based on the practical situation of waste management at swine farms combined with the IPCC methodology, the study has developed the following emission scenarios:

- Scenario 1: the mature was managed following the present mature management observed;
- Scenario 2: the mature waste was treated at digesters and biogas was captured and used for power generation
- Scenario 3: mature waste was separated under the dry solid fraction and pack for sale.

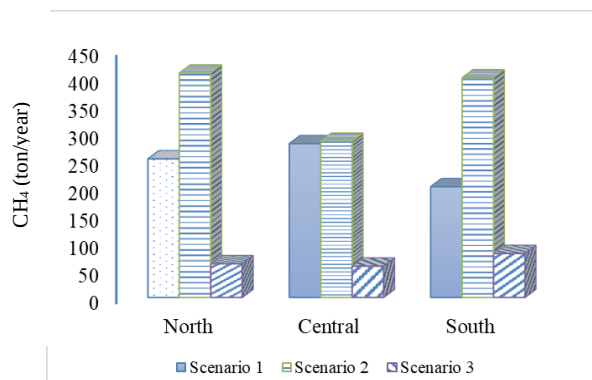


Figure 2. *CH₄ emissions from different*

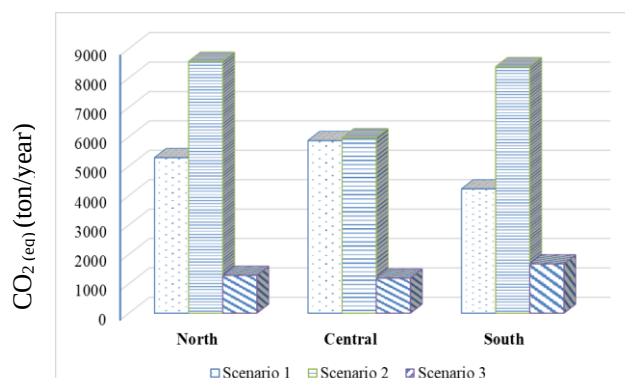


Figure 3. *CO₂ (eq) emissions from different scenarios*

The amounts of CH₄ and CO₂(eq) emissions from swine farms in different regions for three scenarios are described in Figure 2 and 3. These differences are attributed to the variations in the assumptions regarding manure management method. Regardless of swine farms according to region, the largest amounts of CH₄ and CO₂(eq) are found in scenario 1, while the smallest amounts are associated with scenario 3. Scenario 1 represents the current manure management scenario, in which mean amount of CH₄, and CO₂ (eq) emitted from swine farms in three regions are 244 ± 39.7 tons/year, 5128 ± 833 tons/year, respectively. The emission factors for CH₄ are 2.9 ± 1 kg/head*year; 3.8 ± 0.1 kg/head*year, and 0.7 ± 0.1 kg/head*year in scenario 1, scenario 2, scenario 3, respectively, while the emission factors for CO₂(eq) are 30.6 ± 11.3 kg/head*year; 43.5 ± 7 kg/head*year and 7.8 ± 0.5 kg/head*year. These values are lower than the emission factor for greenhouse gases in the second biennial updated report of Vietnam to United Nation framework convention on Climate change (0.85 tCO₂(eq)/head*year) [14] and in swine farms in Lam Dong (0.09 -ton CO₂ (eq)/head*year) [9].

3.4. Cost and Benefit analysis for hypothetical scenarios

The study conducted the onsite surveys at pig farms with a scale of 5000 pigs in the northern regions and analyzed the cost and benefit for scenario 2 and 3 (mentioned above). In this study, the costs were estimated based on the investment cost of power generation equipment (in scenario 2) and equipment for mature separation (in scenario 3). The economic benefits were derived from the revenue generated from selling electricity and carbon credits converted from CH₄ (scenario 2), and the revenue from selling the manure (scenario 3). Meanwhile, the environmental benefits were estimated based on the amount of CO₂ (eq) emissions. The results showed that, for scenario 2, there would be savings of 127,229,168 VND/year and a reduction of 395 tons of CO₂ (eq). On the other hand, for scenario 3, it would result in savings of 365,000,000 VND/year, however, it resulted in 72.4 tons of CO₂ (eq) emissions into the atmosphere. It is assumed that the investment cost for the manure separation equipment is 500,000,000 VND [15]

and the power generation equipment is 4,700,000,000 VND [7], [16], the payback period is estimated to be 3.7 years for scenario 2 and 1.4 years for scenario 3, respectively.

4. Conclusion

The swine farming industry is one of the important subsectors contributing to the GDP of the agricultural sector in the country. Based on the survey results, there is a great potential biogas generation, when as much as above 60% investigated farms didn't capture CH₄ from anaerobic digestors, implying that swine farmers are neglecting a significant energy source and reducing greenhouse gas emissions.

