Biogas Pilot Programme (BPP)

DLF/MAF and SNV-Lao PDR

Final Report on

Biogas Users' Survey - 2007

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EXECUTIVE SUMMARY

- Biogas Pilot Programme (BPP), a joint venture of Government of Lao PDR and SNV Lao PDR, was started in 2006 with the aim to install 6,600 biogas plants across the country during the period 2006 – 2011. Till the end of November 2007, some 80 plants of modified Nepalese design were installed in four selected districts in Vientiane province.
- Realising of the fact that the success of the ongoing BPP depends heavily upon the quality of services being delivered to the users and effects of biogas/bioslurry on the users, BPP proposed a study entitled, 'Biogas Users' Survey -2007'. The overall objective of the study was to conduct an in-depth review of existing biogas plants constructed in Lao PDR under the framework of BPP for assessing quality of services being delivered and effects of biogas/bioslurry on the users. The field study was carried out during the period December 18-22, 2007 in 20 randomly sampled biogas households from four districts in Vientiane provinces. The biogas plants under the study were installed during the period May – September, 2007.
- The average family size in studied households was 5.1, with a maximum of 9 and minimum of 3. The average land holding size of 3.13 ha, average cattle holding of 23, average annual income of US$ 5722.20, average annual expenditure of US$ 2868.0, average net saving of US$ 2854.20 and literacy rate of 92% (female-88% and male-96%) indicated that biogas plants have been installed by relatively well-off peoples in the society. The corresponding national figures are …………………….respectively
- The most popular motivating factors to install biogas plant were easy, comfortable and time saving source of energy (16hhs); economic benefits including saving of time and money (14hhs); environmental benefits such as saving of forest, clear surrounding (13hhs); and availability of subsidy (11hhs). The average size of biogas plants was found to be 4.3 cum. The average cost of installation of 4, 6 and 8 cum plants were US$ 380, US$ 410 and US$ 450 respectively.
- The outcome of the study indicated out of the theoretical quantity of available dung in the stable (calculated based upon the number of cattle) of 105 kg/household on an average, only 44% (25.45 kg/plant/day) was fed into the biogas plants. However, the prescribed quantity of dung based upon the hydraulic retention time of 45-50 days for the Lao PDR context is 35 kg/plant/day. The average feeding rate was 5.9 kg per 1 cum capacity of plant per day, which is 73% of the prescribed quantity. 95% of the households produced required quantity of feeding materials. Water-dung ratio was correct in majority of the cases (80%). There were no latrine-attached plants.
- The theoretical average quantity of gas production from biogas plants under study based upon the daily feeding was 1.4 cum of biogas per plant per day. Actual average biogas production based upon the gas being used is 0.98 cum per plant per day. The calculated performance efficiency of biogas plants collectively is, therefore, 97%. However, when viewed form the overall size of biogas plant (an average of 4.3 cum), the efficiency of biogas plant is 73%. The lower efficiency is the result of lesser feeding than required.
- The average burning hours of stove in the sampled households was calculated to be 2.8 hours/household/day. The gas demand in these households was reported to be an average of 3.1 hours/day/household. Gas was reported to be sufficient only in 85% of the households. The total demand of biogas can be fulfilled if the average feeding rate is increased from the existing 25.45 kg/plant/day to 32.59 kg/plant/day.
- The outcome of the study indicated that the general physical conditions of 85% of the plants were good, and that of the remaining 15% was fair. All the plants were functioning. Out of the 20 plants under analysis, 17 (85%) plants were functioning satisfactorily and the remaining 3 (15%) plants were functioning with some minor problems during the time of field investigation.

- 80% of the users were fully satisfied with the functioning of their plants while the remaining 20% were partly satisfied. The main reasons of not satisfying fully were reported to be less gas production because of the defective construction (5%), small size of plant (5%) and less gas due to leakages from joints (5%).
- The respondents rated easy and comfortable cooking, time saving and workload reduction, liberation from difficult task of firewood collection and charcoal making, improved environmental condition in and around the house and nutrient rich fertilizer as main merits, while increased incidences of mosquitoes, difficulty in draining water from the pipeline due to defective water drain, problematic lamps, and cumbersome and unhygienic process of mixing dung and water to be the main demerits of biogas technology.
- Biogas plants in general were reported to have positive impacts on the users. The findings of the study revealed that a family saved an average of 1 hour 29 minutes per day as a result of biogas plant. The average annual saving of conventional fuel sources accounted to be: firewood- 2.22 kg/hh/day, Charcoal – 0.93 kg/hh/day, LPG – 0.01 kg/hh/day and electricity – 0.22 kWh/hh/day, the monetary value of which was calculated to be US$ 88.67 per year/household, which a significant amount.
- 75% of the users were using bio-slurry in one or other ways where as the remaining 25% were not using it. 10% of the users drain bioslurry directly to open spaces or watercourses. 10% of the users told that they do not have arable land to use it. Slurry was not coming out of the plant in 3 cases (15%). Users who used slurry on farm reported that it is of high nutrient value than the farmyard manure. The use according to them were: use as organic manure without composting (70%), use as manure after composting (15%) and use wet slurry directly from plant (15%). Though the users expressed their views that the production of crop has increased after the use of bio-slurry, they could not exactly quantify the increment.
- Biogas has been found to be beneficial in decreasing the smoke borne diseases in the biogas households. According to the respondents, problems of respiratory diseases, dizziness and headache as well as eye burning have decreased significantly after the use of biogas.
- The FIRR of biogas plant of 4 cum capacity was 17 without subsidy and 34 with subsidy. This indicates that the return on investment made for the installation of biogas plant was above the opportunity cost in the capital market, which is about 12% in Lao PDR. The NPV and B/C ratio also indicated the financial viability of all the biogas plants in the given conditions. The EIRR of biogas plants ranged from 14% to 44% for a 4 cum capacity biogas plant depending upon various variables.
- In conclusion, the outcome of this study suggested that the existing biogas plants are functioning at a satisfactory level and affecting the users positively. Installation of about 80 biogas digester with in a short duration of 7 months has been instrumental in popularization of the technology at the grassroots level. Moreover, the functional plants have been found to be effective tools for the promotion and extension of the technology.
- Based upon the major finding of the study, the following recommendations are made to effectively implement the proposed Domestic Biogas Program in Lao PDR:
    - The users need to be involved in deciding the size of biogas plant to ensure their ownership in the process.
    - The masons should be instructed to follow the set quality standards on construction described in the construction manual. The supervisors should inspect the quality of construction periodically and report problems/defaults, if any, to BPP technical persons. Regular monitoring of construction works is more crucial during the initial phase of programme implementation as in BPP.

- The mason/users should be instructed to provide proper support to the exposed walls of outlet tanks to counteract the slurry pressure.
- The compost pits should be at least 1 m far from the outlet wall as shown in the drawing so that enough earthen support exists in between.
- The minimum volume of slurry pits should be at least equal to the total volume of biogas plant. The slurry pits should be well protected against the surface water flowing in to it, especially during the rainy season, as far as possible.
- A training course for users be designed and implemented on effective composting, handling and application of slurry in the farms.
- To ease the use and ensure effective functioning the water drains should be standardised.
- There is a need of effective post-construction services so that the efficiency, sustainability and reputation of the plants are guaranteed.
- There is high need of user’s training on operation and maintenance of biogas plant to ensure the continual functioning of biogas plant.
- Biogas related activities should be integrated with other developmental activities to achieve synergies.
- Subsidy should continue as driving/motivating factor to penetrate the poorer strata of the society until a demand-driven market is propelled.
- There is need for the diversification of end uses of biogas.
- Poor and marginalized people with strong willingness and commitments to be involved in biogas plant construction need to be given opportunity while imparting training and capacity building initiatives.
- There is need to penetrate into small and marginal farmers and to make biogas technology more affordable trough various incentives and support mechanisms such as mobilisation of micro credit..
- Quality should be the prime concern of the biogas programme. The quality control visits should be made more systematic with the creation of computer database to enter and analyse the QC findings.

ACKNOWLEDGEMENT

During the course of this study, I have received help and advices from a large number of people and professionals, without which successful completion of this study would have been difficult. First of all, I would like to extend my appreciation to all, the names of whose do not appear in the list of acknowledgement.

My special thanks to Ms. Surapha Viravong, The then BPP Programme Manager, Mr. Phouthanouthong Xaysombath, BPP Advisor and Mr. Bounthavy, BPP Technical Officer for their continued support as well as suggestions and feedbacks during the whole process of study. I acknowledge their unfailing support to accompany the field study during the field investigation in all the sampled districts and provided with very useful information which were instrumental in consolidating the study findings, is duly acknowledged.

My sincere thanks and appreciations are due to all the technicians in District Agriculture and Livestock Offices in the sampled districts, who provided their valuable time and assistance during the field investigation. Without their assistance, it would have been difficult for the study team to trace the sampled plants.

I cordially extend my thanks and gratitude to all the respondent plant users who provided their valuable time to answer the long questionnaires. I hope that the study truthfully reflects the views, problems and perceptions of these people.

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ABBREVIATIONS

ASS	After Sales Service
BPP	Biogas Pilot Programme
BPT	Biogas Practice Team
BRE	Biogas/Renewable Energy
CER	Certified Emission Reduction
Cum	Cubic Meter
DLF	Department of Livestock and Fisheries
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
FY	Fiscal Year
FYM	Farm-Yard-Manure
GGC	Gobar Gas (Biogas) Company
hh	Households
HRT	Hydraulic Retention Time
LPG	Liquefied Petroleum Gas
MAF	Ministry of Agriculture and Fisheries
MFI	Micro-finance Institutions
MS	Mild Steel
NGO	Non Governmental Organization
NPV	Net Present Value
O&M	Operation and Maintenance
PVC	Poly Vinyl Chloride
QC	Quality Control
RCC	Reinforced Cement Concrete
R&D	Research and Development
SNV	Netherlands Development Organization

Exchange Rate (October 2005)

1 USD = Kip 10,000
1 Euro = Kip 14,000

1. INTRODUCTION

1.1 Background

Although biogas technology has been disseminated for long time in many developing countries of the world, it is still new for Lao PDR. Only 50 biogas plants were installed in the country since 1996 till 2006 and haft of these were no longer in operation because of lack of maintenance and various other technological defects. Several feasibility studies on the promotion of Biogas Technology in Lao PDR were carried out by SNV since 2002. Based on findings of these studies, Lao PDR has been included in the "Asia Biogas Program: Access to sustainable energy for 1,300,000 people" (Project funded by the Netherlands Ministry of Development Cooperation-DGIS/DMW). Asia Biogas Program aims to provide access to biogas for 1.3 million people in Asia over the period 2006 up to 2011.

In February 2006, an assessment of possible institutional set-up for the large-scale dissemination of biogas technology in Lao PDR was formulated by SNV which concluded that the Ministry of Agriculture and Forestry (MAF) is the most appropriate implementing partner for biogas program. MAF has assigned Department of Livestock and Fisheries (DLF) as coordinating partner for this program. MAF and SNV have established a Biogas Program Office which has the responsibility to manage the Biogas Pilot Program (BPP) with the target to install 6,600 Biogas Plants in the country during the period 2007 to 2010. BPP has selected four districts, viz. Hatxayfong, Pak Ngum, Xaithani, Naxaythong in Vientiane province as its programme area for 2007. BPP has been successful in installing about 80 biogas plants till the end of November 2007. BPP, in its attempt to assess the quality of services being delivered and monitor the effects of biogas and bioslurry on the users, proposed a study, entitled, 'Biogas Users' Survey – 2008'.

1.2 Study Rationale

The success of any biogas programme depends mainly on two major factors; quality of services being delivered to the users and effects/impacts of biogas/bioslurry on the users. A study was therefore proposed aiming at collecting various data and information on functioning of existing biogas plants as well as the immediate effects of biogas on the users. This study has been considered to be instrumental in colleting first hand primary data and information on these issues from the users' level so that the findings could be reflected on the future plans of BPP.

1.3 Objective and Scope

The overall objective of the study was to conduct an in-depth review of existing biogas plants constructed in Lao PDR under the framework of BPP for assessing quality of services being delivered and effects of biogas/bioslurry on the users. Information on the following aspects were collected and analyzed:

a. Socio-economic characteristics of sampled biogas households (population pattern, family size, occupations, land holdings, agricultural production, livestock ownership, educational status etc.)
b. Construction, operation and maintenance of biogas plants including extent of compliances of quality standards
c. Existing physical status and functioning of biogas plant
d. General perception of users on the use of biogas and bioslurry
e. Effects of biogas on users at households and community levels, including improvements on social, economic (fuel saving, time saving, use of bioslurry etc.), health and sanitation as well as environmental conditions.
f. General recommendations for the proposed biogas program

1.4 Approach and Methodology

1.4.1 Study Tools

Both primary as well as secondary data and information were collected during the course of the study. The study was conducted in close accordance with the objectives. Particular attention was paid to objectively verifiable indicators depending on the level of factual, quantitative and statistical information available, and the degree to which it was possible to quantify and extrapolate conclusions from field investigation and observation.

The main instrument of the study was the structured questionnaires and open-ended unstructured interviews with the respective biogas plant user. Additional investigation tools included observations, especially of different components of biogas plants, cattle-sheds, household kitchen and slurry pits in the sampled households, and informal discussions with people in the survey clusters. The structured questionnaires were discussed among BPP staff members prior to the field-testing. During the field survey process, the study team adopted an interactive approach rather than a 'question and answer session' with the respondents to enhance the quality of data and information collected.

