

Small-scale anaerobic digesters in Vietnam - development and challenges

Hầm ủ khí sinh học quy mô nhỏ ở Việt Nam - quá trình phát triển và các thách thức

Review paper

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Small-scale anaerobic digesters, known as biogas plants, were applied as an optimal livestock waste treatment as well as biogas supply for cooking and lighting demand for small-scale farmers in Vietnam. Although the biogas technology was introduced for nearly 30 years, the number of the constructed biogas plants is still limited. The current development of biogas plants is far below the real demand on livestock waste treatment that has increased significantly. This paper gives a comprehensive overview on the biogas plant development in Vietnam and attempts to address the challenges and discuss appropriate solutions for the further biogas development.

Mô hình lên men yếm khí quy mô nhỏ (được biết với tên hầm ủ khí sinh học) đã được ứng dụng hiệu quả trong xử lý chất thải chăn nuôi cũng như cung cấp nguồn nhiên liệu phục vụ nhu cầu nấu ăn và thắp sáng cho các hộ chăn nuôi nhỏ ở Việt Nam. Mặc dù đã hiện diện gần 30 năm, nhưng số lượng hầm ủ khí sinh học vẫn còn hạn chế. Sự gia tăng số lượng hầm ủ khí sinh học chưa theo kịp với nhu cầu về xử lý chất thải chăn nuôi đang ngày càng gia tăng. Bài báo trình bày các chặng đường phát triển của hầm ủ khí sinh học tại Việt Nam, ghi nhận các thách thức trong việc nhân rộng hầm ủ khí sinh học trong thực tế và thảo luận một số giải pháp để phát triển công nghệ khí sinh học.

Keywords: biogas plant, waste management, renewable energy, aerobic digester, Vietnam

1. Milestones of biogas development

The biogas development in Vietnam has a relatively long history but it has been largely focused on the last 20 years. The development of biogas technology in Vietnam can be divided into four major phases starting from the 1960s up to present (Do K. T., 2005; Nguyen G. L. and Nguyen Q. K., 2005). Each phase has reached its own development level on biogas technology.

1.1 Period 1960 ÷ 1975

In the North: in 1960s, the Ministry of Industry published translated documents on "How to make artificial methane and collect the gas". Many people have started paying attention to the biogas at this time. The first experimental biogas plant was built in Bac Thai while the first full-scale biogas plants were built in 1964 in Ha Noi, Ha Nam Ninh, and Hai Hung. However, after short operation almost all these biogas plants were shut down due to improper management and technical issues.

In the South: in the same period of time, the Agriculture - Forestry - Animal Research Department started to study the production of methane from animal manure, but no applications are deployed since liquefied gas and inorganic fertilizers were imported massively. From late '60 to early '70 of last century, the biogas technology was almost forgotten.

1.2 Period 1976 ÷ 1980

After the country re-union, Vietnam's government paid much attention to renewable energy. In 1976, the national research program "Application of biogas technology in Vietnam" was implemented by the Institute of Energy. The floating drum model was chosen for the first testing plant. The digester body was made from brick and cement mortar, and a mild steel drum was placed on top of the digester to collect the biogas produced within the digester. Some of these plants were built in Bac Thai and Ha Bac provinces in 1977 ÷ 1978. However, up to the end of

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1979 there was one successful plant built in Sao Do farm (Moc Chau - Son La province) with a volume of 27 m³.

In parallel, several research institutes, organizations and private individuals were also involved in the design and construction of biogas plants but the outcomes were limited. Of great importance in this period is the Workshop on Biogas Technology organized by the National Committee of Science and Technology in December 1979. The event aimed at presenting detailed information on designing, construction and operation of biogas plants.

1.3 Period 1981 ÷ 1990

A research program on renewable energy (code 52C) took priority in the two five-year national plans (1981 ÷ 1985 and 1986 ÷ 1990). The research program aiming to develop the biogas technology was led by the Energy Science and Technology Research Institute and implemented by several other research institutes, centers, universities, local departments on science and technology, military units, etc. Among the institutions engaged in the program were the Institute of Energy, Hanoi University of Technology, Ho Chi Minh City University of Technology, Da Nang University of Technology, and Can Tho University. The Ministry of Health also processed some applied biogas projects according to sanitation demands.

