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Case Study

Use of solid waste for small-scale biogas production for rural household energy consumption: case study in Takaev Province, Cambodia

Visalsok Touch[1]*, Samell Keo[1], Warinthorn Songkasiri[2], Catalin Stefan[3], Terry Commins[4], Souphab Khouangvichit [5] and Joe Green[6]

1. University of Battambang, National Road 5, Preaek Preah Sdach Commune, Battambang, Cambodia
2. National Center for Genetic Engineering & Biotechnology, Thailand Science Park, Klong Luang, Pathumthani, Thailand
3. Institute of Waste Management & Contaminated Site Treatment, Technical University of Dresden, Pratzschwitzer Str. 15, 01796 Pirna, Germany
4. King Mongkut's University of Technology Thonburi, Pracha Uthit Road, Ratburana, Bangkok 10140, Thailand
5. Faculty of Environmental Science and Development, National University of Laos, P.O. Box 7322, Vientiane, Lao PDR
6. School of Earth & Ocean Science, Cardiff University, Main Building, Park Place, Cardiff CF10 3YE, UK

*Author to whom correspondence should be addressed, email: visalsoktouch@yahoo.com

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Abstract: A survey was undertaken of participants in the National Biogas Program (NBP) in Takaev Province, Cambodia. The purpose of the survey was to better understand the technical aspects of rural biogas application, as well as the economics and the factors contributing to adoption. A total of 74 households were studied. The study revealed that, for many families, the initial investment cost is still too high. Another factor limiting adoption was the required number of livestock for the system to be viable. While there is a clear preferred or "cultural" practice of using firewood and charcoal, where forests have been exhausted wider acceptance of biogas can be expected. Despite these limitations there were however some positive signs and many of the households interviewed reported that biogas was sufficient for their daily cooking and lighting needs.

Keywords: waste recovery, cooking, lighting, manure, renewable energy

Introduction

A large proportion of the Cambodian population live in remote rural areas, often without access to electricity or fossil fuels for cooking. This has lead to the extensive use of charcoal as a major source of energy, which, combined with rapid population growth, has lead to deforestation in many regions. Rapid population growth also leads to an increase in the amount of solid wastes. These wastes, including those from household use, commercial establishments, markets, hotels, restaurants and tourist centres, are usually dumped and burnt in areas of convenience, which in turn has an adverse effect on the environment and public health [1].

One of the more suitable solutions to these problems is to use biogas. Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Bacteria convert organic materials of manure and wastes into combustible biogas (methane, carbon dioxide) and fertilizer (slurry). Biogas can be used like any other combustible gas. It can be burnt, such as for cooking, used for lamps and motors, or to produce electric power or pump water. Its use thus implies a number of ecological as well as economical advantages.

As a result, the Government of Cambodia has been promoting the widespread adoption of biogas technology in areas deemed suitable and having ready access to agricultural wastes, such as animal manure. Promotion falls under the National Biodigester Program (NBP), with plans to install 17,500 plants in the first phase [2]. In order to better understand the processes involved in biogas promotion and use, a key province involved in the NBP was selected for detailed study.

The objectives of this case study were to:

- Better understand the technological aspects of biogas applications employed by farmers.
- Analyze the economics of biogas applications.
- Identify the key factors affecting biogas application and adoption.

Methodology

The study was conducted in four districts of Takaev Province, a mostly rural province in the south of Cambodia and bordering Vietnam (Figure 1). According to a World Food Program report, Takaev is one of the poorest provinces in Cambodia [3] and the Mekong River Commission lists it as an area with the highest deforestation [3]. A total of 74 households in the study area were selected using the purposive sampling method for the interviews. Two officers of the National Biogas Program were also interviewed to acquire information regarding the technical aspects. Table 1 shows the four districts where interviews were conducted and the number of households.

Table 1. **Number of households interviewed in the study.**

District	Commune	Village	Sample Size
Samrong	Slar	A Rong	9
		Kagngeang	7
	Roveang	Krangtnong	7
		Toal	6
	Chiengkoung	Tamove	5
		Tropuangvihea	6
Tramkok	Sreronong	Brochom	4
		Prey Mok	7
	Tropeangkhangcheng	Peakbong Oung	8
	Odomsoriya	Chong Ang	6
Batty	Dong	Kadal	3
Trang	Sangrae	Prey Chongreak	3
	Khvav	Sdeyron	3
Total			**74**