1.4.2 Sampling

The sampling exercise was governed by the available time for the study (3-4 days for the field study) and number of plants that were constructed at least two months prior to the data of survey to ensure that the users have experienced some effects. In total 20 biogas plants were sampled from among 80 biogas plants installed within the framework of BPP till the date of survey. Two-stage random sampling method was used to select biogas households for the field investigation. At first, clusters which had considerable numbers of biogas plants were selected from four districts in Vientiane Province where BPP is implementing its activities. From a list of biogas households in these clusters biogas plants for the survey were selected. A purposive random sampling method was used to select required number of biogas households from each district. The following table shows the districts and number of plants selected from each of them.

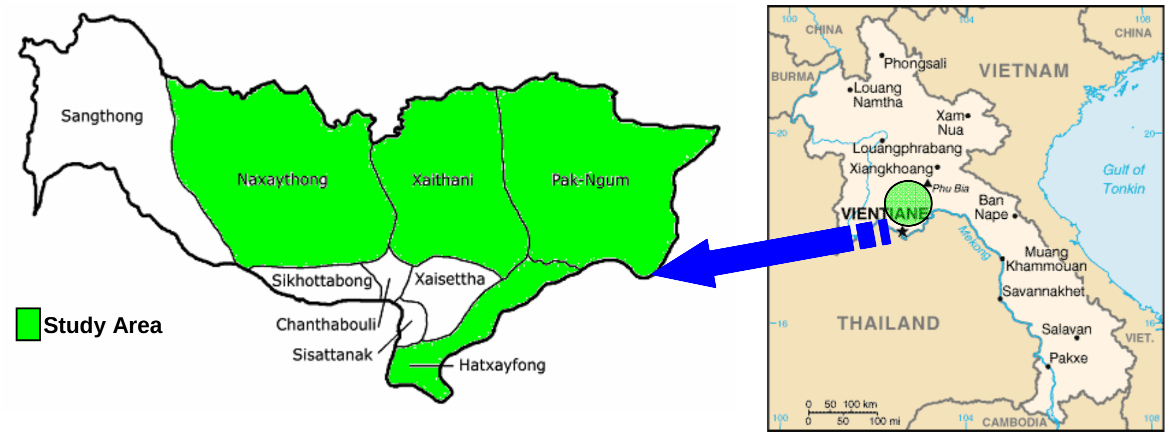
Table-1.1: Biogas Plants Sampled for the Study

Province	District	No. of Plant sampled
Vientiane	Hatxayfong	6
	Pak Ngum	2
	Xaithani	9
	Naxaythong	3
	Total	**20**

As shown in the table, 20 plants from 4 districts across Vientiane province were sampled for the study. Xaithani had the maximum (9 nos.) and Pak Ngum had the minimum number of plants (2 nos.) sampled for the study. Given the total number of plants installed under the framework of BPP (about 80 till the end of November 2007), the sample size was big enough to be representative of the entire picture of biogas program in the province. However, the finding of the study should be considered as indicative rather than representative for the whole country.

The locations of sampled districts are shown in Figure-1.1.

Figure-1.1: Location of Sampled Districts



1.4.3 Methodology

The whole study was divided into three major phases based upon the activities carried out:

a. Inception Phase: Desk Study and Mobilization

The collection of secondary data and information, formulation of field investigation methodologies, preparation of questionnaires, checklists and formats, logistic arrangements for field visits, sampling of biogas households for field investigation were the main activities carried out during this phase. The field visit itinerary was also prepared.

b. Investigation and Data Collection Phase: Field Study

Field investigation works (which consumed 5 days) using appropriate tools and techniques as described above was the main activities during this phase. Biogas plant owners, family members, some key persons in the communities were consulted and their opinion collected. The average time spent in one biogas household to collect data and information was 65 minutes with a maximum of 1 hour and 55 minutes and a minimum of 45 minutes.

c. Concluding Phase: Data Analysis, Interpretation and Report Preparation

Once the field activities were completed, all the data collected from the field and from secondary sources were crosschecked, verified, cleaned, entered into a data base and analyzed using appropriate computer software programmes (EPI Info, MS Excel and MS Word). These primary data and information were triangulated with available secondary data and information. The outcome of the analysis has been incorporated in a concise report.

The general methodology followed during the study has been illustrated in the following diagramme.

Figure-1.2: Methodology Adopted during the Study

Preliminary Phase: Desk Study and Mobilization

Study team formation

↓

Sampling of Biogas Households for study

↓

Desk study of secondary data and information

↓

Preparation of questionnaires, checklists and interview guidelines

Fine-tuning of the questionnaires

↓

Field-testing of the questionnaires

↓

Finalization of the questionnaires

↓

Mobilization for field investigation and data collection

⬇

Investigation and Data Collection Phase: Field Study

Field study using participatory tools and techniques to collect data and information on present status biogas plants

↓

Observation, walk through and case studies

↓

Consultation and informal discussions with community people

⬇

Concluding Phase: Data Analysis, Interpretation and Thesis Report Preparation

Field data compilation, analysis and interpretation

↓

Triangulation of primary and secondary data and information

↓

Preparation of Draft Final Report

↓

Receiving of comments and suggestions on Draft Final Report

↓

Preparation of Final Report

1.5 Limitations

The study team has attempted to be as participatory and consultative as possible during field investigation. However, as in every studies/surveys of this type, this study has its limitations as described hereafter:

a. Given confined coverage, the findings of the study may not represent the whole country. However, the outcome will be significantly same in areas with similar socio-economic, cultural and geographical settings. The outcome of the study therefore, is more indicative than representative.

b. The source of primary data and information was mainly the household survey. It should be noted that views and findings contained in this report are those derived from the responses of the respective respondents.

c. Among many others, the study had intended to explore some basic family/household level information on land holding, income and expenditure. It is possible that there were some shortcomings in dragging actual information on these aspects. It was felt that some of the respondents had general tendency of hiding exact information due to various reasons while some others were hesitant to talk about it, some claimed ignorance and some mentioned an amount that proved to be very low or high later on. The same was the case on time spent on different biogas related activities and total burning hours of biogas stoves. Since it was a survey of the users, there was no actual measurement and as far as quantifiable data and information were concerned, recall method was used, which may not be very exact.

d. Despite genuine efforts, this study having been conducted within a short period of timeframe and with many other constraints might possess some errors methodologically and in the findings presented here in.

2. SOCIO-ECONOMIC CHARECTERISTCS

The outcome of the study indicated that most of the individual biogas households were well off by rural Lao standards, as characterized by higher income level, large and medium land holdings, plenty of livestock, and many educated family members. The findings on socio-economic characteristics of the plant owners under study are described below:

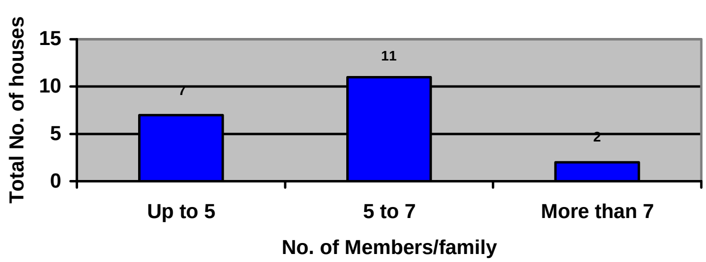
2.1 Demography

The total population of the 20 households under study was found to be 102 among which 54 (53%) were female members and 48 (47%) were male members. The average family size was 5.1, which is quite similar to the national average size of ?????. Household with maximum and minimum numbers of family members had 9 and 3 members respectively. The oldest person was of 83 years of age, a male member in Nahai commune in Hatxayfong district. Table-2.1 and the Figure-2.1 show the population composition and distribution of family members respectively in the studied households.

Table-2.1: Population Pattern

Age Group	No of People		
	Male	Female	Total
Less than 6	1	4	5
6 to 16	10	9	19
17 to 45	20	29	49
46 to 60	11	8	19
61 to 75	5	3	8
Above 75	1	1	2
Total	**48**	**54**	**102**

Fig-2.1: Distribution of Family Members



As can be seen from Table-2.1, economically active population (age group 17 to 60) had share of 66.7% in the total population size. 31.3% of the population were of age below 20. Interestingly, 9.8% of the populations were above 61 years of age. Another fact as seen from the Figure 2.1 is the predominance of 5-7 member-sized families among the biogas users, which comprised of 55% of the total households under study. The finding indicated that biogas plants have been installed in households with small to medium sized family members. The family size in 19 (95%) households remained same before the installation of biogas plants and during the time of survey, whereas it was increased in the remaining 1 (5%) household. The change was reported due to the marriage of one of the family members.

2.2 Economic Status

2.2.1 Occupation

The survey indicated that the primary source of income for the majority of the households (75%) was agriculture and agro-based small and medium entrepreneurship. The major occupations of the family members have been given in the following table.

Table-2.2: Occupation of Household Members

Occupation	Male	Female	Total
Less than 6 years or Old age	4	8	12
Agriculture	10	14	24
Business	5	4	9
Teaching	1	2	3
Government Services	7	3	10
Other services (NGOs etc.)	6	5	11
Study	14	11	25
House-wife	0	6	6
Overseas service	1	0	1
Physically disable	0	1	1
Total	**48**	**54**	**102**

As shown in Table -2.2, 32% of the household members are fully involved in agriculture and agro-based occupations. Interestingly, significant numbers of the population (23%) are having some type of services such as teacher, NGO or government workers etc.

2.2.2 Land Holdings

The average land holding size of the households under study was 3.13 hectors (2.75 ha – arable land and 0.38 ha non-arable land) per households, with a minimum of 0.1 and maximum of 11 ha. The average size was ………… than the national average of ????, which indicated that the biogas plants were installed in ………………. holding households. The standard deviation of 2.7 indicated that the gap of smaller and bigger land holdings is relatively high. The outcome of the study indicated that none of the sampled households either rented-in or rented-out land. Table 2.3 shows the land holding patterns.

Table-2.3: Land Holding Pattern

Land Holdings in ha	No. of HHs possessing		
	Arable	**Non-arable**	**Total Land**
Less than 1	2	13	0
1 to 3	12	6	12
3.01 to 5	4	1	4
More than 5	2	0	4
Total	20	20	20

- Arable Land: Average 2.75 ha (min-0 ha, max-11 ha)
- Non-arable Land: Average 0.38 ha (min-0, max-4 ha)
- Total land holding: Average: 3.13 ha (min-0.1 ha, max-11 ha)

2.2.3 Agricultural / Forest Products

The major crops (cereal and cash crops) cultivated were reported to be paddy, vegetables and fruits. The gross average amount earned from selling of agricultural crops and agricultural product such as milk, milk-products and meat has been given in the following table.

Table- 2.4: Income from Agricultural and Forest Products

Source of Income	Income/year/hh in US$
Cereal crops	639.35
Cash crops	310.00
Fish	70.00
Fruits	7.50
Vegetables	22.34
Meat products	1286.50
Others (wood and wood products etc)	610.30
Total	**2945.99**

2.2.4 Livestock

The biogas households owned cattle (cow, ox, buffalo and pig), during the time of survey, at an average of 23 cattle per household which was much higher than the national average of ????. The maximum number of cattle was 49 and the minimum was 3. The following table shows information on cattle holding.

Table-2.5: Number of Cattle Owned

Type of Cattle	Average/household	Maximum	Minimum	Standard Deviation
Cow/oxen	13	42	0	9.8
Buffalo	1	13	0	3.14
Pig	9	75	0	9.77
Chicken	41	120	0	37.1
Goat	Only one household had goat (5 nos.)			

100% of the cow/oxen and 96% of the buffalo were reported to be open-grazed for about 6-8 hours outside the cattle-shed. The number of cattle was reported to be increased in 30% and decreased in 40% of the households after the installation of biogas plant. The higher standard deviations suggested that the distribution of animals is not homogenous.

2.2.5 Income-Expenditure Pattern

The annual income and expenditure in the biogas households were calculated to be US$ 5722.20 and US$ 2868.00 respectively. The following table summarises the finding on income and expenditure.

Table-2.6: Income and Expenditure

Particulars	Minimum per year in US$	Maximum per year in US$	Average per year in US$	Standard Deviation
Income	1160.0	14038.2	5722.2	4.42
Expenditure	912.0	7200.0	2868.0	1.84
Surplus	-40.0	12363.2	2854.2	3.81

The amounts of average income and expenditure are significantly higher than the national average of US$………… and US$……… respectively. Expenditure was higher than income (deficit) in 1 household in which deficit of US$ 40.00 was reported last year. Other households had more income than expenses. The distribution of income and saving was found to be uneven with the standard deviations 4.42 and 3.81 respectively. However, the gap in expenditure pattern was not much. The higher standard deviation of income-range suggested the extremities in annual income pattern. Interestingly, the value of standard deviation was less in expense range than that of income suggesting that the extremity was less in expenditure patterns.

The biogas owners had pucca houses in 35% cases, semi-pucca houses in 30% cases and kuchha houses in 35% of the cases.

2.3 Educational Status

The overall literacy rate in the sampled households (excluding children below 6 years of age) was 92%, which was higher than the national average of ?????%. The female and male literacy rates were calculated to be 88% and 96% respectively as against the national figures of ???? and ???% respectively. The educational status of the members in the studied biogas families has been given in Table-2.7.

Table-2.7: Educational Status of Household Members

Education	No. of People		Total
	Male	Female	
Illiterate/Not attending Schools	2	6	8
Primary level (up to Grade 5)	14	13	27
Grade 6	0	3	3
Grade 7	1	3	4
Grade 8	2	0	2
Grade 9	0	4	4
Grade 10	1	3	4
Grade 11	2	1	3
Grade 12	15	12	27
Bachelors Degree	8	4	12
Masters Degree	2	1	3
Children below 6 years	1	4	5
Total	**48**	**54**	**102**

More female members (6) were illiterate than male members (2). Out of the 15 persons who had education higher than graduation (bachelor degree), 10 (67%) were male members. Interestingly, the drop-out rate of both the male and female members is high after grade 5 and grade 12. The data on educational status of the biogas family members indicated that though the numbers are much higher than the national average, the pattern is similar to that of the nation as a whole, where the figure are slightly better for male than female.