At this stage, there were three types of biogas plants built in Ho Chi Minh city (**Figure 1**) including floating-drum, fixed-dome and natural rubber tube plants (Nguyen T. V., 1989). Nguyen H. B. and Nguyen H. H. (1989) reported that the first biogas plant was built in Ho Chi Minh city in 1982.

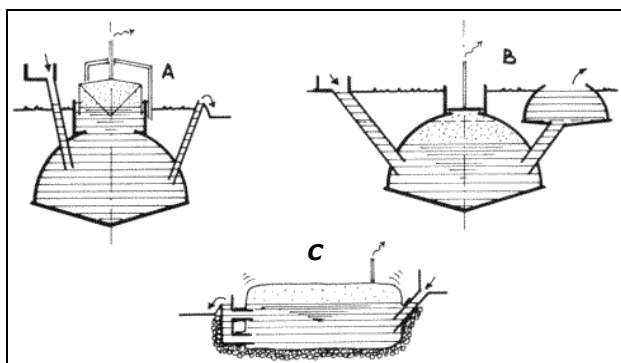


Figure 1. The first biogas plants in Ho Chi Minh city
A. Floating-drum, B. Fixed-dome, C. Natural rubber tube
(Source: modified from Sasse L., 1988)

In 1987, the Renewable Energy Center (REC) at Can Tho University developed and introduced one biogas plant namely CT1 to farmers in the Mekong Delta (MD). The CT1 biogas plant was an upgraded model of cylinder plant but with a fixed gasholder. Up to July 1988, more than one hundred CT1 biogas plants were constructed in Can Tho city (Do N. Q., 1989). At that time, an important improvement was realized by the introduction of the innovative gasholder made of ferro-cement. By this improvement, the CT1 model was airtight, high corrosion resistant, cost effective and had a long lifetime. However, the CT1 model owned some disadvantages that concluded

in stopping its development after the introduction of other models in the MD region.

In March 1989, the Technology University of Ho Chi Minh City held a Workshop on Biogas application in Vietnam to summarize the National Renewable Energy Program 52C (Lam M. T. et al., 1989).

In this period the biogas plant was introduced mainly to alleviate the problem of energy shortage in rural households. At that time, different kinds of barriers inhibited the spreading of biogas technology on large scale. People were not attracted by the biogas due to high investment costs, difficulties in installing and maintenance as well as problematic access of spare parts (Bui X. A., 2002). By the end of this period there were about 2,000 biogas plants installed with capacities from 3 to 10 m³.

Many international organizations contributed with valuable aid to the development of biogas technology in this period: the Institute of Biophysical - Biochemistry - Microbiology (Soviet Union), ACCT (Organization of French-speaking countries), SIDA, Oxfam, UNICEF, etc.

1.4 From 1991 to present

Around 1992, within the framework of the projects of the Ministry of Agriculture and Rural Development (MARD) supported by FAO and SIDA, the National Institute of Animal Husbandry (NIAH), College of Agriculture and Forestry, in Ho Chi Minh City have been introduced plastic bag digesters. Owing to its low cost and simplicity of installation, this technology has been rapidly adopted and disseminated by the network of Agricultural and Forestry Extension, the Association of Vietnam Gardeners and some local private activists (Bui X. A. et al., 1996). Up to 2004, about 25,000 units of the PE digester were installed but mainly in the southern part of Vietnam (Duong, N. K. and Le M. T., 2002; Vo L. et al., 2004).

