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Tracy Zhu
SIT Study Abroad

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Tracy Zhu
Mount Holyoke College
SIT Study Abroad: Mekong Delta
Can Tho University, Viet Nam
Advisor: Truong Thi Nga
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ABSTRACT

The Mekong Delta hosts suitable conditions for promoting the widespread dissemination of biogas systems, such as tropical temperatures, high population density, and widespread animal husbandry. The low-cost polyethylene biodigester (BD) is the most common model in the Mekong Delta, although concrete and brick biodigesters have been implemented to a lesser extent. Biogas systems offer a wide range of benefits, such as improving water quality, enhancing integrated farming systems, and meeting rural energy demand while improving public health. Many projects, especially through Can Tho University (CTU), have promoted the installation of biogas systems, but little research has been done to follow up on the realized benefits and challenges to biogas users. This paper attempts to document some of the challenges in maintaining small-scale biogas systems and avenues in promoting their widespread dissemination in Can Tho City.

Eighteen interviews were conducted, six in each of three villages, An Binh, Long Tuyen and My Khanh, to gather quantitative and qualitative information. Local farmers in each village made introductions to households with a biogas system. Background information was collected from interviews with local government officials of Phong Dien district, the Can Tho City Slaughterhouse, and the Dean of the College of Technology of CTU. Information gathered from 8 farmers with concrete/brick BDs (7 of which are fixed dome models) and 10 farmers with polyethylene BDs indicate a high level of environmental awareness. The greatest concern is the profitability of pigs due to low prices and high price of pig feed. Maintaining a large number of pigs (over 10), breeding pigs to reduce costs, and relying on alternative incomes are great factors in the continuation of individual biogas systems. The dissemination of concrete/brick BDs can be promoted by creating a commercially viable sector that offers little or no subsidy and targets current plastic BD users and large pig farm holders. Local, willing farmers in rural areas should be continued to be trained by CTU and work with NGOs in learning the skills to install and maintain biogas systems. Scientists should work closely with local farmers to identify areas of improvement and convert feedback into researchable problems.

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ACRONYMS

BD	Biodigester, container where animal manure is collected for anaerobic processes
CTU	Can Tho University
ha	hectares
MARD	Ministry of Agriculture and Rural Development
NGO	Non-governmental organization
VACB	Integrated farming system that includes "**v**ườn"(garden), "**a**o" (fish pond), "**c**huồng" (livestock pen), and **b**iogas
VACVINA	Vietnamese Gardeners' Association
VND	Vietnamese đồng (currency)
SNV	Netherlands Development Organization

LIST OF FIGURES AND TABLES

1. Introduction

The advantages of biogas in rural areas of developing countries, such as China, India, and Nepal have long been realized (Fulford 1998; Karki 2006). However, despite the rapid expansion of the national biogas programs implemented in China, in 1982, only half of the seven million installed were still operating due to crude construction and lack of well-trained people to fix them (Bui 2006). Recently, the number of biogas systems[1] installed has dramatically declined because of the reduction in government subsidies with the consequent switching of fuel from biogas to coal. Similarly, the Indian national program rapidly implemented biodigesters and exceeded the country's research and development capabilities of improving the biodigester efficiencies. New developments and designs were not incorporated as quickly as expected, and break down rate was relatively high (Kristoferson and Bokhalders 1991). Some of the problems in fueling a growing biogas program are the difficulty of financing, design faults, and poor maintenance.

In Vietnam, the Support Program to the Biogas Program for the Animal Husbandry Sector (hereafter referred to as the Biogas Program) is funded by the Netherlands Development Program (SNV) and sponsored by the Ministry of Agriculture and Rural Development (MARD) of the Government of Vietnam. SNV estimates that 100,000 biodigesters (BDs) are currently installed; the Biogas Program installed 18,000 fixed dome models at subsidized rates in northern provinces from 2003 to 2006 (SNV 2006a). According to Bui Xuan An (2002), policies based on subsidies were not a long-term viable option because biogas dissemination would become dependent on foreign financing and be negatively impacted by changing government subsidies. Although the 25% of the installation cost of fixed dome models are currently subsidized, SNV and the Vietnamese Gardeners' Association (VACVINA) are working towards the ultimate goal of creating an economically viable biogas sector by training local constructors (Hifab International 2000; SNV 2006a).

Although the fixed dome model made of concrete and bricks is the most popular model in northern Vietnam, the polyethylene, or plastic, model dominates in southern Vietnam

[1] In this paper, biogas systems refer to the equipment that uses manure and other organic wastes to produce biogas, sludge, and effluent. The biogas system can include parts that stores and transports biogas, including the biodigester (container for manure), biogas reservoir (container for biogas), pipes that transport biogas, and safekey (see Figure 1.1 and 1.2).

(SOURCE). Many studies have been conducted on biogas systems in and around Ha Noi and Ho Chi Minh City because the research institutions and non-governmental organizations in both cities have been leaders developing biogas technology suitable for Vietnam's climatic conditions (see below: History of Biogas in Vietnam). VACVINA, based in Ha Noi, developed the first "true" Vietnamese model (Preston and Rodriguez 2002). The Mekong Delta, especially areas around Can Tho City, merit research on the realized benefits and challenges of maintaining biogas systems because increasing popularity of raising pigs creates a demand for plastic and concrete BDs. The Mekong Delta animal husbandry concentrates mainly on pig breeding with the Can Tho City[2] ranking first in pig production the Mekong Delta and second in poultry production (GSO 2005). There have been many biogas projects through Can Tho University (CTU), the leading scientific research institution in the Delta, in the past 20 years (Viet, personal conversation, 2006). However, little research has been conducted on the existing status of biogas systems in the Mekong Delta and their effectiveness in improving livelihoods (Truong, personal conversation, 2006).

The objective of this research paper is to understand the benefits and challenges in maintaining a biogas system as well as to assess the potential for widespread dissemination. Because I could not collect quantitative data of the potential households that demand biogas digesters, I will identify avenues through which biogas can be promoted by collecting anecdotal information from current users.

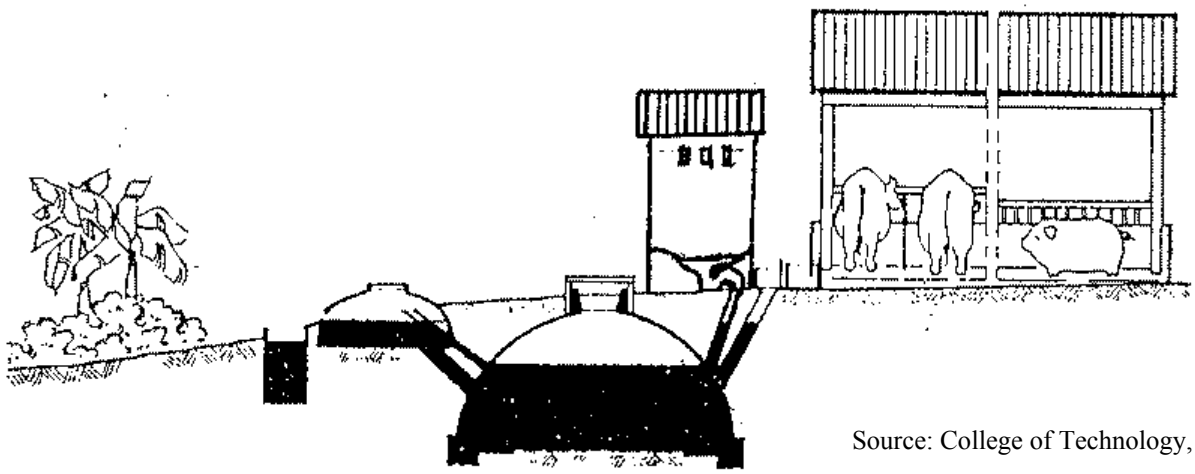
The rest of the introduction will elaborate on the benefits of biogas and its widespread dissemination, particularly to the Mekong Delta, in enhancing integrated farming systems, meeting rural energy demand, and improving water quality. The section on results will review the quantitative and qualitative results of my interviews. In my discussion, I will identify the main challenges in maintaining a biogas system and elaborate on background issues that heavily influence the ongoing use of biogas systems and their continuing dissemination. Suggestions on further research will be addressed in the conclusion.