3. CONSTRUCTION, OPERATION AND MAINTENANCE OF BIOGAS PLANT

3.1 Construction

3.1.1 Plant Location

The biogas households sampled for the study represented four districts from Vientiane province in Lao PDR where BPP is implementing its activities. All the biogas plants were installed in easily accessible areas, where basic infrastructure services existed. Easily accessible roads and electricity grid connections in all the sampled households indicated that these plants were installed in accessible areas.

3.1.2 Reason and Year of Installation

The respondents were asked to give most important reasons/motivating factors for the installation of biogas plants. As per them, the most popular motivating factors to install biogas plant were easy, comfortable and time saving source of energy (16hhs), economic benefits including saving of time and money (14hhs), environmental benefits such as saving of forest, clear surrounding (13hhs), availability of subsidy (11hhs), Motivation from service provider (7hhs), fertilizer of higher nutrient value (3hhs) and health benefits (1hh). The following table shows the responses on the reasons for the installation of biogas plants.

Table-3.1: Motivating Factors to Install Biogas Plant

Motivating Factors	No. of HHs*
Easy, comfortable and time saving source of energy	16
Economic benefits (saves money)	14
Environmental benefits (saving of forest, clean surrounding etc.)	13
Subsidy	11
Motivation from service provider	7
Fertilizer of higher nutrient value	3
Health benefits (clean kitchen, no smoke-borne diseases, proper management of dung)	1

** more than 1 response from the respondents*

Interestingly, difficulty in getting conventional energy sources as well as their high costs was not reported even by a single respondent to be one of the reasons for the installation of biogas plants. In other countries like Nepal and India where biogas plants have been disseminated to a significant extent, the benefit of biogas to replace the conventional fuel sources was reported to be the main motivating factor to install biogas plants. Interestingly, environmental benefits of biogas plants like saving of forest, clean surrounding, and proper use of waste materials etc. were valued highly as in Pakistan and Bangladesh.

Among the 20 plants surveyed during the study, the oldest plants (1 number) was in operation for eight months (installed in May 2007) and the youngest plants (5 numbers) were operating for slightly more than 2 months. The following table shows the operational age of biogas plants sampled for the study.

Table-3.2: Operational Age of Biogas Plants

Operational Age	No. of Plants
8 months	1
7 months	3
6 months	8
5 months	1
3 months	2
2 months	5
Total	**20**

3.1.3 Decision Making for the Installation

When asked the respondents on who made the final decision to install biogas plant, 50% of them told that the decision was taken by the household head – the male members in 40% case and female members in 10%. 35% were reported to have a discussion in the family before deciding, where as the younger members – son or daughters in the family decided in 10% of the cases. The remaining 5% reported that the service providers were responsible for taking the decisions.

The respondents told that they knew about the technology through government officials and extension workers (40%), service providers/masons (35%), biogas users (5%), friends and relatives (5%), community leaders (5%) and the publicity media (5%). The remaining 5% knew about it through more than one of the above-mentioned mediums.

3.1.4 Type and Size of Plant

All the 20 plants selected for the study were fixed dome plants (the modified design of Nepalese GGC model) being disseminated under the framework of BPP.

Among these 20 plants under study, 18 plants were of capacity of 4 cum, followed by one each of 6 and 8 cum. The average size of biogas plants under study was 4.3 cum which is slightly smaller than that of Nepal (6.1 cum) and Cambodia (5.9 cum). The size of the plants was reported to be selected based upon the recommendations from the service providers. It is learnt that the size of biodigester in all the cases were decided by the BPP personnel when carrying out feasibility survey. Some of the users complained that they would have installed bigger biogas plants if they had known that the available dung would have been enough to meet the requirement for such bigger plants. 15% of the respondent felt that the size of the plant was small for them to meet the fuel need. Similarly 10% of them recommended that the sizes need to be increased in the future if biogas technology is to be made popular among the rural people.

3.1.5 Construction Site Selection

The construction sites in all the cases were reported to be selected by the BPP personnel in consultation with the household members. The outcome of the survey indicated that 65% of the plants have been constructed in the most appropriate site when viewed from the availability of land. The following table shows the criteria used by the households in selecting the site for construction.

Table 3.3: The reasons for selecting site for construction of biogas plant

Reasons	Number of households	Percent (%)
Convenience to feed the plant	3	15
Convenience for removing/draining bioslurry	2	10
Convenience for carrying out construction works	4	20
Convenience to convey gas to point of application	3	15
Ensuring the safety of biogas plant (free from inundation, less prone to vandalisms etc.)	4	20
Constrained by the availability of land	4	20
Total	**20**	**100**

9 plants were located in sunny places, 8 in partly sunny places and the remaining 3 in areas under the shadow of buildings or trees. The distance of 12 plants form the kitchen was found to be within 10 m, 3 with in 10 to 20 m and the remaining 5 with in 20 to 30 m. Likewise, the distance from water sources was less than 10 m in 15 cases and 15-20 meters in the remaining cases. The distance of cattle shed was less than 10 m in 10 cases, 10 to 20 m in 7 cases and more than 20 m in the remaining 3 cases.

3.1.6 Construction Management

BPP is directly involved in supporting the installation of biogas plants at the farmer's households in Lao PDR. BPP has trained technical persons from the agriculture and livestock offices in the four programme districts to carry out the task of promotion as well as supervision of the construction works. BPP's promotion and extension officer with the district offices of agriculture and livestock carries out the task of promotion and marketing. BPP provides training to local mason on construction. Once the demand is collected, the trained technicians visit the selected households to discuss on the construction schedule and finalise other arrangements.

The users were responsible to collect locally available construction materials and provide unskilled labours for construction works. BPP contributed cement, MS rods, pipes and appliances as well as the service of a skilled mason needed for the construction as investment subsidy. Once the installation work is done, a completion report is prepared.

When asked to evaluate the skill of the masons who were responsible for the construction and installation of biogas plants, 55% of the users rated the masons as skilled with good knowledge on biogas plant. The remaining 45% reported that the masons were skilled but they lack good knowledge on biogas plant. They pointed out the need to enhance the skill of the masons so that they function more effectively.

Though 85% of the plant owners felt that some technical standards were set by the service providers as regards the quality of construction materials and construction methods, 65% of them did not know anything about those standards. The rest of the respondents believed that no such standards were set.

3.1.7 Quality Control during construction

Quality control is increasingly important concern during biogas programme implementation. Defects or failures in constructed biogas plants can result in costs. Even with minor defects, re-construction may be required and facility operations impaired. Increased costs and delays are the results. The structured QC system is therefore important for the following main reasons:

- To maximize performance, reliability and lifetime of every biogas plant
- To maximize the value for money for Biogas customers, BPP donors and Government of Lao PDR
- To maximize the potential livelihood benefits to customers and communities
- To minimize the risk of accidents or damage to users or property
- To maintain the reputation, credibility and value of the Biogas Program

To facilitate effective monitoring for ensuring quality, BPP has formulated and enforced some standards. These quality standards are basically related to the following aspects:

- Quality standards related to location and size of biogas plants
- Quality standards related to the design and construction of biogas plants

- Quality standards for the operation and maintenance of biogas plants (after-sale-services on behalf of the installers and routine O&M on behalf of users)

Tolerances are fixed based upon the anticipated degree of precisions to ensure effective operation of biogas plants. Most of the quality standards developed for the construction of biodigester allow certain tolerances. BPP has formulated and enforced quality control system to ensure the compliance of quality standards from its onset. The existing mechanisms of quality control of biogas plants within the framework of BPP have been as follows:

- The masons are imparted with training on construction as well as operation and maintenance. They are responsible to construct biogas plants complying the quality standards as set out by BPP.
- The district technicians are responsible to monitor the work of the masons in the respective district. They are supposed to visit each and every biogas plants being constructed and give feedback to the masons.
- The technical officers from BPP visit some of the under construction plants in the districts selected on random sampling basis to monitor the construction works and ensure the quality and compliance of quality standards.
- The district technicians visit all the completed plants for final acceptance.
- The technical officers from BPP visit some plants selected on random sampling basis to monitor the accuracy of reporting as done by the district technicians.

In conclusion, the masons took major responsibility of biogas plant construction and the district technicians are mainly responsible to carry out quality control visits to under construction plants.

A Quality Control log book is maintained for each plant which consists of the filled forms as well as other information related to the biogas plant. The system of documentation is fine. There is however, need for creating a computer database in which all the information are entered and analysed. BPP was in the process of creating such database during the survey period.

3.1.8 Financing for Construction

Biogas plants in Lao PDR under the framework of BPP were financed in two ways – an investment subsidy from the government through BPP on the installation cost and cash and/or kind contribution from respective plant owners to fill gap. The subsidy provided through BPP was not sufficient to meet the total cost of installation and a gap existed which the farmers must bridge. This gap was filled by the cash and/or kind contribution from the users. Average total investment costs of biogas plants were US$ 380 for 4 cum, US$ 410 for 6 cum, and US$ 450 for 8 cum plant. Minimum, average and maximum costs of installation of biogas plants are shown in the following table:

Table-3.4: Cost of Installation of Biogas Plant

Size of plant	Average cost in US$	Minimum Cost in US$	Maximum Cost in US$
4	359	350	380
6	410	410	410
8	450	450	450

The average share of the subsidy form BPP in the total cost was reported to be 55%. The remaining 45% was reported to be contributed by the owners in the form of cash and kind contributions. According to 80% of the respondents, the cost of installation of biogas plant was reasonable. The remaining 20% expressed that the cost was quite expensive. The subsidy on the investment cost has been one of the main motivating factors to install biogas for 11 out of 20 (55%) plant owners. Interestingly, 60% of the respondents told that they would not have installed biogas if subsidy was not provided.

None of the users were reported to have taken loan to install their biogas plants. The outcome of the study revealed a fact that taking loan for constructing biogas plant is not a common practice in Laos. The reasons as mentioned not to take loan were[1]: good economic condition (55%), adequate amount of subsidy from the project (50%), non-availability of credit facility (20%), attitude against the philosophy of taking loans (15%), ignorance on availability of loan facility (10%), enough money from the selling of cattle/household assets (10%) and fear that loans may degrade social prestige (5%).

3.2 Operation

The key to proper operation of biogas plant is the daily feeding with the mix of right proportions of dung and water, frequent draining of condensed water in the pipeline through the water outlet, cleaning of stoves and lamps, oiling of gas valves and gas taps, cleaning of overflow outlet, checking of gas leakage through pipe joints and gas valves and adding of organic materials to slurry pits. As long as these tasks are carried out reliably and carefully the plant will function properly. The subsequent sections describe the finding of the study as regards the operation of the biogas plants.

3.2.1 Plant Feeding

a. Feeding Materials

The amount of gas production in biogas digester depends upon the quantity of feeding supplied to it daily provided the plant is technically all right. Cattle dung was the only feeding materials used to feed into the plants. The following table gives information on dung (feeding material) production in the sampled biogas households.

Table-3.5: Dung Production

Quantity of feeding materials produced (kg/day/hh)	Number of hhs
Less than 20	0
20.1 to 40	1
40.1 to 60	3
60.1 to 80	2
80.1 to 100	5
100.1 to 150	2
More than 150	7
Total	**29**

The outcome of the study indicated that the whole quantity of dung produced in the stable was not fed into the plant. It showed that out of the theoretical quantity of available dung (calculated based upon the number of cattle) of 2100 kg (105 kg/hh/day on an average), 509 (25.45 kg/hh/day on an average) is fed into the plant which is 24% of the total production. However, the prescribed quantity of dung based upon the hydraulic retention time of 45-50 days to for the Laotian context is about 700 kg in total (35 kg/plant/day on an average). The average available quantity of dung (105 kg/hh/day) is far more than the average required quantity (35 kg/plant/day). The average feeding rate thus was 5.9 kg per 1 cum plant capacity per day, which is 73% of the required quantity. In conclusion, the biogas plants are being underfed despite the availability of the required quantity of dung.

Out of the 20 households under survey, 19 (95%) produced required quantity of dung. The remaining one household produced 80% of the required quantity of dung. Ironically, the outcome of the study showed that all the produced feeding material was not fed into the digester and hence the number of underfed plants was higher. The following table illustrates the feeding patterns.

[1] Some respondents had more than 1 answer

Table-3.6: Actual Quantity of Dung Fed into the Plant

Feeding Rate	% of plants
less than 50% feeding	5%
51-60% feeding	0%
61-70% feeding	40%
71-90% feeding	30%
More than 90% feeding	25%

It is apparent from Table-3.6 that 45% of the total plants under study received less than 70% of the prescribed quantity of feeding materials. There were significant numbers of under-fed plants (75%). One of the main reasons was the fact that users were not aware of the total quantity of dung to be fed into their plants daily though they had enough dung to feed. When asked question in this issue, 30% expressed their ignorance on the required quantity of feeding. Those who replied also were found to be misinformed. Only 2 out of the 20 respondents told the correct quantity. 13 of them replied far-less quantity, 3 replied lesser quantity and the remaining 2 told more quantity then needed. According to the answers from the respondents on the prescribed quantity, the average quantity of dung required was told to be 20 kg for 4 cum plant per day which is less than the actual quantity needed (30-32 kg).

b. Water-Dung Ratio

Water dung ratio plays a vital role in ensuring conducive environment for micro-organisms in biodigeters to produce biogas. Higher water-dung ratio results in settling of solid particle in the floor which creates a dead volume and reduces the effective volume of digester. Likewise, feeding with less water adds the risk of formation of scum on the top of slurry layer which in long run obstructs the flow of the produced gas. The outcome of the study revealed that the water-dung ratio was correct (1:1) in 80% of the plants. These plants received equal volume of dung and water. 15% of the total biogas plants received more water than required. The remaining 5% of the plants received less water than prescribed.

c. Night-soil Feeding

The concept of connecting household latrines to biogas digester is not yet a common practice in Laos for a variety of socio-cultural and religious reasons. The thought of using gas from such a source for cooking purpose remains little bit a taboo. Though 60% of the respondents replied that there are not any problems associated with the latrine attached plants; the remaining 40% expressed some difficulties. Some of the responses of plant users as regards the latrine connection to biogas plants were (respondents had more than one answers):

- Gas from latrine attached plants are considered to be un-sacred (25%)
- People are hesitant to handle bio-slurry from latrine-attached plants (10%)
- Though we know that the gas received from night-soil and that received from cattle dung is same, it is still not possible to attach latrine with biogas plant as the elderly members object the ides (5%)
- There are no social and religious taboos in attaching latrines to biogas plants; however, we do not think this is necessary (20%)

3.2.2 Frequency of Operational Activities

Besides feeding of plants, other operational activities were reported to be carried out on as and when needed basis in most of the cases. As regards the frequency of operation of different activities, the responses were as given in Table-3.7.

Table-3.7: Frequency of Operation of Biogas Plant Components

Activities	Daily	Once in a week	Once in two weeks	As and when Needed	Never
Plant Feeding	19	1	-	-	-
Use of Main valve	4	1	-	13	2
Checking leakages	-	4	1	2	13
Use of Water drain	5	5	1	1	8
Cleaning of outlet/ overflow opening	2	9	2	3	4
Maintaining compost pits	6	1	1	1	11
Oiling of gas tap	-	-	-	3	17
Cleaning of gas stove	10	4	1	3	2
Cleaning of gas lamp	-	-	-	-	4

It is clear form Table-3.7 that majority of the plant owners lack knowledge on different operational activities needed to be carried out regularly for the trouble-free functioning of biogas plant and its components. This was due to ignorance of the users, as they have not been provided with training on operation of biogas plants. The outcome of the study also suggested that the operation and maintenance cost of biogas digester was virtually nil. The zero operational cost was due to the dung obtained from livestock they owned and labour for feeding and other operation and maintenance activities incurred no expenditure as these were not carried out.

3.3 After-sale-services

The aim of after-sale-services is to have well functioning plants with satisfied and positive users, leading to farmer-to-farmer motivation. After-sales-service requires the mason thoroughly monitor the plant upon plant owner's request and to sign on the Guarantee Certificate granted to households on the handing over date. As all the biogas plants were relatively new, the need for regular visits to biogas plants by the mason was relatively less. However, some of the users (3 nos.) complained that the masons are not visiting the plants even when requested. 14 out of the 20 users told that they have received after-sales services from the masons regularly, though there were no mandatory provisions of such services.

3.4 Training and Orientation to Users

In fact, the functioning of biogas plant is basically determined not only by the quality of construction and workmanship involved but also by the quality of operation and maintenance efforts from the users. The users should be provided with basic orientation on various aspects of operation and maintenance such as proper feeding of the plant, optimal use of biogas, effective application of slurry, timely maintenance of plant components and improving cooking environment. The following table illustrates the responses of the users when being asked if they have received any training on operation and maintenance of biogas plants from the service providers.

Table-3.8: Training on O&M of Biogas Plant

Type of training received	No. of households	% of households
No training received	1	5
Training not provided but leaflet/booklet/manual provided	2	10
Short orientation training provided by service provider (on the spot instructions from mason/company supervisors etc)	16	80
Short term O & M training (1days or less)	1	5
Long term O & M training (more than 1 days)	0	0
Short Training provided by other NGOs (not the service provider)	0	0
Total	**20**	**100**

It is evident form Table-3.8 that there is high need of training to educate the users on basic operation and maintenance of the installed plants. Existing physical status and functioning of majority of the plants under study also suggested that the users were not fully aware of the importance of effective operational activities and timely repair works for trouble-free performance of biogas plants.

3.5 Maintenance

During the field study, when respondent were asked if they could carry out repair and maintenance works by their own, only 2 respondents replied in positive. 80% of the respondents expressed urgent need of training on minor repair and maintenance works to effectively manage their biogas plants. The responses of the users on being asked on the problems that they are facing are summarised in the Table-3.9.

Table-3.9: Common Problems in Biogas Plants

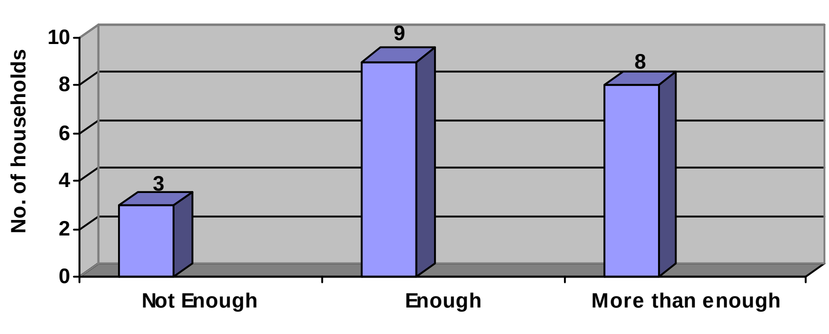
Common Problems Reported	% of plants
Leakage of Gas through pipe joints	20%
Less gas production than anticipated	15%
Leakages in outlet tank (slurry hardens)	10%
Faulty pressure gauge	10%
Problems with breakage of lamps	10%
Broken/damaged pipelines	5%
Leakage through gas tap	5%

As reported, leakage of biogas from the joints in pipes and appliances is the main problem. The outcome of the study suggested that the users had not carry out any repair and maintenance works to their plants. The reason for not doing such repair works was reported to be the short operational life of the biogas plants (2-8 months) in which no major problems were encountered. However, 3 out of the 20 (15%) plants were in need of some repair works during the time of survey.

3.6 Gas Production and Use

The outcome of the study indicated that the main application of biogas was on cooking. Biogas was used only for cooking purpose in all the households though 4 households have also installed biogas lamps. Biogas stoves with single burner manufactured in Thailand were installed in all 20 households. While calculating the gas production, therefore, use of gas for cooking has only been considered. The following chart illustrates the sufficiency of biogas for cooking purpose.

Figure-3.1 : Sufficiency of Biogas



As can be seen from Fig. 3.1, gas is more than enough for 8 (40%) of the households. In other words, these households are receiving more biogas than needed for their cooking needs. These households should be instructed to use biogas optimally so that the produced gas does not escape into the atmosphere.

The average burning hours of stove in the sampled households was calculated to be 2.8 hours/household per day. The gas demand in these households was reported to be an average of 3.1 hours per day per household. Gas was reported to be sufficient in 45% and more than sufficient in 40% of the households. The remaining 15% told that they are running shortage of biogas throughout the year. When asked on the reasons for shortage of biogas, the respondents felt that it was due to less gas production because of the defective construction and technical failures (1 hh), too-small plant (1 hh), and less gas due to leakage (1 hhs). The following table illustrates some facts on feeding and gas production.

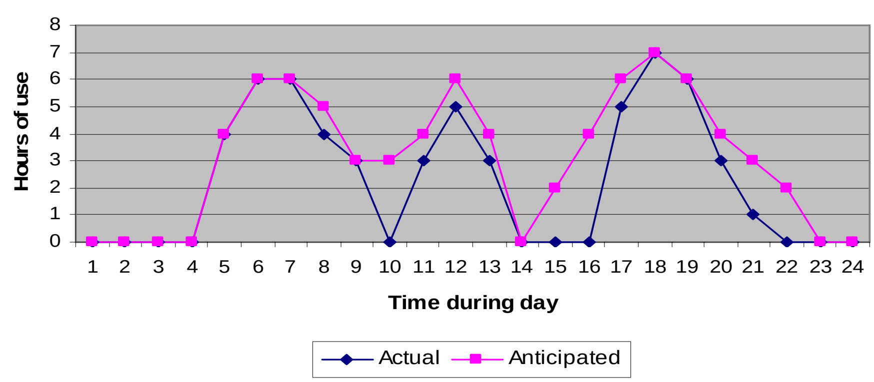
Table-3.10: Some Facts on Feeding and Gas Production

- Theoretical quantity of gas production based upon plant size: **1.4 cum/day**
- Required quantity of dung to be feed: **35 kg/day/plant**
- Available quantity of feeding: **105 kg of dung/day/hh**
- Actual quantity feed into the digester (loading rate)**: 25.45 kg/day/plant**
- Required to Actual feeding ratio**: 0.73**
- Theoretical quantity of gas production based upon actual feeding: **1.01 cum/day/plant**
- Actual quantity of gas being produced based upon stove burning hour: **0.98 cum/day/plant**
- Efficiency of biogas plants based upon their storage capacity and biogas use: **73%**
- Efficiency of biogas plants based upon feeding and burning hour: **97%**
- Average burning hours of stove: **2.8 hour/day/hh**
- Anticipated burning hour as per family requirements**: 3.1 hours/day/hh**

The outcome of the study as given Table-3.10 illustrates that the biogas plants are under-fed (25.45 kg fed as against the need of 35 kg) as well as undersized from the availability of feeding materials point of view. Based upon the available quantity of dung which is 105 kg, the suitable average size would have been 10 cum; however, this will be oversized when viewed from the gas requirement point of view.

Figure 3.2 shows the biogas use pattern in an average biogas household (actual and anticipated) calculated based upon the use of biogas stoves as reported by the users. The distribution of average stove burning hours of 3.1 (anticipated) and 2.8 (actual) have been shown in the figure.

Figure-3.2: Actual vs. Anticipated Gas Use



The above graph (Figure) on biogas use pattern suggests that the produced gas, in totality, was not sufficient to meet the anticipated demand. 10 users reported that the use of biogas would have been more than the existing hours if there was more gas in the plant.

The following figure illustrates the gap between actual and anticipated cooking hours in the studies households. As can be seen in the figure, the anticipated cooking time is more than the existing stove burning hours in majority of the cases in 10 out of 20 households. The demand can be fulfilled if the average feeding rate of existing plants is increased from the existing 25.45 kg/plant/day to 32.59 kg/plant/day.

Figure-3.3: Actual vs. Anticipated Gas Use

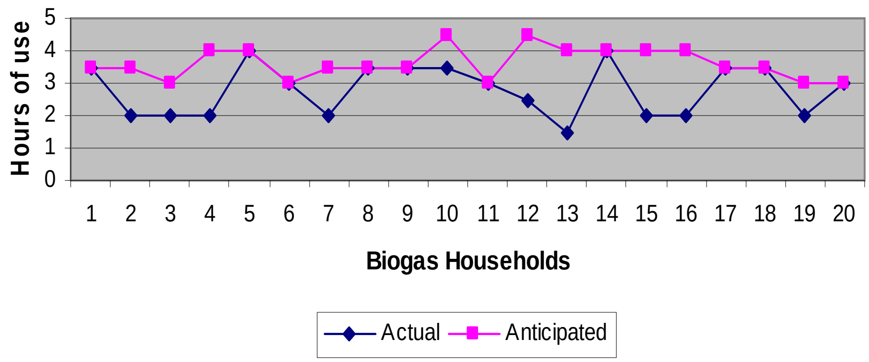


Figure 3.3 shows that 50% of the users would have increased the existing biogas consumption had there been more gas in the biogas plant.

4. PHYSICAL STATUS AND FUNCTIONING OF BIOGAS PLANT

The study attempted to evaluate the overall performance of biogas plant on the basis of: (a) existing physical status and functioning of its different components, (b) present level of benefits being achieved (the gas and bioslurry being produced), (c) response of respective plant users whether their expectation prior to the installation of biogas came true after the plants are operational (evaluated in terms of gas demand and supply), and (d) level of users' satisfaction on the impacts of biogas plants on them.

4.1 Plant Components

The fixed dome designs of biogas plant generally consist of the following components. Some of the major findings of the field investigation on these components, in general, are briefly described hereafter:

4.1.1 Inlet Tank

Cylindrical tanks for mixing dung and water, and either a square or a rectangular tank to flush the pig-manure from sty were constructed. Bricks were used to construct base and walls, which were plastered with cement-sand mortar. PVC pipes of diameter 10 cm were used to convey feeding materials into the digester. The quality of workmanship involved in construction was satisfactory with some rooms for further improvement. However, it meets the required standards in majority of the cases and the finishing touch was at satisfactory level. Users have, on their initiative, used a wedge with handle to block the flow of slurry during mixing. None of the inlet tank was fitted with mixing device.

Photo-4.1: Inlet tanks

4.1.2 Digester and Gas Holder

It was not possible for the study team to verify the quality of construction and compliance of the design at the field by direct observation of the digester tank as it was buried under ground and filled with slurry. However, the exposed top portion of the gas holder, in some cases, was observed to assess the quality of construction.

One of the common defaults observed in biogas plants was the absence of top filling over dome. Top-filling over dome is important to counterbalance the gas-pressure as well as to insulate the plant to minimise temperature fluctuations. Exposed surface of concrete is prone to temperature fluctuations that may lead to minute cracks endangering biogas leakage.

4.1.3 Gas Outlet Pipe

Gas produced in digester and stored in the gas holder is conveyed to the pipeline through a main gas outlet pipe placed at the central top of the gas holder. The gas outlet pipes were properly secured with the construction of turret. As any leakage in the joint in this pipe will lead to a serious problem, gas tightness of this joint is very important.