At the same time, REC introduced a new fixed-dome digester (the TG-BP model) was developed by scientists from Germany, Thailand and China. This biogas model was broadly applied in the southern part of Vietnam but in a limited number due to high investment cost and requirement of skillful laborers. After introduction, this biogas plant has been integrated into the existing VAC farming system (V: garden, A: fishpond, C: animal pen) which was very popular in the MD to form a new eco-farming system called VACB (**Figure 2**), where B stands for the biogas element (Do N. Q. et al., 1999). This biogas model was applied mostly in the southern part of Vietnam with about 3,000 units (Nguyen N. E. and Do N. Q., 2009).

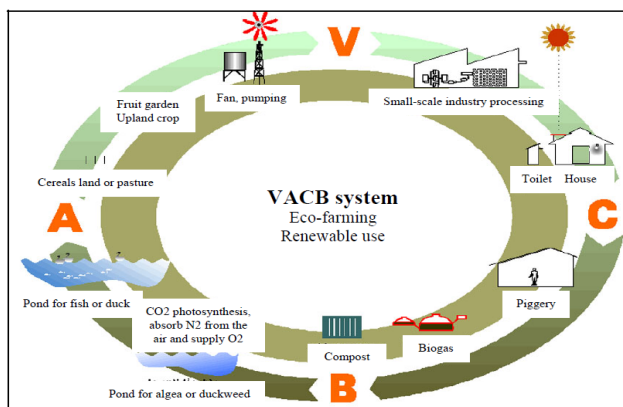


Figure 2. The VACB farming system
(Source: REC)

In 1996, the Rural Development Assistant Center (RDAC) developed the biogas model named RDAC. This plant included the cylinder digester with a ferro-cement hemisphere cover. But due to several disadvantages such as high cost, no trapdoor, easy breakdown etc, this model was replaced by an upgrade version. In the new model, the cylinder digester was changed into the parallelepiped form, with a composite hemisphere cover instead of ferro-cement cover.

In 2000, the Center of Community Research and Development (CCRD) under Vietnam Horticulture Association (VACVINA) developed and introduced a new biogas model named VACVINA. The Toyota Foundation has supported a project to enhance the capacity of VACVINA's staff and disseminate the VACVINA plant nationwide. More than 300 technicians were trained and more than 750 demonstration plants were built in 61 provinces over the whole country. The project had an important positive impact to agricultural production and the protection of the environment. Since 2006, the ETC organization (the Netherlands) and Vietnam's Research Center for Energy and Environment (RCEE) initiated a program on Development Strategy for the Enabling Access to Sustainable Energy (EASE) to put VACVINA plant into a market orientation approach in Thanh Hoa province. Up to now, more than 10,000 VACVINA plants were constructed with technical assistance from trained technicians (CCRD, 2011).

Another milestone in the development of biogas technology in Vietnam is represented by the release in 2002 of the National Standard for small-scale biogas plants. The standard regulates the biogas construction works and includes eight parts (i) General technical requirements, (ii) Requirements for construction, (iii) Requirements for distribution and utilization of gas, (iv) Standard for check and acceptance, (v) Requirements for operation and maintenance, (vi) Safety requirements, (vii) List of necessary parameters and technical specification, and (viii) Standard designs (MARD, 2002).

In 2003, Vietnam and the Netherlands co-operated in the project on "Support to the biogas program for the livestock industry in some provinces of Vietnam". This co-operation program supported farmers nationwide to build biogas plants. Within this project, three types of biogas plant models were selected including KT1, KT2, and

KT3. The KT2 model, an upgraded version of the TG-BP model, is mainly applied nowadays to the MD. In 2006, this project was awarded the Global Energy Prize. With the commitment aid from the Netherlands government, during 2007 ÷ 2011 the project was expanded and covers today over 50 provinces, aiming to construct up to total 140,000 units (Biogas Project Division, 2011).

From 2005 to 2010, the international project "Management of livestock waste" funded by FAO was implemented in Vietnam, China and Thailand. In Vietnam, the Ministry of Natural Resources and Environment (MONRE) was key contact person of this project. This project mainly focuses on the application of large-scale biogas plants for the treatment of the waste from big farms or even from industrial units. Some large-scale biogas plants were constructed for demonstration.