[2] In 2003, Can Tho Province split into Hau Giang Province and Can Tho Municipality. In this paper, Can Tho City refers to Can Tho Municipality, which holds the status of a national city.

1.1 History of biogas in Vietnam

In 1960, the floating drum model, commonly known as the Indian model, was first introduced in northern Vietnam. Constructed of mild steel reinforced with fiberglass-reinforced plastic, the floating drum design was not very successful in Vietnam due to its the high cost and lack of technical expertise. The fixed dome model popular in China was modified in the 1970s, and its construction throughout northern Vietnam was facilitated by the National Renewable Energy Program of the Ministry of Education and Training. The national government program

Figure 1-1 Basic diagram of a fixed dome biodigester model



Source: College of Technology, CTU

ran from 1980 to 1990 but ceased in the following year due to the lack of funding. The Institute of Animal Husbandry in Hanoi and the University of Forestry and Agriculture in Ho Chi Minh City together with the Vietnamese Gardeners' Association (VACVINA) developed the polyethylene BD in the late 1990s (Ho 2006). International non-profit organizations have played an important role in biogas development and dissemination by introducing capital investment (see Appendix 5 for a list of organizations).

In the Red River Delta (RRD) in northern Vietnam, the fixed dome model (see Figure 1-1) is more popular because northern farmers tend to have smaller land holdings than southern farmers. Due to a higher population density in the RRD, the average cultivated land area for a household is 0.28 ha, whereas 63% of the Mekong Delta's farming households own plots of land ranging from 0.5 to 3 ha (Bui and Thi 2001). The benefits of the fixed dome model over the plastic BD are that it requires low maintenance, takes up less surface space, and can have a long lifespan. The Biogas Program has standardized a fixed dome model in addition to providing training for 150 technicians and 350 biogas mason teams. It is planning to expand to 58

provinces in the next three years (SNV 2006a). Farmers in participating provinces are subsidized with one-fourth of the 4 million VND cost of construction, but many see concrete BDs as prohibitively expensive, especially for the rural farmers of the Mekong Delta.

Estimates say that there are 15,000 – 20,000 plastic BDs in Viet Nam (Oxfam 2000; Preston and Rodriguez 2002; Ho, personal conversation; 2006), most in and around Ho Chi Minh City (Wieneke 2005). The main factor in promoting the installation of plastic BDs is the low cost (420,000-1 million VND) and development of effective, quality models. Poor small-landholders have heralded the replacement of firewood with biogas for cooking. According to Bui Xuan An (2002), the transfer of technology is dependent on farmers' participation in maintenance, repair and education of other farmers (see Figure 1-2). Extension workers around Ho Chi Minh City and Can Tho City have relied on key demonstration farms to promote the plastic BD model, which is not receiving attention in creating a commercial biogas sector.

Urban areas are increasingly attracting poor farmers from the rural regions (Poverty Task Force 2003). The Mekong Delta's high population density means that there will be considerable growth in the semi-urban/suburban regions (SNV 2006a). In these areas of widespread animal husbandry, farmers typically raise pigs instead of cows because there is not enough grazing area. The Mekong Delta supplies Mekong Delta supplies 60% of fishery products and 80% of exported pork and ducks (Oxfam 2000). The growth rate of the number of pig herds from 2000 to 2005 was 35%, the highest of any livestock animal (Tran 2006) (see Table 1-1 for recent agricultural production in the Mekong Delta). The delta regions are particularly suitable for biogas because of the high population density that makes handling waste difficult (Hifab International 2000).

	Cultivation / Product	1995	1997	1999	2001	Prel. 2003	total growth in %
Planted area / water surface	**paddy** (thous. ha)	402	389	467	441	453	13
	sugar-cane (thous. ha)	29	22	26	15	17	-42
	aquaculture (thous. ha)	8	11	12	14	17	109
Yields / Livestock	**paddy** (thous. tons)	1.711	1.713	1.980	1.954	2.145	25
	sugar-cane (thous. tons)	1.800	1.483	1.789	1.088	1.227	-32
	farmed fish (tons)	6.263	7.493	11.342	15.057	41.405	561
	pigs (thous. heads)	206	220	243	289	315	53

Table 1-1 Agricultural production in Can Tho City (Source: GSO 2004)

1.2 Adding the "B" to the VACB model

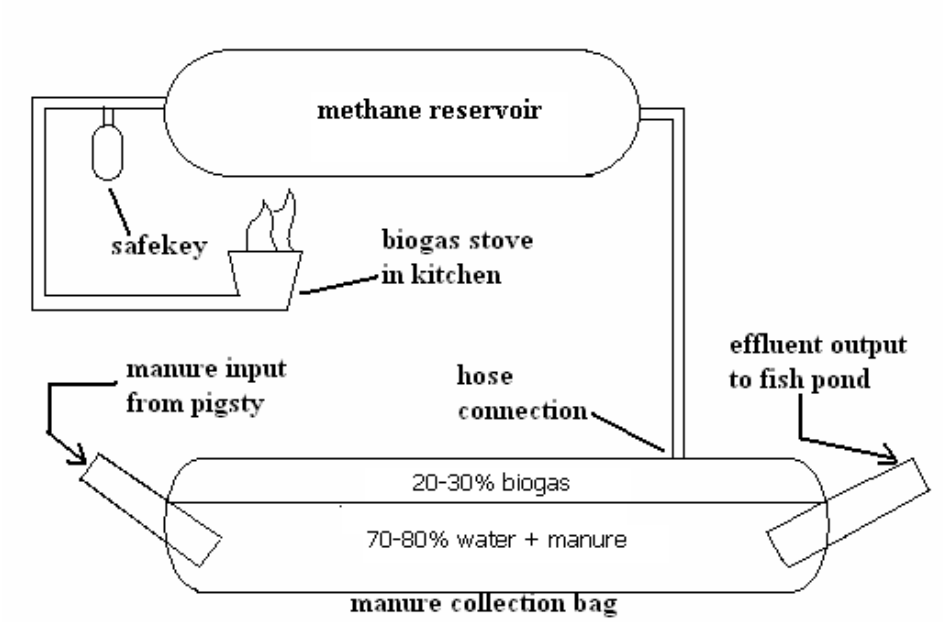


Figure 1-2 Basic diagram of a plastic biodigester system.
Modified from source: Mak *et al.* 2006

Biogas was introduced as a component of the popular Vietnamese integrated farming system, VAC ("vươn" for garden, "ao" for fish pond, "chuồng" for livestock pen). The notion of small-scale integrated farming was pioneered by President Ho Chi Minh in 1960s to deal with the malnutrition and poverty after the American War (known in America as the Vietnam War) (footnote: today, the Vietnamese people and tourists can see what people call the first VAC model in the country, located next to Ho Chi Minh's house at the Royal Palace in Ha Noi). With the motto "Everyone, every family, everywhere applies VAC," the core values of the VAC model were to increase and stabilize the nutritional standard of the rural poor (Le 2001). Today, the VACVINA continues to promote the widespread dissemination of the VAC model, or variations of integrated farming systems: VA (garden and fish pond) or VC (garden and animal husbandry) or AR (fish and rice cultivation) (Vietnam News Agency 2006). The symbiotic system reduces the dependence on outside inputs, while recycling nutrients to generate a variety of income and nutrient sources. However, animal and human waste was disposed of in unsanitary conditions, released raw into the fish pond (Le 2001).

Biogas plants enhance the VAC model by creating a pathogen-free effluent that can be used to increase fish productivity and crop quality, instead of discharging manure into open water bodies. When pig manure is applied to fish ponds, the biological oxygen demand (BOD) increases because decomposition of the organic carbon from the manure consumes oxygen otherwise consumed by fish. Thus, the advantage of anaerobic decomposition is decreasing the BOD of the effluent by converting the carbon to methane (CH_4). The effluent consists mostly of nitrogen in the form of ammonium (NH_4) and phosphate (PO_4), while the carbon has been converted to CH_4 for household cooking (Vo and Watanabe 2004).