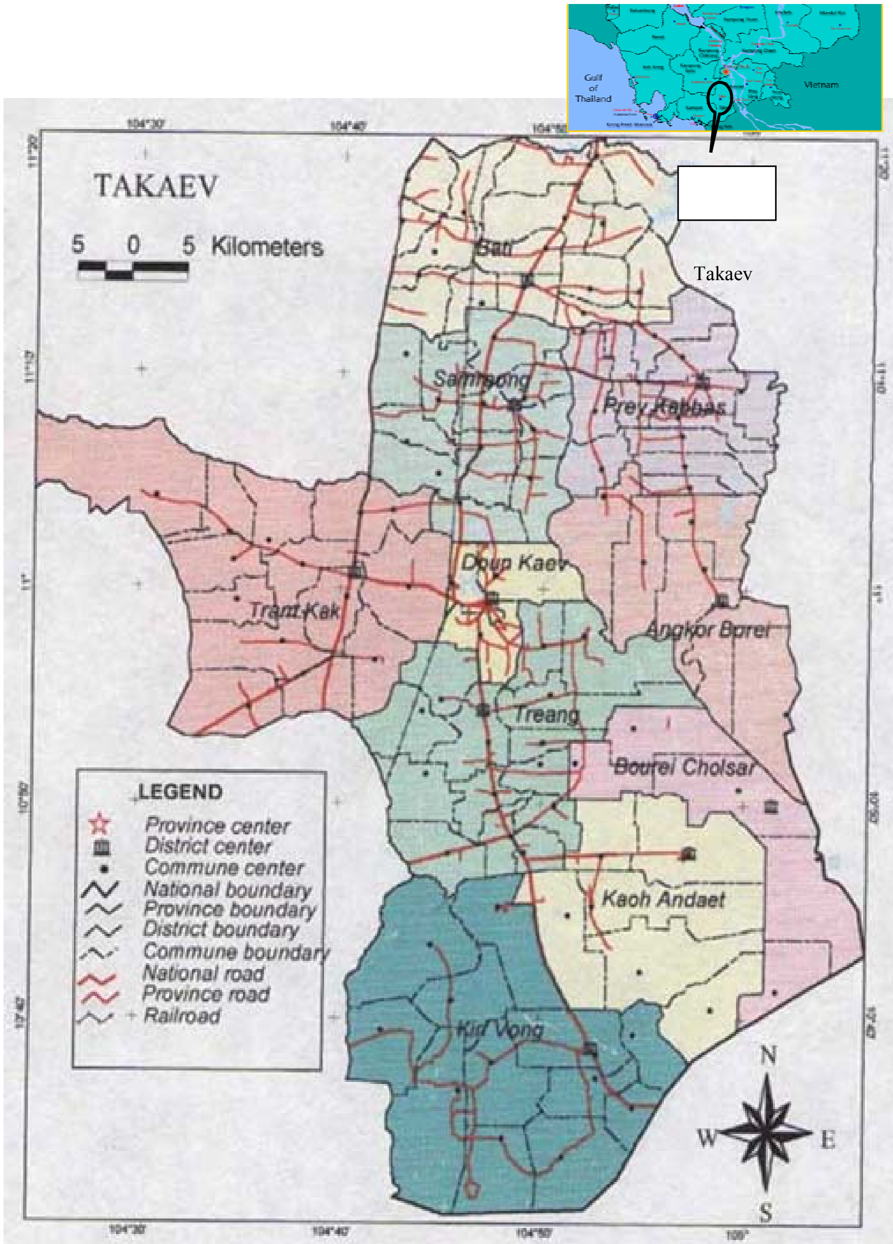

Figure 1. Map of Takaev province showing study locations.

A questionnaire was designed to meet the goals and objectives of the study. Key questions to be asked included:

- Why did they use biogas as a source of energy consumption?
- How did they install the systems?
- For what purpose did they utilize biogas?
- What were the advantages and challenges of using biogas?

All of the respondents were involved in some form of animal husbandry, usually cattle or pigs. This was essential for a regular source of substrate or fuel for the digesters and a further key element was that these animals were housed collectively, at least overnight, for ease of substrate collection.

Results and Discussion

Under the NBP, five different sizes of digester are offered, based on a Chinese model. This is to suit both investment capability, as well as volume of substrate available. From Table 2 it can be seen that digester sizes of 4 and 6m^3 were the most commonly used in the studied areas, since they were found to be consistent with the number of animals, especially cattle, that were available (Table 3). The larger sizes of 10 – 15m^3 were only employed by larger commercial animal raising concerns.

Table 2. Types of digesters used in the studied areas.

Digester Size (m^3)	No. of respondents	%
4	42	56.75
6	30	40.54
8	2	2.7
Total	**74**	**100**

Table 3. Number of animals owned by the interviewed households.

No. of cattle	No. of respondents	%	No. of pigs	No. of respondents	%
≤2.00	8	10.8	0	49	66.2
3–4	39	52.7	1–2	7	9.4
5–6	18	24.3	3–4	11	14.8
7– 8	7	9.4	5–6	2	2.7
> 9	2	2.7	> 9	5	6.7
Total	**74**	**100**	**Total**	**74**	**100**

There were two major reasons why the farmers used biogas, i.e., saving time and the convenience of the technology (Figure 2). According to a report from the NBP, each household can save at least 1 to 2 hours per day or 15 to 30 days per year, compared with those using firewood or charcoal as energy sources. Surprisingly, none of the respondents considered the environmental advantages of the technology.

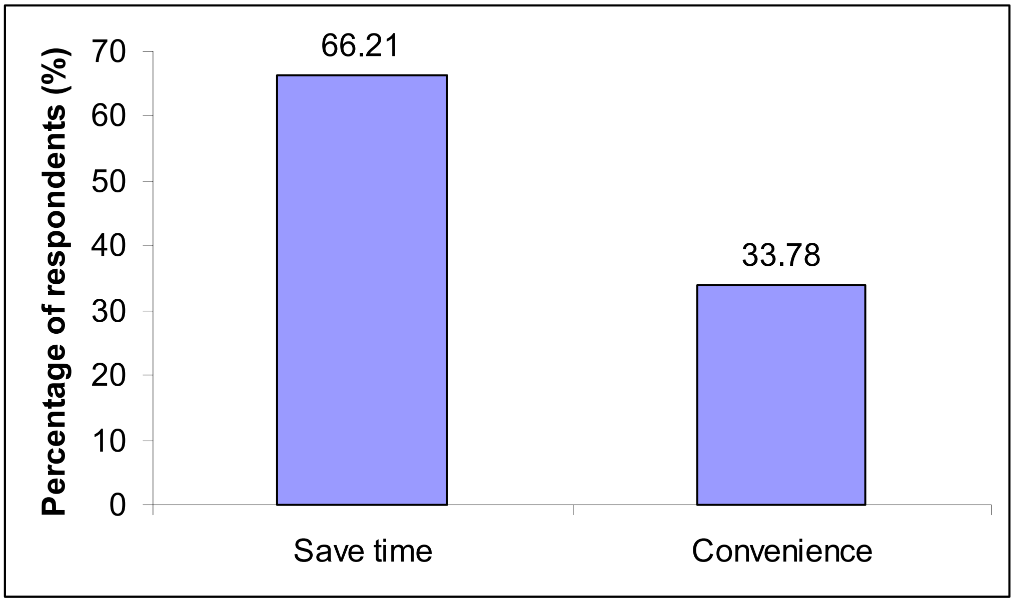

Figure 2. Reasons of using biogas (n = 74).

After selecting an appropriate site close to where animals are housed and where sunlight and water is available, the entire biogas system is constructed by NBP officers. The system consists of three major components: (1) inlet tank where manure is loaded, (2) digester (where the mixture of manure and water is incubated), and (3) slurry storage tank (where the remaining sludge is discharged). The entire system is constructed from concrete and the top of the digester is connected with a PVC pipe forming an outlet for the gas that can be pressurized to a boiler or stove, as illustrated in Figure 3.

A mixture of manure and water is added to the digester with appropriate ratios as shown in Table 4. Pig manure tended to produce methane at a slower rate than that of cow manure. It was thus recommended that cow manure (at least 70%) should be first added to the digester before the use of pig manure, at least for the initial loading. The mixture is incubated for a week in order for methane to be produced in sufficient quantity for use.

Figure 3. Photograph of the installed system showing outlet pipe for the gas.

Table 4. Ratios of manure and water loaded to the digester at first time.

Digester Size (m^3)	Manure Concentration (kg)	Water Volume (l)
4	1500	1500
6	2300	2300
8	3000	3000
10	3800	3800
15	6000	6000

Daily loading of the mixture of manure and water into the digester follows the recommendations of NBP (Table 5). To maximize gas production, the farmers use only fresh manure.

Table 5. Ratios of manure and water daily loaded to the digester.

