ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

TECHNICAL REPORT

Enhancing Capacity for Public Communities to use Renewable Energy (biogas) from Livestock Wastes

Key collaborators and organizations involved:

- Dr. Do Thu Nga - Electric Power University, Vietnam
- Dr. Nguyen Huu Duc - Electric Power University, Vietnam
- Dr. Dinh Duc Truong - National Economics University, Vietnam
- Dr. Wilawan Khanitchaidecha - Naresuan University, Thailand
- Dr. Le Thi Thoa- Deutsche Gesellschaft fü Internationale Zusammenarbeit (GIZ)

Table of Contents

OVERVIEW OF PROJECT WORK AND OUTCOMES

1. Project Information

Project duration:	1 years (2019-2020) and 6 months extension due to Covid-19
Funding Awarded:	39,995$
Key organizations involved:	- Electric Power University, Vietnam - National Economics University, Vietnam - Ministry of Industry and Trade (MOIT), Vietnam - Naresuan University, Thailand

2. Project Summary

Vietnam and other Southeast Asian countries are severely affected by climate change. Development of renewable energy from livestock wastes (production of electricity from biogas) is a solution due to their high proportion of livestock in the economy.

The overall objective of this project is to strengthen the capacity for social communities in producing renewable energy from livestock wastes (PREW) to adapt climate change, toward green growth. To achieve the overall objective, the project is designed into 03 main modules:

Module 1: Evaluating public awareness of global change issues and renewable energy production from livestock wastes with adaptation to climate change (including governmental agencies, private companies and communities), identifying communication needs and capacity building;

Module 2: Organizing training courses of renewable energy from livestock wastes to adapt to climate change for the stakeholders (farmers, agencies, researchers, teachers, students...);

Module 3: Developing a policy brief and disseminating it to policy - making bodies (at sectorial and national levels) to promote the production of renewable energy from livestock wastes, then organizing workshops to inform policy implications to policy makers, academics, universities and other stakeholders.

The project is implemented in one year and based on the collaboration of academic/policy makers in Japan, Thailand and Vietnam, of which, Vietnam is the main site.

Key words: water and energy management, waste management, resilience and disaster risk reduction and management, climate change, greenhouse gas emission reduction

3. Activities Undertaken

Under the three modules of the project, the main activities undertaken include:

MODULE 1: Assess the perceptions of social community of PREW, case study in Nghe An province, Vietnam

- Conduct stakeholder analysis to identify key target groups involved in the implementation of PREW in Vietnam;
- Organize roundtable meetings among target groups for sharing the information, experiences on PREW;

- Conduct questionnaire survey and in-depth interviews to assess the perceptions of local community.

MODULE 2: Organize training courses and disseminate communication materials

- Design communication materials and policy brief based on the findings from Module 1;
- Implement two training courses for local farmers and local managers;
- Organize two seminars for sharing project results in the universities in Vietnam and Thailand.

MODULE 3: Policy brief development and dissemination

- Design policy brief summarizing basic results of the project and disseminating to organizations;
- Organize national workshop to disseminate project findings and recommendations

4. Key facts/figures

Key achievements of the project include:

- Assessment of public perceptions of PREW, a case study in Nghe An province, Vietnam;
- Training for over 80 trainees to raise local awareness of PREW benefits;
- Disseminating project results to over 80 young researchers and students;
- A communication material sharing to 400 livestock farms in Vietnam provinces;
- A document sharing project results for dissemination and recommendation at national workshop;
- A policy brief published and disseminated to 04 state ministries, 10 provinces, 20 environmental and development NGOs and research institutes;
- Peer-reviewed papers on local perceptions of PREW and biogas policy implementation in Vietnam.

5. Potential for further work

At present, there is a lack of policies for biogas renewable energy, incentive loan, credit and trading price. In addition, the awareness of livestock households and stakeholders on renewable energy, GHGs, climate change, especially the understanding of benefit of biogas power generation is limited. Thus, the project mainly focuses on two components: (i) policies and (ii) awareness and capacity. The policy component provides support to remove barriers to the above-mentioned policies as well as provides financial support in the investment cycle. The awareness and capacity components aim to increase awareness of stakeholders on PREW. These components are interconnected and integrated to remove existing barriers and help achieve the mentioned goals. As a result, these activities could then help to extend project impacts to all livestock farms in the country, promoting renewable energy in the agriculture sector.

The potential future activities are as follows:

- Revise and update the communication materials, training documents by consulting with concerned stakeholders in Vietnam;
- Take initiatives in adoption of the project results in the universities in Vietnam and Thailand;
- Expand the scope of training module and initiate trials in other Asian countries with similar livestock farming issues.

6. Publications

1) T.D. Tran and D.T. Dinh (2020) Management of natural resources, environment and CC towards sustainable development in Vietnam from an economic view. *Journal of Economics & Development. No.278(II)*
2) T.T. Le, T.N. Do, D.T. Dinh, N.B. Pham, W. Khanitchaidecha (2020) An Overview of the Key Factors on Changing Local Awareness on Biogas Adoption and Policy Implications - Opportunities and Challenges for Biogas Development in Vietnam. *Proceeding of international conference Climate Change and Sustainability Management in Vietnam and Taiwan ICCSM-2020. Hanoi, 28th October 2020*
3) T.T. Le, T.N. Do, D.T. Dinh (2020) An analysis of potential and barriers for application of biogas in pig waste treatment in Vietnam. *Vietnam Environment Administration Magazine (VEM). Issue (1), March 2021. MONRE, Vietnam.*
4) P. Peungtim, O. Meesungnoen, P. Mahachai, P. Subsoontorn, T.N. Do, W. Khanitchaidecha, A. Nakaruk (2021) Enhancement of nitrate removal under limited organic carbon with hydrogen-driven autotrophic denitrification in low-cost electrode bio-electrochemical reactors*. Journal of Chemical Technology & Biotechnology.* First published on 06 May 2021. https://doi.org/10.1002/jctb.6788.
5) T.T. Le, T.N. Do, D.T. Dinh, N.B. Pham, H.D. Nguyen, A.D. Trinh, W. Khanitchaidecha (2021) Utilisation of biogas as an untapped renewable energy source for reducing greenhouse gas emission and enhancing energy security in Vietnam. *Economics and Policy of Energy and the Environment. Under- reviewed.*

7. Pull quote

“Questions about the efficient use of our biogas technology were answered in this training course. I also have better understanding of the state of policy support on this technology development.” Mr. Nguyen Van Thang, a participant from local training course organized on 21 Jan 2021 in Nghe An province, Vietnam.

“This project results sharing session helps us to understand more about biogas technology, especially in the meaning of reducing greenhouse gas emission in the context of climate change and environmental pollution. Biogas technology is especially interesting for me.” Ms. Ngo Hai Anh, a participant from sharing section organized on 11 Jan 2021 in Electric Power University, Vietnam.

8. Acknowledgements

Project team would like to thank the Nghe An province government, Dien Nguyen district who provided their invaluable inputs and helpful support during the project implementation. The authors express their special appreciation to the representatives of Woman Union in the district for helpful support of conducting data collection, questionaire survey, and interviews, as well as organizing the training courses. We appreciate the Asia Pacific Network (APN) for their generous financial support under the APN CAPaBLE programme for this project (CBA2018-FD05-Do) and for their consideration to extend the project duration due to changes in the project schedule and disruptions due to the COVID-19 pandemic.

TECHNICAL REPORT

1. Introduction

1.1 Background

Energy is a key factor in eradicating poverty and ensuring food security. About 85 per cent of the global population using biomass for cooking lives in rural areas and more than 70 per cent of this population – over 1.7 billion people – are located in South-East Asia and sub-Saharan Africa (IEA, 2006). Indeed, many researchers are of the view that one of the main challenges that humanity will face over the coming decades is how to supply sustainable and reliable energy to low-income rural communities (Keri et al., 2008). Although the impact of smallholding farmers on global anthropogenic greenhouse gas emissions is minimal, the impact of climate-change-related effects on small-scale farmers and livestock keepers is enormous (Jone et al., 2009).

In Asia, Vietnam is one of the countries severely affected by energy shortage and climate change. According to World Bank (2017, 2018a), Vietnam will lose about 10% of GDP by 2050 due to climate change, directly affecting the livelihoods of 23 million people. Vietnam is also at risk of energy shortage due to heavy reliance on hydropower and overexploitation of fossil resources.

Fortunately, Vietnam is a country with climatic and soil conditions being favorable for livestock development, especially pig farming (DLP-MARD, 2016). Development of renewable energy from livestock wastes, e.g., production of electricity from biogas, is a solution for GHGs emission and pollution from untreated livestock wastes, as well as energy shortage. Thus, biogas technology has been researched and applied in Vietnam since the 1960's. To date, about 465,3700 biogas plants have been constructed in the country, and most of them (450,000) were small-scale (MARD, 2016). This number of biogas plants is, however, far below the actual organic waste treatment demand which has increased significantly. About 53 percent of pig farms in the south, 60 percent in the north, and 42 percent in the central regions were reported to use biogas digesters for waste treatment (Vu, 2014). The majority of commercial farms (93,72% percent) had biogas digesters for waste treatment, while only around 72,72% percent of smallholder farms used these techniques. Such numbers of biogas plants demonstrated limiting factors still exist in biogas development in Vietnam.

According to ENV (2014), the greatest difficulty in developing PREW in Vietnam is low awareness of people and society about the role and benefits of PREW. Popular use of tradional energy sources (such as electricity, coal and wood) makes it very difficult to mobilize people to use a new type of energy. Most people do not understand that PREW is a profitable energy solution for households and environmental benefits for society. On the one hand, the investment of PREW is fairly expensive for farms without financial support from the authorities On the other hand, technical support system has not been developed for the design, operation of PREW and providing information about PREW for community. Last but not least, from the side of the authorities, both at central and local levels, awareness of the policies, mechanisms and programs boosting PREW is low and in need of capacity strengthening.

1.2 Objectives of the Project

The overall objective of this project was to strengthen the capacity of social community in producing renewable energy from livestock wastes to adapt climate change (in Vietnam case).

This project was designed to meet the following specific objectives:

1) Study and evaluate public awareness of application and implementation of PREW;

2) Raise awareness of stakeholder of opportunities and application of PREW and strengthen capacity of local managers on its implementation with adaptation to climate change;

3) Implement communication activities on PREW for society

1.3 Capacity Development and Awareness Raising Outcomes

Capacity Development Agenda is enhancing scientific capacity to improve decision-making related to global change and sustainability. In line with APN's 4th Strategic Plan including Research, Capacity Building, Research- Policy and Communication Agenda, this project was designed to address capacity needs and deal with common issues in Vietnam and other Southeast Asian countries through regional cooperation.

Module 1 was designed to study public awareness of and attitude towards PREW (from managing agencies/household/suppliers and community). Hence, it boosted research capacity development of scientists/ practioners and decision makers from APN countries by sharing information, research design, data collection, analysis, impacts for adaptation options in context of climate change and the urge of utilizing resource in a sustainable way. In addition, the project provided information input for designing training courses and policy implication for promoting PREW in Vietnam. Hence it enhanced the science-policy agenda in APN Strategic Plan.

Module 2 mainly focused on capacity building and awareness raising for stakeholders including livestock households, managers, policy makers and universities. Through communication sections and trainings, these stakeholders were provided with needed information and capacity to apply/enhance renewable energy development from livestock wastes.

Module 3 related to further information sharing to promote decision making, training and applying PREW in APN member countries by disseminating the outcomes of research activities to decision makers, social communities, universities in Vietnam and other APN nations.

Thus, Module 2 and Module 3 enhanced capacity development and communication & outreach agendas.

2. Methodology

Regarding to the three main modules of the project, the methodology for each module was developed.

2.1. Module 1: Assess the perceptions of social community on PREW

This was the basis for building training and communication activities to improve the PREW capacity for related stakeholders. Social awareness assessment provided inputs to support policy - making process for promoting PREW at macro level. The evaluation of social awareness about PREW was done through a comprehensive study including the following tasks:

Desk study and Literature review were undertaken to:

- Review the experience of Asian countries in managing and promoting PREW
- Study evaluation approaches and methods of social awareness on PREW
- Provide input to design survey and data collection

A literature review report on the development of biogas digestion and its application in Vietnam and Asian countries has been written and delivered to the participants in the roundtable meeting for comments and suggestions on November 2019.

Stakeholder analysis: Through analysis of the stakeholders, the project identified key target groups involved in the implementation of PREW in Vietnam. They were researchers from university and institutes, managers and policy-makers, local farmers/ managers and biogas suppliers and masons.

A round table meeting was held among those above target groups for sharing the information, experiences on PREW. The meeting was successfully organized in 13th November 2019, inviting 20 people from central ministries, NGOs, province and district authorities, universities and experts from Thailand, Japan and Vietnam for consulting with project planning and future activities. In the meeting, stakeholders shared knowledge and discussed on PREW to find out solutions for promoting PREW from the viewpoints of each stakeholders. This meeting summarized the knowledge gaps and current policy on agricultural wastes (pig manure) and PREW between Vietnam, Thailand and other foreign countries. On the other hand, we discussed the current issues in relation to PREW in the target site, impacted factors of biogas application and the desired topics of the local people in the future training courses, for local farmer and local authorities. Discussion on the PREW policy in Vietnam and Thailand, gaps, needs and challenges was also raised in the meeting by the participants. Thus, the project got closer to the benefits of each stakeholders, helping policy improvement. After the meeting, contents of questionnaires, in-depth interviews, training and communication materials have been revised, preparing for the next steps.

Roundtable meeting in Hanoi on 13th November 2019

Design studies assessing social perception of PREW

- Questionnaire and in-depth interview questions were designed and consulted with the above stakeholders. Each stakeholder group was provided with a questionnaire or interview questions, respectively.
- Sampling:
  + 120 livestock households took part in the survey on PREW awareness. The farms were classified according to their operation scale based on the list by local management agencies in a province.

+ 06 suppliers of PREW system were randomly selected for interviews.
+ Ministry of Agriculture and Rural Development (MARD), Ministry of Trade and Industry (MOIT), Ministry of Planning and Investment (MPI), Ministry of Natural Resources and Environment (MONRE), provincial and district management agencies related to PREW in Nghe An province also participated into in-depth interviews.
+ 02 universities selected involved in-depth interviews were NEU and EPU. These are the two universities which are now implementing training programs related to renewable energy technology and management in Vietnam.

Field surveys on September 2020 in Nghe An province, Vietnam

- Data collection: Data was collected directly on-site at related agencies, livestock farms, PREW suppliers and universities. The livestock households were interviewed by local Women Association staffs or extension officers, who were familiar with interview skill through local development activities. Project members interviewed other stakeholders.

2.2. Module 2: Design and disseminate communication materials for livestock farms

We organized 01 training course for local farmers and 01 for local managers in Nghe An province in January 2021. The training course for local farmers aimed to raise the awareness of PREW, and the one for local managers was for increasing their capacity in PREW. Training materials were made on the basis of results achieved from Module 1.

Besides 80 livestock households and local managers participated in training courses on PREW, the project also strengthened the capacity of other 400 farms in Bac Giang, Bac Ninh, Nghe An and Nam Dinh province through delivering PREW communication. These materials were disseminated through the management staff at district level (Department of Agriculture and Rural Development-DARD, Department of Trade and Industry-DOIT, Department of Planning and Investment-DPI, Department of Natural Resources and Environment-DONRE).

Local training course organized on 21 Jan 2021 in Nghe An province, Vietnam.

2.3. Module 3: Policy brief development and dissemination

An important output of this project was the policy brief. This was disseminated to 04 state ministries- MPI, MOIT, MONRE, MARD - 10 provinces, 20 environmental and development NGOs and research institutes in Vietnam. Connecting with partners in Asia region for sharing experience and results was also an important output of this project. Naresuan University in Thailand involved in sharing activities. Nation workshop was organized on 22 February 2021 to disseminate project findings and recommendations to the stakeholders.

Sharing section organized on 11 Jan 2021 in Electric Power University, Vietnam.

Final workshop organized *on 26 Feb 2021 in Hanoi, Vietnam.*

3. Results & Discussion

3.1. Biogas technology in Vietnam

3.1.1 Chronology of biogas development

The history of biogas in Vietnam can be divided into four periods (MARD, 2006.). The first is 1960-1975, in which the first biogas plants were constructed. Information of biogas use in Great Leap movement in China during 1957-1960 attracted the attention of people in the northern Vietnam. Many individuals and institutes studied and installed biogas digesters in some cities and provinces. However, managerial and technical capabilities limited their effectiveness.

The second period is 1976-1980, in which extensive research was done on various biogas digesters. Till the end of 1979, the first biogas plant was completed and operated well. This success encouraged researchers, managers and local peoples, laying basis for further development of biogas technology in Vietnam.

During the third period 1981-1990, biogas technology was considered one of the priorities of the National Research Program on New Energy (MARD, 2006). Over 2,000 household-sized biogas units were built in this period.

The final period lasts from 1991- till now is the most significant biogas development in Vietnam. Biogas technology has developed vigorously within the framework of sanitation, agriculture and rural development projects with many types of new biogas digesters. The plastic bag type of Colombia was applied in SAREC-S2-VIE22 project, implemented by National Husbandry Institute, Vietnamese Association of Horticulturist (VACVINA), the Department of Agriculture and Forestry Extension (DAFE) and University of Agriculture and Forestry in Ho Chi Minh City (MARD, 2006.). The Rural Development Assistance Centre (RDAC) has developed the fixed dome biogas plant with lower part previously of cylindrical shape and now of cuboid shape built of bricks.

Thanks to assistance of various international donors, the Government of Vietnam (GoV) started various projects on small scale biogas plants and livestock waste management in the whole country.

Around 73,000 biogas units were presented by 2007, and it was 140,000 units by 2010 in Vietnam. With the GoV support, the number of installed biogas digestion increased with total of 450,000 units in 2015, mainly were fixed dome biogas digestion (over 200,000 units), plastic bag and recycle plastic digestion (about 160,000 units) and least were composite biogas plant (about 90,000 units) (MARD, 2016).

3.1.2 Household biogas digester technology and design

As a developing agricultural country, Vietnam has a significant potential in livestock waste for producing biogas. To date, Viet Nam has 2.9 million pig households and farms, of them nearly 2.4 million pig farms at household scale, standing for about 83% of the total biogas plants in the country (GSO, 2020). Figure 1 presents percentage of households and farms by size.

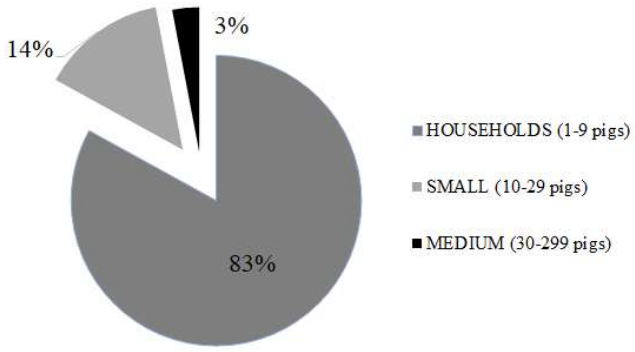

Figure 1: Percentage of households and farms by size until 1 April 2019 (GSO 2020)

This figure implies that the government should pay more attention to household biogas users as the household biogas users is not only the biggest proportion, but also the ones under massive impact of climate changes and environmental issues.