Studies from Cambodia and China report higher fish productivity in fish ponds when effluent was used in comparison with raw pig manure (Ding and Han 1984; Pich and Preston 2001). In addition, biomass yield for cassava and protein content of cassava has been shown to significantly increase when effluent made from either cow or pig manure was used as fertilizer, compared to the same amount of nitrogen applied in the form of raw manure (Le 1998a). Similar findings were reported for duckweed, a protein-rich supplement for fish or pig food, grown in ponds fertilized in effluent or raw manure (Le 1998b). Duckweed and water spinach, both of which grow rapidly in the conditions of the Mekong Delta, can be combined with rice bran and broken rice (common swine feed) to increase nutrition and thus productivity of pigs. The production of effluent creates a more efficient form of nutrient recycling from the local manure resource.

1.3 Economic and organic component of agricultural intensification

The production of an organic fertilizer is one of the obvious benefits of the biodigester. Farmers can use the sludge, the nutrient rich material that builds up in the biodigester, for their crops at no extra cost. Farmers save on the cost of chemical and industrial fertilizers, while increasing the soil fertility. The slurry offers many ecological benefits in tropical countries like Vietnam where a small fraction (2%) of soils is soil organic matter, due to relatively fast decomposition processes (SNV 2006b; Shang and Tiessen 1998). Soil organic matter includes living organisms (roots, earthworms, fungi) and non-living organisms (humus, plant residues, and compost), which help to retain water and nutrients. It is widely accepted that soil organic matter and fertility decreases when land is taken under cultivation (Martius *et al*. 2001). Therefore, adding organic matter to agricultural land is ever more important.

Organic fertilizers, such as sludge, offer benefits that cannot be replaced by chemical fertilizers. Sludge is composed of a broad range of nutrients essential to plant productivity (see Table 1-2). Chemical fertilizers, high only in N-P-K, are often overused and offer short term solutions to

Table 1-2 Plant Nutrients in Biodigester Sludge

Macronutrients
- Primary: nitrogen (N), phosphorus (P), potassium (K)
- Secondary: calcium (Ca), magnesium (Mg), sulphur (S)

Micronutrients (trace elements)
- boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo), zinc (Zn)

Non-Mineral Nutrients
- hydrogen (H), oxygen (O), carbon (C)

(Adapted from source: SNV 2006b)

declining crop production. Leaching, volatilization and fixation commonly occur when fertilizers are applied in large amounts, contaminating canals and waterways. An increasing concern in the Mekong Delta at a time of agricultural intensification, overuse has led to an estimated annual loss of 1-1.2 million tons of urea-equivalent fertilizer in Vietnam (Nguyen 2004). The rich organic material in sludge can increase the water retention capacity of the soil and build resistance to erosion (SNV 2006b), thus retaining nutrients in the soil. The use of sludge can be an essential component of Integrated Soil Fertility Management, which uses an optimal combination of organic and chemical fertilizers at an economical price (SNV 2006b). Studies in Nepal and Bangladesh show that chemical fertilizer used in conjunction with sludge result in higher crop and vegetable yields (Karki 2006; Islam 2006).

1.4 Filling non-urban energy demand

Biogas has the potential to meet rural energy needs in developing countries. In general, one cubic meter of biogas can substitute 5 kilograms of firewood (Sasse 1998). In the Mekong Delta, wood from the garden is the traditionally used as cooking fuel. Along the roads in suburban or rual areas around Can Tho City, it is not uncommon to see pieces of coconut or construction debris drying for fuel wood. 80% of people living in rural Vietnam still rely on traditional sources of energy (Jansen 1998).

Famous for its fresh and relative cheap fruit, Mekong Delta farmers suffered through a devastating disease to citrus trees in the past decade, spurring Can Tho University (CTU), the first to introduce an integrated farming approach, to replace the monoculture farming system (Truong, personal conversation, 2006). According to local farmers, fruit trees are not as abundant as before, and thus, wood availability is declining.

Table 1-3 Composition of biogas

Substances	Symbol	Percentage
Methane	CH_4	50 - 70
Carbon Dioxide	CO_2	30 - 40
Hydrogen	H_2	5 - 10
Nitrogen	N_2	1 - 2
Water vapour	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces
Source: Yadav and Hesse		

Burning biogas, which is mostly composed of methane gas (see Table 1-3), creates less smoke than any other common cooking fuel (see Table 1-4). This particularly affects the health and well-being of women, who are usually in charge of cooking, as it reduces the amount of time

spent in the kitchen (tending to the fire) and improves air quality. Pots and pans commonly dirtied by smoke from burning wood or dried coconuts are cleaner using biogas. Also, local newspapers indicate that the price of liquid petroleum gas (LPG) has hit highest levels in 11 years, the increasing trends similar for the price of oil and electricity. This popular cooking gas can cost up to 176,000-178,000 VND (Mai 2006). Cooking is the most obvious benefit of biogas systems, as households save money and time when they shift from the use of traditional biomass fuels and propane.

Table 1-4 Net total suspended particles' concentrations in flue gas of some cooking fuels .

Fuel	Total suspended particle (mg per m3)
Biogas	0.25
LPG	0.32
Kerosene	0.48
Crop residue	5.74

Source: Acharya 2005

1.5 A component of decentralized integrated wastewater treatment

In addition to increasing agrochemical runoff from agricultural intensification and urban and industrial wastes as key water quality concerns (MRC and UNEP 1997; Tuan *et al.* 2004), wastewater from livestock and households degrades water quality in a culture dependent on waterways for transportation, irrigation, and domestic uses. The World Health Organization says that 90% of wastewater worldwide is inadequately treated or is returned to the water cycle untreated. Only 16.3% of the Mekong Delta households have sanitary toilets, so much of the domestic waste gets discharged into rivers, and worse, canals that localize the pollution. Among households in the average to the poorest quintiles, less than 5% of households had sanitary toilets compared to the 45% among the richest quintile (Povery Task Force 2003). The use of toilets over fish ponds is the common traditional practice of southern Vietnamese, but still practiced commonly even though overhung toilets have been banned from open waterways and are highly discouraged by local governments (Wieneke 2005; Nguyen, interview, 2006).

In developing countries, 80% of diseases and 25% of deaths are attributed to contaminated water (Schlein 2001). Because rural culture traditionally relied on canal and river water for fishing, bathing, cleaning, and sometimes drinking water, high rates of waterborne diseases such as diarrhea, intestinal worms, and gastrointestinal diseases are very common. Use of human waste in agriculture and fish farming creates another problem, since it causes high rates of intestinal parasite infection. Clearly, discharging domestic and livestock waste into

common water sources puts public health in danger, even though rural residents understand the relationship between water, excreta, and health (*Vietnam: Water Resources* 1996).

The historical development of wastewater management was based on efforts to alleviate problems of sanitation and eutrophication (Nhapi and Gijzen 2005). Biogas systems have been introduced as a component of integrated wastewater management systems, especially for decentralized systems that can be operated on a household or community level (BORDA; Wieneke 2005). The plastic BD popular in the Mekong Delta are very effective in treating domestic and livestock waste on a household level because it mitigates the public health dangers of discharging manure into water bodies. Effluent discharge from BD in the Mekong Delta has shown that the concentrations of total coliform bacteria, *E. coli,* and carbon have fallen to acceptable values (Hedel *et al.* 2004). The anaerobic processes in BDs kill many of the harmful microorganisms that cause disease and obtrusive smells before discharge. Many farmers realize the connection between pollution, public health and the environment, and installing biogas is a realistic, economic commitment to improving water quality.