Photo-4.2: Main Gas Pipe & Turret

4.1.4 Outlet (Displacement Chamber) System

The fixed dome plants consists of a outlet tank, also referred to as displacement or hydraulic chamber, to provide necessary pressure to biogas flowing to point of application. The outlet system consists of an outlet opening known as manhole, a tank called outlet displacement chamber and overflow opening of suitable dimension at proper height in the outlet wall. The manhole is provided at a point diametrically opposite to the inlet pipe to avoid short-circuiting of feeding. This opening serves a number of purposes: as a manhole or gate for entry and exit of people during plant construction and maintenance, for emptying the digester for cleaning, for stirring the slurry using long pole or rod is case it forms scum in the top, and to facilitate the outward movement of displaced slurry due to gas accumulation in gas holder and inward movement of slurry from displacement chamber at the time of gas utilization so that there would be sufficient pressure for the gas to reach the points of utilization.

The quality of workmanship in general was good. However, in some cases, outlet tanks were constructed at a raised ground to avoid inundation during rainy season and hence, outlet walls were exposed over the ground. In such cases, outlet walls were not property supported with compacted soils from outside to counter-balance the pressure of slurry exerted from inside. Outlet walls were susceptible to cracks in plants where such support was not provided.

4.1.5 Slurry Pits (Composing Pits)

The slurry coming out of the outlet displacement chamber discharges into the slurry pit which is also known as storage or composting pit. This pit is very important to safeguard and add the nutrient value of the slurry coming out of the biogas digester. The size of such composting pit should at least be equal to the volume of the biogas digester. Two pits are preferable as it eases operation. The depth of pit should be kept minimal to avoid accidents. In majority of the plants (13 out of 20), compost pits were constructed. In the remaining 7 plants, the slurry coming out of the displacement chamber was either conveyed to the near by watercourse (pond or stream) or left to flow elsewhere. It is encouraging to note that the slurry pits were considered to be the integral part of the biogas plant and two pits were constructed. Still the volumes of pit were relatively small and composting was not done properly in majority of the plants.

Photo- : Slurry Composing pits

4.1.6 Pipeline and Fittings

The gas conveyance system in a biogas plant usually consists of main gas valve placed at the top of gas holder immediately after the main gas outlet pipe to control flow of gas to the point of application, a pipeline with required fittings, a water condensation system known as water outlet or water trap and gas taps to control flow of gas to gas stove.

Different types of main gas valves were in use as per their availability in the local market. In majority of the cases, local valves were in use. Though gas valve is one of the important components in biogas plant, users in the surveyed plants were not fully aware of such importance. Majority of the owners (80%)

reported that these valves usually remained open all day long and were not operated regularly. 2 (10%) of the users reported that they never use the main valves.

Gas from the gas holder was conveyed to the point of application through PVC pipe of 15 mm diameter. These pipes are buried under the ground in most of the cases. In some plants, pipes remained exposed to natural sunlight. Continuous exposure to sunlight makes pipe more vulnerable to damage as pipe tends to become more brittle and tougher.

It is encouraging to see that the BPP has come up with a local solution to replace the conventional water drains which are not available in Laos market. A piece of PVC with an end cap has been used to drain the condensed water from pipeline. Though this provision will serve the purpose for the time being, it is not the correct solution. The opening and closing of end cap is not easy task for the users. Moreover, there are always chances of gas leakage when the threads in the end cap gets 'wear and tear' due to periodic operation (opening and closing). The users also complained on the difficulty to open the water drains.

In general, the conveyance systems in the sampled biogas plants were satisfactory with some rooms for further improvement.

4.1.7 Gas Stove and Gas Lamps

Thai model gas stoves designed basically for LPG or natural gas were used. Slight modifications such as adjusting of gas jet were reported to be carried out. Some of the stoves had clogged gas-regulating knob, heavy corrosion of the frame, clogging of burner holes and low pressure yellow flame with less calorific value. All the users told that they do not regulate the primary air intake while burning stoves.

Thai Model Biogas Stoves in use

Biogas lamps of Chinese design were reported to be installed in four households under study. However, these lamps were reported to be not in use because of many problems such as breakage of glass cover, mantle and clay part. As all the biogas plants under study were located in electrified areas, lighting was not the preferred choice of the users.

4.2 Condition of Biogas Plants

The existing condition of different components of biogas plant was observed in detail during the field investigation to assess the quality of construction, effectiveness of maintenance activities carried out and the operational status prior to categorizing them. The existing physical status of different components of biogas plant have been categorized in three different headings viz. good (functioning without defects), fair (defective but functioning) and poor (defective and not functioning) in qualitative manner, dependent on the physical observation of the plant made by the members of the study team during field investigation. The categorization has been made based upon the following indicators:

Table-4.1: Indicators for Categorization of Biogas Plants

Category	Indicators
Condition of Plant as a whole	
Good (functioning without defects)	• All the plant-components are constructed with good workmanship complying with the basic minimum quality standards • All the plant-components are operational without any technical problem • Location and relative orientation of plant components meet the basic minimum standards of site lay-out • Location of plant is managed in such a way that it is at reasonable distances from kitchen (point of gas application), water source, cattle shed and main access way.
Fair (defective but functioning)	• Plant-components are constructed with moderate workmanship. Plants are constructed without giving due attentions to the quality norms and standards • Plant-components are operational with one or more technical problems • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, however, the non-compliance do not affect gas production seriously • Location of plant is either very near or reasonably far from kitchen (point of gas application), water source, cattle shed and main access way.
Poor (defective and not functioning)	• Plant-components are constructed with poor workmanship. Plants are constructed without giving due attentions to the quality norms and standards and in many cases it violets basic minimum standards • Plant-components are not operational and there are one or more technical problems • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, and the non-compliance affect gas production seriously • Location of plant is quite far from kitchen (point of gas application), water source and cattle shed and vary near to main access way.
Condition of Inlet	
Good (functioning without defects)	• Constructed in firm ground and quality of construction meet the basic norms and standards usually adopted. The finished product reflects the work of a qualified mason. • The location of inlet pit is managed in such a way that the opening of inlet pipe to the digester is exactly placed in opposite side (at 180 degrees) of the manhole in fixed dome plants. • Inlet opening is placed in such a manner that inserting of pole or rod is possible to de-block the inlet pipe in case of some blockages • Height of pit facilitates comfortable mixing of dung and water • No cracks or other construction defects are visible • No technical problems that affect the functioning of the inlet seriously are encountered
Fair (defective but functioning)	• Constructed in firm ground however, the quality of construction violets one or more basic norms and standards usually adopted. The finished product reflects the work of a mason who is not trained properly to construct biogas plant. • The location of inlet pit is placed in such a way that the opening of inlet pipe to digester is not exactly in opposite side (at 180 degrees) of the manhole. • Inlet opening is placed in such a manner that inserting of pole or rod is not possible to de-block the inlet pipe in case of some blockages • Height of pit is either high or low which obstruct comfortable mixing of dung and water • Some cracks or other construction defects are visible • Some technical problems that affect the functioning of the inlet to some extent are encountered
Poor (defective and not functioning)	• Constructed in damage-prone ground and the quality of construction violets basic norms and standards usually adopted. The finished product reflects the work of a mason who lacks skills and knowledge to construct biogas plant. • The location of inlet pit is placed in such a way that the opening of inlet pipe to digester is placed very near to the manhole opening • Inlet opening is placed in such a manner that inserting of pole or rod is not possible to de-block the inlet pipe in case of some blockages • Height of pit is either very high or very low which obstruct comfortable mixing of dung and water • Serious cracks or other construction defects are distinctly visible • Technical problems that affect the functioning of the inlet seriously are encountered

Condition of Digester and gas holder: In the case of fixed dome plants, as the main structure remained underground, it was not possible to observe the quality of construction and construction defects in detail. Only physical observation of the exposed portion was possible. Indicators are selected which could be easily verified.	
Good (functioning without defects)	• Located in firm ground with no vulnerability of flood, land-erosion or other natural and manmade disasters • Enough top filling to safeguard the structures against damage. • If plant is constructed above ground to minimize the risk of flood and higher water table, it is well protected from all side with stabilization measures.
Fair (defective but functioning)	• Located in firm ground with little vulnerability of flood, land-erosion or other disasters • Not enough top filling to safeguard the dome against damage, some portion of the dome is exposed and the exposed portion does not illustrates signs of poor workmanship (distorted shape, minute cracks etc.). • If plant is constructed above ground to protect it form flood and higher water table, it is not properly protected from all side with stabilization measures.
Poor (defective and not functioning)	• Location of digester and dome is highly vulnerable to flood, land-erosion or other natural and manmade disasters • No top filling to safeguard the dome against damage, dome is exposed and the exposed portion illustrates signs of poor workmanship (distorted shape, minute cracks etc.). • If plant is constructed above ground to protect it form flood and higher water table, it is not protected from all side with stabilization measures
Condition of Outlet (displacement chamber)	
Good (functioning without defects)	• Located in firm ground with no vulnerability of flood, land-erosion or other natural and manmade disasters • Outer sides of the walls are supported properly with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls do not have any cracks or defects • Protected with good covering • Outlet opening is located in such a manner that there are no chances of flood water entering into the outlet chamber in case of water logging • Outlet opening facilitates the flow of slurry easily to the composting pit • The relative orientation of the plant suits with the engineering requirements
Fair (defective but functioning)	• Located in firm ground, however, is vulnerable to flood, land-erosion or other disasters • Outer sides of the walls are not properly supported with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls have minor cracks or defects • No covering is provided • Outlet opening is located in such a manner that there are chances of flood water entering into the outlet chamber in case of water logging • Outlet opening is partially blocked with dried slurry or other obstructions that hinders easy flow of slurry to the composting pit • The relative orientation of the plant do not suits with the engineering requirements, it is distorted or adjusted to suit with the site condition compromising the quality
Poor (defective and not functioning)	• Location is highly vulnerable to flood, land-erosion or other natural and manmade disasters • Outer sides of the walls are not supported with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls have major cracks or defects • No covering is provided, there is high risk of animal and children to fall in the chamber • There are high chances of flood water entering into the outlet chamber in case of water logging • Outlet opening is blocked with dried slurry or other obstructions that interrupt flow of slurry to the composting pit • The relative orientation of the plant violets the engineering requirements, it is distorted or adjusted heavily to suit with the site condition compromising the quality
Condition of Main Gas Valve	
Good (functioning without defects)	• Good quality gas valve is used, which is functioning trouble-free without any gas leakages • Gas valve is fitted at right place in the pipeline and is protected against further deterioration or damages • Gas valve is easy to operate and regular greasing/oiling is done
Fair (defective but functioning)	• Locally available moderate quality gas valve is used, which is functioning without any gas leakages • Gas valve is not fitted at the right place and is not protected against further deterioration or damages • Gas valve is either tight or too loose to operate and regular greasing/oiling is not done
Poor (defective	• Locally available gas valve is used, which has one or more technical defects (gas leakage, broken knob,

and not functioning)	slipping handle etc.) • Gas valve is not fitted at the right place and is highly vulnerable to deterioration or damages • Gas valve is very difficult to operate and greasing/oiling is not done at all
Condition of Pipeline	
Good (functioning without defects)	• Gas pipeline is aligned in such a way that the length is minimized • Either GI pipe of 15mm diameter or good quality plastic pipe of diameter more than 20mm is used • Pipes are buried under ground at right depth to protect them from vandalism and further damages • Minimum fittings are used and the joints are properly sealed off
Fair (defective but functioning)	• Gas pipeline is not aligned through the shortest route rather another route is followed • Flexible plastic pipe with diameter less than 20mm is used. • Pipes are aligned over-ground and remain hanging from one tree to other or one pole to other or one house to other at considerable height from ground level • There are high risks of pipe vandalism and damages • There are numbers of joints along the pipe alignment • Even with one or more of these defects, pipeline is functioning
Poor (defective and not functioning)	• Gas pipeline is not aligned through the shortest route rather zigzag and longer route is followed • Flexible plastic pipe with diameter less than 20mm is used. • Pipes are aligned over-ground and remain hanging from one tree to other or one pole to other or one house to other at lower height from ground level. • Pipes are damaged or vandalized along its alignment • Leakages are observed along the pipeline • Pipeline is not in operation due to one or many of these defects
Condition of Gas Stove	
Good (functioning without defects)	• Gas stove is operating without any trouble and there are no pending maintenance works • The stove burns with blue flames and at adequate pressure • Burner rests on firm metal frame free from rust
Fair (defective but functioning)	• Gas stove is operating but there are one or few pending maintenance works • One of the burners in double burner stove does not work • The stove burns with blue flames and at low pressure • The burner holes are clogged and the metal frame has rust in it
Poor (defective and not functioning)	• Gas stove is not operating and there are few pending maintenance works • The stove burns with yellow flames and at low pressure • The burner holes are clogged and the metal frame has rust in it
Condition of Gas Lamp	
Good (functioning without defects)	• Gas lamp is operating without any trouble and there are no pending maintenance works • The lamp burns with bright light and at adequate pressure • The metal frame is free from rust
Fair (defective but functioning)	• Gas lamp is operating without but there is one or more pending maintenance works • The lamp burns with relatively deem light and at low pressure • The metal frame has rust
Poor (defective and not functioning)	• Gas lamp is not operating and there are one or more pending maintenance works • The lamp does not burn at all • The metal frame has heavy dust
Condition of Slurry Pit	
Good (functioning without defects)	• Two slurry pits with capacity at lease equal to the volume of digester are constructed at a reasonable distance from the outlet overflow • Slurry in the pit is mixed with other organic material as composts • Slurry pit is covered with shades to avoid direct sunlight over it
Fair (defective but functioning)	• Only one slurry pits with smaller dimensions is constructed at a reasonable distance from the outlet overflow • Slurry in the pit is not mixed with other organic material as composts • Slurry pit is not covered with shades to avoid direct sunlight over it
Poor (defective, not functioning)	• Either slurry pit is not constructed or pit is too small to accommodate the quantity of slurry flowing into it • Slurry flows elsewhere around the pit