From 2006 to 2010, the Luxembourg government provided the financial support of the project "VIE020 - Sustainable production of aqua and agriculture and using renewable energy from water hyacinth and waste" in Hau Giang province. During the implementation of the project, the scientists of Can Tho University designed, built, put into operation and successfully tested two types of biogas plants named EQ1 and EQ2. These plants were approved by the Department of Science, Technology and Environment under the Vietnamese Ministry of Agriculture and Rural Development and regarded as the most advanced techniques for contributing to diversification of the biogas technology. With support provided by the project, over 100 units of EQ1 and EQ2 plants were constructed within the project area and other provinces (Nguyen N. E. and Do N. Q., 2009).

From 2008 to 2011, the Japan International Research Center for Agricultural Sciences (JIRCAS) co-operated with Can Tho University in Vietnam on the project "Study the feasibility of rural development model based on the clean development mechanism in the Mekong Delta". The objective of this project is to cut down CO₂ emissions by supporting farmers to install 1,000 PE digesters and use produced biogas for cooking instead use of firewood. The beneficiaries are farmers in Can Tho city and the project applies a clean development mechanism (CDM) (Matsubara E., 2008).

The composite biogas plant was introduced in Vietnam in 2008. This model originates from China and is produced in large numbers by several companies in Vietnam. The main advantage of the biogas composite is the high durability (the lifetime is 20 years). The construction and installation works are simple, fast and do not require training for mason. Besides, the composite can be excavated out and moved to other location, so it is suitable in areas in trend of urbanization. The disadvantages of this model are its high cost and that is difficult to transport (Tran H. A., 2010). The system was applied mostly in the northern and central part of Vietnam with more than 10,000 units (SEDDC, 2011).

In 2010, the Vietnamese Biogas Association (VBA) was established in form of a social - occupational organization that included individuals, organizations and voluntary

members (MHA, 2010). This organization was established with the purposes of cooperation, connection and mutually support in developing biogas-related activities and protecting the legal rights of its members. Nowadays, VBA plays the key role in connecting individuals and organizations in biogas sector with government offices in raising ideas about the improvement of the institutional system and related policies. It also integrates into international economy by establishing contacts with biogas organizations in the world following respectful, equal and mutually beneficial principal and the Vietnamese law. Overall, VBA contributes to the economy growth and greenhouse emission reduction.

At this stage, the biogas plant was integrated into the National Program on Rural Clean Water Supply and Environmental Sanitation and considered as an optimal tool for the prevention of odor annoyance and water pollution by uncontrolled discharge of livestock wastewater to open water sources. For example, within the project "CARE International in Vietnam's Options and Ownership: Water and Sanitation for Rural Poor in the Mekong Delta", the project's staff introduced two types of biogas plants (the KT2 model and composite plant) to 48 poor and remote villages in Ca Mau and Soc Trang provinces (Vo H. N, 2011).

At this stage, the biogas plant develops both in quality and in quantity using valuable support from domestic and international projects. Up to now, the total number of installed biogas digesters accounts for about 200,000 units (MONRE, 2010).

2. Challenges to biogas development

Thanks to the benefits of biogas technology, a biogas plant can help farmers who raise livestock to solve waste problems as well as to provide biogas for their full demand of cooking and/or lighting. Some farmers were funded by some supporting projects to construct their biogas plants, and some farmers, being aware of the advantages of biogas plants, constructed their plants at their own expense. However, the number of biogas plants already constructed in rural Vietnam is considerably limited in comparison to the actual demand on livestock waste treatment.

Actually, the recent increase of the numbers of biogas plants in Vietnam is mainly based on domestic and international biogas support projects and only in small extend on farmers themselves. Based on currently circumstances, there are still important barriers that slow down the development of biogas plants in this country. These obstacles can be divided into four groups: (i) technical capacity, (ii) social aspect, (iii) financial aspect, and (iv) institutional and policy.