2. Methodology

2.1 Interviews

Structured interviews with a prepared questionnaire (see Appendix XX) were conducted with six farmers in each of the three villages of Can Tho City: An Binh Village, Long Tuyen Village, and My Khanh Village. An interpreter accompanied me to translate the quantitative and qualitative questions into Vietnamese. In An Binh, the vice-chairman of the An Binh's Farmers' Association, Mr. Hung, made introductions to the six farmers, two of which participated in an Oxfam America project and implemented VACB models. In Long Tuyen, a local farmer guided us to six farmers that had participated in a CTU project, called the Mekong-2 project, that helped farmers install fixed dome biodigester, and in some cases, in addition to a VACB model. In My Khanh, Mr. Le Hoang Thanh, a farmer who has had 10 years of biogas experience and whose farm has been identified as a demonstration farm for CTU, led us to farmers with plastic biodigesters. All quantifiable data was aggregated. Problems and techniques in improving the biogas system were compiled. To understand farmers' decision-making processes, we asked about the farmers' perceptions of the advantages and disadvantages of biogas and information about their greatest livelihood concern.

Semi-structured interviews were conducted with local government officials of Phong Dien district, where My Khanh village is located. Interviews with the head of the Economic Sector, a staff member of the Extension Station, and the Vice-chairman of the People's Committee helped put a socioeconomic context behind the dissemination of biogas systems through government channels (see Appendix 2).

I paid a visit to the Can Tho City Slaughterhouse for swine and poultry to learn about the role of biogas in wastewater treatment and issues involved in scaling up, and conducted a semi-structured interview with the Vice Director of the slaughterhouse (see Appendix 3).

Finally, I had a brief conversation with the Dean of the College of Technology at CTU. Since the College of Technology was involved with the Mekong-2 project, I gained an understanding of CTU's past involvement in installing biogas systems (see Appendix 4).

The non-farmer interviews and conversations were used to put context behind the data collected from the 18 farmer interviews.

2.2 Site Descriptions

An Binh village, bordering the main city center and Long Tuyen village, has 3,231 households. The areas near the main city center are typical suburban communities with better infrastructure, smaller land holding, and fewer farm activities. Four of the six farmers interviewed resided in the suburban area with immediate access to roads and markets. The other two farmers lived in the more rural hamlets of An Binh near the village's fish sanctuary, a CTU-Oxfam America project designed to alleviate poverty with community-based conservation. The rural areas of An Binh are undergoing developments in urbanization: the government had seized agricultural land where rice paddies were being filled in with sand and trees were being cleared. In areas where traditional houses made of coconut leaves dominated, concrete houses resembling those in suburban areas were constructed or being constructed using the compensation money from confiscated land. According to data from People's Committee, 150 households use polyethylene BD and 15 households have BDs made of concrete and brick (Wieneke 2005).

Long Tuyen village, inhabited by 2,657 households, resembles a typical suburban community with well-paved roads and concrete houses. Due to its proximity to the main city center and plans for urban development, land prices have risen and farmers sell part of their land to invest in agricultural production as well as in construction of new houses. Agricultural production consists mainly in fruit growing, rice cultivation, and upland crops and aquaculture. The People's Committee reports that 34 households use biogas plants, and 14 of those use the VACB system aided by the Thai-German project (Wieneke 2005).

My Khanh village has the most rural character in comparison to the first two villages. With 2,300 households and located furthest from the main city center, urbanization and migration is not much of a concern (Le 2006). Access to markets by canal or by road is generally low, hampering the dependency on gardens for income. The roads are generally in poor condition, but farmers are preparing and leveling the roads for pavement in the near future. Although many households have fruit trees in their gardens, a citrus disease devastated the area less than 15 years ago. Many farmers now raise pigs as their main source of income. According to the Extension Station of Phong Dien district and Mr. Thanh, there are about 20 households with biogas sytems (Nguyen, interview, 2006).

3. Results

I conducted interviews with 18 farmers, eight with concrete/brick BDs and ten with plastic BDs (see Table 3-1). In An Binh, all four of the plastic BDs visited were currently not functioning (two due to the selling of all their pigs and two had broken). One cement/brick model was a fixed biodigester; the other cement/brick BD was a rectangular prism model and was not using his biogas. In terms of organizational financial aid, one farmer had part of the installation cost covered by an American NGO, while the two farmers received full subsidies from Oxfam (see Table 3-2). The two farmers in the Oxfam project were the only farmers of the six who had a VACB model, but they had sold all their pigs.

Five of the six farmers interviewed in Long Tuyen had participated in Mekong-2, a Thai-German project of the College of Technology at CTU. The sixth farmer hired a staff member of the Mekong-2 project to help her build it. Farmers in the Mekong-2 project received loans of 4.5 million VND or more to pay for the fixed dome BDs, which project staff constructed using cement and brick (four of the farmers repaid the loan to the project). All farmers were satisfied with the BDs and biogas production, while one farmer was planning on building an additional BD made of plastic because she had more manure than the fixed dome model could handle. All six farmers had heard about biogas first either though the Mekong-2 project or through neighbors who had participated in the Mekong-2 project. All six farmers have VACB models, two of which were implemented as a part of the Mekong-2 project.

The six My Khanh farmers visited had plastic BDs. The five farmers with functioning BDs with the use of biogas had VACB systems. One farmer's BD had broken but he was still using the biogas from the reservoir. Three farmers had heard about biogas from one of the interviewed farmers, a local experienced farmer who had received training on the VACB model from CTU 10 years ago. The remaining two heard about biogas from neighbors. One farmer received financial aid from SIT.

Table 3-1 Breakdown of biodigester types by village.

Type of biodigester	No.
An Binh	
- Cement/brick	2
- Plastic	4
Long Tuyen – cement/brick	6
My Khanh – plastic	6
Total	**18**

Table 3-2 Farmers who received organizational financial aid

10 received organizational financial aid
- > 4 full or partial subsidies
  - 2 Oxfam
  - 1 American organization (unidentified)
  - 1 School for International Training (SIT) through CTU
- > 6 loans
  - 6 Mekong-2 project through CTU

The quantitative results were aggregated for all 18 visited biodigesters (see Table 3-3). The average age and number of pigs was not different for cement/brick biodigesters and plastic biodigesters. Six cubic meters was the most common volume for the main compartment of the fixed dome BDs, and 10 meters was the most common length for plastic BDs. One of the major common differences cited between plastic and cement/brick BDs is the cost of installation. All farmers except the two who sold their pigs had more than 10 pigs and were breeding pigs, which meant they were increasing their profit margin by not spending money on piglets. The two farmers who sold their pigs started with four pigs in the Oxfam VACB model.

Table 3-3 Quantitative data for all visited biodigesters

	Mode	Mean	Range
Age (years)		5.4	0.17 – 10
Volume of cement BD (m^3)	6	6.9	4 – 15
Length of plastic BD (m)	10	11.4	8 – 20
Installation Cost (VND)			
- Cement/brick		5,000,000	4.5 – 6,000,000
- Plastic		762,000	420,000 – 1,245,000
Number of pigs		31	0 – 100

3.1 Improving livelihoods

In addition to relying on rearing pigs for income, 14 of 18 of the farmers had supplemental income: five benefit from their garden, three benefit from raising fish, one runs a noodle making business, and six rely on incomes from family members with off-farm activities (construction workers, military members, local government official, shopkeeper, teachers, sewing factory, rice trader). All of the Long Tuyen households are shifting to off-farm activities, while the My Khanh families are dependent on VACB models for their livelihoods.

Because 13 farmers have VACB systems, they all discharged their effluent into ponds to raise fish, including sắc rang, tilapia, tai tương, điêu hồng, catfish, and tilapia (see Table 3-4). However, seven farmers still use fish pond toilets. Only four farmers have domestic waste that goes to the biodigester because they were connected by the Mekong-2 project staff when the BDs were built. It can be safely assumed that the quality of fish pond water for the six farmers who formerly discharged their pig manure into fish ponds improved because of the use of effluent instead of manure. Effluent has a substantially lower biological oxygen demand (BOD), lower organic carbon, and adds less total suspended solids (TDS) to water. Thus, the fish pond water does not need to be changed as frequently (according to one farmer in My Khanh).