Under general guidance of biogas projects implemented in Vietnam, the popular household biogas technologies are anaerobic fermentation with biodigesters made from fired bricks (fixed dome), composite and plastic bag.

- Fixed dome digester

Fixed dome digester model was experimented in China as early as the mid 1930's. This design eliminates the use of costly mild steel gasholder. Based on the principle of fixed dome China model, Vietnam developed two fixed dome digestions with namely is KT1 and KT2. Both model designs were developed based on sectoral standard 10TCN 492:499-2002 and 10TCN 97:102-2006 issued by Ministry of Agriculture and Rural Development (MARD, 2006). The model has three tanks including mixing tank, digester tank and compensation tank. These tanks are connected by inlet and outlet pipes. Gas pipe is installed in the middle of digester's cover or the highest position of digester's neck. Average investment cost of this type is from 45-50 USD/m^3 digestion, payback period is about 3.5 years (MARD, 2016). The average gas produced is 3.78 m^3/day. The number of organic matters could be reduced by 80-90% by biogas treatment.

- Composite digester

Composite plant originates from China. At present, this model is manufactured and developed by several companies in Vietnam. Material, which 100% imported used for composite model is synthetic material of fiberglass, carbon fiber and polyester. Composite model has three main tanks

including digestion tank, gas storage tank and compensation tank. Three parts are designed in one block and buried underground. In comparison with fixed dome digester, the investment cost for composite one is about 10% per m^3 digestion higher. However, gas production and waste treatment efficiency of the fixed dome type is just about 30% and 10% of the corresponding ones from composite type (MARD, 2009).

- Plastic bag digester

Plastic bag digester is manufactured and delivered by Thu Duc University of Agriculture and Forestry (MARD, 2006.). Material of plastic bag digester is PVC which is widely sold in many localities. This model has digestion tank and gas storage but no compensation tank. Gas pressure is created by put a heavy thing on digester or tighten gas nylon bag with an elastic. Plastic bag is made of three nylon layers. This three-layer-bag is then put in prepared hole/drain and covered with bamboo screens. Advantages of this plastic bag digester is cheap and low initial investment cost (20-25 USD per m^3 digestion), payback period is short (2.0-2.5 years), easy to install, and necessary materials is available locally. However, the plastic bag is not so durable, easily exposing to failure during operation and the waste treatment efficiency is very low (40-50%).

Table 1 summarized the advantages and disadvantages of each biogas digestion model.

Table 1: A comparison of household biogas model applied in Vietnam (SEDCC, 2010)

Model	Advantages	Disadvantages	Recommendation
Fixed dome	-average investment cost -durable and safe for end user -available construction material	-complicated maintenance -need trained mason - need strong foundation before construction	To use in places with: -trained mason - long-term plan for animal husbandry
Composite	-easy in installation -easy in O&M - less leakage ability of gas or water -durable -easy to transport to other places	-high cost - need to be transported from other place - size limitation	To use in places with: - high water table - no trained mason nor materials for fixed dome type - no long-term plan for animal husbandry
Plastic bag	- easy to construct, - no need trained mason - low initial investment cost - high availability of construction materials	-difficulty in O&M - non-durable - could be fire-accident - short lifetime	To use in places with: - no trained mason nor material for fixed dome type - no long-term plan for animal husbandry

3.1.3 Key benefits from biogas application

Increase in the global demand for energy, high fuel price and depletion of fossil fuels as well as concerns of global warming have led to the search for alternative strategies for energy production. Biofuels are one key alternative option for the substitution of fossil fuels.

- Clean energy source

Biogas is a clean fuel which can be conveniently used for cooking and lighting. Moreover, biogas can be used as a substitution for gasoline in internal combustion engines in order to produce electricity or drive machines in case of fuel shortage. Biogas can also be used for drying tea, heating chicken. It is even more efficient when being used in cool cellars for preserving fresh fruits or treating crop seeds.

- Mitigation of environmental pollution& climate change

Animal wastes contain heavy metals such as copper and zinc, causing pollution. The direct use of these materials also brings nitrate pollution of soil and groundwater. Besides, this waste leads to the formation of flies and odors. Biogas digestion provides massive reduction of such environment pollution. In addition, with the use of biogas instead of fossil resources, emission of CO_2 and other greenhouse gases is declined, helping to mitigate climate change.

- Provide organic fertilizer and protect crops

Biogas slurry is considered a good source of organic fertilizer as it contains considerable amounts of nutrients that are necessary for plant growth. It has good effects on soil improvement, erosion resistance and humid content increase etc., hence it is especially good for crops and being additional feedstock for pig and fish. The use of biogas slurry promises sustainable agriculture, environment and farming communities.

Bio-slurry can inhibit the development of some plant diseases and pests like spot leaf on rice and wheat, rotten disease on sweet potato. When bio-slurry applied for paddy rice, it can significantly control trunk pest, green leaf hopper, grey leaf hopper, leaf roller and spot leaf.

- Other benefits of biogas application

Biogas helps to improve health and hygiene of household members, especially housewives and children who spend most of their time in kitchen;

Smokeless biogas reduces the incidence of respiratory and eye diseases which are often caused by smoke from firewood, dung cake and plant residue;

- Biogas light is enough for reading and doing household chores;

- Biogas plant if attached with the latrine frees the surrounding of the house from water pathogen, reducing infestation of various water-borne diseases;

- Reduces cooking fuel expenses and cleaning expenditure by keeping house and clothes clean from smoke induced dirt.

3.2. Opportunities for biogas development

3.2.1 Livestock waste - huge available source for biogas development

Currently, the value of Vietnam livestock accounts for 21% of agricultural production (MARD, 2016). According to the General Statistic Office, by the end of 2018, Vietnam's main livestock included 28.15 million pigs, 5.80 million cows and 2.43 million buffaloes. Since 2010, the animal livestock sector has been developed stably, helping Vietnam balances the supply and demand of domestic meat. However, in 2019, the animal husbandry sector of Vietnam witnessed a significant reduction in pigs due to swine fever. Assuming that the sudden change in 2019 is only one-year event and the sector development remains with an average growth rate of about 4% per year, equal to the growth

rate of agricultural production value during this period, the number of pigs, cattle and poultry of Vietnam until 2025 - 2035 is estimated in the Table 2.

Table 2: Overview of Viet Nam main livestock for biogas (MOIT, 2020)

Main Animals	Unit	2018 (*)	2019 (*)	2025 (**)	2030 (**)	2035 (**)
Pig	Head	28.15	19.62	37.05	45.07	54.84
Cow	Head	5.80	6.06	7.64	9.29	11.30
Buffalo	Head	2.43	2.39	3.19	3.88	4.72
Goat, sheep	Head	1.89	2.73	2.48	3.02	3.67
Poultry	Head	409.00	481.08	538.22	654.82	796.69

* GSO (2019)

** projected data from 2018 with annual growth of 4%

This raising number of livestock showing the potential input for biogas plant to generate electricity as an energy replacement in the near future. The economic potential of adopting biogas technology generating electricity from animal wastes is about 504 kTOE by 2020, increasing to 1421 kTOE by 2035 (MOIT, 2020). With the above-mentioned economic potential, it is possible to produce 1,466 million kWh, corresponding to a capacity of 293 MW in 2020 and 4131 million kWh, equivalent to a capacity of 826 MW in 2035.

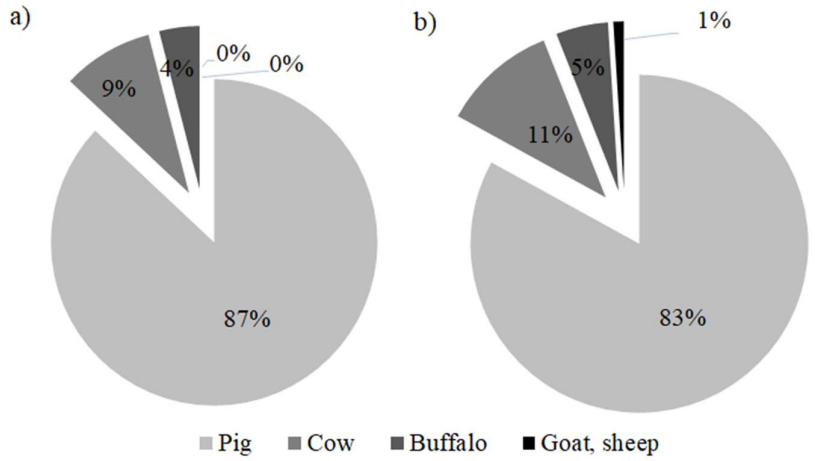

Figure 2: Potential power from livestock waste, calculated for a) year 2018 and b) year 2035

Figure 2 presents the share on power generation of different livestock wastes. The figure reveals that pig and cow manure will play important roles in biogas power generation from livestock waste among the manure sources. Thus, collecting livestock waste in the biogas system has brought great benefits for environmental protection (waste reduction and nutrient-rich residues product) and reduction of GHGs emission, especially, energy generation, otherwise, it leads to negative effects on environment without proper management of pig manure (Hynek et al., 2018).

3.2.2 Solution for future energy shortage issue

Vietnam needs an enormous amount of energy to feed its development while relying on coal and hydropower is not the answer. Vietnam's demand for energy rises by an average 9.5 per cent year-on-year in the last 15 years, reaching 13 per cent increase in 2006-11 and 11 per cent in 2011-16

period. According to Vietnam Energy Outlook 2017 report (MOIT-DEA, 2017), imported energy could account for 37.5 per cent of its total supplies in 2025 and more than half (58.5 per cent) in 2035. Vietnamese economy has transformed itself from an agrarian economy which relied primarily on traditional biomass fuels, to a modern mixed economy, one of the fastest growing ones in the world, resulting in rapid changes in the energy sector. According to the Electricity and Renewable Energy Department under the Ministry of Industry and Trade (MOIT), oil, coal, natural gas, hydropower and non-commercial biomass (woods, agricultural waste) are the main primary domestic energy sources (MOIT, 2017). On the other hand, people face two major global climate problems, global warming and acid rain, which is mainly caused by emission of NO_2, SO_2 and CO_2, respectively. The direct burning of straw and firewood, a very popular daily life activity in the rural of Vietnam, leading to large emissions of CO and other toxic gases. Coal combustion is not only an important source of CO_2 emissions, but also the main source of increases in SO_2 emissions. Besides, coal is also facing the danger of exhaustion. Faced with these problems, GoV must enhance the efficiency of the conventional energy and increase the proportion of renewable energy sources in the total energy budget.

3.2.3 Commitment of Vietnam in clean development mechanism

Dealing with global warming issues, the clean development mechanism (CDM) was proposed in Kyoto Protocol. The clean development mechanism (CDM) allows industrialized countries with a greenhouse gas reduction commitment to invest in projects that reduce emissions in developing countries instead of paying more for emission reductions in their own countries. Therefore, the development of CDM and the sale of verified carbon emission reductions (CER) has encouraged new financial channels for biogas projects in Vietnam (World Bank, 2016, 2018b).

Biogas technology could be considered as a technology helping in GHGs emission reduction from the view point of waste management, fossil fuel replacement and substitution of chemical fertilizers.

Firstly, a portion of organic wastes are decomposed under the natural conditions, emitting methane into the atmosphere. Methane has bigger greenhouse effect than carbon dioxide: one ton of methane is equivalent to 21 tons of carbon dioxide in terms of contribution in global warming. If this organic material is decomposed in anaerobic biogas digester, methane is obtained and can be used as fuel. On being burned, methane is converted to carbon dioxide. Burning one ton of methane, 2.75 tons of carbon dioxide is obtained. Therefore, greenhouse effect is reduced by 21/2.75 = 7.6 times (MARD, 2006). Although CO_2 is a greenhouse gas, it is far less potent than CH_4 and, more importantly, can be considered “renewable” as the CO_2 is absorbed by vegetation.

Secondly, biogas can be used to replace fossil fuels (anthracite, oil, liquid petroleum gas) or to produce electricity to replace those produced by burning fossil fuels, resulting to reduce GHGs emissions. In the rural area of Vietnam, small-scale biogas plant is considered to be an appropriate technology for energy supply to households (Marek et al., 2021). It could cover 60% of households’ cooking needs by replacing traditionally used cooking fuels, such as fuelwood and liquified petroleum gas. On the other hand, a systematic analysis of greenhouse gas emissions from household biogas plants in Vietnam has been applied to determine the emission reduction potential of a typical household biogas plant with a volume of $6m^3$ and an assumed life cycle of 20 years (Hynek et al., 2021). It stated that use of biogas leads to 20% decrease in GHG when compared to firewood combustion.

Last but not least, production as well as application of chemical fertilizer has a GHGs aspect, mainly as a result of the high energy requirement (often sourced from fossil fuels) for chemical fertilizer

production and the nitrous oxide (N_2O) emissions. The "by-product" of a biogas digestion is "bio-slurry", which is a good organic fertilizer that can replace or reduce the application of chemical fertilizer. To the extent to which bio-slurry is actually replacing chemical fertilizer, GHG emissions are reduced.

Due to these benefits many industrialized countries have funded biogas projects in developing countries in order to implement their commitments on GHGs emission reduction on signing Kyoto Protocol.

Vietnam Biogas Programme implemented by MARD and funded by SNV was registered the Golden Standard (as a CDM project) to help improving the life and technology sustainably (SNV, 2016). The achievements of the Biogas Programme make this project an important contributor to the global carbon market, while total credits account for 2.6% of the global credits issued since it commenced in 2003. Specifically, the verified carbon credits from the Biogas Programme in 2018 and 2019 accounted for 5.5% and 3.9% of global Gold Standard credits issued in these two years respectively. In Vietnam, by the end of 2018, a total of 3.39 million Golden Standard VERs were issued with the Biogas project accounting for 70% of the total. Including the credits issued in the fourth monitoring period, this rate increases to 75%.

3.3. Challenges for biogas development

The greatest difficulty in developing biogas in Vietnam is lack of social attention on its role and benefits to human and environmental health (SNV, 2016; DLP-MARD, 2016). Besides, the investment of biogas plant is fairly expensive for farms in condition of lack financial support from the authorities. In addition, Vietnam has not developed technical support system for the design and operation of biogas plant. At present, there is a lack of policies for promoting biogas renewable energy, incentive loan, credit and trading price. Although Vietnam has approved policies on renewable energy development, green growth, livestock development strategy and greenhouse gas emission reduction, gaps remain in policies and regulations, which have not encouraged the electricity generation of biogas technology. These key barriers are related to (i) technology; (ii) financial policy issues and (iii) awareness and capacity.

3.3.1 Technology barriers

Biogas technologies have been proven high efficient and common in many countries in the world, little have been known in Vietnam. At present, no local companies are providing comprehensive biogas modern technology biogas generators. Most of biogas technologies are imported from China, Thailand and EU, whorich has resulted in higher investment and cost of operation and management (O&M). Even worse, there has not been any regulations for testing and quality control of the equipment. A survey was conducted to detect the biogas technology issues at the level of owners of biogas plants and local facilitators in Vietnam (Hynek et al., 2016). The survey revealed that 29% of biogas plant owners experienced at least one problem with this technology. The most frequently encountered problem was linked to leakages from reactors leading to undesired CH_4 emissions, which sometimes stopped the biogas plants from functioning. Other problems concern the failure of biogas cookers to properly function with solid digestate incrustation floating in the main tank, resulting in decreased biogas production (Hynek and Jana, 2019). Therefore, household biogas owner is not so excited about biogas electricity technology.

3.3.2 Financial policy barriers

At present, concrete and comprehensive policies for investment, management and operation of biogas power projects are limited. First of all, that is no incentive for credit policy. Biogas generator

and relevant equipment require large investment capital which is beyond capacity of pig farm owner. Loan incentive policy does not apply to support the investment in biogas electricity development. Secondly, tax of import and trading of biogas generator and other relevant equipment are not in the tax incentive list for importing machine and equipment. Finally, there is not any support for trading price of biogas electricity while cost of biogas electricity generation system is even higher than that hydropower and thermal power (using coal). Without a price support mechanism, biogas electricity is unable to compete with other sources.

3.3.3 Awareness and capacity barriers

Lack of skilled and experienced technicians and workers to undertake the design, construction and maintenance of biogas plants is hindering full dissemination and adoption of biogas production in Vietnam. Biogas digesters are not well operated due to the absence of technician knowledge on repairing and maintaining biogas digestion (Hynek et al., 2016). Meanwhile, benefits of biogas technology have not been fully aware in the country. The knowledge and interest of stakeholders for renewable energy, greenhouse gas and climate change are still very limited. Raising awareness and enhancing interest of stakeholders need to be implemented in line with other measures. Additionally, the GoV has not carried out incentive mechanisms for the sector, which is identified as a reason for low use of biogas.

3.4. Key factors affecting local awareness on biogas adoption

Rogers (1995) defines technology adoption as the level at which an innovation is chosen to be used by a person or an organization. A decision on adopting biogas technology (Abukhzam & Lee 2010) depends on numerous elements, such as perceived usefulness and ease of use, facilitating conditions, e.g., social-economic influence, technology readiness and availability of government support. These factors can make a positive or negative contribution towards biogas technology adoption.

3.4.1 Social-economic factors

Many studies at global level have been conducted on the dissemination and adoption of biogas technology in order to promote it as a viable renewable energy source. However, the decision involving resources allocation includes the contemplation of several reasons and alternatives (Anderson 2002). The socio-economic hindrances in some developed countries undermining the widespread adoption of the technology and the factors that can promote the technology were examined and explored by Mwirigi et al. (2014), Qu et al. (2013) and Kabir He al. (2013).

A review of social-economic factors affecting adoption of biogas digestion in Sub-Saharan Africa (Smith 2005) reported that some main factors affecting adoption were related to investment cost, ability to pay, family income, size of farm and availability of credit facilities. Walekhwa et al. (2009) concluded that household size, numbers of cattle owned, cost of traditional biomass fuels and household income were factors that influence biogas technology adoption in Uganda. Studied same issue in China, Qu et al. (2013) found that the factors that influenced farmers' decision to adopt the technology were support from the government and related household factors, such as level of income, household size and age of household head. In Bangladesh, the determining factors included gender of the head of household, educational level, number of cattle owned and income level (Kabir et al., 2013). The findings in Pakistan by Inayatullah et al. (2018) unravelled the factors influencing biogas technology to include the level of education, daily electricity shortfall and its effect on children's education, female drudgery and awareness of the technology.

In general, social-economic factors affecting adoption biogas digestion were mainly (i) household and setting characteristics and (ii) knowledge/perception.

- Household and setting characteristics

Household and setting characteristics include gender, age and income. Gender role in the household can either positively or negatively influence adoption of a technology. The gender roles can be in form of responsibilities and resource ownership amongst men and women. Women play a crucial role in the provision and use of household energy either for cooking or heating. Women bear the main labor burden of fuel provisioning, but often have less access to credit or income for investment in new energy technologies. As the main users of energy, women also bear the main health burden related to energy use. Energy provisioning and poverty are closely related, as are poverty and gender, with disproportionate impact on women and girls (Muchiri 2008). Their energy concerns are in tune with the search for systems that would relieve them of tiresome repetitive responsibilities (Denton 2005).

The age of household head can positively or negatively influence decision making of whether to adopt biogas technology or not. Old age, according to Nhembo (2003) is associated with conservatism and may influence their willingness to adopt new technologies. Old people are not ready to experiment with new ideas because they are deemed to be more risk averse. However, older people are sometimes regarded as having more resources with a higher economic status that can allow them to engage in capital intensive technologies than younger people. On the other hand, younger households are considered to have long horizons of planning and therefore are more innovative and perceived to take risks related to new technologies. Thus, there are some innovation where younger heads of household stand a better chance of adopting new technology than older heads of households.

Income is another prime factor influencing adoption since it is only with sufficient cash that an individual will be at position to meet technology cost (Mwirigi et al, 2011). Incapacity of farmers to meet the full cost of biogas installation is a key impediment to biogas uptake (Arthur et al, 2011). In support of this argument, Bensah and Brew-Hammond (2011) noted that inability to raise money to meet installation by farmers remained a major impediment to biogas technology uptake in Ghana. The uptake of technology is driven by income earned by households. Thus, higher levels of income are anticipated to readily adopt biogas technology compared to households with lower income levels. Therefore, household income is projected to carry a positive symbol as it is hypothesized that the adoption of biogas technology increases with household income levels.

- Knowledge and perception

The knowledge and awareness of the characteristics of biogas using, perception of environment protection and energy saving have obviously affected the adoption behaviors.

Education level is an important factor affecting the knowledge and perception. Education helps in improving beliefs and habits which in turn creates favorable mental attitude for acceptance of new practices (Omer & Fadalla 2003). Education also increases information acquisition ability thereby providing awareness knowledge to new technologies and beneficial practices. Despite the fact that formal credit markets are becoming increasingly accessible to farmers, illiterates may find the complicated borrowing process and paperwork a major disincentive (Vien 2011).

Awareness of the technology and benefit of this technology also plays a major role in technology adoption. Arthur et al. (2011) acknowledged that lack of knowledge of the technology in Ghana

greatly led to low uptake. Success or failure stories of previous installations can positively or negatively affect uptake. According to Gitonga (1997) information from satisfied users on how well their systems are functioning is about to convince other potential users to install their own. Where the systems malfunction, uptake will be low since other individuals who may be willing to install will get discouraged and run away from such technology.

Main knowledge and perceptions of biogas adoption are presented as below:

- Smoke, health and safety: Acknowledgement of health benefits including fewer episodes of eye and respiratory diseases from not using traditional solid fuel stoves (Bajgain et al. 2005; Kumargoud et al. 2006) and less backache from reduced firewood collection (Mwirigi et al. 2009) were widely described, in particular among women. Some concerns about infectious diseases spreading through handling of manure and increased breeding of insects after plant installation were also reported.
- Cleanliness and home improvement: Perceived benefits of improved sanitation, in particular through the inclusion of latrines during the installation (Bajgain et al. 2005), reduced smoke (Mwirigi et al. 2009), a cleaner home environment (iDE 2011) and cleaner cooking vessels were reported. Biogas is also used for lighting purposes in some settings, but the evidence does not allow any conclusions to be drawn as to whether or not this is considered an incentive for biogas uptake (Bajgain et al. 2005; Kumargoud et al. 2006).
- Total perceived benefits: Other perceived benefits from biogas use included improved quality of life (Jian 2009), convenience for cooking and the possibility of meeting all cooking needs. Additional economic benefits associated with biogas include cost savings made from purchasing less fuel (iDE 2011) and from the production of bio-slurry; the latter is a substitute for chemical fertilizer, but can also be used as an insecticide or fish feed. Moreover, if sold to other households, it can provide a source of income generation.

3.4.2 Institution and mechanism influence

Although digesters can reduce greenhouse gas (GHG) emissions, produce renewable energy, and generate other value-added products such as pathogen-free animal bedding, large capital costs have typically made these systems economically infeasible (Kruger et al. 2008, Lazarus and Rudstrom 2007) but some studies (Kruger et al. 2008; Wang et al. 2011) have found that digesters are not economically feasible for most animal feeding operations so that for sustainable development, the government should have incentives to support biogas program.

For biogas adoption, the government would promote the support beneficiary macro-policy, detailed regulations and rules. It is important to decide distinct rules and regulation to different areas. This includes financial support such as through the ways of low tax and subsidy, financial support from the government would increase the adoption willingness and more important, the adoption behavior at the very beginning facilitate without an increase of residents' financial cost. Cost is needed to build and maintain the biogas digestion. In most cases, the building of biogas digestion is supported by the local government and the self-investment from the resident is very limited (Zhou et al. 2013). The real practice shows that the lack of special funds and subsidies is the main reason causing an abandon of biogas in many areas.

Regulatory frameworks for agriculture and renewable energy are important factors that influence the adoption and implementation of anaerobic digesters as well as the availability of specific feedstock materials. Well-developed regulatory and policy frameworks encourage owners and developers to implement renewable energy systems and, in the context of this report, anaerobic digester systems in the agricultural sector. Interest in anaerobic digestion has increased globally as

governments work to reduce greenhouse gas emissions and identify alternative energy sources for growing populations.

In this project, all the listed impacted factors on changing awareness of local communities on biogas adoption were considered to assess the awareness of local communities. Appropriated training materials and courses were accordingly developed to fulfill the knowledge gaps of local farmers, enhancing their awareness and capacity on PREW.

3.5. Survey on perceptions of stakeholders about PREW

3.5.1 Biogas users (livestock farmers)

The questionaires for the households include four parts:

- Part 1: General information of livestock households

Gender: The respondents are split into 35% male and 65% female. This number implies the fact that women is the main labor source in the rural area.

Age: The age of the respondents in the range from 31 to over 60 years old, whereas the age from 31 to 60 is major.

Income: Survey result proclaims that income of biogas households mainly comes from mainly cultivation (35.0%), raising (30.8%) and service-trade (20.0%). A little percentage of household has income from business (14.2%). Almost households' monthly average income is at low and average level. There is only 2.5% having income of over 10 million VND/month. Household's income from 2 to 4 million VND/month holds highest rate with 40.8%.

Family size: An average number of members in a household are from 4 to 5 people, where labor accounts for 2-3 people (82.5%).

The educational status of respondents indicates that they are at secondary and high school level with few reaching college or university. More than 10% received primary education or less.

Type of animals: 100% interviewed biogas household have pig, only few have both pigs and buffalo (4.2%) or pigs and poultry (0.8%).

General information of the biogas installed in the household (Figure 3):

- Year of construction: Biogas digestion of interviewed households were built from 2003 to 2019. Of the 120 biogas households being interviewed had 72.5% household built after the year of 2015.
- Size of biogas: the selection of capacity depends on some factors as mentioned in Sectored Standards (MARD, 2006), including: type and volume of materials charged; material input: daily or upon demand or combination; specific climate condition in local provinces; biogas using demand. The average size of the biogas plant of investigated households is 11.3m^3, Average volume of the biogas plant trends to increase. It was 6,9 m^3 in 2003, 13.5 m^3 in 2015, and 14.5m^3 in 2019.
- Installation cost of biogas plant: Due to the price of materials and labor increased, it led to the average construction cost of the biogas plants was increased from 884,000 VND/m^3 (for the plant built in 2003) to 1,407,000 VND/m^3 (in 2019).

As for households participating in the questionnaire survey, financial sources for constructing biogas plants included subsidy from the Government and households' own money. All biogas

households received subsidy from the Government. Even the supported amount of 1-1.2million VND/plant has not yet changed over past years, the households have learnt that all benefits from the biogas plants support for their life and they continue to build biogas digestion. Only 04 households had to pay by their own money, and this was quite much in comparison with their income.

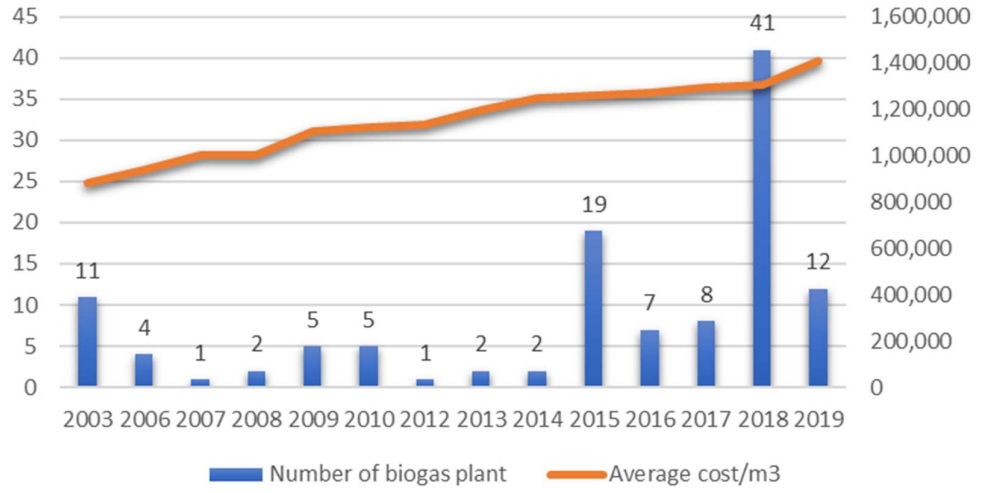

Figure 3: Number of biogas and average cost per volume construction

- Part 2: Understanding of livestock household on the livestock wastes and biogas technology in general.

Q4. Most of households when being asked about the pollution sources in the local area, they all defined that were livestock wastes and domestic wastes. According to the survey results, 100% of households were aware of the impact of un-treatment livestock wastes on the surrounding environments. Untreated livestock wastes lead to negative impact to human health and living condition.

Q5. Household familiarize themselves with biogas plants through many channels. The most common channel is word of mouth. Information about the biogas plant is passed through household's neighbors and friends (30.0%), commune officer (27.5%) and public media (22.5%), which is usually considered a very reliable source. Communication from biogas projects is still the most popular and trusted channel, which accounted for 15%. Only 5.0% of interviewed household learn about biogas technology by themselves.