2.1 Technical capability

- Lack of ability of technicians and skilled labors on biogas construction, operation and maintenance works. Most biogas masons are free masons who have low education level but they got a short training

from biogas projects or just learn by imitation. Thus they are limited on obtaining knowledge about the construction processes, etc. Especially there is very little after-construction service on biogas sector.

- Insufficient and poor quality of feeding materials into the digester since the most husbandry raising is pig. In fact, more than 90% of biogas-user households apply only pig manure as main feeding into their biogas plants, as reported of Tran V. D. et al. (2009). This sole feeding would be much affected in case farmers decrease or stop raising pigs for some reasons (such as pig diseases or low pig market). In these conditions, investing in a biogas plant seems to waste their money and farmers do not want take risks.
- Lack of commercial enterprises that supply biogas equipments and spare parts. At recent time there are inefficient regulations to establish and operate the biogas enterprises on technical offer, equipments supply, biogas research and development, etc.

2.2 Social aspect

- Lack of public awareness on biogas technology and advertisement on the benefits obtained from a biogas plant. Up to now, the biogas development was mainly based on biogas support projects. There is no significant enforcement from the state to promote the biogas sector. In parallel, there is insufficient public awareness on sanitary conditions, especially on water quality and waste management.
- Uncomfortable attitude of people on treating animal waste by biogas plant and then apply the effluent as fertilizer. In the southern part of Vietnam, due to the general habit of applying inorganic fertilizers to agricultural crops, there are not many farmers willing to use organic fertilizer - especially organic fertilizer from a biogas plant - for their farming activities.
- The biogas support projects do not involve all members of the family and this causes disagreement on the construction of a biogas plant. To help farmers access the biogas technology, most biogas support projects introduced biogas information through either representative organizations such as the Women Union, the Farmer Association, etc. Then only one member in the family know the advantages of the biogas technology while the other members not.

2.3 Financial aspect

- Limited financial support from the state budget on the biogas sector. The biogas plant represents a good opportunity to provide not only electricity supply in the rural areas but also environmental sanitation. However, the government did not yet integrate the biogas sector as an element into the framework of rural electrification and rural clean water supply programs.
- Difficulty to access the financing sources due to complicated administrative procedures. The need of

biogas plant construction comes mostly from poor farmers who have no properties or estate. To receive the bank loan, the borrowers need to present their proof on properties or estate as security for their loan but actually they cannot do that.

- Financing support policies are not clear and do not strongly support the investors. There are some regulations available for the financial support of rural clean water supply and environmental sanitation programs that related to biogas sector. In the Decree No. 108/2006/NĐ-CP detailing and guiding the implementation of a number of articles of the Law on Investment, biogas sector programmed in the list of domains entitled to special investment preferences (Vietnam Government, 2006). Biogas sector also mentioned in clause 3, article 1 of the Decision No. 1855/2007/QĐ-TTg approving the National Energy Development Strategy of Vietnam for the period up to 2020 with outlook to 2050 (Vietnam Prime Minister, 2007). However they did not come into practice due to the lack of follow-up documentation issued by the responsible authorities.

2.4 Institution and policy

- Lack of state and local support to promote biogas technology. Recently, the legislation provides general support and encouragement for renewable energies, in general, and for biogas, in particular, and but detailed implementation measures are still lacking. The legislation contemplates incentives for the sector but at this stage, there is no comprehensive approach with regard to biogas sector.
- Lack of policies and framework to biogas development under the national energy policies. Regarding to electricity supplying in areas not connected to national grid, there is still lack of specific guiding regulation on exploitation and utilization of biogas resources to encourage renewable electricity consumption; electrification policies on decentralization power sources is as well insufficiently developed.
- There are no effective investment policies in order to attract private investors to biogas projects. Even developed for about three decades, the biogas projects did not get sufficient attention and did not attract major private investors. By installation of biogas plants in the rural and suburban areas, the investors face low profitability while the investment costs several times higher than the gain profit. However, farmers have no good conditions to obtain loans from banks for the construction of small-scale biogas plants.
- Lack of long-term strategies to follow up the biogas support projects. There were many domestic and international biogas support projects implemented in the country but the local authorities are not sufficiently interacting with these projects so that the project is not systematically documented (e.g. there are no centralized records about the biogas project such as name of beneficiaries, number of installed biogas plants, etc). This leads to a lack of planning in further

systematic development of biogas projects in the respective regions.