Table 3-4 Destination of nutrients generated by farming households

Use of effluent	**No.**
Fish pond	13
Discharge into pond	3
Discharge into canal	2
Treatment of domestic waste	
Hole lined with cement	7
Fish pond toilet	7
Biodigester	4
Treatment of pig manure before biodigester	
Fish pond	6
Compost	4
Started pig rearing and BD together	4
Pond	1

The general environment of households was improved, especially the health of women, with the switch from wood to biogas (see Table 3-5). Households that mentioned the use of wood and propane in addition to biogas said they rarely used them or used them only for cooking pig food (2). Overall a majority of the farmers (13) answered yes when asked if their biogas production was enough for the farmers' needs. Households that did not have enough biogas needed more fuel for cooking pig food each day (2) and the non-biogas user needed lots of fuel to run his noodle making business. Five farmers cited that gas is sometimes not enough because of the cycle of pigs (rearing piglets and selling mature pigs to the market yields low amounts of manure) (3) and the flooding season (increase dilution in the BD or escaping of biogas from the BD) (2). In general, farmers had enough biogas for household usage and pig rearing (see Table 3.6). Other uses of biogas include lighting (1) and boiling water for hot baths (2).

Table 3-5 Cooking fuel comparison before and after biogas installation

Fuel before biogas	
Wood from garden	15
Propane	1
Current fuels in addition to biogas	
Wood	6
Propane	3

Table 3-6 Type of Cooking

Domestic only	6
Domestic & food for pigs	6
Only food for pigs	1
Not using of biogas	3

*Domestic includes boiling water and cooking rice and meals

3.2 Identifying the main problems

The main problems are different in comparing the concrete/brick BDs and plastic BDs. For concrete BDs, too much manure or too much gas production caused the main problems with the biogas system (6 out of 8 users). The volume of manure or biogas caused other problems, such as too much pressure in the BD to allow more manure in or flow of biogas towards the inlet pipe from the pig pen. Too much gas for plastic BD users was not a problem, even though they had more than enough, because all plastic BDs were connected to a biogas reservoir. None of the concrete/brick BDs had a reservoir. Some problems sited by plastic BD users were build up of sludge (2), low gas production during flooding season (2), and too much manure or too much gas (2). Build up of sludge is not a problem for concrete BDs.

The farmer in An Binh who had a concrete/brick BD and did not use the biogas exhibited rusting deterioration of the roofing of his pig pen, which he attributed to the biogas. The corrosive nature of biogas is due to the trace amounts of hydrosulfide, which is also responsible for the mild but typical foul smell of biogas (Sasse 1998). He channeled the biogas with a PVC pipe to escape above the pig pen roof, but so much biogas was being produced that it was going backwards towards the inlet pipe to the pig pen. His reason for not using biogas was because of health concerns, which 2 other farmers in My Khanh cited. This problem was not typical of any other farmer because they burned their biogas and had some type of safekey to release extra biogas. Even though one farmer with a fixed dome BD said that too much biogas might escape through the inlet pipe, none had the problem of corrosive damage.

3 farmers cited the problem of water that collects in the pipes leading from the biodigester to the stove. It was a fairly easy problem that they solved because when the fire fueled with biogas burned red or yellow, they knew that they had to empty the piping of water.

None of the farmers with plastic and concrete/brick BDs had replaced their BDs, except for one farmer in An Binh who had switched from plastic BD to concrete/brick BD in the past year (two farmers are in the process of replacing their BDs because they broke). Three biodigesters were broken, one from overloading of manure, one from overheating from the sun, and one from old age.

3.3 Farmers' Concerns and Perceptions of Biogas

Farmers have a variety of concerns related to biogas and the biogas system. The main concerns are related directly to the profitability of keeping pigs:

- Issues affecting income generated from pigs
    - Current low market price of pig (7)
    - Risk of foot and mouth disease (3)
    - High price of pig food (3)
- Negative health effects of biogas on humans (3)
- Damage of pig pen roof by biogas (1)
- Future damage to plastic BD (2)
- Too much sludge (1)
- High price of concrete BD for other farmers to start (2)

The health concern related to biogas was easily remedied by assuring the farmers that methane is lighter than air (by 20%) so in well-ventilated areas, methane will quickly escape into the atmosphere (FAO and CMS 1996). The damage to the pig pen roof was unique to one farmer as discussed above. Build of sludge, according to Mr. Thanh of My Khanh, occurs hard particles or organic matter gets clogged in the outlet pipe. To ensure that sludge is flowing freely out of the BD, the outlet pipe end must be higher than the level of the discharge pond. Two farmers of the Mekong-2 project expressed concern about the high price of the BD that prevents other farmers from installing a similar model.

The main advantages associated with use of biogas that farmers identified were:

- Improving the environment for the family and neighbors (14)
- Use of biogas for cooking (10)
- Contributing to farm-related income
    - with effluent for fish (9)
    - with sludge for the garden (5)
    - being a component of the VACB system
    - by allowing the farmer to increase the number of pigs (1)
- Saving money otherwise used for propane (6)

A majority of the farmers demonstrated a level of environmental awareness, even though in many cases, improving the environment meant getting rid of the foul manure smell. Improving the environment and use of biogas for cooking were the two most common and obvious answers for why people started using biogas. The third leading advantage of biogas is recognizing its integral part in increasing income (either by farm-related income generation or through savings).

Few disadvantages were cited including: the risk of raising pigs, the need to replace plastic BDs periodically, production of biogas fluctuating due to the cycle of selling and buygin animals, and the need for space that inhibits small-landholders from installing a low-cost plastic BD. Overall, most farmers (14) did not cite any disadvantages.

3.4 Avenues for Promoting Dissemination of Biogas

All of the farmers in Long Tuyen relied on their knowledge gained in the Mekong-2 trainings to deal with maintenance. Additionally, 4 of them could access the project staff or literature for advice. In My Khanh, two farmers sought out an experienced neighbor, one went to

a farmers' workgroup, and one received advice from CTU. *CTU and its collaborating organizations are key players in bringing to the villages outside expertise, as CTU staff or farmers trained by CTU were involved in the installation of 15 farmers' BDs.*

In each village, at least one farmer identified himself/herself as a demonstration farm for his/her neighbors and a community teacher on the construction of biogas systems. The self-identified teacher in Long Tuyen gave poor neighbors piglets to raise, and after the mature pigs were sold, they would repay her for the price of the piglets. She advised neighbors about raising vegetables and fruits to increase their income, so that they can start cultivating small fish to sell to other fish farmers as food. One community teacher in An Binh currently conducts study tours on his farm. Mr. Thanh of My Khanh village conducts farmer trainings through CTU in other villages and provinces and has been involved in the construction of many of his neighbors' BDs. All of the farmers in My Khanh said that they have encouraged not-so-poor farmers with pigs and relatives to use biogas. In My Khanh, five farmers wanted to learn more biogas techniques, in most cases to teach or help other farmers start biogas. All My Khanh farmers, who had plastic BDs, were interested in installing cement/brick BDs but cited the high cost and possibility of poor quality as barriers.

4. Discussion

4.1 Market-based economy and disease disrupting small-scale livelihoods

According to local farmers, diseases have played a devastating role in trying to maintain a stable livelihood. The disease that hurt the orchard-dependent farmers decreased the general amount of available wood. The high price of rice bran and broken rice (common pig feeds) is due to the current rice disease in the Mekong Delta. Foot and mouth disease is a highly contagious pig disease transmitted through contaminated excrements, exhaled breath, milk, or meat (Barclay 2001), and is driving down the market price for pigs. Can Tho City farmers are generally better off with an integrated farming system or income from off-farm activities, instead of relying on one source of income that is vulnerable to disease. However, individual small-scale farmers produce too few pigs to have any bargaining power and influence on market prices. *Disease and market prices that farmers cannot control threaten the viability of pig rearing as the main source of income, and thus threatens biogas production.*

Farmers have to adopt new skills and technology in order to face the challenges of fluctuating economy and disease. According to the Extension Station of Phong Dien district, the most popular topics that farmers are interested in are orchard cultivation followed by pig rearing. As noted in the results of the interviews, all farmers except two had more than 10 pigs, including at least 2 breeding pigs, thus they are able to maintain a profit raising pigs and use the manure to maintain their biogas production. Although the fixed dome BDs can operate with the manure from only four pigs, farmers generally want to increase their pig production to increase their profit. Farmers who are not breeding pigs are losing out, such as the two An Binh farmers involved with Oxfam projects. Even though they have well-built, functional VACB models, they do not have enough supplemental income to make up for the income loss in pig rearing. *Farmers who cannot make pig rearing profitable in the face of disease and unfavorable market prices are most likely to stop using their biogas system.*

4.1.1 Overcoming the High Price of Pig Food

To improve the sustainability of natural renewable resources and the integrated farming system, feed for pigs should be grown on the farm and excreta should continue to be recycled on the farm in ways that reduce use of imported inputs, such as industrial pig food (Bui 2002).

