Modified GGC Model for Lao PDR-2006

Trainee's Manual for Training of Trainers for Construction and Supervision of Biogas Plant

Biogas Pilot Program

SNV Lao PDR

May 2006

Table of Content

PURPOSE OF THIS MANUAL **3**
1. INTRODUCTION OF TRAINING PROGRAMME ..... ERROR! BOOKMARK NOT DEFINED.
2. INTRODUCTION OF BIOGAS PILOT PROGRAMME (BPP) **12**
3. OVERVIEW OF BIOGAS TECHNOLOGY **15**
4. OVERVIEW ON DESIGN AND CONSTRUCTION **25**
5. BIODIGESTER SIZE, CONSTRUCTION SITE AND CONSTRUCTION MATERIALS **28**
6. PROPER CONSTRUCTION OF BIODIGESTER **32**
7. USE OF BIOSLURRY AND COMPOSTING **39**
8. TECHNOLOGY PROMOTION AND QUALITY CONTROL **41**
9. OVERVIEW ON OPERATION AND MAINTENANCE **49**
10. ROLES OF STAKEHOLDERS, SUPERVISORS AND MASONS **59**

ANNEXES **64**

Annex-1: Training Schedules
Annex-2: Quality Standards
Annex-3: Forms and Formats
Annex-4: Drawing of Biodigester

Purpose of this Manual

Building of a quality biodigester requires good knowledge and skills on the part of the constructor, the mason. Good functioning or performance of biodigester is associated with the selection of right size, choosing the right site for construction, selecting the construction materials and appliance to comply with the quality standards, constructing the components with strict adherence to the norms and ensuring effective operation and maintenance activities – all of which are the responsibilities of the mason. In other words, the mason has a very important role to play in effective functioning of a biodigester. It is therefore, important that the mason responsible for all the works as mentioned above has to be provided with a well-designed training and orientation programme.

Building of a quality biodigester not only requires good knowledge and skills on the part of the constructor, the mason, but also effective supervision of installation and post-installation activities on behalf of a supervisor. Non-functioning and poorly functioning biodigesters cause not only capital waste but also do a lot of harms and damages to the reputation of biodigester technology and eventually to the desired future expansion biogas program. In other words the satisfied users are the main and effective extension media for the promotion of the technology and vice-versa. To safeguard the quality of biodigesters, it is important that effective quality control mechanisms be formulated and enforced properly. The quality on construction, operation and maintenance of biodigesters has to be major concern. Supervisors have to play vital role in this regard. This manual envisages helping the participants in imparting effective technical training programmes and preparing the participants as multi-skilled persons to construct/supervise the construction of biodigester as well as to promote the technology at the grass-roots level.

1. INTRODUCTION OF TRAINING PROGRAMME

1.1 Background

A detailed feasibility study carried out by SNV in July 2003 recommended to initiate a moderate Biodigester Program in Lao PDR and accordingly an agreement was signed between the STEA (on-behalf of Government of Lao PDR) and SNV to implement a Renewable Energy Programme. SNV in March 2006 conducted a study on selection of appropriate model of biodigester for wide-scale dissemination of biodigester technology in Lao PDR. The study, after thoroughly reviewing the technical details of five different potential models, recommended the Nepalese GGC or alike to be the most suitable model of biodigester for the Laotian context.

In the process to build the capacity of local artisans especially the masons, by imparting them detail technical knowledge and skills on methods of construction and supervisions of the household Biodigester, a Training of Trainers has been felt needed. The participants of this TOT are expected to organise and conduct technical training programs to masons and supervisors in the future.

1.2 Training Objectives

The overall objective of the TOT is to build capacity especially within STEA/TRI to conduct quality training courses on Construction and Supervision of GGC model Biodigesters; and develop STEA/TRI as the National Training Institute for Biodigester related Technical Training Courses in Lao PDR.

The following are the specific objectives:

a. To familiarise the participants on Biogas Technology, Biodigester Program in Lao PDR and related issues
b. To acquaint the participants on technological aspects of GGC model Biodigester being introduced in Lao PDR
c. To build skills and enhance knowledge of participants on biodigester construction through on-the-job training on biodigester construction
d. To build capacity of participants on imparting training on construction, monitoring, supervision and O&M of biodigesters

1.3 Expected Output

The overall output expected from the training programme is the internalisation of the training process by the individuals as well by STEA/TRI to be able to impart training to masons and supervisors to construct, monitor, supervise, operate and maintain biodigesters in Lao PDR.

The following are the specific outputs expected from the TOT:

- The participants will be familiar about the Biogas Pilot Program (BPP) in Lao PDR
- The participants will acquire detail knowledge on biogas technology, its importance and use of biodigester-products (biogas and bio-slurry)
- The participants will have hands-on knowledge and skills on:
  - Reading plant drawings
  - Selection of plant-size, construction sites and construction materials

- Plant lay-out, digging of pits and construction of foundation
- Construction of digester and gas storage tank
- Construction of Inlet and Outlet chambers
- Laying of pipelines and installation of appliances
- Construction of slurry pits and importance of composting
- Routine operation and maintenance activities
- Monitoring and supervision of construction of bio-digesters
- Quality standards on biodigester construction, operation and maintenance

- The participants will know and realise the roles and responsibilities of Masons and Supervisors on promotion and extension of biodigester technology
- The participants will demonstrate ability to transfer skills and knowledge on above mentioned issues to the larger audiences (masons and supervisors) in the future (Hands on skill to conduct technical training programmes to masons and supervisors)

1.4 Participants

Participants in TOT will include:

- Instructors from STEA/TRI
- Local technical persons from Communities who have hands on skills on masonry works

1.5 Training Venue and Duration

The overall training programme will be conducted in two different phases:

- Theoretical deliberation with practical demonstration; and
- On-the-job practical exercises.

The theoretical part of the training will be conducted in STEA/TRI training centre(?). The participants will be provided with theoretical and practical knowledge through classroom sessions and construction of a demonstration biodigester in the premises of STEA/TRI training centre. The theoretical training and installation of demonstration biodigester will be conducted for 7 days.

The on-the-job practical exercises on biodigester construction will be carried out in different locations in Vientiane provinces at the farmers' household premises for 15 days.

1.6 Training Contents

The contents of training programme has been finalised keeping in view the objectives and expected outcomes. The following table briefly describes the contents of the training programme.

Training Topics, Contents and Methods of Deliberation

Main Topic	Contents	Methods of Deliberation
Training objectives and expected outputs	a. Need for the training b. Objectives of the training c. Expected Outputs	Theoretical
Introduction of Pilot Program on Biogas	a. Evolution of Biogas Pilot Program in Laos b. Program objectives and targets c. Progress/activities undertaken till date	Theoretical
Introduction to Biogas Technology	a. Biogas in general b. Ideal Conditions for gas production c. Benefits of Biogas d. Use of Biogas	Theoretical
Overview on Biodigester Construction and Design/ Drawings	a. Types of biogas plant b. Different Components of a biogas Plant c. Functioning of a biogas Plant d. Plant being introduced in Laos (GGC Model) e. Familiarization on design and drawing of GGC Model of Biodigester	Theoretical and Group exercise
Selection of Biodigester Size, Construction Site and Construction Materials	a. Points to be considered while selecting the size of biodigester (feeding availability vs. family size) b. Quantification of dung based upon cattle numbers c. Hydraulic retention time d. Selection of appropriate size of biodigester based upon dung availability e. Points to be considered while selecting site for biodigester construction (location of plant vs. cattle shed, kitchen, water fetching points etc.) f. Types and quality standards of construction materials g. Quantity requirements of construction materials	Theoretical and practical
Laying out and Digging of Pit	a. Methods of laying out of biodigester (fixing the relative positions of inlet, digester, manhole and slurry pits) b. Methods of digging the pit c. Fixation of the centre point d. Preparation of the base	Theoretical and practical
Construction of base	a. Firming-up of foundation base b. Methods of preparing mortar c. Methods of fixing the base for round wall d. Laying of bricks and mortar to construct round wall	Theoretical and practical

Main Topic	Contents	Methods of Deliberation
Construction of Digester	a. Checking of central pillar for its verticality b. Fixation of chord/string to facilitate the construction of round-walls c. Methods of preparing mortar and bricks for construction of wall d. Construction of round wall e. Fixing of inlet pipe f. Construction of manhole g. Construction of floor (brick soling and plastering) h. Plastering of walls i. Backfilling in cavity outside the wall j. Curing of wall	Theoretical and practical
Construction of Dome (gas holder)	a. Filling of earth in digester b. Shaping of the dome with the use of template c. Preparation of surface for concreting (watering and sprinkling of sand) d. Fixing of the position of main gas pipe e. Concreting of dome and maintaining the thickness of dome f. Fixation of main gas pipe g. Curing of concrete	Theoretical and practical
Plastering of Dome	a. Taking out of soil-mould b. Preparation works (scrubbing and washing) c. Application of plastering layers d. Application of acrylic emulsion paint e. Importance of dome plastering	Theoretical and practical
Construction of Outlet	a. Preparation for the base b. Brick soling and plastering of the base c. Construction of walls d. Plastering of walls e. Casting and fixing of RCC cover slab f. Soil stabilization to safeguard walls against slurry pressure g. Curing of plastered surface	Theoretical and practical
Construction of Inlet	a. Preparation for the base b. Construction of base c. Construction of round wall d. Fixation of mixing device e. Plastering and finishing woks f. Curing of plastered surface	Theoretical and practical

Main Topic	Contents	Methods of Deliberation
Installation of Pipeline and Appliances	a. Construction of Turret b. Fixation of pipeline alignment and digging of trench c. Installation of main gas valve d. Pipe-laying works e. Installation of water-trap and chamber f. Fixation of gas taps, rubber hose pipe, stove and lamps g. Checking for leakages	Theoretical and practical
Construction of Slurry Pits	a. Site preparation and laying out b. Digging of pits c. Stabilizing of the slopes d. Importance of composting and shading of pits	Theoretical and practical
Overview on Operation and Maintenance	a. Filling up of the digester with feedstock b. Importance of routine operation activities (plant feeding, use of gas valves, draining condensed water from pipeline etc.) c. Minor maintenance activities d. Potential problems and likely solutions (ex. Slurry in the pipeline)	Theoretical and Group exercises
Quality Management (Quality standards, Supervision and Monitoring)	a. Importance of Quality Management b. Quality Standards and Quality Management Systems c. Supervision and monitoring visits and feedback to Masons/Users d. Familiarisation with forms and formats and practice to fill these forms e. Filling of Quality Control Form for Under-construction Biodigester (Visit to under-construction plant) f. Filling of Quality Control Form after the Completion of Construction (Visit to Completed plant to fill Construction Completing Report)	Theoretical lectures, discussions, demonstration and practical exercise
Role of Mason and Supervisor	a. Roles of mason and supervisor for quality plant construction b. Role of mason and supervisor for promotion and extension of the technology	Theoretical, Group exercises and simulation

1.7 Training Events and Process

Training management activities to be carried out during the process of the TOT can broadly be classified into three phases as described below:

1.7.1 Pre-training Preparatory Phase

Pre-training activities mainly include the agreement with STEA/TRI, finalisation of design and drawing of GGC model of Biodigester, selection of participants, formulation of aim, objectives and expected results, planning of sessions and events, preparation of hand-outs, arrangement of training aids and other logistic arrangements.

1.7.2 In-training Operational Phase

The in-training operational phase will be divided into two main sub-phases: theoretical classes with practical demonstration, and on-the-job training. The schedules of each of the sub-phase have been given in the Annex. Operational activities included all the events that will take place during the conduction of training sessions. In general training sessions will consist of the following:

- Opening ceremony
- Class room deliberations and discussion
- Field demonstration and construction of one demonstration biodigester
- Installation of pilot biodigesters by the trainee in the process of on-the-job training
- Sharing of lessons learnt and collection of comments and suggestions
- Closing ceremony

The in-training program, especially the on-the-job training will be instrumental in internalising the steps of installation. It is expected that the participants, after the training, will realise that the construction technique is not as difficult as anticipated, if the steps and norms of construction are followed strictly.

1.7.3 Post-training Concluding Phase

Post training activities will include documentation of events, process, review of learning and questions that may emerge. Preparation of concise training report consisting of participants, session plans, schedules and evaluation by the participants on the training program will be a major part of the post-training activities. The main outcome of the post-training phase will be the finalisation of the Curricula for New Mason's Training and Curricula for New Supervisor's Training. Other main achievement during this phase will be the finalisation of cost and quality estimates based upon the field experience.

1.8 Programme Overview

1.8.1 Inaugural (Opening) Session

The formal inauguration program will be organised and conducted with active participation of STEA/TRI.

1.8.2 Training Sessions

The detailed training schedules for Deliberation and Demonstration Session and Practical (on-the-job) Training Session have been given in Annex-1.

a. Introduction and Expectation of the Participants

Following the short inauguration session, the main training session will start with the introduction of participants and the facilitators. The reasons for their participation in the training program (the expectations), will be asked with the participants and documented.

b. Pre-test

To assess the general knowledge of participants on biodigester technology, they will be provided with a standard set of questionnaire to answer. The pre-test will aim at assessing the level of understanding of the participants on biodigester technology, which in turn, will guide the facilitators to plan the session contents and deliberations.

c. Deliberation and Demonstration Session

The detailed schedule of the session has been given in the Annex. The training program will be conducted as per the schedule. Slight alterations can be made depending upon the need of the participants.

d. Practical (on-the-job) Training Session

The participants of the TOT will be divided into groups, each comprising of 2-3 members, to install biodigesters in the process of the application of their theoretical learning to the real field situation. The following criteria will be used for the selection of households for installation of biodigester.

- Households in clusters to facilitate the monitoring of activities during construction, sharing of lessons learnt and optimisation the resources
- Availability of feeding materials (at lest 20 kg of cattle dung or 15 kg of swine manure)
- Commitment of the owner to operate the plant efficiently for a longer run
- Willingness to use of gas for both cooking and lighting purposes
- Commitment of the owner to provide non-skilled labours (??) required for the construction works
- Assurance from the owner that the family will entertain the visitors who come to monitor and observe the plant for research or learning purposes

1.9 Installation Modality

Prior to the selection of households for installation of pilot biodigesters, an implementation modality has to be agreed with the households selected to install biodigesters. For discussions purpose, the following proposal is made:

SNV will be responsible to:

- Prepare tentative bills of quantity and cost and hand over it to the respective team leaders for the purchase of construction materials
- Reimburse the cost of construction materials, tools and equipment upon the receipt of bills and vouchers from the respective team leaders
- Provide all the pipes and appliances to the users free of cost
- Facilitate the installation process through technical back-stopping services

The respective households selected for the installation of biodigester will be responsible for:

- Providing unskilled labour needed for the installation of the biodigester
- Procurement and transportation of construction materials in consultation with the trainees and submit bills and vouchers for payment through the trainees

The trainees will be responsible for:

- Overall construction management as the lead mason.
- Constructing of biodigester as per the design/drawing.
- Supporting households in procuring construction materials that meets quality standards.
- Facilitate the biodigester owners in getting final payment of the expenses incurred to purchase construction materials.
- Sharing of lessons learnt with other participants and facilitators.

1.10 Training Evaluation

Evaluation of training program will consist of the two tasks – the first will be the task of assessing participants' level of understanding and the second aims at getting feedback from the participants on various aspects of the training programme including the issues related to training management, performance of trainers and effectiveness of the training methods.

A post test will be conducted at the end of the first phase of the training to assess the level of understanding of the participants. The marks obtained by the participants before and after the training will be compared to assess the effectiveness of the training.

Similarly, participants will be asked, through a questionnaire, to provide their constructive comments and feedback on overall aspects of the training programme, including, training and facilitation techniques, learning climate and effectiveness of the training to fulfil the anticipated objectives.

1.11 Closing

At the end of the Phase-1 and 2 of the training program, a closing ceremony will be organised in which overall review and recapitulation of the training program will be made. The participants who complete the course successfully will be distributed with the certificates.

2. INTRODUCTION OF BIOGAS PILOT PROGRAMME (BPP)

2.1 General

Considering that SNV has extensive experience with Biogas and on the request of the Dutch Ministry of Development Cooperation, SNV explored ways to extend biogas technology in Asian countries. With regard to Lao PDR, several feasibility studies were commissioned by SNV with regard to biogas development in Lao PDR (First fact finding mission in February 2003 and Second fact finding mission in July 2003 as well as the Biogas in Lao PDR - Appraisal report of June 2004).

This first study recommended that a follow-up study be carried out which should concentrate on the niche areas identified (Champassak and Savannakhet) with emphasis on an integrated approach. The second fact finding study was more optimistic but at the same time identified several issues which needed to be addressed in order to ensure success.

- Before the first biogas plant is constructed, a conducive environment for the dissemination of biogas should be created.
- At present insufficient data are available to estimate more precisely the economic and social potential of biogas in Lao PDR.
- The technical quality of the biogas plants produced under the framework of STEA/TRI was found to be largely satisfactory but the cost of the existing Lao model is very high (beyond the capacity of rural population to afford).
- STEA/TRI should coordinate with MIH, MAF, CPC, APB and LWU to implement the biogas program. However, intra-department cooperation leaves much to be desired so there may be a need for a preparatory phase to develop a "Cooperation Strategy"
- STEA/TRI should focus on strengthening of and involvement of the private sector.

Considering that the 1st and 2nd studies were to some extent contradictory and the issues which needed to be addressed, SNV decided to commission an external appraisal. While the appraisal basically concluded that a national biogas program was not feasible, it nevertheless recommended to start with a modest pilot program as the basic technology is available, government policies in the areas of private sector development, credit supply and sustainable energy development are promising and national and international institutions are supportive to investigate and invest in further development of the RETs including biogas.

Based on those findings, Lao PDR was included in the "Asia Biogas Programme: Access to sustainable energy for 1,300,000 people" (Project funded by the Netherlands Ministry of Development Cooperation - DGIS/DMW). This Asian Biogas Program or ABP, aims to provide access to biogas for 1.3 million people in Asia over the period 2005 up to 2011. The Dutch Minister for Development Cooperation signed a Memorandum of Understanding on the financing of the proposal with SNV on 14 December 2004.

A MoU on the technical assistance for a Biogas Pilot Program is expected to be signed in the near future with the Ministry of Agriculture and Forestry (MAF) Lao PDR and SNV Lao PDR. At present two SNV advisors on Renewable Energy Technologies (1 international and 1 national advisor) are stationed in Vientiane to develop a.o. the Biogas Pilot Program (BPP). As part of the preparation for the implementation of a Biogas Pilot Program the following activities have been undertaken:

- In September 2005, the survey on potential user and data collection of potential Household of biogas was conducted in Vientiane Capital;
- Consultation rounds with potential partners in the Biogas Pilot Program were conducted;

- Existing biogas digesters were surveyed and their appropriateness studied for use in the Biogas Pilot Program;
- Study on selection of the most suitable digester design for Lao PDR.

2.2 Program Objectives and Expected Output

The overall objective of the BPP is to improve the livelihoods and quality of life of rural farmers, and reduce the impact of biomass resource depletion in Lao PDR through exploiting the market and non-market benefits of domestic biogas plants.

It aims at establishing a series of pilot activities to form the basis of a future larger scale programme that will establish a commercially viable domestic biogas sector

The main benefits expected from the program are as follows:

- reduction in the rate of deforestation and environmental deterioration by substituting fuel wood, agricultural waste and in some cases dung cake to meet the energy demand of the rural population;
- improvement of hygiene and health of the rural population, especially of women and children, by elimination of smoke produced during cooking on fuel wood and by stimulation better management of dung and night soil by attachment of latrines;
- improvement in the long run of the financial situation of households by eliminating the need to buy expensive fuel wood;
- increase in agricultural production by promoting optimum utilisation of digester effluent as organic fertiliser.

2.3 Proposed Activities

Component 1: Promotion and Marketing
To stimulate and inform stakeholders on the benefits and costs of domestic biogas and to publicise the programme

Component 2: Financing
To lower the financial threshold and improve access to credit and repayment assistance, to facilitate easier access to domestic biogas for all potential implementing agencys, with particular emphasis on the poor, women and other disadvantaged groups

Component 3: Construction and After Sales Service
To facilitate the construction and continued operation of 6600 biogas plants

Component 4: Quality Management
To maximise the effectiveness of the investment made by the biogas owners and to maintain consumer confidence in domestic biogas technology

Component 5: Training
To provide the skills for business people to run biogas SMEs and for biogas users to be able to operate their plants effectively

Component 6: Extension
To provide the information to allow biogas users to effectively exploit all the benefits of biogas

Component 7: Institutional Support
To maximise the ability of key biogas related institutions to be able to provide the services and support required by the biogas sector to facilitate access to domestic biogas and the development of quality biogas products

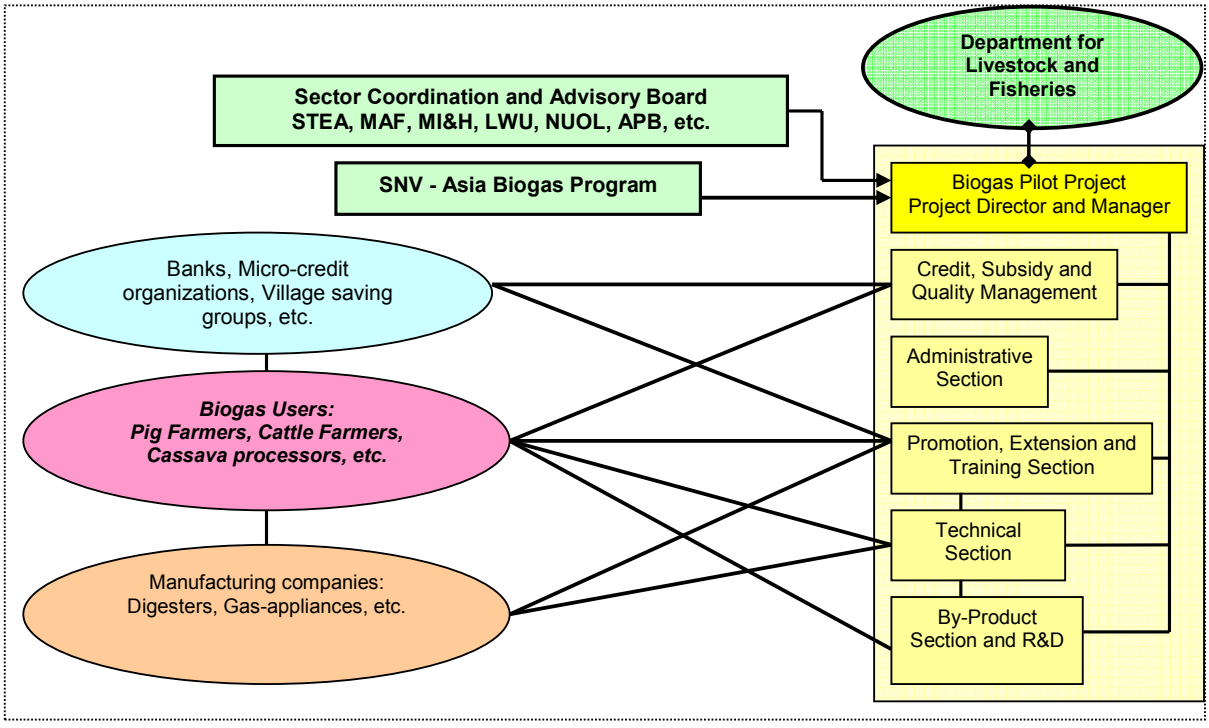
Component 8: Monitoring and Evaluation
To identify project progress and impact on stakeholders/other aspects in order to facilitate knowledge transfer

Component 9: Research and Development
To increase knowledge about domestic biogas issues to maximise effectiveness, quality and service delivery of the biogas programme

Component 10: Project Management
To support and coordinate the activities driving the development of a commercially viable biogas sector

2.5 Organisation Structure

The proposed organisation structure has been shown below:



3. OVERVIEW OF BIODIGESTER TECHNOLOGY

3.1 General

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biochemical carbon cycle. Methanogens (bacteria producing methane) are the last link in a chain of micro-organisms, which degrade organic compounds and return metabolites to the biosphere cycle. In this process biogas, a source of renewable energy is generated.

Biogas is a mixture of gasses, composed chiefly of:

- methane (CH_4) 50-70 vol.%
- carbon dioxide (CO_2) 30-50 vol.%
- others
  including
  - hydrogen (H_2) 0-1vol.%
  - hydrogen sulfide (H_2S) 0-3 vol.%

The characteristic properties of biogas depend on the pressure and the temperature that prevail during its generation. They are also affected by the moisture content of the substrate to be digested.

The calorific value of biogas is about 6 KWh/m^3. This corresponds to about 5.5 kg of firewood. The net calorific value depends on the efficiency of the burner or other appliances. Methane is the valuable component under the aspect of using biogas as a fuel.

3.2 Ideal Conditions for Biogas Production

The process of biogas fermentation is affected by many environmental factors. In this document we only consider the main factors affecting the construction and operation of digester to guarantee the best of anaerobic process or expected biogas production.

There are many biogas bacteria are involved in the process of biogas fermentation, in which methane-producing bacteria is the most important group. They are anaerobes in the strict sense and very sensitive to oxygen: They will die or grow very slowly if oxygen appeared in the slurry of fermentation environment. Therefore an airtight digester is required for digestion. The following are the main factors that should be taken into account for effective gas production.

a. Anaerobic condition

There are many groups of biogas bacteria involved in the process of biogas fermentation, in which methane-producing bacteria is the most important group. They are anaerobes in the strict sense and very sensitive to oxygen: they will die or grow very slowly if oxygen appeared in the slurry of fermentation environment. Therefore an airtight digester is required for digestion. Since methane bacteria are among the most strictly anaerobic micro organism known, quantities as low as 0.08mg/liter of dissolved oxygen completely inhibit their growth of these anaerobic bacteria. Therefore a biogas plant should be absolutely leak proof.

b. Temperature

Action of methane producing bacteria is strong affected by temperature. Ideal temperature in operation of simple digester is about 35^{o}C. The yield of biogas reduces significantly when the temperature drops and the fermentation process will stop if temperature drops under 10^{o}C. There are three temperature ranges in which the methane is produced:

i. Thermophilic

The digestion temperature ranges in 45-60 ^{o}C. Thermophilic digestion can be operated with a high loading rate consequently a high gas production obtained. The heating system and insulation are needed.

In the case that wastewater must be have high quality in output, thermophilic digestion is suggested. The cost of both construction and operation are a bit high.

ii. Mesophilic

Its temperature is about 10-45^{o}C. The mesophilic digestions run at a medium gas production, lower than that of thermophilic. While the cost is lower than that of the thermophilic.

iii. Psychrophilic

Certain special microbes can conduct anaerobic digestion at low temperature (below 10). At present, it is still operated in laboratory.

iv. Ambient temperature

The digestion temperature always changes with ambient temperature seasonally instead of keeping constant, resulting in seasonally changing of digestion performance. It is very popular for family scale digester due to low cost and simple operation. In tropical countries, the performance of ambient temperature digestion is good.

The bacteria which grow in mesophilic range are different from those which grow in the thermophilic range, In either range, the rate of growth of bacteria increases remarkably with temperature and then decreases. A temperature of about 35° C is considered as the optimum value of operation in the mesophilic range. Almost all biogas plants in Lao PDR are operated in mesophilic range, meaning 5°- 45° C temperature range.

Tips to enhance digester heat during winter seasons:

1. Plant should be constructed in very sunny place and any object blocking the sun should be removed.
2. Should always maintain 40 cm top filling on dome.
3. Carry out heap composting on top of dome by mixing slurry and other organic dry materials such as straw, leaves and agricultural wastages. Thickness of such composting should be of 2 to 4 feet and if the composting is covered with mud plaster the heat produced during composting will be preserved to maintain optimum temperature for biogas production in winter seasons.
4. Even if the composting is not done one should cover the dome portion of the biogas plant to maintain temperature in cold season.
5. Mix dung and water in the morning and let it heat till after noon and feed the plant, this too will help to maintain temperature in cold season.

Radical drop in digester temperature, higher difference in minimum and maximum temperature affects gas production negatively and causes problems to the plant functioning.

c. Feeding

i. Feeding Quantity

Once the initial feeding is done, the user has to feed the biodigester daily with the required quantity of feeding as prescribed. The quantity of dung to be fed is mainly determined by the size of the plant and the hydraulic retention time (HRT). The following table shows the total quantity of feeding materials needed for initial and daily feeding of the digester assuming 45 days retention time in the context of Lao PDR.

Biodigester size	Initial Feeding (cattle dung or pig manure)	Daily dung feeding (kg)	Water to mix with dung (litre)	Use of Biogas Stove (hour)	Use of Biogas Lamp (hour)
4	1500	20-40	20-40	3.5 to 4	8-10
6	2300	40-60	40-60	5.5 to 6	12-15
8	3000	60-80	60-80	7.5 to 8	16-20
10	3800	80-100	80-100	9.5 to 10	21-25

ii. Feeding Quality

Total Solids Concentration (TS)

All feeding materials consist of solid matter and water. The solids in turn consist of volatiles (VS volatile solid) (organic matter) and non-volatiles. Non-volatiles (FS fixed solid) are not affected during digestion and come out of the digester unchanged. Fresh cattle dung for example, consists of about 80% water and 20 % total solids (TS). This 20% total solids approximately contain 70 % VS and 30 % FS. For easy mixing and handling an 8 – 10% TS in the feeding is recommended. Thus to bring the TS to 8 – 10 % fresh cattle dung is to be dilute in the ratio of 1:1 with water.

Carbon / Nitrogen ratio (C/N ratio)

Organic matter contains various chemical elements, in which the main elements are carbon (C), hydro (H), nitrogen (N), phosphor (P) and sulphur (S). Carbon nitrogen ratio is an importance index to evaluate the capacity decomposes of materials. Generally, biogas microbes need the carbon thirty fold than nitrogen. Therefore the optimum carbon nitrogen ratio of feedstock is 30/1. The feedstock with low carbon nitrogen ratio start fermentation more quickly than those with high carbon nitrogen ratio and moreover the later are likely to acidify and bring about the failure of fermentation.

The carbon nitrogen ratio of pig and cattle manure is suitable, while that of human and chicken dung is low. The carbon nitrogen ratio of plants is high and this ratio is getting very high in old plants. Therefore these materials should be mixed in proper proportions in order to start fermentation process and raise the yield of biogas.

Biogas production varies as per the carbon to nitrogen ratio of feeding material. Favourable C/N ratio for biogas generation is 20 to 30. The following table give some facts about C/N ratio of various organic substances:

Animal waste:

Sr.#	Description (Source of feed stock)	Nitrogen (% dry wt)	Carbon (% dry wt)	C/N (ratio)	Moisture* (Content %)	Total** (Solid %)
1	Cattle manure	1.66	30.00	18	80 – 85	15 – 20
2	Sheep/Goat manure	3.80	83.6	22	75 – 80	20 – 25
3	Poultry manure	6.55	97.5	15	70 – 80	20 – 30
4	Pig manure	3.80	76.0	20	75 -80	20 – 25
5	Horse manure	2.30	133.40	58	80 – 85	15 – 20
6	Duck manure	2.00	54.00	27	70 – 80	20 – 30
7	Elephant manure	1.30	60.00	46	70 – 85	15 – 30

House hold and human waste:

Sr.#	Description (Source of feed stock)	Nitrogen (% dry wt)	Carbon (% dry wt)	C/N (ratio)	Moisture* (Content %)	Total** (Solid %)
1	Night soil	6.00	48.00	8	75 – 80	20 – 25
2	Potato peals	1.50	37.50	25	50 – 70	30 – 50
3	Kitchen garbage	2.50	62.5	25	50 – 70	30 – 50

Crop/ Agricultural waste:

Sr.	Description (Source of feed stock)	Nitrogen (% dry wt)	Carbon (% dry wt)	C/N (ratio)	Moisture* (Content %)	Total** (Solid %)
1	Young grass	4.00	48.00	12	40 – 60	40 – 60
2	Wheat Straw	0.50	60.00	120	20 – 40	60 – 80
3	Rice Straw	0.30	18.00	60	20 – 40	60 – 80
4	Corn Stalk & leaves	1.00	55.00	55	25 – 40	60 – 75
5	Fallen leaves	1.50	75.00	50	40 – 60	40 – 60
6	Sugarcane Biases	0.30	45.00	150	25 – 40	60 – 75

Note: C/N ratio = $\frac{\text{Carbon (\%dry wt.)}}{\text{Nitrogen (\%dry wt.)}}$

Percentage of Hydrogen (pH)

The pH of a solution is a measure of the concentration of hydrogen ions and it indicates whether the solution is acidic, alkaline or neutral. A neutral solution will have a ph of 7.0. Alkaline solution will have ph greater than 7.0 and acidic solution will show less thane 7.0 ph. Most bacteria live on light alkali with pH value in the range of 6.8-7.5. However, methane-producing bacteria is still grown in pH value in the range of 6.5-8.5

Hydraulic Retention Time (HRT)

HRT can be defined as the total time required by a given amount of dung to produce approximately 80 to 85% of the total gas. Thus HRT is also the time spent by the feed inside the digester before it is completely digested. HRT is highly determined by the temperature of slurry and the volume of digester. The volume of digester is generally chosen so as to retain the daily feed in the digester for a period equal to the HRT so that most of the slurry is digested. As HRT is largely dependent on temperature, retention periods differ from place to place. For the context of Laos the biodigesters are designed with a HRT of 45 days.

In practice, the decomposition process of feedstock is lower than anticipated due to the changed in ambient temperature. For animal manure decomposition period could be the months. For wastes from plants, this period is longer than that of manure, even few months. However, the speed of biogas production is the highest in the beginning two to three weeks and then reduces sharply as the days increases.

3.2 Design Principles of a Biodigester

The starting point of the design of biodigester is the quantity of cattle-dung or swine manure (undiluted). It is important that the actual amount of cattle-dung or swine manure reliably available with the household be measured before deciding the size of a biodigester. The steps of designing has been given in the following sections:

a. Calculate the weight of feeding materials available per day (W). Assume the gas production rate (G) and calculate the total gas production (Gt). Total gas production will be therefore equal to available quantity multiplied by rate of gas production (Gt = W x G). The following table illustrates the rate of gas production from different organic materials.

Type of Feeding Material	Rate of Gas Production in litre (cum)	Dung Production per no. per day in Kg
Cattle dung (cow/ox)	35-40 (0.035-0.040)	10-15
Buffalo	35-40 (0.035-0.040)	15-20
Swine manure	40-60 (0.040-0.060)	2-4
Poultry dropping	55-70 (0.055-0.070)	0.02-0.03
Human Excreta	40-50 (0.040-0.050)	0.18-0.34

If total gas production is taken as constant keeping in view the number of family members, quantity of dung required can also be calculated. While assuming gas requirement generally 0.3 to 0.4 cum gas per capita per day is assumed.

b. Based upon the quality of dung to be fed, active slurry volume (Vs) has to be calculated. The active slurry volume in the digester is directly related to the Hydraulic Retention Time (HRT) and is calculated as:
Vs = HRT x 2W/1000 cum
Assuming HRT as 40 days, Vs = 0.08W

c. Based upon the active slurry volume and total gas production, calculate the total volume of the digester. Now, once total volume is identified select the radius (for spherical plants) or calculate the height of cylindrical portion of the digester and diameter of the digester. There is no strict rule for the relative values of H and D, however, in areas with high ground water table it can be D = 1.5 to 2 H. For other areas it can be D = 1 to 1.5 H.

d. Now, slurry displacement inside the digester has to be calculated. The selection of suitable value depends upon the gas use pattern. As cooking is usually done two times a day, 50% of the gas produced in a day should be made available for one cooking span. But, there is a continuous production of gas from the digester during the cooking time which should also be considered. The gas during cooking time could also be neglected to compensate the uneven distribution of gas use for example 60% in the morning and 40% in the evening. Therefore, a storage capacity of 50% of the total production per day can be considered. Once the total gas production is known, gas storage capacity and the volume of slurry displacement in the digester could be calculated.

e. Once gas storage capacity is calculated, the design of outlet or the displacement chamber has to be calculated. The volume of outlet is designed to be equal to the volume of slurry displacement in the digester which in turn is equal to 50% of the total gas production per day. Slurry displacement in the inlet pipe is taken as negligible in this case. However, if the diameter of inlet pipe is more than 20 cm, it is advisable that the volume of displacement chamber be volume of displaced slurry minus the volume of inlet pipe up to the overflow level.

f. Once the volume of displacement chamber is known, the length, breadth and height of the displacement chamber need to be calculated. The maximum pressure attained by the gas is equal to the pressure of water (slurry) column above the lowest slurry level in the displacement chamber. The pressure range is generally 70 to 120 cm of water column. Usually, 80 to 95 cm is taken as ideal as a safe limit for brick/concrete dome. Assuming a suitable value in the range height of displacement chamber can be calculated. The length of displacement chamber is assumed to be 1 to 1.5 m of the breadth. Assuming any value in between, the length and breadth can be calculated. Now, all three dimensions of the displacement chamber are calculated.

3.4 Benefits of Biodigester Technology

Economic Benefits

- Saving of expenditures on fuel sources
- Saved time to utilize in other income generation activities
- Enhanced soil productivity because of the use of bio-slurry (added N,P,K values)
- Reduction in the quantity of chemical fertilizers due to the use of bio-slurry
- Reduction on health expenditures due to decrease in smoke-borne diseases
- Employment to local people
- Private sector development that produces economic goods
- Livestock development

Health Benefits

- Reduction in smoke borne diseases (dizziness, headache, eye-burning, respiratory tract-infection, nausea etc.)
- Improved household sanitation due to attaching of latrines into bio-digesters, absences of black soot, ashes, firewood/dung cakes in kitchen
- Decrease in burning cases

Environmental Benefits

- Preservation of forest
- Increase in soil productivity due to added NPK as well as use of slurry and agricultural residues that used to be burnt
- Reduction in green-house gases especially the methane
- Prevention in land-fertility degradation due to excessive use of chemical fertilizers

Social Benefits

- Extra time for social activities
- Enhanced prestige in the community
- Workload reduction especially of women

- Bright light to help in quality education and household works
- Increase in rate of enrollment of girls in school because of the liberty from fuel collection

3.5 Gas Production

If the daily amount of available dung (fresh weight) is known, gas production per day in a warm climate will approximately correspond to the following values:

- 1 kg cattle dung 40 litres biogas
- 1 kg buffalo dung 40 litres biogas
- 1 kg pig dung 50 litres biogas
- 1 kg chicken droppings 60 litres biogas
- 1 kg human faeces 50 litres biogas

For normal seized adult animals, the following daily dung production can be expected:

- Cow: 10-14 kg/day
- Buffalo: 15-20 kg/day
- Pig: 2-4 kg/day
- Chicken (100) 5-7 kg/day
- Human 0.25 kg/day

3.6 Use of Biogas

Biogas can be used for three main purposes:

- Cooking
- Lighting
- Running engine

One ordinary biogas stove with single burner consumes 350 to 400 litres of gas her hour. In other words 10 kgs of cattle dung will be enough to produce enough gas to burn stove for one hour. Biogas lamp consumes slightly less than half the quantity needed for a single-burner stove (150 to 175 litres of gas per/hour). One cum biogas will be equivalent to:

- 5 kg of firewood
- 1.6 kg of charcoal
- 0.75 litre of kerosene
- 0.45 kg of LPG
- 1.6 to 1.7 Kwh of electricity

Running engine is not preferred in household biodigesters.

3.7 Use of Bio-slurry

Biogas slurry consists of 93% water, 7% dry matter of which 4.5% is organic and 2.5 % is inorganic matter. The percentage of NPK (Nitrogen, Phosphorus and Potassium) content of slurry on wet basis is 0.25, 0.13 and 0.12 while in dry basis it is 3.6, 1.8 and 3.6 respectively. In addition to the major plant nutrients, it also provides micro-nutrients such as zinc, iron, manganese and copper that are also essential for plants but required in trace amounts.

If bio-slurry is composted the nutrient value will be added into it. Digested slurry is an excellent material for fastening the rate of composting of refuse, crop waste and garbage etc. It also provides moisture to the computable biomass.

3.8 Cost of a Biodigester

As far as costs of biodigester are concerned, there are two major categories:

- construction cost;
- operation and maintenance cost;

a. Construction Cost

The construction costs include everything that is necessary for the installation of the biodigester e.g.: excavation work, construction of the digester, the gas pipes, appliances and the construction materials. The construction cost and bill of quantities for the different sizes of the modified GGC model are given in the following table:

Bill of Quantities and Cost for Biodigester Capacity 4, 6, 8 and 10 m^3

SN	Item	Unit	Unit Cost USD	4m^3		6m^3		8m^3		10m^3	
				Quantity	Total Cost USD	Quantity	Total Cost USD	Quantity	Total Cost USD	Quantity	Total Cost USD
I	**Construction Materials**										
1	Bricks	pcs	0.02	2700.0	54.0	3100.0	62.0	3500.0	70.0	4000.0	80.0
2	Cement	bag	3.50	12.0	42.0	16.0	56.0	20.0	70.0	24.0	84.0
3	Gravel 1x2	m^3	5.00	1.1	5.5	1.2	6.0	1.3	6.5	1.4	7.0
4	Coarse sand	m^3	8.00	0.9	7.2	1.0	8.0	1.1	8.8	1.2	9.6
5	Fine sand	m^3	8.00	1.1	8.8	1.2	9.6	1.3	10.4	1.4	11.2
6	Inlet PVC pipe 10cm dia, length 2m	piece	3.50	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0
7	Iron bars ø 6	kg	0.70	10.0	7.0	12.0	8.4	14.0	9.8	17.0	11.9
8	Binding wire	kg	0.90	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
9	Acrylic emulsion paint	Lit	3.00	1.0	3.0	1.0	3.0	1.0	3.0	1.5	4.5
				Subtotal 1	**135.0**		**160.5**		**186.0**		**215.7**
II	**Accessories**										
10	G.I, Gas outlet pipe Ø 0.5", 0.6m length	pcs	3.00	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
11	Caste iron nipple, Ø 0.5" for connection from 90^o cast iron elbow to main gas valve	pcs	0.35	1.0	0.4	1.0	0.4	1.0	0.4	1.0	0.4
12	Main gas valve (Ball valve Ø 0.5")	pcs	2.00	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0
13	Male-female socket Ø0.5", for connection from main gas valve to PVC. (PVC with aluminum thread).	pcs	0.45	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5
14	PVC 90^o elbow	pcs	0.12	4.0	0.5	4.0	0.5	4.0	0.5	4.0	0.5
15	T-socket Ø0.5" for water trap (aluminum thread inside)	pcs	0.40	1.0	0.4	1.0	0.4	1.0	0.4	1.0	0.4
16	Glue for PVC connection	bottle	0.70	1.0	0.7	1.0	0.7	1.0	0.7	1.0	0.7
17	Water drain	pcs	3.00	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
18	Gas tap	pcs	5.00	1.0	5.0	1.0	5.0	2.0	10.0	2.0	10.0
19	Teflon tape	pcs	0.25	1.0	0.3	1.0	0.3	1.0	0.3	1.0	0.3
20	Liquid gasket rubber	bottle	1.40	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7
21	PVC pipe Ø 0.5",	m	1.30	10.0	13.0	10.0	13.0	10.0	13.0	10.0	13.0
22	Gas rubber hose pipe Ø 0.5"	m	0.40	1.0	0.4	1.0	0.4	2.0	0.8	2.0	0.8
23	Stoves - single burner	pcs	10.00	1.0	10.0	1.0	10.0	2.0	20.0	2.0	20.0
24	Lamp	pcs	5.00	1.0	5.0	1.0	5.0	1.0	5.0	1.0	5.0
				Subtotal-II	**44.7**		**44.7**		**60.1**		**60.1**
III	**Labours**										
25	Skilled Labour	No.	5.00	9.0	45.0	10.0	50.0	11.0	49.0	12.0	60.0
26	Unskilled Labour	No.	2.00	20.0	40.0	25.0	50.0	30.0	60.0	35.0	70.0
				Subtotal III	**85.00**		**100.00**		**109.00**		**130.00**
				Total	**265**		**305**		**355**		**406**
	Overhead, Guarantee and After-sales Services(15%)				40		46		53		61
	Total Cost of Installation				**304**		**351**		**408**		**467**

Note: If stone is used in place of brick, the quantities needed are:

4 cum plant - 2 cum
6 cum plant - 2.5 cum
8 cum plant - 3 cum
10 cum plant - 3.5 cum

b. Operation and Maintenance Cost

The operation and maintenance costs consist of wage and material cost for:

- collection and transportation of the substrate
- water supply
- feeding and operation of the plant
- supervision, maintenance and repair of the plant
- storage of the effluent

The operation cost of biodigester is virtually negligible if feeding material is not needed to be purchased. However, it is assumed to be 3-5% of the total cost of installation per year.

c. Financial Viability

One biodigester with 4 cum capacity can produce up to 1.40 cum of biogas per day, which is enough to burn single burner stove for 3.5 to 4 hours. Assuming that 80% of the produced gas (1.12 cum) is used per day, it can replace about 6 kg of firewood, 2 kg of charcoal, 0.7 litre of kerosene, 0.5 kg of LPG and 1.9 units of electricity. The following table shows the monetary value of the quantity of different fuels saved:

Type of Fuel Sources	Quantity saved	Cost per unit in USD	Total cost saved per day in USD	Total cost saved per year in USD	Payback period without subsidy in Years	Payback period with USD 120 subsidy in Years
Firewood in Kg	6.00	0.02	0.12	43.80	6.9	4.2
Charcoal in Kg	2.00	0.12	0.24	87.60	3.5	2.1
Kerosene in Litre	0.60	0.60	0.36	131.40	2.3	1.4
LPG in Kg	0.50	0.80	0.40	146.00	2.1	1.3
Electricity in Kwh	1.90	0.20	0.38	138.70	2.2	1.3

It is clear from the above table that biogas has higher replacement value if it is used to replace kerosene, electricity and LPG. The replacement value for firewood is very low and that for charcoal is relatively better than that of firewood. The minimum and maximum savings because of the use of biogas are US$ 44 for firewood and US$ 146 for LPG per year. Without any subsidy, the payback period of a 4 cum biodigester is about 7 years if used to replace firewood, which is financially not attractive. However, if the biogas is used to replace electricity/LPG/kerosene the payback period is about two years. When subsidy of USD 120 (euro 100) is provided the pay back period reduces to 4 years for replacing firewood and less than 1.5 years in case of replacing kerosene/LPG and electricity.

3.9 Relevance of Biodigester Program in Lao PDR

a. Energy Situation in Lao PDR

Lao PDR has some exploitable energy sources available like abundant hydropower and biomass as well as some coal deposits with all the coal being exported at the moment. the energy consumption for 2005 in Lao PDR can be characterized as being heavy biomass based as is shown in table 2 as well as table 3:

Energy Consumption by Type 2005

	Energy Consumption in 2005					
	Electricity	Oil	Gas	Charcoal	Fuel Wood	Sawdust
Tera Joules	4,633	11,430	88	7,283	40,176	318
% of Total	7.25	17.88	0.14	11.39	62.85	0.50

Source: EdL Annual report 2005 and DoE statistics.

Shares of Different Fuels in the Household Energy Mix 1995

Type of Fuel	Urban	Rural	National
Fuel wood	75.3	97.7	92.7

Charcoal	10.0	1.6	4.3
Electricity	10.4	0.1	1.9
Sawdust	2.7	0.3	0.7
Others	1.6	0.3	0.5

Source: DoE.

As is evident from the table, biomass (fuel wood, sawdust and charcoal) accounts for over 74% of all energy used in the country. However, this dependence on biomass energy sources in fact is higher if the conversion factor from wood to charcoal is taken into account (1 kg of charcoal requires 3-4 kg of wood). Most of the biomass is used for cooking and space heating as well as for small scale industrial applications (brick making, etc).

One of the reasons of the heavy dependence on biomass is the easy availability of wood and charcoal and consequently low price in almost all rural areas as well as some of the more urban areas. In fact in most areas fuel wood and to a lesser extent charcoal are not monetized as a lot of people collect their own fuel wood and make their own charcoal. While no generally valid price of fuel wood and charcoal can be given.

Unfortunately very little information is available on household fuel consumption other than what was collected during field visits. Based on these very limited number of consumption data, the average fuelwood consumption for a family would be about 10 kg. per day while, if charcoal is used, from 1-1.5 kg per family per day is used.



c. Potentials

Biogas is generally considered to be feasible in those places where:

- the temperature is warm (tropical and sub-tropical conditions);
- collecting and transporting of quality construction materials is easy;
- skilled and unskilled labour for plant construction is locally available;
- feeding materials such as water and cattle dung are easily available;
- other household energy sources are either scarce, not available or are expensive; and
- bio-slurry is appreciated as an organic fertiliser and/or fish feed.

Looking into the above conditions, Lao PDR does meet some but not all of the conditions indicated. In most areas, temperature is not a problem but could pose some problem in the northern mountains and other high lying areas where during wintertime the temperature can drop to 10 degrees centigrade or lower.

With regard to construction materials, Lao PDR generally has good quality bricks available although in remote(r) areas bricks may not be available or are expensive due to transport costs. Cement and iron bars are no problem but sand and stones (aggregate/chips) sometimes are expensive again due to high transport costs. Availability of skilled labour (masons) as well as unskilled labour is generally not a problem. Water is commonly available from local sources like wells, streams and rivers.

In regards to the availability of dung/manure, a study carried out in 2002 showed that in 1999 the total cattle, buffalo and pig population amounted to 944,000 (cattle), 992,000 (buffaloes) and 1,036,000 (pigs). To properly operate a biogas plant, three to nine head of cattle that spend at least the night time in a stable would be required. Less than three head would provide insufficient gas to justify the investment, more than nine head would, in most cases, provide more gas then can be used for domestic cooking purposes. Similar to cattle, a biogas plant would require approximately 3 to 9 buffalo to meet the gas requirements of the owner while, in the case of pigs, a farmer should keep between 7 and 30 mature pigs. These figures are indicative only, as for the selection of the proper size of the plant, the daily available amount of dung has to be considered. Considering the number of livestock required, the potential for biogas appears to be considerable as there are some 70,000 farmers with a sufficient number of cattle, some 60,000 farmers with a sufficient number of buffalo and roughly 20,000 farmers with enough pigs as shown in table 5. In practice the number will be higher as many farmers will not only have cattle but buffalo and/or pigs as well so that farmers with smaller holdings may well have a sufficient number of livestock (cattle and/or buffaloes and/or pigs). While it is difficult to estimate the technical potential due to many uncertainties, one may assume that, based on livestock holdings, the potential for biogas digesters could be well over 100,000 units.

However, in practice the potential number will be far lower due to prevailing livestock practices, policies by the Lao PDR government as well as the availability of competing sources of energy like fuel wood and charcoal which in almost all rural areas are available in abundance and at low or no cost.

Table 1: Livestock Holdings in Lao PDR

Livestock	Agro-based	HH with	Number of HH with number of Livestock					Average
Type	HH	Livestock	1	2	3-4	5-9	10+	per HH
Cattle	668,001	208,140	33,923	48,489	55,114	50,459	20,155	4.5
Buffaloes	668,001	322,142	83,490	82,500	96,373	51,592	8,187	3.1
Pigs	668,001	327,500	125,383	76,148	59,244	48,782	17,943	3.2

e. Program Integration

Biodigester has a number of synergies with other development sectors like health, women's development, agriculture, forestry and livestock management. In addition to cooking fuel, biogas can be viewed as a wood saving and forest conservation technique. It can also be promoted to improve the quality of life for women by reducing the drudgery fuel wood collection and cooking in smoke-filled kitchen. Biogas can also be used to produce good-quality organic fertilizer at low cost complementing agriculture-related programs. 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.

There could be numbers of motivational factors for the potential farmers to install biodigesters. It could be improvement on the quality of life of the families, especially that of women. The second motivation could be the use of slurry bi-product as organic fertilizer. It is therefore recommended that the biogas program in the provinces be integrated with the women's development programs being implemented by various organisations. It can be integrated with women development, agriculture and health programs. There are also rooms to integrate biogas program with wood saving and forest conservation programs.

Importantly, there is a need to develop and establish linkages between potential stakeholders for program integration at the policy level as well.

4. OVERVIEW ON BIODIGESTER DESIGN/DRAWINGS AND CONSTRUCTION STEPS

4.1 Types of Biodigester

There are different designs of household biodigesters being in use today. Broadly, they can be classified as: fixed dome plants and floating drum plants. Fixed dome plants are getting popularity these days. Some of the models of fixed dome plants are shown hereafter:

4.2 Different Components of Biodigester

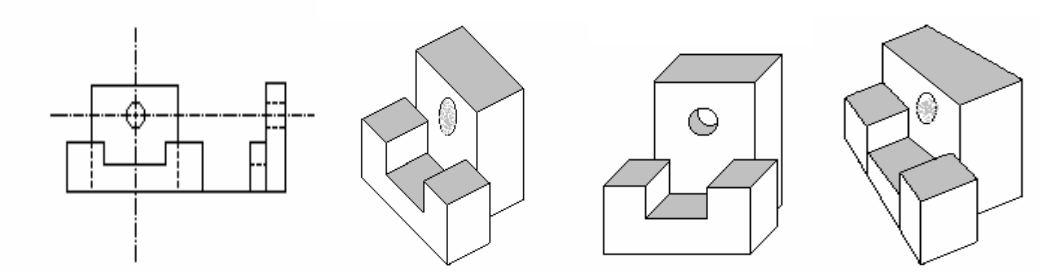
There are 6 main parts of the biodigester: inlet (mixing chamber) for cattle dung fed plant and maturation pond for swine manure, digester (digestion chamber), gas holder (storage chamber), outlet (displacement chamber) and gas conveyance system and slurry compost pit(s). The mix of dung and water (mixed in inlet or mixing chamber) or pig swine manure flushed from stable passes through the inlet pipe to the digester. The mixer produces gas through digestion process in the digester and the produced gas is stored in the gas holder (top of dome). The digested slurry passes out from digester to outlet tank (displacement chamber) and flows out to the compost pits through overflow opening in the outlet tank. The gas is then supplied to the kitchen through the pipe line. The modified GGC model of Biodigester generally consists in detail of:

1. Inlet (Mixing Tank) with Mixer for Cattle dung-fed plants, collection channel with a maturation chamber for swine-manure fed plants
2. Inlet Pipe(s) separate for cattle dung/pig manure and latrine
3. Digester
4. Gas Holder (dome)
5. Manhole and Outlet (Displacement Chamber) and overflow opening
6. Main Gas Pipe and Turret
7. Main Gas Valve
8. Pipeline and Water Outlet (Water Trap or Drain)
9. Gas Tap
10. Gas Stove with rubber hose pipe
11. Gas Lamp (Optional)
12. Slurry pit(s)

4.3 Drawing Reading

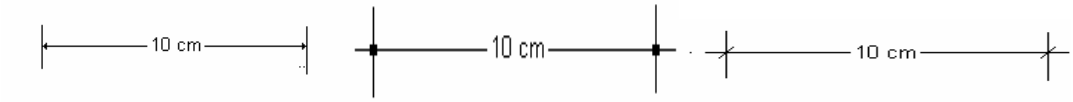
Since earlier times, people have used drawings to communicate and record ideas so that they would not be forgotten. The earliest forms of writing, such as the Egyptian hieroglyphics, were in illustrative/graphic form. The word graphic means dealing with the expression of ideas by lines or marks impressed on a surface. A drawing is a graphic representation of a real thing. Drawing therefore is a graphic language, because it uses pictures to communicate thoughts and ideas. Because these pictures are understood by people of different kinds, drawing is referred to as a "universal language." Artistic drawing is concerned mainly with the expression of real or imagined ideas where as technical drawing is concerned with the expression of technical ideas or ideas of a practical nature, and it is the method used in all branches of technical industry.

These technical drawings are projected in different four projections; 1. Orthographic Projection, 2. Isometric Projection, 3. Oblique Projection and 4. Perspective Projection. The most used projection in the technical drawing is the Orthographic Projection. Orthographic Projection must contain three dimensions; length, width and depth or height. In order to include all the required three dimensions, Orthographic Projection contains two views: Plan View and Section view. Plan view provides the length and width of the subject while section view provides the depth or height.



Orthographic Projection Isometric Projection Oblique Projection Perspective Projection

Such technical drawing will only be considered complete when all the dimensions are indicated in the drawn subject because, without dimensions the subject cannot be constructed in the correct proportion. The lines that indicate measurement of the subject in the drawing are called dimension lines. Dimension lines can be drawn in different styles such as:



4.4 Drawing of a Modified GGC model of Biodigester

The drawings of various sizes of biodigesters have been given in the Annex.

4.5 Operating Principle of Biodigester

In the initial state of the operation cycle, the surface of the slurry in the digester and the surface of the slurry contacting with the atmosphere at the inlet and outlet are equal and are at the "zero level". At this time the biogas pressure in the digester is equal to 0 ($p = 0$).

The upper part of the digester contains a certain amount of gas. However this amount of gas cannot be extracted for consumption, as there is no pressure to push it out of the tank. This part of gas can be called "dead gas". The portion of space containing the dead gas is called the "dead portion" of the digester.

More and more gas will be generated and accumulated in the upper part of the digestion tank. It will push the slurry up to the outlet tank and the inlet pipe. As the inlet pipe is small, the volume of the slurry displaced will be mainly stored in the outlet tank. The surface of the slurry in the digester lowers down; in the meantime the surface of the slurry in the outlet tank rises up. The difference between these two surfaces represents the gas pressure. The more gas generated the higher the pressure.

The highest level to which the slurry in the outlet tank rises is the "overflow level". At this time the level of the slurry in the digester lowers down to the "lowest level" and the gas accumulation stage of a correct operation cycle of the plant terminates here. That is the final state of the gas accumulation stage of the operation cycle. At this time the gas pressure reaches the maximum value ($P = P_{max}$). The volume of the gas generated in the cycle is equal to the amount of the slurry displaced by the gas and kept in the outlet tank.

When the gas is released for consumption, the slurry from the outlet tank flows back into the digester tank and dispels the gas out. The surface of the slurry in the outlet tank lowers down; in the meantime the surface of the slurry in the digester rises up. The difference between these two surfaces and the gas pressure gradually decrease.

Finally, when the difference between the two surfaces of the slurry is equal to zero, the biogas plant returns to the initial state of the operation cycle, $P = 0$ and the gas outflow stops. The volumes of gas which can be extracted for consumption is equal to the volume of the slurry contained in the outlet tank.

4.6 Steps for the Construction of a Biodigester

- Selection of correct size of biodigester
- Selection of construction site
- Collection of construction materials that meet the quality standards
- Lay-out of plant and digging of the pit
- Fixing the diameter and laying of collar (base layer for brick work) for digester and manhole walls
- Construction of digester walls and manhole
- Installation of inlet pipes
- Backfilling the empty spaces outside the digester wall
- Construction of the top of manhole
- Construction of the gas holder (dome-shaped)
- Constructing gas holder (preparation of earthen mould, concreting, fixing of dome gas pipe)
- Constructing Inlet and outlet chambers
- Constructing outlet covers
- Plastering of the inside of dome
- Construction of turret
- Installation of pipeline, fittings and appliances
- Testing for leakages
- Filling the plant with feeding
- Constructing slurry pit(s)
- Filling the top of dome and sides of outlet tank with earth
- Cleaning the site

5. BIODIGESTER SIZE, CONSTRUCTION SITE AND CONSTRUCTION MATERIALS

5.1 Selection of Construction Site

Selection of construction sites are mainly governed by the following factors:

- The site should facilitate easy construction works.
- The selected site should be such that the construction cost is minimised.
- The selected site should ensure easy operation and maintenance activities like feeding of Plant, Use of main gas valve, Composing and use of slurry, Checking of gas leakage, Draining condensed water from pipeline etc.
- The site should guarantee plant safety

Based upon the above mentioned factors, it is recommended to select plant location based upon the following considerations. Please note that it will not be possible to meet all the requirements as stated below, however, it should be ensured that as many as possible points are considers.

- For effective functioning of biodigesters, right temperature (20-35°C) has to be maintained inside the digester. Therefore it is better to avoid damp and cool place – Sunny site is preferable.
- The area to construct plant should have even surface.
- The site should be in slightly higher elevation than the surrounding. This helps in avoiding water logging. This also ensures free flow of slurry from overflow outlet to the composting pit.
- To make plant easier to operate and avoid wastage of raw materials, especially the dung/swine manure, plant must be as close as possible to the cattle shed or pig sty.
- To mix dung and water or flush swine manure to the digester, considerable quantity of water is required. If water source is far, the burden of fetching water becomes more. However, the well or ground water source should be at least 10 meter away from the biodigester especially the slurry pit to avoid the ground water pollution.
- If longer gas pipe is used the cost will be increased as the conveyance system becomes costly. Furthermore, longer pipeline increases the risk of gas leakage. The main gas valve which is fitted just above the gas holder should be opened and closed before and after the use of biogas. Therefore the plant should be as near to the point of application as possible.
- The edge of plant should be at least 2 meter away from the foundation of house or any structure.
- There should be enough space for compost-pit(s) as these are integral parts of the biodigester.
- The site should be at sufficient distance from trees to avoid damage of bio-digester from roots.
- Type of soil should have enough bearing capacity to avoid the possibility of sinking of structure.
- When space is a problem, the pig-sty can be constructed on top of the plant after proper backfilling.

5.2 Selection of Size

Modified GGC Biodigesters are fixed dome design plants. 4, 6, 8 and 10 m3 biodigesters of Modified GGC Biodigester models are eligible for obtaining subsidy from the Government of Lao PDR under the Biogas Pilot Programme. No other sizes and designs will be eligible to receive subsidy under the programme. The following table shows some basic information related to different sizes of the biodigester being introduced.

Quantity of Feeding Required

SN	Capacity of plant (M3) *	Daily gas production (M3)	Fresh dung required every day ** (Kg)	Water required every day (litre)
1	4	0.8 - 1.6	20-40	20-40
2	6	1.6 - 2.4	40-60	40-60
3	8	2.4 - 3.2	60-80	60-80
4	10	3.2 - 4.0	80-100	80-100

* *Capacity of plant means the volume of digester and gas storage dome*
** *Average retention time: 40 day*

The size and dimensions of the biodigesters have been decided based upon 40 days retention time and 50% gas storage. This means that the fresh feeding fed into the digester should remain inside it for at least 40 days before it comes out through outlet. Likewise, the plant should be able to store 50% the gas produced in 24 hours. Therefore the size of the biodigester has to be selected based upon the daily available quantity of feeding materials.

Before deciding the size of biodigester to be installed, all the dung available from cattle or the swine manure has to be collected to know how much feeding material is available every day. The following table shows the capacity of biodigesters to be decided based upon the availability of feeding material (dung or swine manure).

Quantity of feeding material available daily (kg)	Recommended Size of Plant (cum)	Quantity of Fuel wood saved per day (kg)
20-40	4	4 to 8
41-60	6	8 to 12
61-80	8	12 to 16
More than 80	10	16 to 20

If the plant is not fed properly as per the requirement, gas production will be less than the theoretical expectation. If gas production is less, the gas collected in the gasholder will not have sufficient pressure to push the digested slurry to the outlet. In such case, the slurry level will be raised and reach to the gas holder instead of flowing to outlet. When the main gas valve is opened in this situation, the slurry also passes to the pipeline together with the gas. Therefore, if there is not enough quantity of feeding material available as per the prescribed rate, bigger size of biodigester should not be installed. Underfed and bigger plants will just increase the cost of installation and also create problem in operation. **The important point to be considered while deciding the size of biodigester is that the basis for selecting size is the availability of dung not the family size or gas demand. If the farmer has higher number cattle or pigs then only the size is determined by the gas demand which is usually taken to be 0.33 cum gas per person per day.**

5.3 Quality Standards of Construction Materials and Appliances

If the construction materials to be used for the construction of biodigester are not of good quality, the biodigester will not function properly even if the design is correct and workmanship involved in construction is excellent. The plant will never be of high quality if inferior quality of construction materials is used. In order to select these materials of best quality, required quality standards and specifications of these materials are briefly described below:

Cement
Cement should be high quality Portland cement from a brand with a good reputation. It must be fresh, free from lumps and stored in dry place. Cement with lumps should be used for construction. Bags of cement should not be stacked directly on the floor or against the walls. Wooden planks have to be placed on the floor to protect cement from dampness. Cement bags should be stalked at least 20 cm away from any walls.

Sand
Sand should be clean and should not contain soil or other materials. Dirty sand will have very negative effect on the strength of the structure. If sand contains more than 3% impurities, it must be washed. The quantity of impurities especially the mud, in the sand can be determined by a simple 'bottle test'. A small quantity of sand is put into a transparent bottle and water is poured into it. The bottle is shacked vigorously for a while. The bottle is then left stationary to allow the sand particles to settle down. The particles of sand are heavier than that of silt and clay, so it settles faster where as the mud particles settle slower. After 30 minutes, the layer of mud verses sand inside the bottle is measured without shaking the bottle. If the depth of mud is more than 3% of the total depth, than it can be concluded that the sand contains too much mud. If this happens, the sand should be washed before use. Coarse and granular sand are best for concreting, however, fine sand has to be used for plastering works.

Gravels
Size of gravel should not be very big neither very small. It should not be bigger than 25% of the thickness of the concrete product where it is used. The thickness of concrete layer in the foundation and that of outlet slabs is not more than 7.5 cm (3"), therefore the maximum size of gravels should be 2 cm or ¼ size of the size of thickness of concrete layer. Gravel should be clean, hard and of angular shape. If it is dirty, it has to be washed properly before use.

Water
Water is mainly required for making the cement mortar for masonry works, concreting works and plastering. It is also used to soak bricks before using. Besides, it is required for cleaning or washing construction materials if they are dirty. The water from ponds or cannel may be dirty so it is better not to use it. Dirty water will have an adverse effect on the strength of structure. Water from water tap or well or any other sources that supply clean water has to be used.

Bricks
Brick plays a very important role in construction especially for Modified GGC model of biodigesters. Bricks should be of high quality (no.1), usually the best quality available in the local market. The bricks should be well burnt, straight, regular in shape & sizes and should not have cracks or broken-parts. High quality bricks make a clear metallic sound when hitting them to each other. Such bricks should be able to bear a pressure of 120 Kg per square centimetre. Before use, bricks must be soaked for few minutes in clean water. Wet brick will not absorb water from the mortar which is needed for setting properly.

Acrylic Emulsion Paint
It is used to make the gas holder (dome) of biodigester air-tight. Paint of this type should meet quality standard and they must be approved from concerned quality control authority.

Mild Steel Bars
MS bars are used to construct the covers of outlet tank and water drain chamber. It should meet the engineering standard generally adopted. For plants of 4, 6 and 8 cum, MS rods of 8 mm diameter and for plant of 10 cum capacity 10 mm diameter is recommended. MS bar should be free from heavy rust.

Main Gas Pipe
Gas stored in the gas holder is conveyed to the pipeline through this pipe which is placed in the topmost portion of the dome. The joint of reduction elbow with this pipe should be perfect and gas tight otherwise gas leakage from this joint can not be stopped easily. Therefore it is recommended that the reduction elbow has to be fitted in a workshop to ensure perfect air-tightness of the joint. The gas pipe should be properly galvanised and approved by concerned quality control authority. This pipe should be made up of light quality iron and MS rod has to be welded at one end to embed it with the concrete during installation. The length of this pipe should be at least 60 cm.

Main gas valve
It controls the flow of biogas in the pipeline from the gas holder. It is opened when gas is to be used and closed after each use. If substandard quality of main gas valve is used, there is always risk of gas leakage. This valve should be of high quality and approved by the concerned quality control authorities.

Pipes and fittings
The pipe to be used to convey gas from gas holder to the point of application should conform to quality specification as per the standard of Lao PDR. Light quality Galvanised Iron pipe is best suited for this purpose; however, high quality PVC pipe could also be used. The pipe should be of at least half inch diameter. For length of more than 60 m (30 m if two burners are to be used at a time), ¾" diameter pipe has to be used. If GI pipe is to be used, a six meter pipe should weigh at least 6 kg. The fittings used in the pipeline of a biogas plants are socket, elbow, tee and nipples. These fitting should meet the required quality standards.

Water Outlet
It drains the water condensed inside the pipeline when biogas comes in contact with the cool pipe. This is an important component of biogas plant and therefore, its quality should carefully be controlled. It should be easy to operate and threads in it should be perfect. It should be ensured that the hole in the screw nut is bored properly and is located at the right place. The thickness of the nylon washer has to be 4mm and either a 4 cm long handle pin or a properly knurled opener should be used. This appliance should be approved by the concerned authorities.

Gas Tap
Gas tap is used for regulating flow of gas to the gas stove. Care should be taken to install gas tap of high quality. It has been often complained by the users that this taps are becoming problematic with gas leakage through them. It is important that the 'o' ring is placed properly and is greased thoroughly and regularly. The gas tap should not be too tight or loose to operate. The taps to be used in biodigesters should be approved by concerned quality control authority.

Rubber Hose Pipe
It is used to convey gas from the gas tap to the stove. This pipe should be made up of high quality neoprene rubber and should not develop cracks when folded. It should have 15 mm outer and 9 mm inner diameters. The minimum wall thickness of the pipe should be 2.5 mm.

Gas Stove
Gas stoves can be found with single and double burners. In general a single burner gas stove used for household purpose consumes 350 to 400 litre of gas per hour. The efficiency of gas stove is very important for the successful functioning of the biodigester. The stove should be of good quality and strong enough to firmly rest in ground. The primary air intake should be easily adjustable and the holes should be properly placed. The jet and pipe leading to the burner should be straight and aligned properly. The holes in the burner cap should be evenly spread across it.

Gas Lamp
Gas lamp is another important appliances used in biodigesters. Often users complain about the malfunctioning of these lamps. These lamps should be of high quality with efficiency more than 60%. Usually, a biogas lamp consumes 150 to 175 litres of biogas per hour. