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Small-scale biogas plants in Vietnam: How are affected by policy issues?

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Abstract. Both developed and developing countries are working towards creating an emission free planet. Vietnam, as one of the highest contributors to greenhouse gas emissions, has implemented several policies to curtail this phenomenon. Most of these policies are geared towards the development of renewable energy technologies such as biogas. The country's policy on environmental protection, clean energy, climate change, and rural development has been based on small-scale biogas programs and projects. However, how are these small-scale biogas plants affected by arising policy issues? To answer this question, an intensive literature review was conducted and accompanied by a consultation with biogas experts with a focus on Vietnam. The data collected were analysed using the policy cycle analytical approach. The results showed that several policy instruments, such as the price of other conventional fuels and feed-in-tariffs, affect small-scale biogas plants. Furthermore, thousands of small-scale biogas plants have been installed due to good policies such as the Vietnam National Biogas Program. Finally, funding remains the biggest barrier to biogas policy amendments and implementation; the several biogas programs implemented over the decade could have yielded more positive impact if financial barriers like co-financing by the beneficiaries were set up more appropriately. In addition, new policies in the future will favour mid- to large-scale biogas plants rather than small-scale biogas plants. This policy implication threatens the sustainability of small-scale biogas plants; therefore, policy makers must be adroit in addressing policy issues that affect biogas production in Vietnam.

Key words: biogas; Vietnam; policy; policy cycle analytical approach; renewable energy; rural development.

1. Introduction

An increase in economic growth has led to a high rate of greenhouse gas emissions (Raupach et al., 2007; Steckel et al., 2011), environmental pollution arising from animal manure in connection with climate change and human health is also on the rise. Asia produces large quantities of manure most especially from livestock and poultry production which contributes enormously to global warming (Vu et al., 2015). Vietnam has a vibrant livestock sector, with its pig sector comprising 80% of its total meat production and providing a livelihood for millions of small-scale farmers (Nga et al., 2014; Thi et al., 2015). The livestock industry has played a significant role in poverty reduction and income distribution among highly poor Vietnamese farmers (Roubík et al., 2017). With an increasing demand for pork in Vietnam, there has been a shift from small-scale livestock farms to large-scale over the past decade (Nga et al., 2014; Dinh, 2016), demonstrating the increasing growth of the livestock sector. Over 40% of livestock waste is dumped in rivers and canals, causing water, soil and air pollution (Dinh, 2016). In addition, due to economic growth and rapid power consumption, Vietnam is facing energy supply problems and thus has been reliant on imported electricity, steam coal

and oil (The World Bank, 2010). To simultaneously solve the problems of energy supply inefficiencies and environmental pollution, the government implemented the National Biogas Program (SNV and Fact, 2014; Roubík et al., 2020); biogas technology had the potentials to solve these problems (Thien Thu et al., 2012). The technology has helped in the mitigation of environmental pollution, energy supply and job creation in rural communities (International Energy Agency, 2020).

This article aims to uncover the answer to the question: ‚How are these small-scale biogas plants affected by emerging policy issues?' To answer this question, an intensive literature review was conducted coupled with interviewed biogas experts with a focus on Vietnam. The data collected were analysed using the policy cycle analytical approach.

2. Energy, Policy, and Biogas in Vietnam

2.1. Sources of energy in Vietnam

Vietnam is one of the countries that consumes enormous amounts of energy coupled with increasing energy demand (ASEAN Centre for Energy, 2015; Danish Energy Agency, 2017; Mersmann et al., 2017). Energy consumption further increased after the national electrification program was introduced (Khanh Toan et al., 2011). The country relies on an energy mix from both renewable and non-renewable sources such as coal, hydropower, natural gas, biofuels and oil (Khanh Toan et al., 2011; Mersmann et al., 2017; Shem et al., 2019) . It also hopes to cover some of its energy sources from geothermal energy (Shem et al., 2019). The main sources of electricity are coal, hydropower, and gas (ASEAN Centre for Energy, 2015; Mersmann et al., 2017). For renewable energies, due to the low growth of biomass energy usage, availability of commercial fuels, and untapped hydropower, the contribution of renewable energy to total energy was expected to drop by 40% in 2005 and more than 10% by 2030 as the economy develops (Khanh Toan et al., 2011). However, in current times, the high percentage of the demand is recurrent for fossil fuels (Zimmer et al., 2015). Diesel oil is the most consumed petroleum product within the country (Khanh Toan et al., 2011). The country has also moved from the use of traditional biofuels and hydropower to a heavy dependence on fossil fuels due to rapid growth (Duc Luong, 2015; Asian Development Bank, 2016; Economic Consulting Associates, 2016). Furthermore, the country's carbon emissions within the energy sector have increased enormously from 1971 to 2010 (Zimmer et al., 2015). The share of greenhouse gas emissions from Vietnam's energy sector is presumed to be three-quarter of total emissions produced by the country by 2030 (World Bank, 2011). Emissions within the energy sector have decreased over time, however, they are still very high compared to other industrialized countries (Steckel et al., 2011).

2.2. Overview of Energy Policies in Vietnam

Energy plays an important role in transforming our environment into a sustainable one. To develop energy within the country, the government has developed a national plan known as the National Energy Development Strategy. Some of the elements within the policy include; increasing the share of renewable energy to total energy supply by 3% in 2010, 5% in 2020, 5% in 2025 and 11% in 2050 (Khanh Toan et al., 2011; Quirapas et al., 2015; Chang et al., 2016). Also, in 2010, Vietnam's energy sector was reformed through the introduction of the National Master Plan for the Development of Power and the Law on Economical and Efficient Use of Energy (Decision 1208/QD-TTg, 2011). The plan indicates the share of electricity that must be produced by renewable energies (except for hydropower). Renewable energies should account for 4.5% of the electricity produced in 2020 and 6% in 2030 (Decision 1208/QD-TTg, 2011). Vietnam's energy efficiency and conservation policy, known as the National Energy Efficiency Program, only aimed to save total national energy consumption for a short period. The program started in 2006 with a target of 3-5% between 2006 and 2010 and 5-8% between 2011 and 2015 (Minister THEP, 2018a). The program also experienced a lot of lapses (Minh Do & Sharma, 2011). In addition, there is a need for environmental protection in the production of energy. The energy sector has been identified to contribute to more than 50% of greenhouse gas emissions (Mersmann et al., 2017). The National Plan for Environment and Sustainable Development contained policies and strategies that aimed to promote the energy sector and, at the same time, ensure a clean and healthy environment. One of such polices what the Environmental Protection Law which came into effect in 1993 (Minh Do & Sharma, 2011). However, environmental laws in Vietnam are not substantial (Wesseler, 2010). Another policy is the Green Growth Strategy; developed by the Ministry of Planning and Investment (Mersmann et al., 2017). The Green Growth Strategy is a Vietnam energy development strategy that started in 2011 to 2020 and with a vision to continue to 2050 with the aim of reducing climate change. Furthermore, several policy instruments and mechanisms have been implemented to help reduce emissions from the building and transport sector (Shem et al., 2019). The country's energy policies focus mainly on climate change, electrification, efficiency, and renewable energy (Gould et al., 2017). However, to achieve most of its actions that aim to reduce Climate Change to its target level, Vietnam would have to seek external funding (Government

of Vietnam, 2015). To conclude, energy policies in Vietnam were biased and thus skewed to one side by the driving force of energy supply instead of considering consumption (Minh Do & Sharma, 2011; Shem et al., 2019a). Financial, institutional, information gaps, and technical barriers were hinderances to policies enacted to achieve low carbon transition (Mersmann et al., 2017). Subtly, there is a need for a policy coherence between all existing policies to reduce overlapping (Wilkinson, 2011; Huttunen et al., 2014).

2.3. Renewable energy in Vietnam

Governments in the South East Asian region are developing and encouraging the use of renewable energy sources within the region (Chang et al., 2016; Hu et al., 2018). The biggest impediment to renewable energy technology is awareness, accessibility, and affordability (Erdiwansyah et al., 2019). Its share in electricity generation in Vietnam is estimated to be 23% by 2030 (Asia Pacific Economic Coorperation, 2013). Investing in renewable energy can serve as a pillar of sustainable development (Erdiwansyah et al., 2019) and lead to the achievement of more than one Sustainable Development Goal (IRENA, 2018). Furthermore, research and development helps facilitate the adoption and use of renewable energy technologies (Liu et al., 2019). Governmental and non-governmental organizations, academic institutions and several agencies in Vietnam are interested in research in renewable energies (Duc Luong, 2015). Research and development support for renewable energy is greater when partnered with feed-in tariffs (Lindman & Söderholm, 2016).

2.4. Renewable energy policies

A review of renewable energy policy instruments from the International Energy Agency by Pitelis et al. (2020) over the year 1990-2014 revealed that renewable energy policies have been successful in fostering innovations in renewable energy technologies. To mention only a few policy instruments for renewable energy technologies, Hille et al. (2020) identified tax reduction, greenhouse gas certificate trading, renewable energy quotas (with and without trading certificates), renewable energy targeting, feed-in tariffs, research and development programs, tax credits, and low-cost loans. They influence each renewable energy technology differently (Nesta et al., 2014; Pitelis et al., 2020). Internalization of pollution cost by renewable energies should serve as a way to enjoy incentives from public policies (Liu et al., 2019). Most comprehensive renewable energy policies and instruments support innovations related to wind and solar energy (Hille et al., 2020). Financial incentives, obligatory schemes, quota and mandatory requirements enormously impact renewable energy application in a positive light (Bird et al., 2005; Menz & Vachon, 2006). Pitelis et al. (2020) argued again that, demand-pull policies can facilitate innovations in renewable energy technology as compared to other policy instruments. By analysing public policies on renewable energy among 29 countries over a 15-year period, Liu et al. (2019) identified grants and subsidies for renewable energy as a common policy adopted by all countries. The subsidies help to increase renewable energy output by reducing the cost of equipment and the production cost. Nevertheless, they found out that tax instruments do not encourage the development of renewable energies. In addition, the functions of the carbon markets of renewable energy are distorted by targeting (Moselle, 2011; Nordhaus, 2011).

In 2003, the Vietnam government adopted the 'Decree on Energy Conservation and Use' as part of its electricity laws. The promotion and use of renewable energies were part of this policy. The policy provided subsides for capital investment for renewable technologies, preferential tariffs for renewable energy products and loans (Khanh Toan et al., 2011). Furthermore, in March 2016, the Vision 7 National Power Development Plan policy was implemented to increase the share of non-hydro renewables (Mersmann et al., 2017). Its objective was to increase the power generation capacity of renewable energies by 12.5% by 2015 and 21% by 2030. The country plans to increase the share of renewable energy in primary energy to 32.3% and 32% in electricity production by 2030. The share of renewable energy in electricity production is at a shortfall; it has become less prominent as coal and gas are emerging. In 2016, the support systems for renewable energy such as biomass, wind, and solar have opened the country to private sector investment and the integration of these technologies at all planning levels within governance (Mersmann et al., 2017). To mention a few, the other policy measures that were implemented were the development of renewable energy projects in rural areas, the use of renewable energy sources for demonstration projects, and the encouragement of the local manufacture of renewable energy equipment (Full Advantage Co. Ltd. (Thailand), PITCO Private Limited (Pakistan), 2017). Tariffs were also adopted for solid waste, small hydro power, solar photovoltaic and biomass (Erdiwansyah et al., 2019). Renewable energies also enjoyed import tax exemptions and other incentives (Mersmann et al., 2017). Fossil fuel substitutes existed until 2020, when attention has now been shifted to the use of clean energy to help mitigate greenhouse gases. The removal of these subsidies is estimated to have only a little effect because the subsidies were predominantly for oil and gas, and this could cause a shift to the use of other alternative conventional fuels like coal or nuclear (Shem et al., 2019). Even without subsidies, renewable energy projects are economically less competitive compared to other

alternatives (Wang et al., 2012, 2013), conversely, a study in China identified that without subsidies, biogas projects are not profitable (Wang et al., 2016). Strong renewable energy policies prevail in Vietnam nevertheless, other approaches accompanied with specific renewable energy laws are yet to be considered (Shem et al., 2019). In the US, democratic representatives, nongovernmental organizations, and customers who patronize green innovations were identified to facilitate the transmission of policies in renewable energies (Delmas & Montes-Sancho, 2011). For a successful use of clean energy, Vietnam would have to develop an appropriate legal framework that encourages energy security, technological advancement, private, international and government cooperation (Danish Energy Agency, 2017). Vietnam has been successful in the creation of renewable energy polices but measuring its implementation and level of success is difficult.

2.5. Biogas Technology

The use of biogas has been largely supported by several governments and international organizations (Møller et al., 2004; Eriksson & Olsson, 2007; Roubík et al. 2017; Xue et al., 2020). Biogas reduces the dependency on fossil fuels and protects ecological resources (Gao et al., 2019). In China, it was estimated that biogas replaced tons of coal per year and positively contributed to energy security (Xue et al., 2020). The World Biogas Association has emphasized that, the efficiency of the biogas industry can help achieved 9 out of the 17 Sustainable Development Goals (Bartoli et al., 2019; Sarika et al., 2019). The technology has been wide spread in developing countries (Bond & Templeton, 2011), however, it has only been mostly used for lighting and cooking purposes (Deng et al., 2014). The technology has the potential to contribute enormously to Vietnam's animal waste management problems and offers additional global warming reduction, environmental and economic benefits (Thien Thu et al., 2012; Cu et al., 2015; Vu et al., 2015; Roubík et al., 2016), in addition, the potentials for biogas in the country is twice as high as its current generation (Roubík et al., 2018). Besides animal waste, human excreta can also be used to generate biogas (Mackie Jensen et al., 2008; Jewitt, 2011). The adoption of the technology is faced with bottlenecks such as technical and sociocultural problems (Walekhwa et al., 2009), high cost of installation and operation (Mittal et al., 2018), efficient supply of feedstock to digester (Lwiza et al., 2017) and transport of energy. In Cuba, farmers use a simple method to store and distribute biogas. The raw biogas is carried in big plastic bags to neighbours who need the gas, this method can be employed in Vietnam too. The amount of feedstock fed into a digester influences its operation (Kumar, 2012). In Ethiopia, it was identified that rapid adoption of technology is impeded by socioeconomic problems such as low purchasing power of resource-poor households, political insecurity and low level of education (Kamp & Bermúdez Forn, 2016).

2.6. Small scale biogas plants

There are more than 50 million micro digesters worldwide (Sarika et al., 2019), more than 100,000 domestic digesters have been installed in Vietnam (SNV and Fact, 2014). Economically, large-scale biogas digesters are feasible; nevertheless, it is the same for small-scale biogas digesters too; users do not face any significant opportunity cost in using the system (Wesseler, 2010). Small-scale biogas plants provide a comprehensive solution to environmental pollution, hygiene and health issues accruing from biodegradable waste, plays a big role in farming systems (Roubík et al., 2016), provides clean energy for cooking at house hold levels (Mwirigi et al., 2014; Abadi et al., 2017) and are advantageous over other forms of renewable energies (Zhang et al., 2013). Furthermore, they can help provide energy and maximize the use of scare resources for farmers in developing countries who are unable to afford the installation of large biogas plants due the cost of investment (Limmeechokchai & Chawana, 2007; Mwirigi et al., 2009). Anaerobic digesters have been in existence and used for more than 30 years in Vietnam (Anh, 2016). In Central Vietnam, not all farmers have adopted the technology because of financial barriers (Roubík et al., 2018). Some farmers use their own resources for the construction of the biogas plant (Roubík & Mazancová, 2016). The adoption of a small-scale biogas plant can be significantly affected by the age and level of literacy of the household head (Mottaleb & Rahut, 2019), number of farm animals owned, access to physical infrastructure and credit (Katuwal & Bohara, 2009; Mengistu et al., 2016; Lwiza et al., 2017). However besides considering some of the above factors , in Vietnam, farmers that use the biogas plant adopted it based on the perception that it was environmentally clean, money saving, provides gas for cooking and produces higher heat than wood (Roubík et al., 2018).

2.7. Biogas Policies

Policies in Europe shows how producing biogas from agricultural waste is a cost-effective way of reducing greenhouse emissions (Nguyen, 2007). However, some of these same policies focus only on total biogas production and thus, has divert to the use of energy crops as food, but rather for energy production (APEC, 2012). Specifically in Finland, energy policies and strategies were geared toward making bioenergy the future form of energy (Riku, 2017). Problems can prevail when there are no clear cuts between

the use of energy crops for food and energy generation, and biogas production could threaten food security (Kumar, 2012). By Germany revising its renewable energy policies over half a decade, it showed the possibility that it could lower its subsidy for biogas projects and abolish subsidy on energy crop for power generation (Gao et al., 2019). The policy framework must recognize the benefits of biogas and should tailor biogas to partner with food production systems rather than compete with them (IRENA, 2020). Advanced biofuels are those considered to have a lower effect on food resources and land use due to the use of waste materials, non-food, and non-feed biomass as feedstock for energy generation (Kumar, 2012; IRENA, 2019). By comparing two biogas policies (old and new policy) in Italy, Bartoli et al. (2019) identified that the new policy scheme helped decrease greenhouse gas emissions by promoting the utilization of agricultural waste for biogas production instead of using energy crops. New policies in Europe focusing on sustainability and renewable energy targets have now been fine-tuned to limit the amount of energy crops dedicated to bioenergy production; the concentration has been geared to only the use of agricultural waste and residues (Cherubini & Strømman, 2011; Scarlat et al., 2018).

Making better transfer from biogas policies around the world to Vietnam, within the document Decision no. 153/ 2004/QD-TTg of Vietnam, are policies aiming at environmental pollution, support for environmentally friendly technologies, and contributions to the United Nations 1992 Framework Convention on Climate change (Khanh Toan et al., 2011). Furthermore, since the 1990s, Vietnam has been part of several climate change negotiations and indirect policies aimed at energy and natural resources; conversely, it has only started to treat it with much specificity after the National Target Program to Respond to Climate Change policy was introduced in 2008 (Zink, 2013; Minister THEP, 2018b). The National Green growth strategy policy followed in 2012 with the aim of combing, energy, economic and climate policy to achieve a low carbon economy (The Prime Minister, 2012). The Green Growth Strategy forced the country to gradually reduce its subsidies attributed to fossil fuels (UNDP, 2012). It went ahead to also implement cap by introducing certification for greenhouse gas emissions and carbon tax (The Prime Minister, 2012). Furthermore, because among the South Eastern Asian countries, Vietnam is the country with the highest greenhouse gas emissions, consequently, being a member of the Paris Agreement in 2015, the government also has an objective to undertake the Nationally Determined Contribution (NDC) to help fight climate change and encourage the use of renewable energy (Danish Energy Agency, 2017; Nguyen et al., 2019; Shem et al., 2019). The Nationally Determined Contribution is to evaluate how climate change will potentially impact vulnerable sectors within the country and prioritize climate change adoption and mitigation actions between the years 2021 to 2030. It has a conditional and an unconditional element which covers several sectors but does not cover greenhouse gas emissions from the industry sector (Mersmann et al., 2017). Out of 197 countries, only 181 countries were committed to the Paris Agreement, including Vietnam. The policy aims at reducing greenhouse gas emissions by 8% by 2030 when compared to its Business as Usual (BAU) and also with the help from international bodies, reduce it further by 25% (Government of Vietnam, 2015). The strategies would focus on renewable energies and energy efficiency (Danish Energy Agency, 2017). Vietnam has implemented numerous policies for climate change mitigation, conversely Zimmer et al. (2015) argued that, they did more harm than good. They emphasized that, if not for a global call and externally forced regulation, Vietnam would have no incentives to engage in climate change policy because they only contribute a small share of the global greenhouse gas emissions. The country has a significant low-cost potential to reduce carbon emissions, yet they are unexploited (World Bank, 2011). (Shem et al., 2019) also emphasized that to achieve these targets and fulfil the agreements, Vietnam would have to have an external engagement with its international partners and internally focus on its policy reforms, implementation, and enforcements within the energy sector.

However, before some of these policies and agreements, the government had already implemented a biogas program that does not only help reduce greenhouse gas emissions through proper organic waste management but also helps to produce clean energy for households (SNV and Fact, 2014). Organic waste can be used for production of clean energy and has great potentials for sustainable development (IRENA, 2020). To promote biogas development, research and to increase the number of biogas plants, the Vietnamese Ministry of Natural Resources amended policies and plans that harmonized the animal husbandry sector with the entire economy (Wesseler, 2010). In 2003, the Vietnam government and SNV (Dutch Development Organization) implemented the National Biogas Program. In Central Vietnam, thousands of household biogas plants have been established through this program, the technology has now become affordable and suitable for small-scale farming (Thien Thu et al., 2012; Ghimire, 2013). Thousands of rural individuals from different provinces have been trained and benefited from this program (Ghimire, 2013). Wesseler (2010), is of the view that, the perfect biogas strategy is the SNV project. In contrast, that project is held high esteem by only few provinces within the country. The biogas program ended in 2020. Qu et al. (2013) elaborated that there can be a possible failure of biogas technology adoption when

governments halt their biogas programs. To encourage the adoption of new technologies in renewable energies is largely dependent on a governments ability to make them popular in the various communities (Tumusiime et al., 2019). Besides government, the media can play an important role with regards to information on energy policy and available opportunities to inspire different actors to participate in energy production and adoption of new energy technologies (Cox, 2010; Sengers et al., 2010; Nygrén et al., 2015). More vivid details about biogas technology were missing in most newspaper coverage, the technology was always presented as something novel. For instance, in Finland, national biogas polices where presented as unambitious by newspapers and therefore were not considered as salient energy source throughout the country (Lyytimäki, 2018). A review of the biogas program by Shem et al. (2019) revealed that, a successful biogas program can bring about, climatic, economic, food and health benefits to rural localities; the International Energy Agency (2020), made same remarks on the use of biogas. In China, policies have led to the increased in installation of biogas digesters across the country and are putting in more policies that would enable the biogas industry to upgrade to the production of biomethane for the transport sector (International Energy Agency, 2020).

2.8. Potential for biogas

Globally, there is an increasing potential for the use of bioenergy. Ten percent of the world's energy demand comes from bioenergy. The energy comes in a liquid, solid and gaseous state; the most used bioenergy is solid biomass (IRENA, 2020). However, in the development of sustainable electricity systems, bioenergy was second to solar (Ahmad & Tahar, 2014). The technology comes with several benefits. Biogas can be used to produce biomethane through upgrading and purification, and to produce biochemicals and bioplastics. (Sarika et al., 2019). Biogas and biomethane can lead to resource efficiency, build-up of circular economy and energy security benefits (IRENA, 2020). They can also serve as a revenue generating tool for economic development when it is connected to the international carbon market (Gu et al., 2016) and its by-products are sold (IRENA, 2020). By reviewing the biogas situation in developing and developed economies of several countries, Nevzorova & Kutcherov (2019), identified infrastructure as the major barrier affecting the biogas industry. Furthermore, IRENA (2019), also discovered that technical, economic, environmental, institutional, market access, and political issues were prevailing obstacles for biogas development; sociocultural barriers also existed (Qu et al., 2013).

Biogas has a great energy generation potential in Vietnam (Shem et al. 2019). Within the country, major impediment to the potentials of biogas adoption and promotion is the issue of cost, information flow (Wesseler, 2010; Bond & Templeton, 2011; Qu et al., 2013), and maintenance of biodigesters (IRENA, 2020). However, Wesseler (2010), identified that sociocultural constraints in biogas projects and programs in Vietnam are less prevalent. The barrier of cost is partially due to operation and the price on instruments. The two main factors that can help develop biogas potential are policy and technology advancement (Gao et al., 2019). Even though the technology has existed in Vietnam for more than three decades, there is only limited number of biogas plants constructed (Nguyen, 2011; Nguyễn Võ Châu Ngân et al., 2012; Roubík & Mazancová, 2016). Rich farmers are likely to neglect the use of biogas digesters because the opportunity cost for labour is higher for them, the technology is likely to be easily accepted by upper- and middle-income farmers (Fan et al., 2011; Wang et al., 2016). Agricultural households and people who own their own houses are likely to adopt the biogas technology, however, small holder farmers with less ha of lands are less likely to adopt it because they cannot produce enough waste to feed the biogas plant (Mottaleb & Rahut, 2019). Government and private sector partnership, community grants and subsidy programs, government-backed investment plans can help reduce some of the barriers associated with adoption of the technology (IRENA, 2020). There should be a biogas market that deals with biogas appliances and installation materials which can lead to the development of a local and international market niche within the country and eventually increase the number of biogas users (Wesseler, 2010). Installation of household biogas systems can be encouraged using economic instruments and there should be a biogas network and management offices across the country; it would help facilitate processes for farmers. Policy makers considers biogas more expensive when compared to fossil fuel. To create a level playing field between biogas and fossil fuels, fossil fuel subsidies must be removed (Sarika et al., 2019).

2.9. Biogas and Rural Development

Globally, 2.5 million people died from causes relating to the use of polluted cooking stove and 3 million deaths from outdoor air pollution in 2018 (IRENA, 2020). In India, indoor pollution has reduced productive life by 5% (Rohra & Taneja, 2016). The adoption of small-scale biogas plants by rural households reduces indoor air pollution (Abadi et al., 2017). It can help rural communities meet their energy needs as well as provide them with a sustainable and healthy life (Singh & Sooch, 2004). The provision of household biogas digesters is a good way to support rural development. The technology has been used to provide clean cooking for rural communities in Asia and Africa since the

1980s (IRENA, 2020). Biogas digester in rural areas can have positive economic benefits over their lifespan. In China, it was discovered that, rural households produce the largest amount of total biogas within the country (Gu et al., 2016). Conversely, in India, implemented biogas technology was unaffordable for a lot of rural households. This was due to the high cost of small-scale biogas plants and small number of livestock; a lot of them were also left out from the benefits of the new technology and government subsidies (Katuwal & Bohara, 2009). In Vietnam, there has been a major change in rural setting due to rapid urbanization and economic growth across the country and this has impacted on small-scale biogas production (Vu et al., 2015). Biogas systems in rural household's face labour constraints associated with large volumes of slurry and input water. However, this problem can be solved through the design of integrated biogas systems within the community (Tucho et al., 2016). Another constraint with the technology is reducing of building value, biogas systems can impact rural building prices. In United States of America, it was identified that rural buildings value declines as big biogas facilities gets closer and increases with small-scale biogas plants (Lee et al., 2017). Zemo et al. (2019), suggest that policy makers should consider compensations for rural houses close to large biogas plants since it can pose a threat their wellbeing.

3. Methodological approach

The survey relied on data collected from existing literature on renewable energies, biogas production in Vietnam, prospects for continuous biogas usage in Vietnam, and biogas experts involved in small-scale biogas developmental projects in Vietnam and Asia. A total of 12 experts from different countries who are actively involved in the field of renewable energy and biogas technology in Vietnam were successfully interviewed. Biogas experts from Vietnam's Ministry of Agriculture and Rural Development and National Agricultural Extension, Hue University of Agriculture and Forestry (Vietnam), Czech University of Life Sciences (Prague), Government College University (Faisalabad, Pakistan), Development Worldwide and Technische Universität Berlin-Department of Circular Economy and Recycling Technology (Germany) were snow balled due to the limited number of experts in this field. Background information on interviewed biogas experts is presented in Table 1. Descriptive data were analysed using nominal variables and a Likert scale. A five-point Likert scale ranging from very strong, strong, neutral, weak, and very weak was used to assess the level of awareness of renewable energy policies within Vietnam among respondents, their level of awareness of biogas policies within Vietnam, respondent's view on the level of conformity of biogas policies in Vietnam with other International Policies on Renewable Energy and how it promotes global biogas usage, respondent's organization's level of participation in biogas policy formulation and implementation within Vietnam, the level of cooperation between respondent's organization and other organizations tasked with biogas policies in Vietnam. Nominal variables were used to assess respondent's knowledge on organic waste management policies within Vietnam, knowledge on the number of implemented biogas programme by respondent's organization, level of support from Vietnam government to implemented biogas programmes by respondent's organization and issues presented by the beneficiaries of the implemented biogas projects to the respondent's organization. Qualitative data was analysed using policy cycle approach and comparison of gathered data to reviewed literature.

Table 1. List of interviewed respondents

Name of Organization	Type of Legal Entity	Number of representatives
Technische Universität Berlin	Higher Education Institution	Two
Vietnam National Agricultural Extension Centre	Ministry	One
Development Worldwide	Non-Governmental Organization	One
Czech University of Life Sciences, Prague.	Higher Education Institution	Four
Government College University Faisalabad	Higher Education Institution	One
Hue University of Agriculture and Forestry, Hue University, Vietnam.	Higher Education Institution	Two
Vietnam Ministry of Agriculture and Rural Development.	Ministry	One

3.1. Analytical Approach

The policy cycle or process is a tool that can be used to analyse the impact of policy (Milovanovitch, 2018). It examines each of the various stages involved in the drafting and implementation of a policy. This analytical approach was used to assess how small-scale biogas plants in Vietnam are affected by policy issues. Figure 1 demonstrates the six stages involved in policy implementation and how all the stages work as a whole to make decisions that eventually gives rise to biogas policy issues that may affect small-scale biogas industry of Vietnam.

Figure 1. Policy Cycle for Small-scale Biogas Plants

4. Results

From Table 2, the results show that, 16.7% of the respondents (experts) had a very strong level of awareness of renewable energy policies within Vietnam, 41.7% of them had a strong level of awareness, 25% were neutral, followed by 8.3% each for weak and very weak. The level of participation of the organizations interviewed in the formulation and implementation of renewable energy policies in Vietnam was strong, representing 41.7%, 25% were neutral, 16.7% were very weak, 8.3% for both very strong and weak. The respondents also had a strong level of awareness of biogas policies within Vietnam which represented 41.7%, 25% were neutral, 25% were very strong, 8.3% were very weak, and none were weak. 50% of the respondents were neutral on how the biogas policies within Vietnam were in accordance with existing international policies on renewable energy and its promotion to global biogas use, 41.7% had a strong opinion, while 8.3% disagreed with the statement. In addition, the organizations had a high level of participation in the formulation and implementation of biogas policies within Vietnam, representing 33.3% of the results, followed by 25% that were neutral, 16.7% that were very weak and weak, and 8.3% that was very strong. There was a strong level (41.7%) of corporation between the organizations interviewed and other organizations involved and tasked with biogas policies within Vietnam, 25% were weak, while 16.7% represented neutral and very strong. In addition to the above, 88.3% had heard about organic waste management policies in Vietnam, while 16.7% of them had not heard of such policies. A larger proportion of the respondents were aware of the small-scale biogas programs implemented by their organization, which stood at 91.7% while 8.3% were not. 58.3% of the respondents agreed to the statement that their organization received some form of support from the Vietnam government while conducting their biogas programs within the country, while 41.7% disagreed with the statement. There was also a neutral position on whether the beneficiaries of the implemented biogas programs confronted the implementing organization with problems related to biogas production and usage. The results, also presented in Table 2 showed that, 50% of the organizations were confronted with some form of biogas issues by benefactors while the other 50% were not. 66.6% of the organizations made changes to implemented biogas programs to address arising biogas issues, the rest did not. Most of the respondents, representing 41.7%, are of the view that the government and other stakeholders' response to arising biogas issues within Vietnam has not been sufficient, 33.3% were against this statement, while 25% did not have any strong opinion on this statement and therefore were neutral. Also, 66.6% were of the view that, the government of Vietnam together with other stakeholders have the sufficient capacity to enact policies and implement programs that would enable the continuous use of biogas (most especially small-scale biogas plants) within the country, 16.7% disagreed with statement and 16.7% of them were neutral to the statement.

Table 2. Descriptive Statistics on Implemented Small-Scale Biogas Programmes and Projects in Vietnam (N=12)

Statement	Response (%)		
	Yes	No	No strong opinion
Knowledge on organic waste management policies in Vietnam	88.3	16.7	0
Awareness of small-scale biogas projects and programmes implemented in Vietnam	91.7	8.3	0
Did implemented biogas projects and programmes implemented by your organization receive any form of support from the Vietnam government?	58.3	41.7	0
Did the beneficiaries of the biogas program(s) implemented in Vietnam confront your organization with issues related to biogas production and use?	50	50	0
Was your organization able to make changes in the implemented program that addresses arising biogas issues?	66.4	33.6	0
Has the government and other stakeholders' response to arising biogas policy issues within Vietnam been sufficient?	33.3	41.7	25
Do you think the government of Vietnam together with other stakeholders have the sufficient capacity to enact policies and implement programs that would enable the continuous use of biogas (most especially small-scale biogas plants) within the country?	66.6	16.7	16.7

4.1. Policy Analysis Using the Policy Cycle Approach

Public policies are course of actions instituted by governments, nevertheless, they must be in the best interest of citizens (Amosa, 2018). While policy analysis is the systematic evaluation of implemented policies to make way for improvements and new sound policies. Policy analysis erupted after the second world war to tackle water resource problems and improve health polices, however, in recent times, its wings has spread to several public sectors (Milovanovitch, 2018). Policy cycle or policy process follows up by assessing how a stakeholder or a change in power can influence the implementation of policies (Milovanovitch, 2018; Amosa, 2018). The process of the policy cycle approach cuts across five stages (Bardach & Patashnik, 2015; Milovanovitch, 2018; Amosa, 2018). For this study, the keen interest is an ex-post analysis of policies by focusing on stakeholders who are into small-scale biogas plants in Vietnam and thus only four stages of the cycle were focused on using Milovanovitch (2018) guide to policy analyses. The first to the third stage of the cycle would be elaborated in this chapter and the final stage would be elaborated in the prospects and recommendation subchapter of this study. The first process in the policy cycle or process approach is identifying the problem. As clarified extensively in the introduction and literature review, Vietnam's problem was organic waste from a vibrant livestock industry and energy inefficiencies. Vietnam is among the top countries that is into the production and consumption of livestock, most especially pigs. Pig production is among the 32 major greenhouse gas emission sources in Vietnam (Dao et al., 2020). The second step is collecting data and describing the evidence at had to identify a possible solution Milovanovitch, 2018; Amosa, 2018), thus, the Vietnamese government instituted the policy known as "The National Biogas Program" (Vietnam Biogas Program SNV World, n.d.) and other environmental protection and energy policies (Minh Do & Sharma, 2011; Minister THEP, 2018a). Besides the Vietnam National Biogas Program, Table 3 illustrates some key policy interventions by the government to help tackle this phenomenon. In conjunction, these policies have led to the promotion of energy supply, energy efficiency, renewable energy promotion and development, environmental protection, and climate change mitigation strategies. Elaborating more on policies on biogas, the Vietnam National biogas programme was established through a deliberate collaboration between the Netherlands Development Organization and Vietnam's Ministry of Agriculture to create a viable biogas market (SNV, 2014), and to provide households and farms the opportunity to manage their organic waste while generating biogas for cooking. The third stage is interpreting the outcomes using the evidence at hand. There was a solid confirmation that, interviewed stakeholders were aware of several renewable energy policies in Vietnam but the most dominant one was the Vietnam National Biogas Programme. The outcome of these policies had both positive and negative impacts. To begin with the positive side, policies focusing on renewable energies and biogas to be precise has really been beneficial to the people of Vietnam, respondents indicated also that most of these policies successfully achieved their stated goals. The results of this study showed that policies like the Vietnam National Biogas Program have sprouted interest in many international organizations with a focus on climate change and rural development to undertake several biogas projects in Vietnam; justifies the increasing role that international organizations play in the implementation of Vietnam's policies (Shem et al., 2019). Millions of small-scale biogas plants have been installed across the country by international organizations and non-governmental organizations (Dao et al., 2020). This has also increased the value chain of biogas in Vietnam and created jobs for masons around the country. Although the programme received several emission certificates and reached its goals (SNV, 2014), it also faced some setbacks. The study found out that, due to the problems with co-financing and feed-in-tariffs enjoyed by only a few, there was the rapid build-up of low-tech biogas plants within the small-scale biogas market of Vietnam. In addition, energy policies that reduced the price of conventional fuels made technologies such as biogas more expensive among people. These assertions confirm the arguments made by Nesta et al. (2014) and Pitelis et al. (2020) that, each policy instrument affects renewable energy differently. It further affirmed that low electricity prices and subsides on fossil fuels make renewable energy technologies less competitive (SNV, 2014).

From our results, it was clear that many biogas projects in Vietnam were unsuccessful without subsidies from the government and funding; this affirmed that, biogas projects were unprofitable without subsidies (Wang et al., 2016). In addition, some projects under the Vietnam National Biogas Program presented too ambitious outcomes to project beneficiaries, resulting in many setbacks in project participation in the following years. In addition to the Vietnam National Biogas Program, evidence from our results indicated that renewable energy policy programs have not been fully able to change the mindset of locals toward the transition to a circular economy. It further showed that several policies within Vietnam lacked regulations that checks for compliance with the law. This supports the arguments made by Wesseler (2010) that, environmental laws in Vietnam are not treated with much importance. From our results, the study is in the same point of view with Shem et al. (2019) on the unavailability of adequate baseline data for evaluating some implemented policies for further reform.

Table 3. Summary of Key Energy Policies in Vietnam

Policy	Summary
The National Energy Development Strategy	To increase the share of renewable energy to total energy supply to 11% by the year 2050
Vietnam Power Development Plant VII (PDP 7)	This is to supplement the Vietnam's National Energy Development Strategy to 2030 and outlook to 2045
Decree on Energy Conservation and Energy Use	Provided subsides for capital investment for renewable technologies, preferential tariffs for renewable energy products and loans
Environmental Protection Law	Protecting the environment while ensuring the use of clean energy
Green Growth Strategy	Focused on reducing climate Change
Vietnam National Biogas Programme	Focused on organic waste management, provide clean energy, and develop a viable biogas market
National Climate Change Strategy	Focused on climate change mitigation and adoption strategies
The Paris Agreement	Focused on climate change and renewable energies
Biomass Energy Development and Utilisation policy	Focused on renewable energies
Biofuel Blending Mandate	Focused on renewable energies and energy efficiency

4.2. Policy Coherence

Policy coherence is when policy instruments and other policy goals are in consistency with one another (Beck et al., 2009; Engel et al., 2013; Brooks, 2014). The analysis of policy coherence is to find out the inconsistency in implemented policies (Huttunen et al., 2014). A country's policy coherence can also be measured. King et al. (2012) identified that internal coherence, intragovernmental coherence, and intergovernmental coherence were the three main stages for measuring policy coherence among developed countries. When there is no coordination among policies, the sustainable transition of innovations is likely to result into a failure (Weber & Rohracher, 2012). For a successful transition of technologies such as biogas, policies that cut across several sectors are needed (Wilkinson, 2011; Lybæk et al., 2013). The study did not make any assessment of internal coherence; however, a slight assessment of external coherence was carried out. The study tried to infer from the respondents' point of view the level of coherence between the policies in Vietnam that promote biogas production and other international policies that promote the production and use of biogas. The results which can be found on Table 4 turned out to be neutral. Many of the respondents had not come across some of ISO's standards on biogas production and use. The interview revealed that half of the interviewees were also not exposed to other international policies on biogas. The International Organization for Standardization has developed several international standards on biogas such as 'ISO 20675: 2018' which provides guidelines that facilitate international trade on biogas installation and cooperation, helps to reduce technical barriers and contributes to the development of regional and national regulations on biogas production and application. It is very prudent for biogas experts in Vietnam to be frequently abreast with such international standards to help in the rapid development of the technology.

Table 4. Descriptive Statistics on Renewable Energy Policies in Vietnam (N=12)

Statement	Level of Response (%)				
	Very Strong	Strong	Neutral	Weak	Very Weak
Level of awareness on renewable energy policies in Vietnam	16.7	41.7	25	8.3	8.3
Level of participation in renewable energy policies formulation and implementation in Vietnam	8.3	41.7	25	8.3	16.7
Level of awareness on biogas policies in Vietnam	25	41.7	25	0	8.3
Level of conformity of biogas polices in Vietnam with existing international laws and its promotion to global biogas usage	0	41.7	50	8.3	0
Level of participation in biogas policy formulation and implementation within Vietnam	8.3	33.3	25	16.7	16.7
Level of cooperation between the organization and other organizations tasked with biogas policies within Vietnam	16.7	41.7	16.7	25	0

4.3. Biogas Value Chain in Vietnam

The biogas sector in Vietnam is partially market based, many masons can offer their building biogas digesters in the open market. The technology has also opened doors for rapid investment in the country. According to a report from the International Biogas Workshop on Small and Medium Scale Biogas on November 2013 in Hanoi, the Asian development bank has signed a financial support agreement with Vietnam to implement programmes focusing on project management, credit for biogas value chain, technology transfer in agricultural waste management practices and livestock waste management (SNV, 2014). More laws and new policies must be developed to further develop the

biogas value chain of Vietnam. Although the government of Vietnam longs for a public-private sector partnership within the biogas sector, it has mixed reactions on how to go about it due to its less experience in such partnerships. The lack of public private partnership has also been linked to policy development and conflict of interest (SNV, 2014). However, to be attractive to international investors, biogas markets must be fully developed. For this market development to take place, there must be an identification of the type biogas plants that would be suitable for the market (small, medium, large and industrial scale), the availability of experienced construction and maintenance teams, potentials for private sector investment, access to digester inputs and finally biogas demand and supply mechanisms (Wesseler, 2010). There is still less awareness on opportunities offered by the technology and access to information on biogas technology within the Vietnam biogas market, it is yet to reach its maximum point. Government must ensure that, its policies promote good economic and environmental outcomes.

5. Discussion

The most common renewable energy policy known by interviewed experts was the Vietnam National Biogas Programme. Others had also heard of the Master Plan to increase renewable energy in Vietnam, the Vietnam Power Development Plant VII (PDP 7), the Green Growth Action Plan and Decision number 2068/Q-TTg by the Vietnam Government in 2015, it was about the strategy for renewable development in Vietnam from 2030 to 2050. The results also indicated that the respondents were aware of waste management policies in Vietnam that forced farms, especially larger ones, to treat their wastewater, however, there was no obligation for them to use it for biogas production. Vietnam's Ministry of Agriculture and Rural Development also stated that, in relation to organic waste management policies, since 1994, the Ministry of Natural Resources and Environment has passed several environmental protection laws with sub sections that focuses on organic waste management within the country. Biogas experts from Hue University of Agriculture and Forestry of Vietnam also declared decree number 38/15 and direction number 41/CT/TTg by the government as one of the policy strategies that promotes organic waste management. In the quest to contribute to renewable energy usage and biogas policies in Vietnam, the Technische Universität of Berlin (Department of Circular Economy and Recycling Technology) together with Herbst Umwelt Technik GmbH (department of environmental engineering) undertook several biogas projects in Vietnam. Since 2016, they have launch three biogas projects in Vietnam which included the BioRist Project (2016-2019), it focused on a technological process for producing biogas from rice straw. Between the years 2017 and 2018, they launched another project known as the UKAVita project. The project was carried out in Mekong Delta to help assess the problems of mid and small-scale biogas plants and find possible solutions. The PICO Absorber project (2019-2021) was also presented to them for the development of an external filter for small-scale biogas plants in Vietnam that removes Hydrogen sulphide (H_2S) from the biogas produced. They contributed to biogas policies by organizing stakeholder workshops on how to improve biogas technology in Vietnam and cooperating with GIZ Vietnam on how to promote the share of biomass energy in Vietnam. Vietnam's Ministry of Agriculture and Rural Development had contributed enormously to biogas policies in Vietnam by coordinating and managing the activities of the Vietnam National Biogas Programme. Hue University of Agriculture and Forestry also contributed to biogas policies in Vietnam by undertaking several researches for policy development in Vietnam. In Hue province, biogas experts from the Czech University of Life Sciences Prague, in collaboration with Czech Development Cooperation, have installed 700 small-scale biogas plants and have provided capacity building for more than 800 small-scale biogas users within the province; since 2010, they have also organized other technological projects, supplementary workshops and projects that were in coherence with the Vietnam National Biogas Programme. They continued to contribute to biogas usage and biogas policies in Vietnam by undertaking several scientific researches on biogas technology for the local authorities, publications and partaking in national biogas projects. The results also showed that the National Agricultural Extension Centre of Vietnam contributes its quota by using the results of increased production through farmer deployment. To propose policies that encourage the use of biogas while reducing environmental pollution, they also organized biogas projects, forums, and seminars. Non-governmental organizations such as Development Worldwide also undertook renewable energy projects which included biogas development projects within the rural areas of the Thua Thien Province from the year 2011 to 2013. Some of the key things that the institutions considered while drafting their biogas projects and programs were the economic situation of the target area, the number of beneficiaries and the size of the household, the sources of energy, the prices of other conventional fuels, the number of small-scale biogas plants within the country and how best to improve their efficiency, environmental pollution and organic waste management, the availability of feedstock, the number of farm animals, the demand for digestate, awareness and education on green energy, expert advice on biogas from within and outside Vietnam, funding and donor request based on the Vietnam

National Biogas Programme, and many more. While implementing these projects and programmes, the institutions received supports such as, project funding and co-financing, research allowance, agricultural maps, agreements with local authorities, facilitation of project implementation, sensitization and mobilization within target area, networking, and information support from the government of Vietnam. In the process of implementing these projects and programmes, the institutions were also faced with some obstacles. Some of the institutions faced problems in getting grants for follow up projects after successful pilot projects. Obtaining baseline data for the implementation of new and subsequent projects was also difficult since most of the respondents within the targeted area were unwilling to be interviewed and some of the developed biogas models were unsuccessful. Biogas experts from Technische Universität Berlin who were working on rice straw for biogas production indicated that, the current policy framework within Vietnam makes rice straw biogas plants economically inviable and thus made project implementation difficult. Furthermore, one major problem that most of the biogas experts interviewed brought up was the mindset of the people. Because change occurs gradually and due to lack of sufficient awareness, most of the natives of targeted areas found it difficult to understand why they are to use manure for cooking. Another problem identified by these biogas experts that they considered to be one of the salient factors reducing the wide acceptance and use of small-scale biogas plants in Vietnam was low electricity prices, which hindered the economic viability of small-scale biogas plants. Additionally, there were problems with sustainability and project ownership, the people relied only on donor subsidies and were not interested in investing in their own development and maintenance of the technology. The beneficiaries of these projects and programs also confronted the implementing institutions with some important issues on technical difficulties with operation and management of the biogas plants, problems with financing of own biogas plants, and low project output and outcomes than they expected. After being confronted with these issues, most of the implementing institutions made some adjustments to their projects. Development Worldwide, improvised into its project the supply of pigs to its targets when they recognized that most of the local household did not have enough pigs to produce enough manure to make their small-scale biogas plants function efficiently. Czech University of Life Sciences Prague in collaboration with the Czech Development Agency also asked its beneficiaries for less co-financing of their small-scale biogas projects, and this made more of its beneficiaries, most especially rural farmers to have access to small-scale biogas plants compared to the Vietnam National Biogas Programme. In addition to the above, the Vietnam National Agricultural Extension Centre increased training and awareness for farmers and small-scale biogas users to enable them solve issues related to technical difficulties, and proper handling and maintenance issues presented to them during project implementation. The results also indicated that all the biogas expectants interviewed in this survey are of the view that the use and sustainability of small-scale biogas plants in Vietnam is largely dependent on viable policies. They emphasised that policies that focus on regular safety checks of small-scale biogas plants can help weed out low-tech biogas plants that create a bad impression on the entire biogas sector of Vietnam. In addition, they indicated that if implemented policies create programs that create awareness and simultaneously make organic waste treatment mandatory to farmers through appropriate regulatory checks backed by law, it can lead to the increased use and sustainability of biogas technology and renewable energy within the country. They were also of the view that, policies like the Vietnam National Biogas Program played a big role in the use of small-scale biogas plants and more of such policies should be encourage. Finally, the results showed that, the factors hindering the continuous development of the small-scale biogas sector in Vietnam through policy development, amendment and implementation were, the influx of low-tech small-scale biogas plants, a shift from small-scale animal husbandry to large-scale may lead to the possible implementation of policies that would encourage mid and large-scale biogas production rather than small-scale (the government may use this to increase feed-in tariffs for business generating their own electricity from biogas), lack of cross-sectional cooperation, policies on cost of conventional fuels, emission trading policies limiting the potentials of renewable energy use, husbandry diseases such as the African swine flu has caused lots of local households to keep few pigs or no pigs at all and thus the use of small-scale biogas plants by such households becomes irrelevant, non-enforcement of the law in terms of waste manage regulations, lack of transparency, economic, social and technical barriers.

By connecting each of the steps in the analytical process (Milovanovitch, 2018) to create a meaningful narrative, the analytical approach has provided the evidence that, biogas has only been a successful renewable energy technology in Vietnam through no other means other than policy implementation. The analytical approach also provided evidence which corresponded to findings on biogas from other researchers within the region of study. The first stage of the policy cycle analysis helped to identify the stakeholders involved in biogas policy formulation and implementation in Vietnam. Although stakeholders from big government institutions such as Vietnam's Ministry of Agriculture

and Rural Development, Vietnam's National Agricultural Extension Centre, and other local and international institutions play an active role in the formulation and implementation of biogas policies, there was no evidence that beneficiaries of small-scale biogas plants, especially those from rural communities, are actively involved in the decision process. Besides the government of Vietnam, the stakeholder with the highest stake in small-scale biogas policy implementation for rapid technological transition was SNV. The second stage of the analytical approach provided evidence on the how the identified stakeholders formulated and implemented programmes and projects to address the problem identification of the first stage of the policy cycle. Although the identified problem at the first stage of the analysis was organic waste management and energy inefficiencies, a much broader picture was to reduce the impact of climate change. Thus, several policies on climate change mitigation and adaptation were instituted before the inception of biogas policies like the Vietnam National Biogas Programme. Some of these policies are the Environmental Protection Law, Green Growth Strategy, National Climate Change Strategy, and the Paris Agreement which can be found at Table 3. In addition to hydropower, several of these policies have been formulated to implement projects and programs that facilitate the use of renewable energies such as biogas. Examples of such policies are the National Energy Development Strategy and the National Master Plan for Power Development, which aims to increase the output of renewable energies to total energy supply and reduce the use of fossil fuels. Linking the above with the second specific objective of this study proves that most implemented small-scale biogas programs and projects were not formulated to only supply rural households with energy and organic waste treatment strategies, but rather to tackle climate change as a global pressing need.

The International Organization for Standardization defines conformity assessment as the ability to meet the specific requirements to produce a particular product. Even though one of the policy issues faced by Vietnam is the infiltration of low-tech biogas plants, from my point of view, Vietnam meets the conformity assessment of International Organization for Standardization for production of biogas under anaerobic digestion. Over the past decades, they have successfully installed thousands of small-scale biogas plants, nevertheless, they are not yet technologically advanced to upgrade biogas to biomethane. Also, in other countries where bioenergy is in competition with arable lands for food production to produce energy, such conflicts did not exist in Vietnam as most digesters are fed with animal waste. In contrast, the locals are now discovering the potential use of residues for biogas generation instead of solely relying on animal waste. Further interpretation of the findings revealed that a major issue that can affect small-scale biogas plants in the future is their potential viability when medium- and large-scale biogas plants become more dominant. The government of Vietnam and other major stakeholders such as large international organizations can provide massive financial and technical support through policy amendments to large industries and companies that are ready to make a change from the use of fossil fuels to biogas. This is because such companies produce the highest quota to carbon dioxide emissions. As the policy cycle has previously revealed climate change as the ultimate motive behind biogas policies in Vietnam, more attention would be paid to the highest contributors to carbon dioxide emissions rather than the low contributors, and this puts the viability of small-scale biogas plants at a disadvantage. Policies that solely promotes support for medium and large-scale biogas installations will lead to the gradual fade out small-scale biogas plants. In addition, a policy instrument like taxation and subsidies can pose as a serious policy issue for small-scale biogas plants in Vietnam. Tax instruments discourage the development of renewable energies (Liu et al., 2019; Shem et al., 2019), while subsidies for fossil fuels make renewable energies such as biogas more expensive (Sarika et al., 2019; Wang et al., 2016). Subsidies often coming as a form of government support is a major element that ensures the financial stability of small-scale biogas plants. There are no coherences between these policy instruments when comparing fossil fuels to renewable energies. To make biogas more attractive than fossil fuels, more government grants and subsidies should be placed on renewable energies, while higher taxes should be imposed on the use of fossil fuels. This would increase the value chain for biogas production within the country and will also create incentives for more international cooperation and rapid adoption of the technology. The Vietnam biogas value chain can be more viable and profitable if more attention is paid to the small-scale biogas industry by creating favourable policies that protects infant biogas companies from large-scale giant biogas companies. This is because Vietnam is a lower middle-income country and thus majority of the population cannot afford the services of medium-large scale biogas companies.

5.1. Prospects and Recommendation

New policies are hardly developed, nevertheless, they rather erupt from existing policies through policy analysis and reformation of policy instruments to better suit new policy goals (Kern & Howlett, 2009). The final stage of the policy cycle approach is to formulate recommendations based on the findings. Policy recommendation helps to suggestion alternatives for decision makers and serves as a template for policy decisions (Milovanovitch, 2018). As the livestock

industry in Vietnam is changing from a small-scale industry to a large-scale industry, the biogas industry is also gradually changing from small-scale to industrial production. There should be policy support for the small-scale biogas industry of Vietnam to prevent it from fading out when the shift gradually reaches its peak. Also, since Vietnam's biogas industry is partially market-based, the government must develop policies that would protect the small-scale biogas industry from the penetration of inferior biogas technologies. Besides achieving the theory of change, small-scale biogas projects in Vietnam should aim at transforming beneficiaries to invest in their own sustainable livelihood rather than being reliant. New policies on renewable energy should categorically state the share of specific renewable energy to be developed. Its projects and programs should also state the goals for each renewable energy in achieving the sustainable development goal of affordable and clean energy, and how it would address climate change. Renewable energy policies should not focus solely on energy production; however, renewable energy policies and environmental protection policies should have harmonised rules and regulations that aim at reducing climate change. Policy makers should enact similar standards and principles when drafting small-scale to large-scale biogas projects and programmes. Due to the resource requirements in achieving some policy goals, policy makers should be wary not to substitute policies that require higher government expenditure to those that can easily be undertaken by the private sector. An instance could be policies focusing on small-scale biogas plants for rural development being substituted for partnership projects in the private sector for medium to large-scale biogas plants due to government trying to cut off expenditure. Both programmes and projects should be treated with equal priority.

Furthermore, small-scale biogas users, especially those who benefit from biogas programs and projects through policy implementation, should invest more in the maintenance of their plants to ensure its sustainability. The practice of maintenance culture for small-scale biogas plants provides an assurance for investment security. In the long run, such investments will ensure the continuity of technology among small-holder farmers and households and help project goals and objectives to reach full capacity. At the national and regional levels, attention should be paid to knowledge transfer and raising awareness on available benefits of biogas production and usage, especially as the current biogas market is still immature. People will be willing to invest more in the technology when they are aware that in addition to the use of biogas for heating, cooking, and electrification, biogas can also help them to have a fair and stable climate for agricultural production through mitigation and adaptation of climate change. To add to this, since Vietnam is a developing country with lower middle income, making biogas technology popular at the local level is very important for the rapid diffusion and sustainability of the technology. As a national strategy, the government can help majority of the households to upgrade their sewage systems in small-scale biogas plants. The government can draft policies that may require commercial farms to install biogas systems as their waste treatment plants. In addition, in Vietnam, most small-scale biogas plant users are reliant solely on animal manure, as new technologies in biogas production are emerging, there is a need for massive education on the use of other forms of input such as agricultural residue. This can help those with low feed-in stock to meet their average input requirements for their digester. Globally, through the sustainable development goals, every country is aiming at producing affordable and clean energy by 2030. This has placed a higher value on primitive technologies like biogas within the energy sector. Vietnam must take advantage of this opportunity by expanding its biogas value chain through technological advancement, market expansion, research, international corporations, and private sector partnerships. Finally, except for projects and programs under the Vietnam National Biogas Program, there is the need to assess the effectiveness of other specific biogas programs implemented in Vietnam; this can be the basis for further study.

6. Conclusion

Climate change stands as the major element driving the diffusion of biogas technology in Vietnam. However, the infiltration of low-tech biogas plants could discourage people from using the technology if the benefit cost ratio for the installation of the plant does not look reasonable after a short life span. Relevant policies such as the National Biogas Program, the Vietnam Power Development Plant VII (PDP 7), the Green Growth Action Plan, and the government's decree on organic waste management created positive impact by increasing the number of small-scale biogas plants installed in the country. As a form of protection for the small-scale biogas industry, government policies should state its quota of contribution to small-scale biogas industry development when compared to the medium-large scale biogas industry. A higher percentage of government support through policy amendments should be given to the small-scale biogas industry because the technology provides support for smallholder farmers in rural communities who are contributing actively in the quest to feeding the universe by 2050 when global population is expected to increase. International bodies outside Vietnam have contributed enormously to the use of small-scale biogas plants within the country through the implementation of several projects over the past decade. There should be more policies that makes

international cooperation with the local government more favourable. Funding remains the biggest barrier to biogas policy amendments and implementation. The several biogas programs implemented over the past years could have yielded more positive impact if financial barriers like co-financing by the beneficiaries did not exist. Finally, there should be a system that monitors implemented policies and evaluates the effectiveness of implemented biogas programmes to enable the proposal of new realistic polices.

References

Abadi N., Gebrehiwot K., Techane A & Nerea H., 2017, Links between biogas technology adoption and health status of households in rural Tigray, Northern Ethiopia. Energy Policy 101: 284–292. Elsevier.

Ahmad S. & Tahar RM., 2014, Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. Renewable Energy 63: 458–466. Elsevier Ltd.

Amosa M.D.U., 2018, Policy Analysis and Engagement Toolkit. A guide for Pacific Non-government Organizations in the Fisheries Sector. World Wildlife Fund. Suva, Fiji.

Anh H., 2016, Feasibility assessment of anaerobic digestion technologies for household wastes in Vietnam. J. Viet. Env. **7**:1–8.

ASEAN Centre for Energy, 2015, The 4th ASEAN Energy Outlook 2013-2035. The ASEAN Centre for Energy, p. 10–27.

Asia Pacific Economic Cooperation (APEC), 2012, Peer Review on Energy Efficiency in Indonesia. Asia-Pacific Economic Cooperation Energy Working Group report.

Asia Pacific Economic Coorperation (APEC). 2013. APEC Energy Demand and Supply Outlook 5th Edition-Economic Reviews. Page Asia Pacific Energy Research Centre.

Asian Development Bank, 2016, Viet Nam: Energy Sector Assessment, Strategy, and Road Map December 2015.

Bardach E. & Patashnik E.M., 2015, Practical Guide for Policy Analysis: The Eightfold Path to More Effective Problem Solving (Fifth Edition). CQ Press. ISBN-10: 1483359468

Bartoli A., Hamelin L., Rozakis S., Borzęcka M. & Brandão M., 2019, Coupling economic and GHG emission accounting models to evaluate the sustainability of biogas policies. Renewable and Sustainable Energy Reviews 106: 133–148. Elsevier Ltd.

Beck S., Kuhlicke C. & Gorg C., 2009, Climate policy integration, coherence, and governance in Germany. Page Helmholtz Zentrum Für Umweltforschung, UFZ- ….

Bird L., Bolinger M., Gagliano T., Wiser R., Brown M. & Parsons B., 2005, Policies and market factors driving wind power development in the United States. Energy Policy 33: 1397–1407.