Being able to grow food on the farm for pigs would be ideal, but it is very difficult to be able to grow the quantity of food that pigs require consistently every day. One suggestion is to use effluent to grow aquatic plants, such as duckweed or water spinach, as both are very nutritious supplements to the rice bran or broken pig feed. These two plants have been shown to have a higher mass and protein content when raised on effluent compared with manure (Ho 2003; Lampheuy 2003).

The relatively high price of rice decreases the profitability of rearing pigs. Two farmers found innovative alternatives to purchasing rice products by collecting food scraps from the market or city restaurants at the end of the day. Creative solutions help farmers overcome fluctuations of the market that they can't control. *Further research should be developed on the types of feed that can be grown consistently on the farm to either supplement or replace the rice feed that most farmers have to buy.*

4.2 Urbanization and Migration

According to the Chairwoman of the An Binh's Women's Union, one of the big issues is migration: the village population is increasing and urbanization is displacing farmers. Declining agricultural work for farmers who raised rice or found work on neighboring rice farms is due to the seizure of land. Rice fields are being filled in with sand by companies that pay the compensation to farmers, develop the land and pay a land tax to the government (Nguyen 2006) Urbanization, particularly in An Binh, threatening livelihoods of those who only have agricultural skills. According to one farmer, the government is seizing land at very low price compared to the urban market price for land but fairly high for rural land so after the land gets developed, the surrounding land will be very expensive. Small farmers are being displaced and losing their income without their voice being heard.

In contrast, households in Long Tuyen are increasing their off-farm activities because people are leaving the villages to industrial and business districts to find higher paying jobs. Two farmers mentioned industry as an alternative work for low educated, low skilled villagers. A local government official said that industrial jobs make up for the lost agricultural work (Nguyen 2006). Development will also improve infrastructure, and thus access to markets, a concern of two Long Tuyen farmers who want to increase their fish production to sell at the markets.

Urbanization is not well studied in understanding its effect on pig production. More research should be done on the impact of urbanization on migration and shifting of livelihoods.

4.3 Sustainability by Promoting the Market-based Approach

Discussions on sustainability of biogas systems fall into two categories: the long lifespan of individual biogas plants and the self-sustaining ability for biogas technology to spread from household to household (Oxfam 2000). Because international organizations and academic institutions, such as Can Tho University, have developed effective models that are easily maintained, efforts have been focused more on technology transfer and training than on improving current models. Widespread dissemination of biogas technology can be facilitated by the creation of a market-oriented biogas sector (Oxfam 2000; SNV 2000a) or by building capacity in communities by training farmers. From international examples, such as the one in Nepal, it has been recognized that dependency on foreign aid will create a weak infrastructure in continuing domestic research and development. As many domestic Vietnamese – scientists, farmers, masonries, technicians – should be trained properly and work with across sectors to develop knowledge locally.

According to the Renewable Energy Program of Vietnam, government policy as well as NGOs are focused on the dissemination and commercialization of renewable energy (Jansen 1998). The Biogas Program coordinated by SNV and MARD as well as VACVINA are dedicated to introducing biogas technology through training of local constructors so that farmers can hire these private services at will (Hifab International 2000). If the Biogas Program moves to Can Tho City, in addition to the obvious target group (households with pigs and land and not considered very poor), fixed dome BDs should be marketed towards current users of plastic BDs. All of the farmers that I spoke with in My Khanh who had plastic BDs were very interested and willing to install a concrete/brick model, but the main constraint was price. The farmers in Long Tuyen started off very similarly to farmers in My Khanh, relying on hard work and the VACB model to increase their income. Five out of the six Long Tuyen farmers were able to repay loans of 4.5 – 35 million back to the Mekong-2 project within 5 years. *Farmers like those in My Khanh – willing, hardworking, firsthand benefactors of biogas – are principle targets for subsidized fixed dome biodigesters.*

4.4 Sustainability by Increasing Technology Transfer from Farmer to Farmer

From this case study Can Tho City and others in rural Viet Nam, it is evident that the participation of farmers has plays an essential role in the dissemination of technology (Bui 2002). Mr. Thanh of My Khanh is a principle example of how one farmer has continued to be a village resource and peer educator, not only in his village but in many provinces around the Mekong Delta. Selection of suitable demonstration farms is important in promoting a high degree of farmer participation in digester introduction and providing technical feedback. A key element is ensuring that leading farmers in the community have the knowledge and skills to build and maintain the system. In this way, farmers who are motivated enough to invest their own capital in a biogas system can draw upon local knowledge. Therefore, a community will be more resilient in adapting to economic or ecological disturbances, such as falling pig prices or disease.

From the lessons that CTU learned in the past two decades, development in urban areas is improving the economic well-being of those closest to the city (Le, personal conversation, 2006). Farmers, especially in the suburban areas, are increasing their income through off-farm sources and their children are finding alternative livelihoods to agriculture. Thus, the people who benefit the most from biogas are farmers in more rural areas who see their future on the farm. In Bui Xuan An's (2002) experience in rural northern Vietnam, "true farmers" (farmers that depend predominantly on on-farm activities) should be targeted because they will have the highest demand for fuel and agricultural technology. *Future extension services should promote plastic BDs in rural areas further from the city where most or all of farmers' incomes come from farm activities.*

In any extension work, it is important to involve farmers as creators and collectors of local knowledge as well as peer educators. Often, scientists and researchers can learn a lot from farmers because the trial-and-error learning process of farmers is not unlike the process of scientific inquiry. In contrast, farmers see university professors and scientists as "experts" or "bearers of knowledge." Mutual collaboration can benefit both parties in identifying problems worth researching and the outcomes of solutions implemented.

To continue the development of biogas technology, the relationship between farmers and scientists should be strengthened in order to convert feedback into researchable topics (Bui 2002). Scientists and farmers should investigate the viability of growing nutritious plants for pig feed or supplementing pig feed using the effluent or sludge. Also, by passing along common

scientific knowledge, such as the harmlessness of methane with plenty of ventilation, to leading farmers or farmers' associations, information dissemination will happen more quickly.

4.5 Conclusion

"Allowing some time for the farmers to "digest"
the biodigester technology is essential…"
- Bui Xuan An, University of
Agriculture and Forestry Ho Chi Minh City

Scientists, government officials, and farmers recognize the effectiveness of biogas in providing energy alternatives and protecting the environment. However, these overriding advantages have little significance in the farmers' actual decision to invest. Emphasizing the role of biogas in improving the integrated farming system to increase income offers a relevant incentive to farmers to improve their livelihood. The effluent and slurry play key roles in increasing the quality of products (fish, crops, and pigs) at no extra cost.

For farmers who recognize value of biogas as a component of an integrated farming system, the benefits usually outweigh the initial investment. Despite the common arguments that rural farmers are too poor to care about their environment and are attached to their cultural acceptance of using manure in the field (Wieneke 2005; Hifab International 2000), farmers more than anyone else realize the interconnectedness of health, pollution, and elements in their environment. By helping farmers to integrate biogas technology in improving their income and livelihood, biogas systems can be an effective, low-cost way of improving the lives and environment of rural farmers.

5. Appendices

Appendix 1: Questionnaire for Structured Interviews with Farmers

Date of visit: _____

RESEARCH QUESTIONNAIRE ON HOUSEHOLD BIOGAS PLANTS:
Focus on problems/challenges and techniques for improvement
Identify modes of information dissemination to increase quality

Name of owner: _____ **Main source(s) of income: _____**

Village: _____ Hamlet: _____ **_____**

I. Biodigester information:

*1) BIODIGESTER **TYPE**:*

Plastic ☐ Cement ☐ Bricks ☐ other: _____ ☐

2) **Age** of biodigester: ____ years

3) **Volume**: ☐ m^3 **Length**: ☐ m **Height/diameter**: ☐ m **Width**: ☐ m

4) Initial **cost** to set-up: _____VND
Materials: _____ VND
Labor: _____ VND

Financial aid from organizat'n: _____
Amount of financial aid: _____VND

5) Uses of **effluent**

Fish pond ☐ Fertilizer for garden ☐ Sold or given away ☐ None – discharged into (specify) ☐ _____

6) Number of **pigs**:

Type	Mature	Adolescent
Quantity		

All manure put in the biodigester? Yes **O** No **O**
If No, treatment of unused manure:_____

7) Is your **toilet** connected with the digester? Yes **O** No **O** Considered?: **O**

7a) Reasons why toilet is not connected _____

7b) Where domestic waste goes: septic tank ☐ raw in fish pond ☐ canal ☐ other ☐ _____

Before the biogas system was installed

8) Treatment of unused dung before biodigester installed?

☐		☐	☐	☐
Release to water body: Other _____		Started biodigester & raising pigs together	Composted for the field	Other:
River/canal	Fish pond			
O	O			

9) Before you installed the biogas system, what did you use to cook with?

Coal	Wood	Propane canisters	Other
☐	☐	☐	☐
	O market **O** garden		

10) In question above, circle any current cooking fuels instead of or in addition to biogas.

II. Social Capital

11) **First learn** about biogas from: Neighbor ☐ Relative ☐ Media ☐ Other ☐_____

12) **People involved** in building the biogas system

CTU	Experienced local farmer	Private labor	NGO (specity) _____	Other:_____ _____
☐	☐	☐	☐	☐

14) Main reasons **why you started** a biogas system:

For cooking	Less pollution affecting family	Saves money	Produces fertilizer	Improves water/enviro	Other:_____ _____
☐	☐	☐	☐	☐	☐

15) Do you know anyone who **started a biogas system and stopped**? Yes **O** No **O**

Reasons for stopping: _____

16) Have you **encouraged** anyone to build a biogas system? Yes **O** No **O** Who?_____

III. Biogas Information:

17) How many **hours of cooking**? ☐ Hours Non-cooking uses: _____

18) **Type of cooking** meals ☐ boiling water ☐ other ☐ _____

19) Gas often is not **enough**? yes ☐ no ☐ depends ☐

20) If not enough gas, reasons are:

Cycle of animals	weather	too much scum	too much input/wrong dilution	other: _____
☐	☐	☐	☐	☐

IV. Maintenance and Challenges

21) **Problems** you have had with the biogas system (Put * next to biggest problem)

Check here for No Problems ☐

	Not enough or irregular gas production		Biogas causes damage to the buildings
	Lack of technical knowledge		Plastic quality
	High maintenance cost		Scum
	Too much manure/too little manure		Damage to parts of biogas system
	Other		

22) What are you **biggest concerns regarding the biogas** system?

_____

_____

23) **Source of after-installation advice**: What do you do when you need advice on your biogas system?

Self-help; sought no help	Literature	Experienced neighbor	Local official	University	Other: _____ _____
☐	☐	☐	☐	☐	☐

Would you like more information about biogas? Yes **O** No **O** Medium (below):

CTU training	Training from mass org (women, farmers, youth unions)	Experienced farmer	Literature	Other:_____ _____
☐	☐	☐	☐	☐

24) **How did you fix** the problem?_____
_____
_____
_____

25) *For Plastic Biodigesters*: How often **parts are changed**

Biodigester: _____ months Cost: _____ VND
Biogas reservoir: ____months Cost: _____ VND
Other parts: _____ Cost: _____ VND

26) *For plastic biodigesters:* Are you interested in changing your plastic biodigester to a **concrete or brick model**? Why or why not? Yes **O** No **O**

Expensive	No training	Not enough information	Other: _____ _____
☐	☐	☐	☐

27) What are the **advantages** of using biogas?

Easy cooking	Less pollution affecting family	Saves money	Produces fertilizer	Improves water/enviro	Other:_____ _____ _____
☐	☐	☐	☐	☐	

What are the **disadvantages** of using biogas?

Dangerous to human health	Damages housing/roofing	Too much biogas produced	Too little biogas produced	Other:_____ _____ _____
☐	☐	☐	☐	

28) What is your **biggest concern** right now to improve your livelihood/life?

_____
_____

Other comments/observations: _____
_____
_____
_____
_____
_____
_____
_____

Results of the interviews available upon request (contact author at tracyzhu@mtholyoke.edu).

Appendix 2. Semi-structured Interviews with Local Officials of Phong Điền District

Nguyễn Thị Hồng Điều, head of Economic Sector, People's Committee
Trần Than Hải, staff member of the Extension Station
People's Committee building, Mỹ Khánh village, Phong Điền district, Can Tho City
30 November 2006

1. Which events/trainings are famers most likely to attend? What topics are they most interested in?
2. What are farmers' biggest concerns?
3. What do you do to promote biogas?
4. In your opinion, what are the advantages of biogas?
5. How many people in the village have biogas? How many households have pigs? How many households are in the village?
6. What is the status of the pig market?
7. Due to urbanization, farmers are losing agricultural work. Besides receiving financial compensation, how are farmers being helped?

- Mỹ Khánh village has 10 people with concrete BD and 10 plastic BD
- Every year, the Extension Station holds one training on biogas (25-35 farmers in attendance); sometimes trainings are combined with animal husbandry trainings
- Topics farmers prefer are fruit tree farming, then livestock, especially pig rearing
- Farmers' concerns: fluctuating pig price, not weight of pig
- No local regulations on the village level for environmental pollution, but local officials remind pig farmers to not pollute
- Only national laws instated
- Urbanization
    - even though all or part of farmer's land is taken away, there are industrial jobs to rely on
    - believes that financial compensation is enough
    - private companies pay compensation to farmers, pay tax to the government, and develop the land
    - general plans take into consideration areas of high-yielding rice, clean vegetables and "eco-tourism"
- Advantages of biogas: protect the environment and good for people (creates alternative to wood)
- Disadvantages: Hai does not encourage more farmers to use biogas because unstable price of pig
- About 1,400-1,600 pigs in Mỹ Khánh village
- About 11-13,000 pigs in Phong Điền district
- Data from government veterinarian who goes from house to house to vaccinate pigs

Vice Chairman of Phong Điền District
His home, Mỹ Khánh Village, Phong Điền district, Cần Thơ City
30 November 2006

- Fixed dome BD: 4-5 years old, 4 m^3 (smallest possible size)
- Uses propane too
- Can make rice but biogas usually used only to boil rice
- 3,400 VND/kilo of broken rice to pay for pig food, considered expensive
- Recently sold the piglets
- Effluent used for fruit garden
- Started biogas system for fuel, protect the environment, decompose domestic waste
- Why farmers don't use biogas system: price of pig low, price of food high; must use broken rice for pig food, no other food
- Migration in Mỹ Khánh
    - Adding 20 households a year
    - 5 years ago: 2,000 households, now: 2,300 households
    - People affected by urbanization tend to go to other rural areas to buy land with compensation money
    - Migrants come from the city to the suburbs
  - 90% of the people use groundwater
  - Extension service provided by communal water for 150 households but only 10 households use because they don't want to pay 2,500 VNĐ/m^3
  - Costs USD $100 USD to set up pump for groundwater
  - Government doesn't support fish pond toilet but doesn't force people to stop using them because modern latrines are expensive
  - 1995 law doesn't allow toilets to be built over open waters (northern law imposed upon the south)
  - Farmers with many pigs don't necessarily use biogas or wastewater treatment; still direct release into the water