Q6. During recent years, propagandizing and organizing the biogas projects has been implemented so that benefits of the biogas technology is known by the rural people. However, the local farmers are not yet enough to convince them for constructing biogas without support from GoV.

Nearly half of respondents thought that the biogas plant is a good solution to ensure environmental hygiene when developing livestock, they expected to get better the living activities such as cooking more comfortably, non-smoke cooker and save cost of fuel.

Q7. In the survey area, local people have already taken part in some training courses and seminars organized by NGO projects or the local authorities previously. Content of the activities focused on using the biogas plants, materials for the biogas technology and biogas benefits.

Q8. The interviewees proposed the training courses should be focused on (i) benefits of biogas application (28%); (ii) use of biogas plant (42%); (iii) O&M biogas plants (20%); (iv) construction (10%).

Q9. Impacts of the training courses on the households using the biogas plant is very essential. According to the interviewed households, for effectively organizing a course, the training materials must be designed vividly, with lots of pictures and, if possible, organize field visits to exchange and learn from each other. 47 respondents (39.1%) said that the training materials should be designed with lots of pictures, with illustrative examples and should go on a field trip after study, while 46 respondents (38.3%) said that the materials should be designed with lots of pictures and field trips.

Q10. Most of surveyed households use biogas for cooking only (95.0%), both cooking and lighting (5.0%). Currently, the application of biogas is still low quality. However almost biogas using equipment had no clear brand name or they are handmade ones. Observation at site indicated that there were many cookers, when being used, having fire not only on the surroundings but also in the middle of cookers. That showed quite large volume of gas was wasted during cooking.

Q11. When being asked about surplus produced gas (if any), 61.6% interviewed households said that they left to their neighbors for utilization; 35.8% of households said that they burned off excess biogas and very little households (2.6%) discarded into surrounding environments. The survey showed that households are more and more interested in the ability to use electricity generators.

Q12. Only 35% of livestock household used biogas by-products for crops, because they had backyard square or the cultivated land nearby. Remaining users was not used because they were not sure about the benefits of the by-products (25%) and some farms had not the cultivated land (30%), or that it is difficult to transport and use the liquid biogas slurries (10%).

- Part 3: Awareness of biogas technology and application, and impacted factors on the decision to construct biogas plants

Q13. When households are asked about the factors that influence their decision to install biogas digestion, the investment cost is the most important factor. The number of animals is the second important factor contributing to the construction decision. Other factors, such as construction land, type of animal, benefits from biogas in reducing pollution or clean energy for cooking, are also significant in the farmers' decisions.

Q14. When asked about their perceptions on biogas application, most households completely agreed that using biogas makes the living environment cleaner. However, more than half of respondents felt difficult in biogas O&M.

- Part 4: Impacts of policy and mechanism on the biogas application

Q15. Few households reported that one million supports to biogas users is very necessity. However, the money always be transferred after construction completed for several months. That lose the meaning of this financial support. Besides, respondents also stated that supporting equally one million per biogas plant for all households were not appropriate. This support was more meaningful for the low-income households, and it would contribute much in making construction decision. In addition, to cope with the increase of construction materials prices, this support should be brushed up.

Q16. Development of biogas plant and the use of it are depending a lot on livestock prices. When the production price is going down, there is a tendency of down scale of raising livestock or even

stop raising. When being asked about the impacts of existing policy, most households (78%) said that the policy had positive impact to the scale of livestock of households. Before building biogas plant, households have the expected number of livestock, so the increase of livestock is not easy because it depends on the demand, economic conditions, land square, etc. especially the market price.

3.5.2 Central ministries

Representatives of four central ministries have been selected for interview in this project, e.g., Ministry of Agriculture and Rural development (MARD), Ministry of Natural Resources and Environment (MONRE), Ministry of Industry and Trade (MOIT), and Ministry of Planning and Investments (MPI). It depends on the functions of each central ministry, interview questions focus on different aspects of biogas, including role of biogas in livestock waste treatment, legacy framework in encouraging biogas application in each central ministry, improvement needs and lacks in the current governmental policy, national plan of biogas development in near future, etc.

- MARD

According to MARD, the livestock sector in Vietnam plays an important role in agriculture sector. The husbandry sector has become a major commodity producer with industrial animal breeding farms providing 60 percent of the sector's output. Rising demand for livestock products has led to the intensification of livestock systems. The livestock sector in Vietnam is undergoing a structural change involving a move toward intensive systems and larger production scale. In the past decade, the number of livestock producers has declined over the years and, at the same time, production has gradually shifted from small to larger scale and industrial farming scale.

Together with the trends of larger scales and intensification, environmental pollution is getting more severe due to improper handling of animal wastes and inappropriate use of commercial feeds. Environmental pollution caused by livestock production is the biggest risk for both livestock and public health. Animal wastes are currently being managed in a variety of ways that include composting, use of biogas digesters, and direct use of raw manure as fertilizer. In composting, solid wastes are collected and composted to produce organic fertilizers whereas the liquid fraction is washed off the floor and discharged to the surrounding environments or fishponds. In biogas, wastes are collected and treated in biogas tanks; gasses produced are used for cooking and biogas effluents are used as fertilizers or discharged into fishponds for farming fish. In some places, raw manure (that is, chicken manure) is sold and applied directly to crops as organic fertilizers. Waste management practices are diverse, depending on specific farm conditions, such as types of animals, housing systems, locations, and farm sizes.

MARD officer said that in large-scale production systems, animal waste management is generally more effective. However, the shift to larger-scale production has not always improved environmental outcomes, despite the higher capacity for pollution management that one might expect from a larger scale, professional operation. When thousands of pigs are concentrated in a small area, their environmental and health impacts become concentrated, too. Managing the environmental risks associated with the intensification of the livestock requires more effective enforcement of policies and legal documents relating to the protection of the rural environment.

At present, livestock waste management in smallholder farms is neither monitored nor enforced. From the producers' perspective, the treatment of wastes requires onerous investments in infrastructure, which small farmers can hardly afford. A lack of awareness about the importance of waste treatment also affect to farm-level decisions. Meanwhile, waste management regulations

are not uniformly and systematically enforced by the government, especially among smallholder farms. The result is that farmers tend to avoid treating animal wastes when and where possible. In recent years, the government has initiated livestock projects that offer financial support (for example, matching grants) to smallholder farmers to help them handle livestock wastes better, notably through the construction of biogas digesters and composting facilities. However, financial resources as well as management capacity still limited, very small number of livestock farms could get the support. It is important to note that livestock owners have not yet understood importance and benefits of biogas plants, they deny to pay for the initial construction cost. So, sharing sections or training course are needed to raise local awareness in biogas application and O&M.

- MONRE

Livestock wastes cause different types of pollution, including water, soil, and air pollution. As previously noted, it is estimated that only around 60 percent of animal wastes are treated; the remainder are discharged directly into the environments (that is, dumping on land, fishponds, canals, rivers, and so on). Enforcement is frequently a big challenge in Vietnam, especially in rural areas, and this needs to change if the government really wants to lessen the impact of the livestock sector. The government needs a clear road map and action plan to implement its existing policy of relocating large-scale farms—many of which are currently located in residential areas—to livestock cluster zones benefitting from province-level support. It also needs to continue providing technical assistance to smallholder farms to help them improve their waste management practices.

Due to lack of information, most people are still not aware of all the risks associated with improper management and treatment of animal wastes. For instance, a recent study showed that the main reason for farmers to build biogas digesters is because they wanted to reduce the problems of bad odor and flies. Many farmers are not aware that biogas effluents are not yet safe to be discharged directly to water bodies, which is used for water supply sometimes, or for irrigating in vegetables.

There are many legal documents related to livestock pollution, such as decree No.79/2008/ND-CP dated 18 July 2008 on “Provides regulations on management of solid waste and the rights and obligations of entities related to solid”, QCVN 40/2011/BTNMT on “technical standard for animal wastewater refers to Vietnam’s technical standard on industrial wastewater”, QCVN 62/2016/BTNMT on “livestock wastewater”. However, a comprehensive and systematic review of environmental regulations, implementation, and enforcement is needed to replace those that are not practical or less effective in reality. The division of responsibilities relating to environmental protection and management currently lacks clarity at the central, district and commune levels. In addition, capacity building in environmental management at the district and commune levels is urgently enhanced.

- MOIT

As a developing country with an agricultural sector accounting for 14.68% of whole GDP of Vietnam and 39.35% of total population of the total workforce in 2018, Vietnam has a huge potential for biogas resources, which can be exploited for producing energy, especially electricity. If being exploited effectively, biogas sources will not only help the country reduce its dependence on traditional electricity sources, but also help to decline carbon emissions as well as environmental pollution.

According to this revised Vietnam’s Power Development Master Plan VII, the national electricity capacity will increase from 38,537 MW in 2015 to 60,000 MW in 2020 and 129,500 MW in 2030. Total electricity production and import is estimated at 265 -278 billion kWh/a in 2020 and 572-632

billion kWh/a in 2030; and prioritize the development of renewable energy sources for electricity production; increase the proportion of electricity generated from renewable energy sources (excluding large-scale, medium-scale and pumped storage hydro power) up to around 7% (17.23 GWh) in 2020 and above 10% (61.2 GWh) in 2030.

In addition, the Decision No. 1208/QD-TTg dated June 21st, 2011 of the Prime Minister to approve the National Power Master Plan of Vietnam to 2020 with outlook to 2030 has emphasized the necessity to increase the share of electricity produced from renewables. Specially in the resolution No.55 /NQ-TW dated on 11th February 2020 given the target to develop renewable energy which the proportion of renewable energy sources in the total primary energy supply will reach about 15-20% by 2030; 25-30% by 2045.

Recognizing this, the Government of Vietnam has increased efforts to work out various support policies for the promotion of renewable energy in recent years. Besides, among renewable energy sources which have been identified in Vietnam, until now there are only four sources which have been financially supported as following: i) small hydro power, ii) wind power, (iii) solar power, and (iv) biomass (co-generation) power. The development road map for biogas electricity has been set in the Renewable Energy Development Strategy, however, there is no support mechanism (such as a feed-in tariff) for biogas power. In 2020, MOIT now is implementing the evaluation of the theorical, technical and economic biogas potential in Vietnam for the period up to 2025 with an outlook to 2030 and develop the mechanism to support biogas power development in Vietnam, hereby meeting the Government's targets as set out in the Decision No. 1208/QD-TTg and Resolution 55-NQ/TW.

- MPI

Livestock is one of the fastest growing subsectors in the national economy, and demand for livestock products continues to increase. To meet this increasing demand, the number of medium and large-scale farms is likely to grow in the years to come. In addition, government policies are reinforcing this trend by providing financial support to smallholder farms to expand their production scale. This shift will result in greater volumes of animal wastes. In the transformation from smallholder to intensive and large-scale livestock systems, livestock producers are facing a number of constraints, such as limited knowledge and skills in management practices, including diseases and waste management practices, limited land available for expanding livestock-raising area and for waste treatment, and limited access to credit. With these constraints, it is highly likely that producers will compromise the standards of waste treatment and management to devote their scarce private resources for other economic activities. The government needs a clear road map and action plan to implement its existing policy of relocating large-scale farms—many of which are currently located in residential areas—to livestock cluster zones benefitting from province-level support. It also needs to continue providing technical assistance to smallholder farms to help them improve their waste management practices.

It is important to note that most farmers know that if livestock wastes are not properly handled, it would pollute surrounding environments and affect human health. However, smallholder farms are facing more constraints in adopting waste treatments. Among different livestock waste management practices adopted by smallholder farms, biogas digesters may require the greatest level of capital investment. Other methods such as composting or fishponds require less investment. Regardless of manure treatment methods, investment in environmental protection is an additional burden, which will increase production costs and reduce farming profits, at least in the short run. In the context of weak enforcement in environmental protection at local levels, many

farms just want to avoid animal waste treatment to reduce their investment expenses as much as possible.

At present, there is little control and planning of smallholder livestock farming in rural areas. So far, this part of the sector has developed spontaneously, driven by economic factors that are outside the government's control. There is also lack of participation by community-level stakeholders (that is, villagers/ farmers, local authority, NGOs, and so on) in planning, monitoring, and enforcing laws especially as related to livestock waste management plans.

Although the national effluent standards exist, the enforcement of and compliance with these standards in practice are very weak. Many farms just install a biogas digester as a symbol of treating livestock wastes to reassure local authorities, regardless of whether they are meeting environmental standards or not. In many cases, when livestock waste volumes are excessive, they are dumped outside without treatment. These violations are known by local villagers but are rarely caught by local authorities unless there are serious complaints. Insufficient enforcement is mainly due to institutional weaknesses coupled with a lack of human and financial resources for monitoring operations.

3.5.3 Local departments

Local officers in Nghe An provinces has participated in the in-depth interview. They are from Department of Agriculture and Rural development (DARD) and Provincial Agriculture Extension center. Real situation of biogas usage in the local place is presented.

In Nghe An province, the percentage of animal husbandry production in total agriculture sector is 47.0 % in 2019. The recent growth rate of animal husbandry sector is estimated to be 5 - 5.5 %/year. The population of livestock has been increasing in Nghe An province except for buffalo and pig. The major consumption of meat is still pork, and the percentage of pork is about 70 % of total meat amount. But the population of pig has been decreasing because of the limitation of land, high cost of commercial feed for pigs and environmental problem. Reflecting the diversity of taste due to the recent urbanization and increase of income, the production of beef, chicken, milk, goat and honey has been increasing in Nghe An province instead of the pork. As for livestock, all kind of livestock in 2019 occupy high percentage in Nghe An; that is 8% in cattle, 12% in buffalo, 3% in pig and 5% in poultry as nationwide ratio. It should be noted that Nghe An province has the largest population of cattle and buffaloes among 63 provinces nationwide.

Treatment of livestock waste has been concerned by some organizations and official agencies but not closely. There are a number of measures to minimize and treat livestock wastes in farming areas, such as planning of livestock area, treatment in biogas tank, use of biological products, organic composting, etc. Biogas plants were constructed under the support of project "Biogas development program for livestock sector in Viet Nam" conducted by MARD and Development Cooperation Organization Netherlands (SNV) jointly from 2003. The province had policies to support for building of biogas tanks as 1 million vnd per digestion, but it is not efficient due to high cost of construction materials recently.

In fact, many constructed biogas tanks do not promote maximum efficiency, causing waste of produced biogas. It is due to the inappropriate scale calculation, e.g., huge wastes but small tank and vice versa. There are many tanks that create large energy but not used up, while people do not know how to share or sell it to neighbor households leading to burn or discharge into the environments. To exploit the most effective energy source from biogas tanks, the Government should have supporting policies for organizations and businesses as well as households in industrial

biogas production. Along with that, it is necessary to request scientists and donors in establishing standard set for biogas-used equipment, or research in using of biogas in other forms, such as biogas-liquefied for internal combustion engines in order to use up energy from biogas.

Regarding to propose the mechanism to support PREW, the subsidy should be divided the support packet according to biogas scale, farm size and household's size so that the small farms could also be supported. Local governments need to pay greater attention to environmental enforcement for both large-scale and small-scale farms to strictly monitor waste handling, as well as encouraging the livestock owner to apply biogas plants. So that, enhancing local livestock owner's awareness is always necessary.

3.5.4 Biogas suppliers

We had interviewed four mason groups and three biogas agencies in Nghe An province. They shared following information:

The scale of livestock raising is affected by price of livestock products and price of commercial feed for pig. A number of factors affect farmers' adoption of improved animal waste management practices, including production scale, farming and other land availability, access to extension systems, income levels, and family labor availability.

A greater percentage of large-scale farms adopt waste management practices than smallholder farms because they have strong financial and technical capabilities to construct waste treatment facilities to comply with the requirements. However, in many cases, due to high intensification and land availability constraint, some large-scale farms were not able to treat all the wastes. This is commonly observed in intensive pig and poultry farms in city and towns. The most bothersome problems observed in these farms include noxious odor and an abundance of flies concentrated in the areas.

Due to increasing market competition, many farmers had to increase their farming sizes, which led to greater volumes of manure being generated than those they could handle. Some farms had the financial capacity and invested in biogas digesters to treat their excessive wastes and produce gas for home consumption. Some could not afford digesters decided to discharge their wastes into the environment without treatment. When one person can do it, other people follow.

The subsidy to support to biogas users is very necessary. However, the money always be transferred after completion of construction of biogas plant for several months so that this amount of money sometimes was not meaningful as contribution to the construction cost and not being used as it supposed to be used.

In order to improve the utilization of biogas, the programme may need to develop several demonstration models on biogas utilization at full options (biogas for cooking, lighting, electric generator, pumping, water heating….) and conduct more training on operation and maintenance so that the household can be utilize the use of biogas at their ability and wishes. At that time, the biogas plant will help not only in solving waste problem of livestock activities but also in saving energy for society and saving cost of energy uses in each household.

3.5.5 Universities

Lecturers in Electric Power University (EPU) and National Economics University (NEU) in Vietnam have shared their viewpoints regarding to benefits from the expected project results to their research, their lectures and society in general.

Renewable energy is very familiar with students in Vietnam. Biogas technology is taught in the university. However, students have learnt about its technology in theory, they need some examples of biogas application in the reality. Students have studied about benefits of biogas, but they have not yet known the reason why biogas application is still limited in the rural area. This project results will bring students evidences. Organizing seminars in the universities for sharing project results is really great idea. Students could become a communication channel for development of biogas application in their hometown.

This project results will be valuable for further research on the perspective of local farmers on adopting biogas plants. Providing good reasons and solutions for O&M of biogas will be a way to convince local people to use biogas technology. Improving biogas technology is the responsibility of researchers, scientists. Understanding the real situation of biogas plant in the household, knowing the user feedback, the technology could be fixed. Once its disadvantages can be solved, it expects more biogas users. On the other hand, sharing the importance of biogas application to the environments and society will encourage students in research and study on biogas development.

4. Policy implications and recommendations for PREW in Vietnam

4.1. Existing national and local supporting policies for PREW development

4.1.1 Clean development mechanism

Dealing with global warming issues, the clean development mechanism (CDM) was proposed in Kyoto Protocol. The clean development mechanism (CDM) allows industrialized countries with a greenhouse gas reduction commitment to invest in projects that reduce emissions in developing countries instead of paying more for emission reductions in their own countries. Therefore, the development of CDM and the sale of verified carbon emission reductions (CER) has encouraged new financial channels for biogas projects in Vietnam (World Bank, 2016, 2018b).

4.1.2 Financial subsidy

To promote biogas plant, the Government had issued the Decision No. 50/2014/QD-TTg dated 4/9/2014 of the Prime Minister on policies on subsidies for improvements in farmer household animal husbandry in 2015 – 2020 periods for subsidy on livestock waste treatment "one-time subsidy up to 50% of the expenses for the construction of biogas" (TTCP, 2014). A subsidy of no more than VND 5 million (equivalent to about 200 USD) for a biogas digestion per household; one-time subsidy up to 50% of the expenses for biological carpets; subsidy of no more than VND 5 million for a household.