Bond T. & Templeton M.R., 2011, History and future of domestic biogas plants in the developing world. Energy for Sustainable Development 15: 347–354. International Energy Initiative.

Brooks J., 2014, Policy coherence and food security: The effects of OECD countries' agricultural policies. Food Policy 44: 88–94. Elsevier Ltd.

Chang Y., Fang Z. & Li Y., 2016, Renewable energy policies in promoting financing and investment among the East Asia Summit countries: Quantitative assessment and policy implications. Energy Policy 95: 427–436. Elsevier.

Cherubini F. & Strømman A.H., 2011, Life cycle assessment of bioenergy systems: State of the art and future challenges. Bioresource Technology 102: 437–451. Elsevier Ltd.

Cox R., 2010, Environmental and the Public Sphere 2nd ed. The University of North Carolina at Chapel Hill. ISBN 978-1-4129-7211-6.

Cu T.T.T., Nguyen T.X., Triolo J.M., Pedersen L., Le V.D., Le P.D. & Sommer S.G., 2015, Biogas production from Vietnamese animal manure, plant residues and organic waste: Influence of biomass composition on methane yield. Asian-Australasian Journal of Animal Sciences 28: 280–289.

Danish Energy Agency, 2017, Vietnam Energy Outlook.

Dao K.M., Yabar H. & Mizunoya T., 2020, Unlocking the energy recovery potential from sustainable management of bio-resources based on GIS analysis: Case study in Hanoi, Vietnam. Resources 9: 1–24.

Decision 1208/QD-TTg, 2011, Decision Approval of The National Master Plan for Power Development of the 2011 – 2020 Period with the Vision to 2030. The Vietnamese Priminister, p. 1–14.

Delmas M.A. & Montes-Sancho M.J., 2011, U.S. state policies for renewable energy: Context and effectiveness. Energy Policy 39: 2273–2288. Elsevier.

Deng Y., Xu J., Liu Y. & Mancl K., 2014, Biogas as a sustainable energy source in China: Regional development strategy application and decision making. Renewable and Sustainable Energy Reviews 35: 94–303. Elsevier.

Dinh TX, 2016, An Overview of Agricultural Pollution in Vietnam: The Livestock Sector. The World Bank, p. 1–79.

Duc Luong N., 2015, A critical review on Energy Efficiency and Conservation policies and programs in Vietnam. Renewable and Sustainable Energy Reviews 52: 623–634. Elsevier Ltd.

Economic Consulting Associates, 2016, Made in Vietnam Energy Plan.

Engel P., Lein B., Van Helden B. & Van Seters J., 2013, European Centre for Development Policy Management EU Policy Coherence for Food Security Aligning parallel agendas. (ECDPM Discussion Paper 153), ECDPM, Maastricht.

Erdiwansyah, Mamat R., Sani M.S.M. & Sudhakar K., 2019, Renewable energy in Southeast Asia: Policies and recommendations. Science of the Total Environment 670: 1095–1102. Elsevier B.V.

Eriksson P. & Olsson M., 2007, The Potential of Biogas as Vehicle Fuel in Europe – A Technological Innovation Systems Analysis of the Emerging Bio-Methane Technology. Chalmers University of Technology, Göteborg, Sweden. Report No. 2007:6, ISSN: 1404-8167.

Fan Jie, Liang Yu-tian, Tao An-jun, Sheng Ke-rong, Ma Hai-Long, Xu Yong, Wang Chuan-Sheng & Sun Wei, 2011, Energy policies for sustainable livelihoods and sustainable development of poor areas in China. Energy Policy 39: 1200–1212. Elsevier.

Full Advantage Co. Ltd (Thailand), PITCO Private Limited (Pakistan), 2017, Policy review and recommendations on the promotion of renewable energy and energy efficiency in industries in Pakistan, vol. 2. Energy Efficiency Policy (Final Report), 123 pp.

Gao M., Wang D., Wang Y., Wang X. & Feng Y., 2019, Opportunities and Challenges for Biogas Development: a Review in 2013–2018. Current Pollution Reports. DOI: 10.1007/s40726-019-00106-7

Ghimire P.C., 2013, SNV supported domestic biogas programmes in Asia and Africa. Renewable Energy 49: 90–94. Pergamon. Available from https://www.sciencedirect.com/science/article/pii/S0960148112000699 [Accessed March 17, 2020].

Gould T, et al., 2017, Southeast Asia Energy Outlook 2017 – World Energy Outlook Special Report. International Energy Agency.

Government of Vietnam, 2015, Intended Nationally Determined Contribution of Viet Nam, Submission to UNFCCC, 11 pp.

Gu L., Zhang Y.X., Wang J.Z., Chen G. & Battye H., 2016, Where is the future of China's biogas? Review, forecast, and policy implications. Petroleum Science 13: 604–624.

Hille E., Althammer W. & Diederich H., 2020, Environmental regulation and innovation in renewable energy technologies: Does the policy instrument matter? Technological Forecasting and Social Change 153: 119921. Elsevier.

Hu H., Xie N., Fang D. & Zhang X., 2018, The role of renewable energy consumption and commercial services trade in carbon dioxide reduction: Evidence from 25 developing countries. Applied Energy 211: 1229–1244. Elsevier.

Huttunen S., Kivimaa P. & Virkamäki V., 2014, The need for policy coherence to trigger a transition to biogas production. Environmental Innovation and Societal Transitions 12: 14–30. Elsevier B.V.

International Energy Agency, 2020, Outlook for biogas and biomethane: Prospects for organic growth. IEA, Paris. https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth

IRENA, 2018, Renewable Energy Market Analysis: Southeast Asia. IRENA, Abu Dhabi. ISBN: 978-92-9260-056-3

International Renewable Energy Agency, 2019, Advanced biofuels. What holds them back? IRENA, Abu Dhabi. ISBN: 978-92-9260-158-4

Jewitt S., 2011, Poo gurus? Researching the threats and opportunities presented by human waste. Applied Geography 31: 761–769. Elsevier.

Kamp L.M. & Bermúdez Forn E., 2016, Ethiopia's emerging domestic biogas sector: Current status, bottlenecks and drivers. Renewable and Sustainable Energy Reviews 60: 475–488. Elsevier.

Katuwal H. & Bohara A.K., 2009, Biogas: A promising renewable technology and its impact on rural households in Nepal. Renewable and Sustainable Energy Reviews 13: 2668–2674.

Kern F. & Howlett M., 2009, Implementing transition management as policy reforms: A case study of the Dutch energy sector. Policy Sciences 42: 391–408.

Khanh Toan P., Minh Bao N. & Ha Dieu N., 2011, Energy supply, demand, and policy in Viet Nam, with future projections. Energy Policy 39: 6814–6826. Elsevier.

King M., Keijzer N., Spierings E. & Matthews A., 2012, Measuring Policy Coherence for Development Final Report. European Center for Development Policy Management.

Kumar S., 2012, Biogas. IntechOpen. https://doi.org/10.5772/1793

Lee G.E., Loveridge S. & Joshi S., 2017, Local acceptance and heterogeneous externalities of biorefineries. Energy Economics 67: 328–336.

Limmeechokchai B. & Chawana S., 2007, Sustainable energy development strategies in the rural Thailand: The case of the improved cooking stove and the small biogas digester. Renewable and Sustainable Energy Reviews 11: 818–837.

Lindman Å. & Söderholm P., 2016, Wind energy and green economy in Europe: Measuring policy-induced innovation using patent data. Applied Energy 179: 1351–1359. Elsevier Ltd.

Liu W., Zhang X. & Feng S., 2019, Does renewable energy policy work? Evidence from a panel data analysis. Renewable Energy 135: 635–642. Elsevier Ltd.

Lwiza F., Mugisha J., Walekhwa P.N., Smith J. & Balana B., 2017, Dis-adoption of Household Biogas technologies in

Central Uganda. Energy for Sustainable Development 37: 124–132. International Energy Initiative.

Lybæk R., Christensen T.B. & Kjær T., 2013, Governing innovation for sustainable development in the danish biogas sector – a historical overview and analysis of innovation. Sustainable Development 21: 171–182.

Lyytimäki J., 2018, Renewable energy in the news: Environmental, economic, policy and technology discussion of biogas. Sustainable Production and Consumption 15: 65–73. Elsevier B.V.

Mackie Jensen P.K., Phuc P.D., Knudsen L.G., Dalsgaard A. & Konradsen F., 2008, Hygiene versus fertiliser: The use of human excreta in agriculture – A Vietnamese example. International Journal of Hygiene and Environmental Health 211: 432–439.

Mengistu M.G., Simane B., Eshete G. & Workneh T.S., 2016, Factors affecting households' decisions in biogas technology adoption, the case of Ofla and Mecha Districts, northern Ethiopia. Renewable Energy 93: 215–227. Elsevier Ltd.

Menz F.C. & Vachon S., 2006, The effectiveness of different policy regimes for promoting wind power: Experiences from the states. Energy Policy 34: 1786–1796.

Mersmann F., Wehnert T., Andreeva T., Wuppertal Institute for Climate Environment and Energy, in cooperation with Fekete H. & Luna L., New Climate Institute, Cologne and Streitferdt V., Synergy Efficiency Solutions, Jakarta, 2017, Implementation of Nationally Determined Contributions. Indonesia Country Report.

Milovanovitch M., 2018, Guide to Policy Analysis. European Trading Foundation. DOI: 10.2816/60610

Minh Do T. & Sharma D., 2011, Vietnam's energy sector: A review of current energy policies and strategies. Energy Policy 39: 5770–5777. Elsevier.

Minister THEP, 2018a, Decision No. 79 / 2006 / QD-TTg of April 14, 2006, approving the national target program on economical and efficient use of energy. Ngoại tuyến DECIDES: Ngoại tuyến, p. 2–8.

Minister THEP, 2018b, Decision No. 158 / 2008 / QD-TTg of December 2, 2008, approving the national target program on response to climate change. Ngoại tuyến, p. 2–14.

Mittal S., Ahlgren E.O. & Shukla P.R., 2018, Barriers to biogas dissemination in India: A review. Energy Policy 112: 361–370.

Møller H.B., Sommer S.G. & Ahring B.K., 2004, Methane productivity of manure, straw and solid fractions of manure. Biomass and Bioenergy 26: 485–495.

Moselle B., 2011, Climate Change Policy – Time for Plan B.

Mottaleb K.A. & Rahut D.B., 2019, Biogas adoption and elucidating its impacts in India: Implications for policy. Biomass and Bioenergy 123: 166–174. Elsevier Ltd.

Mwirigi J., Balana B.B., Mugisha J., Walekhwa P., Melamu R., Nakami S. & Makenzi P., 2014, Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan Africa: A review. Biomass and Bioenergy 70: 17–25. Elsevier Ltd.

Mwirigi J.W., Makenzi P.M. & Ochola W.O., 2009, Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya. Energy for Sustainable Development 13: 106–115. International Energy Initiative.

Nesta L., Vona F. & Nicolli F., 2014, Environmental policies, competition and innovation in renewable energy. Journal of Environmental Economics and Management 67: 396–411. Elsevier.

Nevzorova T. & Kutcherov V., 2019, Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. Energy Strategy Reviews 26: 100414. Elsevier Ltd.

Nga N.T.D., Ninh H.N., Hung P. Van & Lapar M.L., 2014, Smallholder pig value chain development in Vietnam: Situation analysis and trends. International Livestock Research Institute.

Nguyen K.Q., 2007, Wind energy in Vietnam: Resource assessment, development status and future implications. Energy Policy 35: 1405–1413.

Nguyen P.A., Abbott M. & Nguyen T.L.T., 2019, The development and cost of renewable energy resources in Vietnam. Utilities Policy 57: 59–66. Elsevier.

Nguyen V.C.N., 2011, Small-scale anaerobic digesters in Vietnam–development and challenges. Journal of Vietnamese Environment 1: 12–18. http://openaccess.tu-dresden.de/ojs/index.php/jve/article/view/16.

Nguyễn Võ Châu Ngân, Phan Trung Hiếu, Võ Hoàng Nam, 2012, Review on the most popular anaerobic digester models in the Mekong Delta. Journal of Vietnamese Environment 2: 8–19.

Nordhaus W., 2011, Designing a friendly space for technological change to slow global warming. Energy Economics 33: 665–673. Elsevier B.V.

Nygrén N.A., Kontio P., Lyytimäki J., Varho V. & Tapio P., 2015, Early adopters boosting the diffusion of sustainable small-scale energy solutions. Renewable and Sustainable Energy Reviews 46: 79–87. Elsevier.

Pitelis A., Vasilakos N. & Chalvatzis K., 2020, Fostering innovation in renewable energy technologies: Choice of policy instruments and effectiveness. Renewable Energy 151: 1163–1172. Elsevier Ltd.

Qu W., Tu Q. & Bluemling B., 2013, Which factors are effective for farmers' biogas use?-Evidence from a large-scale survey in China. Energy Policy 63: 26–33. Elsevier Ltd.

Quirapas M.A.J.R., Lin H., Abundo M.L.S., Brahim S. & Santos D., 2015, Ocean renewable energy in Southeast Asia: A review. Renewable and Sustainable Energy Reviews 41: 799–817. Elsevier.

Raupach M.R., Marland G., Ciais P., Le Quéré C., Canadell J.G., Klepper G. & Field C.B., 2007, Global and regional drivers of accelerating CO2 emissions. Proceedings of the National Academy of Sciences of the United States of America 104: 10288–10293.

Riku H., 2017, Government report on the National Energy and Climate Strategy for 2030.

Rohra H. & Taneja A., 2016, Indoor air quality scenario in India-An outline of household fuel combustion. Atmospheric Environment 129: 243–255. Elsevier Ltd.

Roubík H. & Mazancová J., 2016, Small-scale biogas sector in central Vietnam: ways of financing of the technology, [in:] Agrarian perspectives XXV. Global and European challenges for Food Production, Agrobusiness and the Rural Economy, 14.09.2016, Praha. Czech University of Life Sciences, Prague, p. 312–318.

Roubík H., Mazancová J., Banout J. & Verner V., 2016, Addressing problems at small-scale biogas plants: A case study from central Vietnam. Journal of Cleaner Production 112: 2784–2792.

Roubík H., Mazancová J., Phung L.D. & Banout J., 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.

Roubík H., Mazancová J., Phung L.D. & Dung D.V., 2017, Quantification of biogas potential from livestock waste in Vietnam. Agronomy Research 15: 540–552.

Roubík H., Mazancová J., Rydval J. & Kvasnička R., 2020, Uncovering the dynamic complexity of the development of small–scale biogas technology through causal loops. Renewable Energy 149: 235–243.

Sarika J., Newman D., Nzihou A., Dekker H., La Feuvre P., Richter H., Gobe F,, Morton Ch. & Thompson R., 2019, Global potential of biogas. World Biogas Association, p. 1–56.

Scarlat N., Dallemand J.F. & Fahl F., 2018, Biogas: Developments and perspectives in Europe. Renewable Energy 129: 457–472. Elsevier Ltd.

Sengers F., Raven R.P.J.M., Van Venrooij A., 2010, From riches to rags: Biofuels, media discourses, and resistance to sustainable energy technologies. Energy Policy 38: 5013–5027. Elsevier.

Shem C., Simsek Y., Hutfilter U.F. & Urmee T., 2019, Potentials and opportunities for low carbon energy transition in Vietnam: A policy analysis. Energy Policy 134: 110818.

Singh K.J. & Sooch S.S., 2004, Comparative study of economics of different models of family size biogas plants for state of Punjab, India. Energy Conversion and Management 45: 1329–1341.

SNV, 2014, International Workshop on Small- and Medium-Scale Biogas The Evolution of Public-Private Partnerships to Accelerate the Development of Commercial Biogas Sectors. p. 1–50.

SNV and Fact, 2014, Roductive Biogas: Carrent and future development; Five cases studies across Vietnam, Uganda, Honduras, Mali and Peru. Netherlands Development Organisation, p. 1–109.

Steckel J.C., Jakob M., Marschinski R. & Luderer G., 2011, From carbonization to decarbonization?-Past trends and future scenarios for China's CO2 emissions. Energy Policy 39: 3443–3455. Elsevier.

The Prime Minister, 2012, Decision No. 1393/QD-TTg on Approval of the National Green Growth Strategy.

The World Bank, 2010, Vietnam – Expanding Opportunities for Energy Efficiency, p. 1–32.

Thi N., Nga D., Hung P. & Duong N.H., 2015, Household pork consumption behavior in Vietnam: Implications for pro- smallholder pig value chain upgrading. Tropentag 2015, Berlin, Germany, September 16-18, 2015.

Thien Thu C.T., Cuong P.H., Hang L.T., Chao N. Van, Anh L.X., Trach N.X. & Sommer S.G., 2012, Manure management practices on biogas and non-biogas pig farms in developing countries – Using livestock farms in Vietnam as an example. Journal of Cleaner Production 27: 64–71. Elsevier Ltd. http://dx.doi.org/10.1016/j.jclepro.2012.01.006

Tucho G.T., Moll H.C., Schoot Uiterkamp A.J.M. & Nonhebel S., 2016, Problems with biogas implementation in developing countries from the perspective of labor requirements. Energies 9(9): 150.

Tumusiime E., Kirabira J.B. & Musinguzi W.B., 2019, Long-life performance of biogas systems for productive applications: The role of R&D and policy. Energy Reports 5: 579–583. Elsevier Ltd.

UNDP, 2012, Fossil Fuel Fiscal Policies and Greenhouse Gas emissions in Viet nam.

Vietnam Biogas Programme | SNV World. (n.d.).

Vu T.K.V., Vu D.Q., Jensen L.S., Sommer S.G. & Bruun S., 2015, Life cycle assessment of biogas production in small-scale household digesters in Vietnam. Asian-Australasian Journal of Animal Sciences 28: 716–729.

Walekhwa P.N., Mugisha J. & Drake L., 2009, Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications. Energy Policy 37: 2754–2762.

Wang C., Zhang L. & Liu J., 2013, Cost of non-renewable energy in production of wood pellets in China. Frontiers of Earth Science **7**: 199–205.

Wang C., Zhang L., Yang S. & Pang M., 2012, A hybrid life-cycle assessment of nonrenewable energy and

greenhouse-gas emissions of a village-level biomass gasification project in China. Energies 5: 2708–2723.

Wang C., Zhang Y., Zhang L. & Pang M., 2016, Alternative policies to subsidize rural household biogas digesters. Energy Policy 93: 187–195. Elsevier.

Weber K.M. & Rohracher H., 2012, Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive "failures" framework. Research Policy 41: 1037–1047. Elsevier B.V.

Wesseler P.J., 2010, The Economics and Policy of Biogas Production. A Vietnamese Case Study. MSc. Thesis. Wageningen University, Netherlands. Thesis Code: ENR-80424.

Wilkinson K.G., 2011, A comparison of the drivers influencing adoption of on-farm anaerobic digestion in Germany and Australia. Biomass and Bioenergy 35: 1613–1622. Elsevier Ltd.

World Bank, 2011, Climate-Resilient Development in Vietnam: Strategic Directions for the World Bank, p. 1–115.

Xue S., Song J., Wang X., Shang Z., Sheng C., Li C., Zhu Y. & Liu J., 2020, A systematic comparison of biogas development and related policies between China and Europe and corresponding insights. Renewable and Sustainable Energy Reviews 117: 109474. Elsevier Ltd.

Zhang L.X., Wang C.B. & Song B., 2013, Carbon emission reduction potential of a typical household biogas system in rural China. Journal of Cleaner Production 47: 415–421. Elsevier Ltd. http://dx.doi.org/10.1016/j.jclepro.2012.06.021

Zimmer A., Jakob M. & Steckel J.C., 2015, What motivates Vietnam to strive for a low-carbon economy? – On the drivers of climate policy in a developing country. Energy for Sustainable Development 24: 19–32. International Energy Initiative.

Zink E., 2013, Hot Science, High Water. Assembling Nature, Society and Environmental Policy in Contemporary Vietnam. Nordic Institute of Asian Studies. Copenhagen, Denmark. ISBN: 978-87-7694-127-7