Appendix 3. Interview and Visit to the Cần Thơ City Slaughterhouse

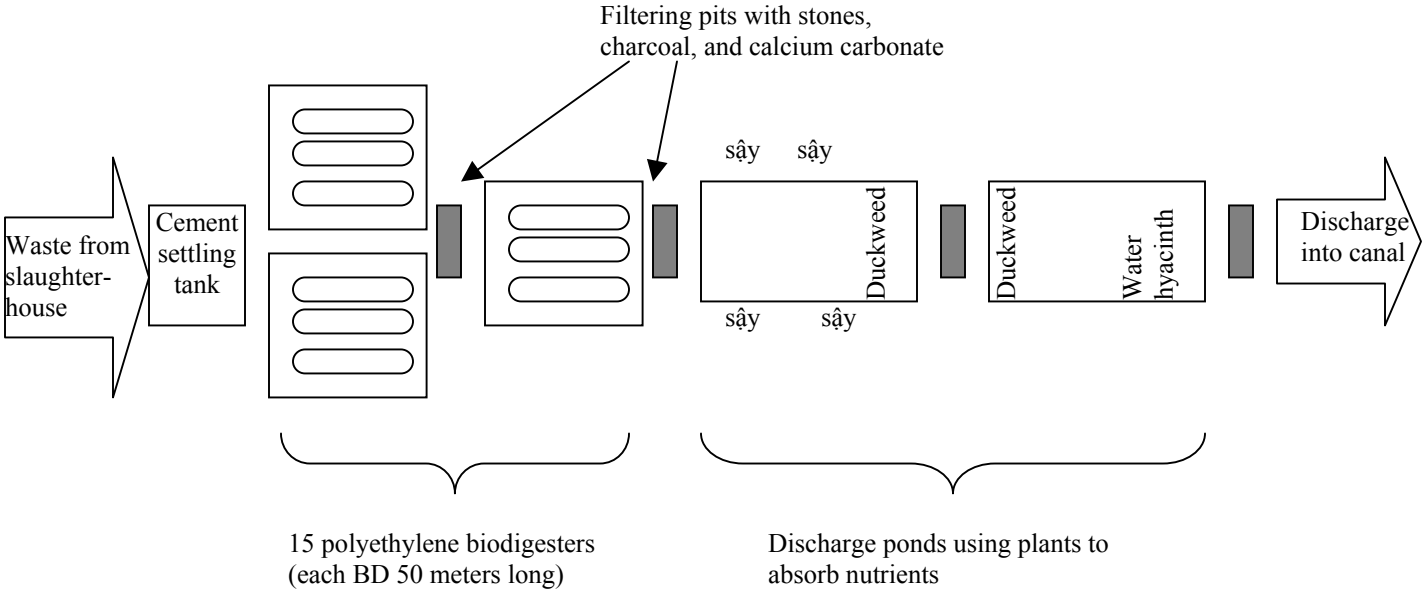
Võ Văn Mải, Vice Director
Ninh Kiều District, Cần Thơ City
26 November 2006

- Slaughterhouse can operate only if it meets VN standards
- Only the government officials conducts tests
    - 2 informed visits and 2 uninformed visits in one year
    - Noise and water quality tests (COD, BOD, N)
    - Does interviews with farmers in the vicinity
- Price of pig food high (3,500 VND/kg) b/c currently rice disease in MD
- Farmers with few pigs are failing because of low price of pig
- Benefits: low, low cost, easy design
- Problems/concerns: takes a lot of land, smell, damage from trees, time intensive for maintenance
- Wants new, smaller and expensive treatment plant; got offers from Germany and America orgs
- Gets advice from CTU and Song Hau farm

Observations

- 400 pigs and 800-1,000 chickens killed per day
- Slaughter from 11:30pm to 5am
- water hyacinth does not look healthy, requires a lot of light → not enough light because of tree cover
- 50 meter long polyethylene BD
- Wastewater treatment began in 2000
- Gas released, even when farmers living in the vicinity could utilize it
- Calcium carbonate ($CaCO_3$), chlorine, and charcoal used for odor control
- Water hyacinth not harvested

Wastewater Treatment for the Slaughterhouse



Appendix 4. Personal Conversation at the College of Technology, Can Tho University

Le Hoanh Viet, Dean of the College of Technology, CTU
22 November 2006

1. Does CTU offer training courses for farmers on biogas?
2. How can biogas be properly harnessed so that the possibility of explosion doesn't occur?
3. How can leaking be prevented?

- in 1996, CTU and Canadian collaboration offered farmer trainings on biogas
    - taught bookkeeping
    - funds transferred to women's union after project was done
    - trainings principally held in Hậu Giang and Cần Thơ City
    - 2003 ended trainings and biogas was incorporated into integrated farming systems trainings
    - Organized 20 trainings with 25-35 people in each training
- In 1985 evaluation of the BD in MD
    - Focused on implementing rubber BD but easily damaged
    - Changed to model CT1 made of ferrocement/concrete; installed 150 CT1
    - CT1 took up little space so poor people in urban areas wanted to use them
- In 1992 the economic situation changed and many people stopped using them
- In 1996 German-Thai project (with the help of the College of Technology) developed the Chinese fixed dome model
    - More than 300 fixed domes were installed mostly in Than Phu Dong hamlet in Đồng Tháp province
- If people are properly trained, they know that explosion will not occur
    - Safety valve is automatically lets gas out if there is too much

Appendix 5. A List of NGOs Involved with Implementing Biogas Systems

Oxfam – America and Quebec – www.oxfam.org

- Introduced VACB models in An Binh Village, Can Tho City
- Through CTU, Oxfam is extending the An Binh model to An Giang province (Truong 2005)

Heifer International – www.heifer.org

- Based in Can Tho City, Heifer operates in 19 provinces promoting animal husbandry among the rural poor
- In conjunction with "giving the gift" of cows or pigs, Heifer introduces poor farmers to biogas technology

Youth with a Mission (YWAM) – www.ywam.org

- Based in Ha Noi

Vietnamese Gardeners' Association (VACVINA) – www.vacvina.org.vn

- VACVINA's main activities include implementing technology and management progress of the VAC system for producing the best nutritious foods and improving family diets
- The VACVINA biogas model is one of the most progressive models that eliminates the overpressure problem of cement/brick BDs and automatically controls scum

Appendix 6. Further Discussion Nutrient Cycling: Hampered by Modern Latrines

The government plan to give out loans for villagers to build modern latrines can be a threat to nutrient cycling that traditionally occurs with fish pond toilets. According to two farmers in My Khanh village, the Ministry of Health is giving 4 million VND loans to villagers to build a latrine that disposes of domestic waste in a hole lined with cement. The modern latrine carries urban attitudes to sanitary concerns outside the main city center: urban wastewater in Vietnam is commonly associated with disposal rather than reutilization or actual treatment. A national law was recently passed that banned fish pond toilets over open waters (MARD and MOC 2000). The Ministry of Agriculture and Rural Development and the Ministry of Construction emphasize the environmental pollution and sanitation problems caused by fish pond toilets in the flood prone area (Wieneke 2005). Although fish pond toilets are not the most sanitary, nutrients are at least being decomposed and reused. The modern latrines compile waste and take nutrients and organic matter out of nutrient cycling processes. Beyond encouraging current biogas users to connect their modern latrines to the BD, the construction of building modern latrines should go hand in hand with promoting biogas systems.

When implementing biogas systems, should provide information or training about VAC model, and emphasize the importance connecting biogas so improving production of farm components. Although training masonries to teach the VACB approach to their consumers is not feasible, masonries can be an effective medium for disseminating knowledge about the use of effluent and sludge. It is very crucial to emphasize the usefulness of the BD byproducts so that farmers build a dependency on their BD besides the use of biogas for cooking, and thus maintain motivation to prolong its lifespan.

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