Digester Size (m^3)	Manure Concentration (kg)	Water Volume (l)
4	20-40	20-40
6	40-60	40-60
8	60-80	60-80
10	80-100	80-100
15	120-150	120-150

All of the respondents reported that they used biogas for daily cooking and lighting. Most of them (67 respondents or 90%), answered that the gas generated was sufficient for daily use, although 7 respondents (or 9.5%) found that they were occasionally short of gas and had to compliment this with firewood. Figure 4 shows a typical two-burner cooking system using biogas. According to NBP (2007), the duration of energy consumption may depend largely on the digester size (Table 6) and amount of manure loaded.

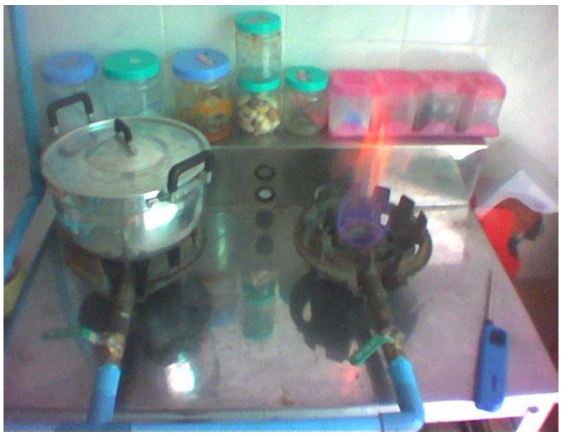

Figure 4. Typical biogas cooking set-up as used by the households.

Table 6. Duration of energy consumption (NBP, 2007).

Digester Size (m^3)	Stove (hours)	Lamp (hours)
4	3.5-4	8-10
6	5.5-6	12-15
8	7.5-8	16-20
10	9.5-10	21-25
15	14-15	28-32

Using a subsidy from the NPB, farmers need to spend from US$283.5 to US$500 on the cost of the biogas system construction, the cost depending on the digester size. The average cost of the biogas system construction found in this study were relatively higher than the standard costs as reported by NPB (Table 6). When properly installed and maintained, each biogas system has a life expectancy of up to 20 years, meaning that each household needs to save between $1.18 to $2 per month to recover the construction cost. Before the construction of these biogas systems, farmers in the studied areas used batteries as a source of energy for lighting, in addition to firewood for cooking. On average, the interviewed farmers used to spend approximately $1.5 and $15 per month on battery charging and firewood, respectively.

Table 6. A comparison of total expenses on biogas construction between NPB standard cost and cost estimated from the studied households.

Digester Size (m^3)	Standard Cost of NPB (US$)	Cost estimated from the studied households (US$)	Cost subsidized by NBP (US$)	Costs covered by each household (US$)
4	320	383.3	100	283.3
6	375	392.7	100	292.7
8	430	600	100	500
10	490	-	100	-
15	755	-	100	-

Another significant impact of using biogas was the by-product of slurry, used to fertilize their crops. Although being unable to provide exact figures on this use, all of the respondents found that using this slurry could significantly save their expenses on purchasing chemical fertilizer. Research by Thy and Buntha found the slurry to be well suited for vegetable production in Cambodia [4]. It was also observed that the use of slurry could provide more advantages over the use of compost, as the farmer's plants tended to grow faster and the growth of weeds could also be minimized.

Most of the farmers interviewed found that the environments surrounding their houses were significantly improved if compared with the time when they used firewood and charcoal, since there was less waste left laying around. Use of manure as the substrate also meant that their animal housing (usually under or adjacent to the house) was significantly cleaner, resulting in less susceptibility of animals to disease or infestation.

What could not be accurately measured during this survey, and what did not occur to the farmers themselves, was the reduction in deforestation through the use of an alternative to charcoal and firewood. As the study area is in a depleted area, it could also be assumed that the collection of firewood involved journeys of some distance and labour.

According to qualitative data acquired from the interviewed households, the major factors affecting biogas applications could be summarized as follows:

- The cost for installation of biogas digesters was still too high, excluding many poor farmers who not afford to pay.
- The high input requirement for animal manure is another factor limiting the application of the technology. To maximize the benefits from this biogas model, each household should have at least 4 to 6 animals.
- The odor and smell of the gas is not favoured by many users. Many, if not all, users believe that food cooked with firewood or charcoal is better tasting than that cooked with biogas.

Conclusion and Recommendations

The use of farm waste for biogas production for energy consumption in the studied area appears to be an appropriate alternative, not only because of the environmentally friendly conditions, but also due to the economics of the technology. The technology should be introduced more widely to other rural communities, especially where forests become scarce. This study has shown the optimum size of digester combined with the optimum number of farm animals and this information should be helpful when considering this technology for other areas.

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