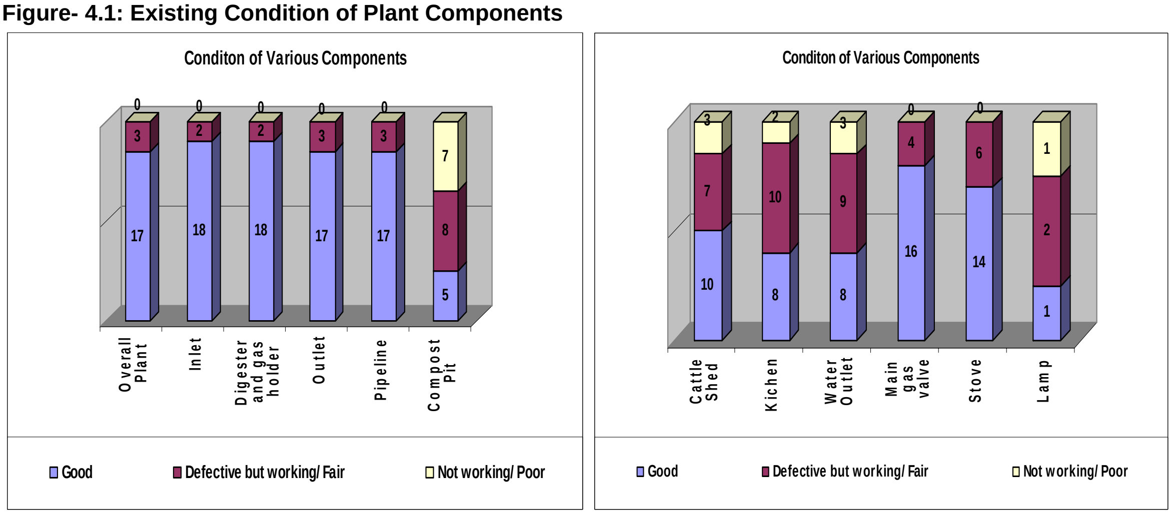
The following table shows the categorization of general condition of biogas plant and its components based upon the above-mentioned criteria.

Table-4.2: General Physical Condition of Biogas Plants

Plant Component	No. of Plant		
	Good (functioning without defects)	Fair (defective but functioning)	Poor (defective and not functioning)
Biogas Plant as a whole	17	3	0
Inlet tank	18	2	0
Digester and dome (gas holder)	18	2	0
Outlet (displacement chamber)	17	3	0
Pipeline	17	3	0
Main gas valve	16	4	0
Gas lamp[2]	1	2	1
Gas stove	14	6	0
Water Outlet	8	9	3
Slurry pit	5	8	7

The findings have been illustrated in the bar diagramme as shown below:

Figure- 4.1: Existing Condition of Plant Components



It is evident form Table-4.2 and Fig.4.1 that there are some rooms for further improvements in biogas plants and their components. The poorest component was observed to be the slurry pit as 35% of the pit falls under poor category.

4.3 Functional Status

The outcome of the study indicated that despite number of defects and weaknesses, the functional status of biogas plants on an average was satisfactory. Out of the 20 plants under analysis, 17 (85%) plants were functioning satisfactorily without any problems and the remaining 3 (15%) plants were functioning with some minor problems. There were no non-functional biogas plants existing during the time of field investigation. The following pie-diagram illustrated the functional status of biogas plants under study:

[2] Only four lamps installed

Figure- 4.2: Existing Functional Status of Biogas Plants

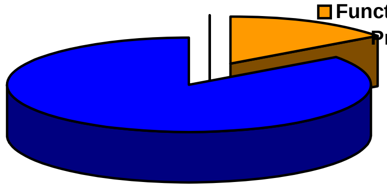


Table-4.3: Relationship between Training Received and Functional Status of Plant

Type of Training Received	Functional Status of Plant (No of Plants)			
	Not Functioning	Partly Functioning	Functioning Satisfactorily	Total
No training received		1		1
Training not provided but leaflet/booklet/manual provided		1	1	2
On the spot instructions from mason/company supervisors etc		1	15	16
Short term O & M training (1 days or less)			1	1
Long term O & M training (more than 1 day)			0	0
Short Training provided by other NGOs (not the service provider)			0	0
Total	0	3	17	20

It is apparent from Table-4.3 that training received and functional status of biogas plants have some distict relationship. For example, the users who did not receive any training had a plant with partly functional status.

Likewise relationship between quantity of feeding received and functional status of biogas plants has been shown in Table-4.4.

Table-4.4: Relationship between Quantity of Feeding and Functional Status of Biogas Plants

Quantity of Feeding Received (% of prescribed quantity)	Functional Status of Plant (No. of Plants)			
	Not Functioning	Partly Functioning	Functioning Satisfactorily	Total
Less than 50% feeding	0	0	1	1
51-60% feeding	0	0	0	0
61-70% feeding	0	3	5	8
71-90% feeding	0	0	6	6
More than 90% feeding	0	0	5	5
Total	0	3	17	20

As shown in Table-4.4, 11 out of 17 plants that were functioning satisfactorily received more than 70% of the prescribed feeding. However, one plant that received less than 50% of the feeding is working satisfactorily.

4.4 Efficiency of Biogas Plant

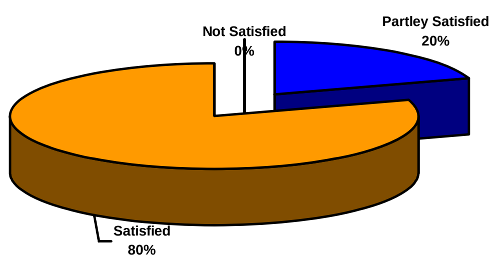
Attempts have been made to assess the efficiency of biogas plants. Efficiency of biogas plant is the ratio of input to output. Cattle dung added into the biogas plant have been considered as input and gas produced per day as a result of anaerobic digestion in the digester is the output. The amount of gas being produced was estimated from total burning hours of gas stove installed therein. While calculating the gas production, it is estimated that one kg of dung produces 40 litres of gas and one biogas stove consumes 350 litres of gas per hour. In totality, the theoretical amount of gas production from all the biogas plants under study based upon the daily actual feeding is 20.2 cum of biogas per day (1.01 cum/plant/day). Total biogas production based upon the gas being used is 19.6 cum per day (0.98 cum/plant/day). The calculated **performance efficiency** of biogas plants collectively is, therefore, 97%. However, when viewed form the overall size of biogas plant the efficiency of biogas plant is 73% (Anticipated production 1.4 cum vs. actual production 1.01 cum).

4.5 Users' Perception

4.5.1 Perception on Plant Performance

The respondents were encouraged to evaluate the performance of their plants by asking various direct and indirect questions. There responses have been analyzed carefully to come to a conclusion on whether the respective users' were satisfied with the output from and effects of their plants on them. On being asked if they were satisfied with the functioning of their biogas plants, 16(80%) responded that they were satisfied and 4 (20%) responded that they were partly satisfied. None of the users expressed their dissatisfaction during the time of the survey.

Fig-4.3: User's Level of Satisfaction



Users' satisfaction is also reflected in their answers to the question on whether they will advice others to install biogas plants in which 100% have in positive.

4.5.2 Perception on Merits and Demerits of Biogas

Users were also asked to mention three main merits and demerits of biogas plants based upon their experience with the technology. Weights were then allocated according to the number of responses. The highest was given 5 points while subsequent two answers were allocated 3 points and 1 point each. The result of analysis has been summarized in the following table.

Table-4.5: User's Perception on Merits of Biogas Plant

Merits	Score
Easy, fast and comfortable cooking (can be used any time, easy to ignite and burn, no need of constant caring while cooking, no smoke)	24
Saves time and money (no need to purchase charcoal)	15
Liberation from collecting firewood from jungle (saves time and efforts)	13
Time saving – children get time to study	12
Clean surrounding/good environmental condition	10
Good organic fertilizer	9
Easy to clean cooking utensils	9
A very reliable energy source	8
Improvements in health and hygiene	8
Reduces bad smell in and around the houses	6
Proper use of waste materials (dung)	5
Cattle stable remains clean	4
Kitchen remains clean	4
Saves chemical fertiliser	3
Clean and healthy energy source	3

Similar scores were given to the demerits of a biogas plants. The following table shows that result of analysis.

Table-4.6: User's Perception on Demerits of Biogas Plant

Demerits	Score
Increased incidences of mosquitoes and worms	18
Difficult to drain water from water outlet	14
Lamps are very problematic	8
Cumbersome and unhygienic process of mixing dung and water	8
Opening and closing of main valve is difficult during rainy season	3
Food cooked in biogas is less tasty	2
Problem when gas finishes while cooking	2

The respondents rated easy, fast and comfortable cooking (can be used any time, easy to ignite and burn, no need of constant care while cooking, no smoke), saving of time and money (no need to purchase charcoal), liberation from collecting firewood from jungle (saves time and efforts) and time saving – children get time to study as main merits, while Increased incidences of mosquitoes and worms, difficulty in draining water from water outlet and problematic biogas lamps as the main demerits of biogas technology. Interestingly, 12 households told that they had not experienced any demerits of the biogas plant.

4.5.3 Suggestions for Future Program

The respondents were encouraged to give suggestions for the effective implementation of the biogas program in the country in future based upon their experience with biogas technology. The responses received from them were:

- Diversify the end use applications (Provide gas lamps, biogas cooker, run engine) (6 respondents)
- Ask the mason to provide regular after-sale-services (should visit the plant when problems encountered) (4 users)
- Promote bioslurry as it is good fertiliser (3 users)
- Improve the quality of construction (2 respondents)

- Instruct the mason to build compost pits too (2 respondents)
- Improve the skills of masons(2 respondents)
- Provide training to users on use of biogas and bioslurry (2 respondents)
- Develop ways to use biogas for milling machines (2 users)
- Provide subsidy to install lamp and other appliances (1 respondent)
- Lamp is not necessary, it is problematic, do not install it (1 respondent)
- Identify the reasons of less gas production in my plant (1 respondent)
- Develop mechanisms for bottling of biogas so that it can be transported (1 respondent)

The responses as summarized above indicated that the users perceive diversified use of biogas as one of the motivating factors for the promotion and extension of biogas technology. They also strongly pointed out the need for training on operation and maintenance as well as proper after-sale services.

5. EFFECTS OF BIOGAS ON USERS

5.1 Effects on Time Saving and Workload Reduction

5.1.1 Cooking

The finding of the field investigation indicated that biogas plants have positive impact on reduction of time for cooking household meals. Maximum, average and minimum time-savings after the installation of biogas plant were reported to be 1.55 hours, 52 minutes and 30 minutes per day respectively. Among the 20 households, 3 households reported that they did not experience any time saving. According to the users, cooking is biogas stove is far easier and comfortable than that in conventional systems.

5.1.2 Collection of Water

It was observed that collection of additional quantity of water to mix dung and water to feed into biogas plant was not a problem for all the households as water sources especially the wells and hand pumps were readily available in the courtyards of the biogas households. The maximum distance of water source from the biogas plant was not more than 20 meter. Water source was available within 10 m in 15 households and within 10-20 m in the remaining households. 11 households experienced a slight increase in total time allocated to collect water after the installation of biogas plant. The added average time has been calculated to be 5 minutes/households/day, which was not that significant.

5.1.3 Plant Feeding

Mixing of dung and water is an added work to be carried out each day. In an average, one household was reported to need 12 more minutes to carry out this task. 2 households complained that the work of mixing dung and water to feed into the biogas plant was unhygienic and cumbersome task.

5.1.4 Collection of Fuel

Firewood, charcoal, LPG and electricity, were reported to be the main conventional fuel sources used in the biogas households for cooking. Charcoal was reported to be used in all the households and fire wood in 80% of the households. Half of the studied households (50%) who used firewood for cooking before the installation of biogas plant purchased fuel wood from the local market and the remaining collected it from nearby forest. Electricity was used in 9 hhs to complement other sources. Likewise, LPG was used in 2 households. When asked if they have experienced any changes in allocated time to collect fuel before and after the installation of biogas plants, 6 of them replied that there was no difference while the remaining experienced decrease in time. The total time saving per household per day ranges from 15 min to 55 minutes, with an average of 32 minutes.

5.1.5 Cleaning of Cooking Vessels/Utensils

All the 20 respondents reported that they have experienced a significant duration of time saving to clean cooking vessels in absence of black soot that used to be a major problem while cooking food using fuel wood. The time saved to carry out this task ranged from 15 minutes to 1 hour depending upon the number of family members and types of food being cooked. The average time saving in this case was reported to be 25 minutes/household/day.

5.1.6 Caring of Animals

When asked if the users have felt any difference in time allocated for cattle care before and after the installation of biogas plants, majority of the respondents (18 out of 20) replied that they did not experience any changes. According to the remaining 2 respondents, more time was needed to care cattle because they were forced to stall-feed the cattle to produce more dung to feed into the digester. The average time added to care animals after the installation of biogas was 3 minutes/hh/day, which is quite insignificant.

5.1.7 Summary on Time Saving

Besides the above-mentioned six activities related to biogas plant, users did not feel any difference in allocated time before and after the installation of biogas plants. The total time saving after the installation of biogas plants as responded by the users has been summarized in the following table.