4.1.3 Law/Regulation/Decision in renewable energy

The Government of Vietnam has issued many strategic directions in responding to climate change, efficient use of energy and encouraging the development of renewable energy. The major policies include: National Strategy on Climate Change (TTCP, 2011), Green Growth Strategy (TTCP, 2012), Strategy for National Renewable Energy (TTCP, 2015), National target program on energy saving and efficiency (TTCP, 2019), and the National Energy Development Strategic Direction of Vietnam to 2030, Vision to 2045 (Resolution of the Political Ministry 2020) (TTCP, 2020). Due to environmental challenges and an ambition for clean energy development, the GoV has recently paid more attention to biogas technology. The Government had set up its objectives to 2025 in the revision of the National Strategy on Integrated Management of Solid Waste to 2025, with a vision to 2050, which is called as Decision No. 491/QD-TTg issued by the Prime Minister on 7th May 2018 (TTCP, 2018). According to the decision, 80% of waste generated from livestock, cattle and poultry

activities and food processing will be collected, reused or recycled as compost and biogas as well as treated to meet environmental protection requirements.

4.2. Policy recommendations for PREW development

4.2.1 Development and improvement policy and mechanisms

Experience shows that the introduction and success of any technology is dependent on the Government's policy framework. Policies are important because the Government is the key actor to enable an environment for mobilizing resources and encouraging private investment. Therefore, the GoV should develop supporting mechanisms for biogas digestion development. For example, beside subsidies, the Government should further promote its tax policies (current tax exemption is shown not to be sufficient), create investors' access to green loans and develop favorable loan mechanisms including grace periods, longer timelines and favorable interest rates. The Government can also mobilize capital though ODA and/or bilateral foreign loans as well as develop testing and standards of biogas technologies to improve the reliability of biogas technologies.

4.2.2 Financing mechanism

A specific funding line needs to be introduced for biogas units, which included some sub-solution such as (i) giving easier access to credit line with a concessional interest and favorable term of maturity, establishing a specific credit system of the line and local bank's distribution, and (ii) introducing a tax incentive consisting of reduced import taxes and partial exemption from value-added tax of the biogas equipment.

4.2.3 Capacity building for stakeholders

The capacity building should include the dissemination and update of policy to maintain transparency and credibility for attracting potential domestic investors. Training courses should be provided to technical staff of biogas digester on operation and maintenance as well as to bank staff on financing biogas plants and procedures for managing and implementing the credit line created for support biogas owners (Hynek et al., 2016; Marek et al., 2021).

5. Conclusions

The Association of Southeast Asian Nations (ASEAN) has set the aspirational target of securing 23% of its primary energy from modern, sustainable renewable sources by 2025. ASEAN Member States recognize that these goals cannot be achieved without close regional cooperation. Joint efforts in capacity building in renewable energy policies and technical expertise will contribute towards achieving ASEAN renewable energy target.

This project has raised awareness, enhanced capacity for stakeholders and informed decision-making in APN member countries to contribute partly ASEAN renewable energy target. The project evaluated social awareness of the roles, benefits, advantages and challenges in the production of renewable energy from livestock wastes, contributing to reducing greenhouse gases. Training courses were organized to raise awareness of livestock farmers of benefits and application of renewable energy production from animal wastes (including information on supporting policies). Training courses on climate change and renewable energy production from livestock wastes were given to strengthen capacity of local managers. Policy brief and the social awareness assessment report is a valuable material to the policy makers and managers. Project results and implications were disseminated to national and sectoral decision makers, universities for promoting policies to encourage renewable energy from livestock wastes. Five peer-reviewed papers have been developed and published to sharing worldwide the results of this CapAble project.

References

Castel V., de Haaan C., Gerber P., Rosales M., Steinfeld H., and Wassenaar T. (2006). Livestock's Long Shadow Environmental Issues and Options, [online]. Available at: ftp://ftp.fao.org/docrep/fao/010/A0701E/A0701E00.pdf (FAO)

DLP-MARD (2016). Overview of Vietnam Livestock Sector Development Strategy and Restructuring Plan. The International Workshop Vietnam Livestock Sector in Economic Integration: Experience Sharing- Future Orientation. Hanoi, October 27. Department of Livestock Production, Ministry of Agriculture and Rural Development (DLP-MARD). Hanoi, Vietnam.

GSO (2020). Vietnam General Statistical Office. Livestock sector.

Hynek R., Sergio B., Dinh V.D., Le D.P., Jana M. (2020). Emission reduction potential of household biogas plants in developing countries: The case of central Vietnam. Journal of Cleaner Production, 270, 122257. https://doi.org/10.1016/j.jclepro.2020.122257.

Hynek R. and Jana M. (2019). Small-scale biogas plants in central Vietnam and biogas appliances with a focus on a flue gas analysis of biogas cook stoves. Renewable Energy,131, https://doi.org/10.1016/j.renene.2018.08.054.

Hynek R., Jana M., Jan B., Vladimír V. (2016). Addressing problems at small-scale biogas plants: a case study from central Vietnam. Journal of Cleaner Production, 112, https://doi.org/10.1016/j.jclepro.2015.09.114.

Hynek R., Jana M., Le D.P., Jan B. (2018). Current approach to manure management for small-scale Southeast Asian farmers - Using Vietnamese biogas and non-biogas farms as an example. Renewable Energy, 115: 362-370, https://doi.org/10.1016/j.renene.2017.08.068.

IEA (2006). World Energy Outlook 2006: Focus on Key Topics – Energy for Cooking in Developing Countries

Jane K.M. (2009). Global warming and livestock husbandry in Kenya: Impacts and adaptations. Ecological Economics, 68 (7): 1915-1924

Keri B.C., Thomas D., Kyoung S.R., Patrick G.H. (2008). Livestock waste-to-bioenergy generation opportunities, Bioresource Technology, 99 (17): 7941-7953

MARD (2006). Training material for Biogas technician. Department of Livestock Production, Ministry of Agriculture and Rural Development (DLP-MARD). Hanoi, Vietnam.

MARD (2010). Evaluation study for household biogas plant models. Department of Livestock Production, Ministry of Agriculture and Rural Development (DLP-MARD). Hanoi, Vietnam.

MARD (2016). Real situation and solutions for environmental treatment of livestock production. Report Document 2016. Ministry of Agriculture and Rural Development (MARD). Hanoi, Vietnam.

Marek J., Jana M., Dinh V.D., Le D.P., Jan B. and Hynek R. (2021). Quantification of the impact of partial replacement of traditional cooking fuels by biogas on global warming: Evidence from Vietnam. Journal of Cleaner Production, 292, https://doi.org/10.1016/j.jclepro.2021.126007.

MOIT (2017). National Biomass Energy Utilization and Development Plan. Ministry of Industry and Trade, Vietnam (MOIT), Vietnam

MOIT (2020). Analysis of existing situation of biogas development and policies in Vietnam and other countries-Development of a Biogas Feed-in tariff in Vietnam. Report. Ministry of Industry and Trade (MOIT). Hanoi, Vietnam.

MOIT-DEA (2017) Vietnam Energy Outlook Report 2017. Kobenhavn, Denmark. Ministry of Industry and Trade & Danish Energy Agency (MOIT & DEA) 2, 12, 13, 16, 17, 18, 20, 23, 31, 39.

Peter G.J. and Philip K.T. (2009). Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change, Environmental Science & Policy, 12 (4): 427-437

Political Ministry (2020). Resolution No.55-NQ/TW of February 11, 2020: The National Energy Development Strategic Direction of Vietnam to 2030, Vision to 2045.

SEDCC (2010). FINAL REPORT. Evaluation Study for Household Biogas Plant Models. Biogas Project for the Animal Husbandry Sector in Vietnam 2007-2011. Sustainable Energy Development Consultancy Joint Stock Company (SEDCC). Vietnam.

SNV (2016). Vietnam Biogas Programme https://snv.org/project/vietnam-biogas-programme

TTCP (2011). Decision No. 2139/QD-TTg of December 5, 2011: Approving the national strategy for climate change, Vietnam.

TTCP (2012). Decision No. 1393/QD-TTg of September 25, 2012: Approving National Green Growth Strategy. Hanoi, Vietnam.

TTCP (2014). Decision No. 50/2014/QD-TTg of September 04, 2014: Policies on subsidies for improvements in farmer household animal husbandry in 2015 – 2020. Hanoi, Vietnam.

TTCP (2015). Decision No. 2068/QD-TTg of November 25, 2015: Approving the development strategy of renewable energy of Vietnam by 2030 with a vision to 2050. Hanoi, Vietnam.

TTCP (2018). Decision No. 491/QD-TTg of May 7, 2018: National Strategy on Integrated Management of Solid Waste to 2025, with a vision to 2050. Hanoi, Vietnam.

TTCP (2019). Decision No.280/QD-TTg of March 13, 2019: Approving the National Energy Efficiency Programme (VNEEP) for the period of 2019-2030. Hanoi, Vietnam.

Vinh Q.N. (2017). Electricity regulation in Vietnam: overview. Practical Law. Energy and Natural. https://www.tilleke.com/sites/default/files/2017_Sep_Vietnam_Energy.pdf

Vu T.K.V. (2014). The report of survey on assessing impacts of climate change on livestock and disease prevention, proposing adaptive solutions (In Vietnamese: Báo cáo điều tra đánh giá tác động của biến đổi khí hậu tới chăn nuôi và phòng trừ dịch bệnh, đề xuất các giải pháp thích ứng)

World Bank (2018a). The World Bank in Vietnam: overview. Retrieved 28/03/2018, from. http://www.worldbank.org/en/country/vietnam/overview.

World Bank (2018b). Launching of $102 Million Project to Help Vietnam Improve Energy Efficiency in Industrial Sector.

World Bank (2016). Vietnam's Climate Change and Green Growth Agenda Receives $90 Million Boost.

World Bank (2017). An Overview of Agricultural Pollution in Vietnam: The Livestock Sector. International Bank for Reconstruction and Development Vietnam.

Appendix

A1. Roundtable meeting

A2. Questionnaires form for survey in Nghe An province, Vietnam

A3. Report of Social Awareness Assessment

A4. Communication Materials

A5. Published papers

A6. National workshop