- Lack of sanction measures on animal waste treatment before discharge into open water sources. In actual Vietnamese regulations on waste and wastewater discharge, there are no regulations assigned on standards for livestock waste and wastewater discharges. This is the main reason why farmers just simply discharge the livestock waste and wastewater directly into open water sources without any treatment.

3. Solutions for biogas development

The biogas studies in Vietnam were documented since the 1960s. However, since 1980s, the research and application of biogas technology were given a considerable attention. Up to 1990', the biogas technology was developed both in quality and in quantity. Due to a mixed influence of technology transfer, there are many types of biogas plants now applied nationwide such as PE, TG-BP, RDAC, VACVINA, KT1, KT2, KT3, EQ1, EQ2, composite, etc. The number of biogas plants is also increasing due to financial support from biogas projects as well as self-financing by the people themselves. Furthermore, due to the depletion of fossil fuels in recent years, the installed biogas plants trends are converging to increasing and receiving more support from both domestic and international projects.

However, the number of the installed biogas plants is still much reduced against the actual demand. The lack of biogas plants leads to accumulation of untreated waste disposed freely into the open air or open water sources at the suburban and rural areas where most people's life is based on animal husbandry. This uncontrolled waste disposal leads to environmental problems such as worsening the quality of surface and groundwater resources, spreading water born diseases, bad smelling etc. However, it is not easy to increase the number of biogas plants due to mentioned barriers so the enforcement of all stakeholders is required for solving the problems that slow-down the biogas development.

Firstly, the newly VBA can play a key role on establishing a network of scientists, technical staff, mason groups on biogas technologies at national and local communities levels. By this networking, all biogas related topics such as biogas techniques or biogas models will be collected and shared among each other. The biogas models in Vietnam have their own strengths and weaknesses and are adapted to local conditions allowing the farmers to select the optimal model for their households and farms. In parallel, the VBA should play a bounding role in the organizing of professional training for the biogas masons on construction, operation and maintenance works.

At macro level, the biogas related authorities such as MARD and MONRE need to review and improve the legal framework in such a way that it will strongly support the development of the biogas sector. The biogas technology needs to be considered as a tool for public health protection (waste and wastewater treatment), rural electricity supply (self-supply electricity), poverty elimination (opening an animal husbandry chance), sustainable

agriculture activities (establishing an eco-farming system), etc. The policy system needs to attract more investors and do not waste the initial capital cost. Besides that, the state shall offer a good financing mechanism to increase the number of biogas plants. This mechanism needs to present in detail the qualifying criteria for receiving financial support and clearly present the forms and conditions of financing support. For example, the main actor to provide financial support could be the Bank of Agriculture while the financing form could be in the form of a loan with low interest up to 50% of the investment cost of the biogas plant.

Furthermore, a broadcast media program is needed to advertise nationwide the biogas technology and the benefits of using biogas plants. In parallel, information on the negative effects of uncontrolled waste and wastewater disposal are to be announced to the wide audience. Television and radio programs, newspapers, cultural activities, social events, etc. are good channels to transmit essential information to audience. These programs must be coordinated by the state and run constantly in order to develop a new attitude of farmers toward biogas.

Another important step is the development of a biogas market. In the past, most biogas support projects focused on the construction of biogas plants for demonstration purpose but did not pay attention to the establishment of a biogas market. Another weakness of the biogas support projects is that they only focus on one type of biogas plant model but do not introduce more biogas models to beneficiaries. People who want to build a biogas plant and cannot adapt the technology to their needs cancel the construction plants since they do not have access to information on other suitable biogas models. By introducing the biogas plants to the market, a dynamic platform is opened for the biogas service suppliers and more opportunities are created for farmers to access the biogas technology.

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