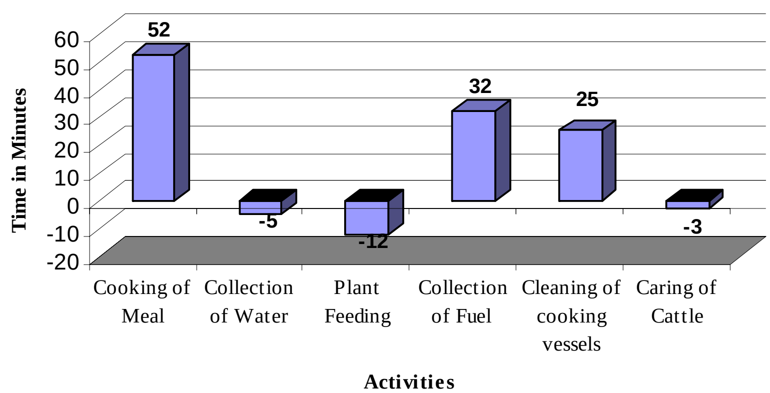
Table-5.1: Time Saved after the Installation of Biogas Plant

Activity	**Average time saving /min/day**
Cooking of Meal	52
Collection of Water	(5)
Plant Feeding	(12)
Collection of Fuel	32
Cleaning of cooking vessels	25
Caring of Cattle	(3)
Average time saving	**89 minutes (1 hour 29 minutes)**

** Numbers inside bracket indicated time added*

The following figure illustrates the graphical representation of the time being used in various biogas related activities by the biogas households under study.

Figure-5.1: TIme Used for Biogas Related Activites



The findings of the study therefore revealed that, in general, a family saved an average of 1 hour 29 minutes per day as a result of biogas plant. Whether biogas reduced the drudgery is debatable. What is done is that the biogas households substituted the drudgery of firewood collection, cooking in smoke-filled environment and cleaning vessels with black soot, for activities that helped in producing economic gain for the family. Even though majority of the respondents agreed that there was considerable time saving from biogas plant installation, none of them was in a position to say exactly how much additional financial earnings they made out of that or how much drudgery they reduced.

5.2 Effects on Saving of Conventional Fuel Sources

Saving in the quantity of cooking fuel is directly an economic benefit of biogas plant to the concerned household. Theoretically, based on effective heat produced, a plant producing 1 cum of biogas each day can replace about 135 kilograms of firewood per month depending upon its quality of the firewood consumed. In monetary values, if the quantity of gas is used to replace fuel wood, it saves US$ 8 per month. The field finding revealed that 19.6 cum of biogas is produced by the operational plants under study per day. This saves about 88 kgs of firewood per day. The average saving of firewood was therefore 1609 kg/year/hh which results in monetary saving of US$ 96.00 per year.

The study attempted to assess the quantity of conventional fuel used in the biogas households before and after the installation of biogas plant. The findings have been summarized in the following tables.

Table-5.2: Saving of Conventional Fuel after the Installation of Biogas Plant

Fuel Sources	Before (day/hh)	After (kg/day/hh)	Saving (kg/day/hh)
Firewood	3.15 kg	0.93 kg	2.22 kg
Charcoal	1.35 kg	0.42 kg	0.93 kg
LPG	0.03 kg	0.02 kg	0.01 kg
Electricity	0.46 kWh	0.24 kWh	0.22 kWh

Based upon the quantity of saving of conventional fuel sources, yearly monetary saving because of the use of biogas has been given in the following table.

Table-5.3: Financial Gain from Saving of Conventional Fuel

Fuel Source	Quantity saved/ day/hh	Unit	Cost per unit	Financial saving/ day/hh (kip)	Financial saving/ year/hh (kip)	Financial saving/ year/hh (US$)
Fuel wood	2.22	Kg	600	1332.00	486180.00	48.62
Charcoal	0.93	Kg	1000	930.00	339450.00	33.94
LPG	0.01	Kg	11250	112.50	41062.50	4.11
Electricity	0.22	kWh	250	55.00	20075.00	2.00
Total				**2429.50**	**886767.50**	**88.67**

Average financial saving from biogas plant was calculated to be US$ 88.67 per year/household, which a significant amount. The maximum saving was reported to be US$130, where as the minimum was US$20. The following table shows the financial saving in the biogas households under the study. This figure is slightly less than the theoretical figure of US$ 96 as calculated above.

Table-5.4: Financial Saving in Biogas Households

Amount saved (US$/month)	No of HHs	% of HHs
Zero saving	1	5
Saving less than US$ 25	1	5
Saving US$ 25 to 50	3	15
Saving US$ 50 to 75	6	30
Saving US$ 75 to 100	4	20
Saving More than US$ 100	5	25
Total	**20**	**100**

Table-5.4 clearly points out that all the biogas households whose plant is operational are experiencing financial benefit from biogas plants. Responses of 95% of the respondents mentioning that they experienced tangible financial benefit from biogas plants is encouraging in a situation that people often tend to overlook such gain because of the fact that biogas plants do not earn cash rather it only saves cash. This response also justifies validity of the calculation on financial benefits as shown in Table-5.3.

The responses of users on being asked if they have experienced any advantages of biogas over other conventional fuel sources have been summarized in the following table:

Table-5.5: Advantages of Biogas over Conventional Fuel Sources

Responses	% of respondents[3]
Easy, fast and comfortable cooking (can be used any time, easy to ignite and burn, no need of constant caring while cooking, no smoke)	60
Saves time and money	25
Clean surrounding/good environmental condition	20
Easy to clean cooking utensils	15
A very reliable energy source	10
Improvements in health and hygiene	10
Kitchen remains clean	10
Clean and healthy energy source	5

Table-5.5 indicated that the users considered comfortable cooking in smoke-free environment, time saving, reduction in expenditure and time saving to be the most advantageous things of cooking in biogas.

Among the few disadvantages mentioned by the users, problematic when biogas finishes in the middle of cooking (5%), bad smell in the kitchen when gas escapes (5%), less tasty foods (5%) and negative attitude of people on gas from dung (5%) were the major ones.

5.3 Effects of Bio-slurry

Biogas slurry when composed, stored, handled and applied properly is considered to be of high nutrient value. It is well-recognized fact that the economic benefit of biogas technology is greatly increased if the slurry bi-product is used effectively on farms. A 4 cum biogas plant produces slightly more than 6 kg of dry organic manure per day if the prescribed quantity of dung is fed into the plant per day. During field investigation process, it was observed that 75% of the users were using bio-slurry in one or other ways; where as the remaining 25% were not using it. The reason for not using were the lack of agricultural land or crops to use (10%) and bioslurry not-coming out of the biogas digester (15%). The users who did not use the slurry drain it directly to surrounding areas and watercourses. Draining slurry to the nearby watercourses means that the farmers are loosing nutrient fertilizer in one hand and in the other excessive accumulation of slurry in watercourses expedites the process of eutrification, which is environmentally hazardous.

Though the users are yet to realise the effects of bioslurry, still, 85% of the users who used slurry on farm reported that it is of high nutrient value than the farmyard manure and the remaining 15% reported that the nutrient value of bioslurry is somewhat same as the FYM. The use according to them were: use as organic manure without composting (70%), use as manure with composting (15%) and use wet slurry directly to the crops (15%). Though the users expressed their views that the production of crop has increased after the use of bio-slurry, they could not exactly quantify the increment.

Whether bioslurry had been beneficial in replacing the use of chemical fertilizers was still not realised by the users as the functional ages of the biogas plants were less than 8 months in all the cases. Among 20 households under analysis, 11 (55%) were using chemical fertilisers in their agricultural lands. According to them, it is likely that the quantity of chemical fertilisers will be reduced by a significant quantity with the use of nutrient bioslurry. Reduction in use of chemical fertilizer not only saves money spent to purchase it but also helps to safeguard soil fertility.

[3] Respondents had more than one answer

5.4 Effects on Health and Sanitation

At least 2.4 billion people in the world depend on biomass fuels (wood, dung, agricultural residue) and coal to satisfy their domestic energy needs. Indoor air pollution from the incomplete combustion of these fuels is the cause of an estimated 1.5 million deaths annually, mainly among children under 5 and women (Rehfuess et al. 2006). A change in stove-fuel combinations by using biogas is one of the means by which indoor air quality can be improved. Use of biogas for cooking eliminates the hazardous smoke that is produced from burning of firewood and charcoal resulting in lesser incidences of smoke-borne diseases. It also helps in improving environmental sanitation in and around the house.

The outcome of the study indicated the following effects of biogas on the health and sanitation:

- Cooking before having biogas plants was mainly by fuel wood, and charcoal which caused dusts and smoke. When biogas was used for cooking, 85% of the households, when being asked, said that the smoke in kitchens was reduced. However, 15% of the households considered that the situation is not changed.
- 2 users who had at least one member in a family with the problem of respiratory diseases felt that the problem is reduced after the use of biogas.
- 5 out of 8 users who had at least one member in a family with the problem of dizziness and headache felt some improvements.
- 2 of the 3 users who had at least a member in a family with the problem of eye burning felt total reduction of the problem.

6. FINANCIAL AND ECONOMIC ANALYSIS

6.1 Financial Analysis

Financial analysis is the most commonly used tool that helps to decide whether a user benefits from installation of a biogas plant and, if so, by how much. The basic underlying assumption of financial analysis is that people will adopt a new technology only if they expect to have a positive impact in their financial situation. In financial analysis for biogas plants in the present case, all costs and benefits are valued from the point of view of the users.

Benefits and costs of biogas plant will vary depending upon the use of inputs and outputs by the particular user. For the present purpose rather than analysing the costs and benefits at the individual user's level, an average values as calculated based upon the outcome of field investigation have been used.

The financial analysis of biogas plants under study has been done with the following major assumptions:

- Though a biogas plant may lasts for more than 30 years depending on the quality of construction materials and workmanship as well as status of operation and maintenance, the economic life span period of biogas plant was taken as 10 years mainly because any cost and benefit accrued after 10 years will have insignificant value when discounted to the present worth.
- Cost of construction of biogas plant was based upon the responses from the users under study and different costs are summed up to calculate the average cost per plant. The average cost of installation of a 4 cum plant is calculated to be US$ 359.
- As the biogas plants under the survey were relatively new and user's were not experiencing any costs related to operation and maintenance, these costs have been assumed to be 6% of the installation cost (4% for operation and 2% for maintenance) through out the economic life span of the plant. Hence, operation and maintenance costs are taken to be US$ 14.36 and US$ 7.18 respectively. It is assumed that the maintenance cost will be zero for the first year of the installation.
- All investment costs for the plant were assumed to be expended in the first year and all maintenance costs and all resulting benefits were assumed to be constant over the 10 years life of the plant.
- Annual income from plant included saving on conventional fuel sources and saving on chemical fertilizer because of the use of bio-slurry. The saving of time because of the installation of biogas plant was not considered as no evidence was found to justify that the time is used in other income generating activities. Moreover, it did not include added nutrient value of slurry and other health, social or environmental benefits. The relationships between the quantity of gas produced, the quantity of conventional fuels saved and the value of such savings were based on the following assumptions:
    - 0.040 cum of gas was produced per kg of fresh dung
    - 1 cum of gas was equivalent to 4.5 kgs of firewood given the quality of firewood used in Lao PDR
    - The cost of fuel was the average of all the cost as responded by the users which is US$ 88.67 per plant per year for average plant capacity of 4 cum.
    - Saving in chemical fertilizer because of the use of bioslurry was US$ 10 per household per year
- The salvage value of biogas plant was not included in the benefit stream of financial analysis because after 10 years of operation, the plant or its parts will not be re-saleable.

In such calculation, quantity of conventional fuels saved has been taken into consideration not the value of total gas produced as equivalent to the cost of fuels. The following tables show the financial analysis of the average plant size of 4 cum gas.

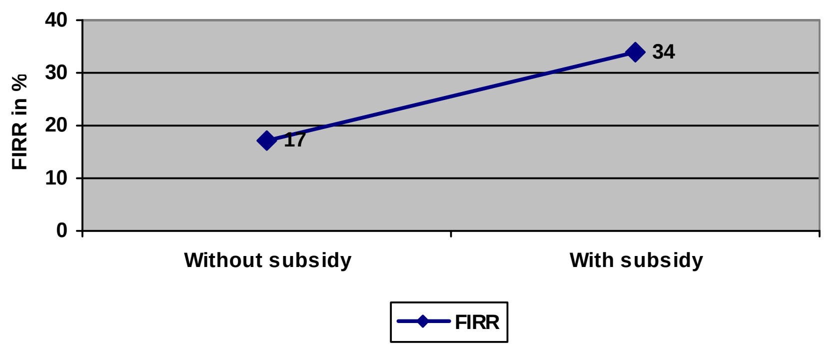
Table-6.1: Financial Analysis (At the cost of installation as responded by the users)

Parameters	4 cum biogas plant	
	Without subsidy	With subsidy of Euro 100 (US$ 140)
FIRR in %	17	34
NPV in US$	74.30	199.30
B/C Ratio	1.7	2.3

The FIRR of biogas plants calculated based upon the cost of installation was above 12%, the discount rate assumed, in both the cases. This indicated that the return on investment made for the installation of biogas plant was above the opportunity cost in the capital market. The outcome of the analysis indicated that biogas plants are financial viable even without subsidy.