The average estimated amounts of CH₄ and CO_{2 (eq)} gases from the swine farms in the three regions were 1190 ± 330 tons/year and 24996 ± 6922 tons/year, respectively, when tier 1 method was applied. On the other hand, the amounts were estimated to be 252 ± 40 tons/year of CH₄ and 5128 ± 834 tons/year of CO_{2 (eq)} in applying tier 2 method. Managing mature waste through biogas production and usage for electricity generation both can save and reduce greenhouse gas emissions into the environment. Specifically, with scenario (1) managing current manure, there was an emission of 244 tons CH₄/year, equivalent to 5128 tons CO₂/year; with scenario (2) capturing biogas from anaerobic digestors, there was a recovery of 364 tons/year of CH₄, resulting in a reduction of 7637 tons CO_{2(eq)}. With scenario (3) separation and sale of manure, there is an emission of 66 tons/year of CH₄, equivalent to 1385 tons/year of CO_{2 (eq)} emission. Preliminary cost-benefit evaluation for a 5000-pig farm in the northern region shows that scenario 2 achieves a value of co-benefits, balancing economic and environmental benefits. The results of this initial study align with the routine towards net-zero emissions in Vietnam by 2050.

REFERENCES

- [1] F. X. Philippe and B. Nicks, "Review on greenhouse gas emissions from pig houses: Production of carbon dioxide, methane and nitrous oxide by animals and manure," *Agriculture, Ecosystems & Environment*, vol. 199, pp. 10-25, 2015, doi: 10.1016/j.agee.2014.08.015.
- [2] GSO, *General statistics office, statistical yearbook 2021*, Statical publishing house, 2021.
- [3] L. T. Nguyen, "Developing the bioenergy potential in Vietnam contributes to reducing greenhouse gas emissions and fulfilling commitments at COP26," 2022. [Online]. Available: <https://moit.gov.vn/phat-trien-ben-vung/phat-trien-tiem-nang-khi-sinh-hoc-tai-viet-nam-gop-phan-giam-phat-thai-khi-nha-kinh-thuc-hien-cac-cam-ket-tai-cop26.html>. [Accessed July 5, 2023].
- [4] J. R. Banu, Ed., *Anaerobic Digestion*. IntechOpen, 2019, doi: 10.5772/intechopen.73348.
- [5] K. Moses and O. Oludolapo, "Biogas Production and Applications in the Sustainable Energy Transition," *Journal of Energy*, vol. 2022, 2022, Art. no. 8750221, doi: 10.1155/2022/8750221.
- [6] L. Hin, B. Ngo, L. Lor, S. Sorn, D. Theng, C. Mean, and B. Frederisks, "Assessment of Biogas Production Potential from Commercial Pig Farms in Cambodia," *International Journal of Environmental and Rural Development*, vol. 12, no. 1, pp. 172-180, 2021.
- [7] GIZ, "Researching specialized sectors to harness bioenergy for electricity and heat generation (BEM) (BEM), under project: Climate Protection through Sustainable Bioenergy Market Development in Vietnam," 2021.
- [8] SNV Vietnam, "BPP Vietnam Green Recovery Application Business Plan on Bioenergy for Circular Agriculture (BeCA)," under project, Scaling bioenergy on commercial farms in Vietnam, 2022.
- [9] T. T. Nguyen, T. A. Cao, B. D. Nguyen, and Q. H. Le, "Studying to assess of Greenhouse Gas Emissions from Concentrated Pig Farming in Lam Dong Province," *Science and Technology development Journal*, vol. 20, no. M2, pp. 5-13, 2017.
- [10] D. T. Dang, Q. V. Tran, and L. D. Pham, "Study to Determine the Total Greenhouse Gas Emissions from the Swine Waste Management System in Da Nang," *Journal of Science and Technology, Da nang University*, vol. 9, no. 94, pp. 10-13, 2015.
- [11] E. Espagne, T. D. Ngoc, M. H. Nguyen, E. Pannier, M. N. Woilliez, A. Drogous, P. L. Huynh, T. T. Le, T. H. Nguyen, T. T. Nguyen, T. A. Nguyen, F. Thomas, C. Q. Truong, and Q. T. Vo, *Climate change in Viet Nam: impacts and adaptation: a COP26 assessment report of the GEMMES Viet Nam project*, Paris: AFD, 612 p.2021

- [12] H. Dong, J. Mangino, and T. McAllister, "IPCC Guidelines for National Greenhouse Gas Inventories", chapter 10, Institute for Global Environmental Strategies, 2006.
- [13] A. Konstantina, G. P. Laliotis, and I. Bizelis, "Comparative Assessment of Greenhouse Gas Emissions in Pig Farming Using Tier Inventories," *Environments*, vol. 9, no. 59, 1-17, 2022.
- [14] Minister of natural resources and environment, *The second biennial updated report of Vietnam to United Nation framework convention on Climate change*, 2014.
- [15] V. T. Hoang, "Study to Assess the Bioenergy Potential at Pig Farms in Vietnam," Thesis, Hanoi University of Science and Technology, 2022.