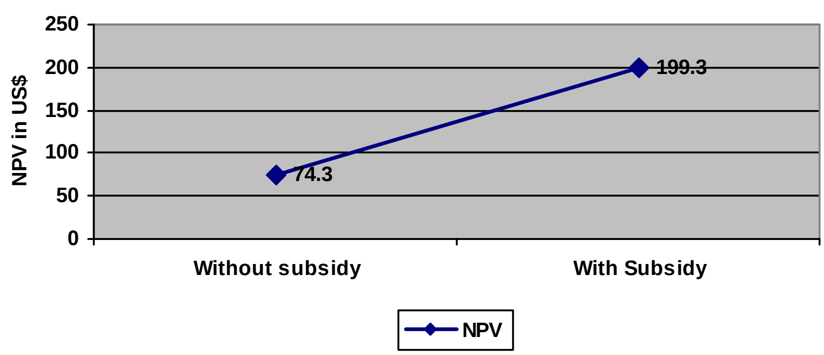
The results have been summarized in the following figure:

Fig-6.1: FIRR of 4 cum Biogas Plant



The Net Present Value, the present value of net cash flow, at 12% discount rate is positive in both the cases as shown in the following graph. This also indicated that the biogas plants are financially viable even if subsidy is not provided.

Fig-6.2: NPV of 4 cum biogas plant



The benefit-cost ratio ranged from 1.7 to 2.3; indicating that the biogas plants are viable even without subsidy. In both the cases the B/C ratio exceeds one, which indicates the financial viability of the biogas plants in the given conditions.

6.2 Economic Analysis

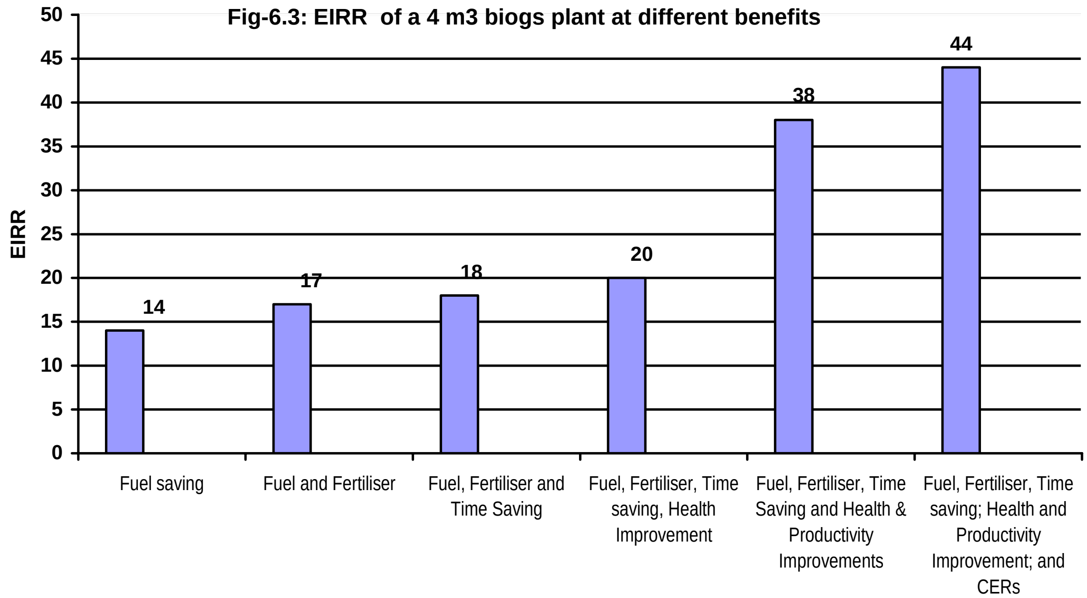
Some of the benefits and cost of biogas plants are not limited to the users. For example, if a large number of biogas plants are installed in a community, the non-users will also be benefited due to a cleaner community and conservation of forest in the area. Such benefits and costs that accrue even outside of the user's household is a subject matter of economic analysis. A single biogas plant does not significantly affect the economy as a whole. Therefore, economic analysis may not be relevant for a single plant but is of an immense importance at the community program level where the impact of the program on the economy is assessed.

In analyzing the economic viability of biogas program some intangible benefits like environmental impacts such as protection of forest, land-productivity improvement, reduction in carbon emissions (potential CER values) etc; reduction in smoke-borne diseases and improvement in general health; improvement in economic condition due to employment opportunities and proper use of saved time; increased yield of crop with the use of nutrient-rich bio-slurry; social prestige and satisfaction etc. should be valued. Difficulties involves in identifying all these items of benefits and adjusting their market prices to reflect social preferences have been the major limitation of the economic analysis. The situation requires some level of generalization, simplifications, and even some restrictive assumption.

Due to the limited scope of this study, the economic analysis had to rely both on primary and secondary data. These data provide a reasonable basis for the economic analysis. The principal assumptions relate to the conversion from financial prices to economic prices. Economic benefits resulting from improved sanitation through toilet attachment and employment generation were left out of consideration. The analysis is based on calculating the economic internal rate of return (EIRR) for the net annual benefits associated with the biogas plant. All investment costs for the plant were assumed to be expended in the first year and all maintenance costs and all resulting benefits were assumed to be constant over the 10 year life of the plant. It is thus expected that the economic internal rates of return (EIRR) of an investment into household biogas would be much higher than FIRR, once other non-cash benefits are also included. These benefits will likely include the following:

- Time saved by women and children in the collection of firewood and the making of charcoal as well as time saved through faster cooking and cleaning equivalent to US$ 0.375/day/household (assuming 1.5 hours savings per day as responded by the users at the rate of US$0.25 per hour).
- Health benefits to family members from reduced indoor smoke equivalent to US$8.00/year (assumption).
- Benefits from increased productivity of land valued in terms of quantity of bio-slurry produced, approximately US$54.75 (Per day 6 kg of dry manure @ US$25/ton) for a 4 m^3 plant.
- Benefits to the global environment as a result of reduced greenhouse gas emissions (2 tons of CO_2 equivalents per year at $10 per ton) equivalent to US$20.00/plant/year.

Figure 6.3 below show how the EIRR of a 4 m^3 biogas plant increases as the different benefits are added.



Based on the assumptions used for this economic analysis, it is clear that there is an economic justification for the subsidy of Euro 100.00 per plant. Furthermore, it is unlikely that the Laotian farmers would have sufficient financial incentives to adopt the biogas plants. The earlier financial analysis clearly indicated how sensitive the FIRR is to the price of biomass. As most farmers do not directly purchase biomass, their perception is that the price of biomass is at or near zero. As a result, their perceived FIRR is negative. When the other principal non-market benefits of the biogas plant are added, the EIRR rises to 46 percent. This provides an additional justification for the subsidy for the biogas plants.

7. OVERALL CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The general outcome of this study suggested that the existing biogas plants are functioning at a satisfactory level though there are some rooms for further improvement. Installation of about 80 biogas digester within a short period of time of 7 months has been instrumental in popularization of the technology at the grassroots level. Moreover, the functional plants have been found to be effective tools for the promotion and extension of the technology.

Though biogas technology has already created a ground at the rural communities in the country, to effectively harness the high potential of domestic biogas plants across the country, there is need of more coordinated approach and collaborative efforts of the sector institutions in the days to come.

The majority of the plants under study were under-fed. The average feeding rate was 5.9 kg per 1 cum capacity biogas plant, which is 73% of the required quantity, though the available average quantity of dung per day per households was 105 kg. Operation and maintenance status of biogas plants in the sampled districts indicated that there are rooms for further improvement. There is high need to optimization of biogas plants. Out of the 20 plants under study, none was operating at its full capacity. The functional conditions of 17 (85%) plants were satisfactorily and 3 (15%) plants were functioning with some problems. This data clearly illustrate that there are rooms for further improvements.

In terms of saving of conventional fuel sources, one biogas plant on average have contributed cutback of 2.22 kg of firewood, 0.93 kg of charcoal, 0.01 kg of LPG and 0.22 kWh of electricity per household per day. Such savings have resulted in monetary gain of US$ 88.67 per household per year, which is a substantial amount.

Though the figures on conventional fuel saving are encouraging, the relatively lower efficiency of biogas plants when viewed from their storage capacity (73%), under-fed digesters, some technical defects and emerging problems related to operation and maintenance are some of the obstacles for speedy dissemination of the technology in Lao PDR. In general, the outcome of this study revealed that:

- BPP has been successful in installing more than 80 plants in mere 7 months, which is encouraging. The programme is aiming to construct 120 biogas plants as against the set target of 100 for FY 2007.
- The quality of construction and workmanship in general is good.
- The users' level of satisfaction on the output of biogas plant has been high. Majority of the users (80%) were fully satisfied with the working of their plants.
- It is encouraging that 75% of the users have been using bioslurry. The main reason for the remaining 25% not to use is the lack of agricultural land. Majority of the users (85%) reported that it has better nutrient value than FYM. The remaining 15% who considered it to be the same as FYM.

7.2 Recommendations

The success of biogas program depends much on the functioning of the installed plant which is directly associated with the quality of construction, besides some other variables like quality of after-sale-services, operation and maintenance mechanisms etc. The outcome of the study indicated that there are rooms for improvement in installing quality plants to receive anticipated benefits. In general, the outcome of the study indicated that there are certain issues that need special considerations for speedy promotion and extension of biogas technology in Lao PDR. These are summarized below:

a) The users need to be involved in deciding the size of biogas plant to ensure their ownership in the process.

b) The masons should be instructed to follow the set quality standards on construction described in the construction manual. The supervisors should inspect the quality of construction periodically and report problems/defaults, if any, to BPP technical persons. Regular monitoring of construction works is more crucial during the initial phase of programme implementation as in BPP.

c) Some of the biogas plants lack proper backfilling against outlet walls which increases risks of cracks in walls due to the pressure exerted by slurry when the outlet chamber is filled with slurry up to the overflow level. The mason/users should be instructed to provide proper support to counteract the slurry pressure.

d) It is encouraging to observe that slurry collection/composting pits have been constructed in most of the biogas plants. However, in majority of the plants, these pits have been constructed adjacent to the outlet wall without leaving any space between the two. It is recommended to construct compost pit at least 1 m far from the outlet wall as shown in the drawing so that enough earthen support exists in between.

e) The capacities of slurry collection/composting pit in majority of the cases were found to be smaller than required. The minimum volume of slurry pits should be at least equal to the total volume of biogas plant. The slurry pits should be well protected against the surface water flowing in to it, especially during the rainy season, as far as possible.

f) One of the factors noted during the field investigation is the relatively higher level of awareness of users on effectiveness of bioslurry from biogas plant. It is therefore recommended that a training course for users be designed and implemented on effective composting, handling and application of slurry in the farms. There is need to make people aware of the benefits of attaching toilet to biogas plants by highlighting the major benefits such as improvement in environmental sanitation in and around the house, production of more gas, elimination of harmful pathogens after digestion of excreta into the digester and enrichment of bio-slurry by added nutrient value.

g) Locally produced water drains have been used in all the plants which were reported to be difficult to operate. To ease the use and ensure effective functioning these drains should therefore be standardised.

h) Timely repair and maintenance help biogas plants to function effectively for a longer duration. The plant owners in most of the cases were not able to carry out required maintenance of all defective parts on time due to technical constraints. After-sale-service provisions therefore should be viewed as major tool to preserve the interest of the users and safeguard the fate of the plant against any further deterioration. It is obvious that early failure of biogas plant results adversely in the future extension program and business of the service providers too. All these necessitate effective post-construction services so that the efficiency, sustainability and reputation of the plants are guaranteed.

i) There is high need of user’s training on operation and maintenance of biogas plant to ensure the continual functioning of biogas plant. As some of the plants were observed to have some defects such as; under-feeding, improper water-dung ratio, ignorance on feeding-requirements, improper use of main gas valve, zero maintenance of defective parts etc. users need to be made aware more seriously in these regards.

j) Biogas technology has a number of synergies with other development sectors like health, women’s development, agriculture, forestry and livestock management. In addition to energy supply, biogas technology can be viewed as a time saving and environmental conservation technique. It can also be promoted to improve the quality of life for women by reducing the drudgery of fuel wood collection and cooking in smoke-filled kitchen. The synergies can be utilized effectively if biogas integrated functionally with other programs. Integration essentially means identifying these synergies and incorporating them in the process of implementation.

k) Subsidy should continue as driving/motivating factor to penetrate the poorer strata of the society until a demand-driven market is propelled.

l) There are lots of rooms to optimize the plant-use in majority of the cases. In some cases, it was observed that the users were still using firewood to cook cattle feed even though there were prospects to increase the production of biogas with added feeding. Diversification of end uses of biogas seems necessary.

m) Poor and marginalized people with strong willingness and commitments to be involved in biogas plant construction need to be given opportunity while imparting training and capacity building initiatives.

n) The field findings on socio-economic indicators such as educational status, land holdings, income from agricultural production and other sources indicated that biogas plants has been installed by well off farmers. To penetrate into small and marginal farmers and to make biogas technology more affordable, one of the major efforts would be to provide credit to spread loan period over a longer period of time, there by reducing the size of each payment. Given the relative newness of the technology in the rural areas, low level of awareness on the benefits of the technology and the lack of credit history of the majority of the target population financing institutions may be hesitant to provide biogas loans. A massive awareness campaign to disseminate the usefulness of the technology is needed. Group loans without collateral would be beneficial to include more small and marginal farmers under the framework of the biogas program.

o) Non-functioning and poorly functioning biogas plants cause not only capital wastes but also harm the reputation of biogas technology and eventually to the desired establishment of permanent biogas sector. Therefore ‘quality’ should be the prime concern of the biogas programme. The quality control visits should be made more systematic with the creation of computer database to enter and analyse the QC findings.

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ANNEXES

Annex-1: Information on Sampled Plants

Annex-2: Drawing of Modified GGC plant

Annex-3: Questionnaires used for the Survey

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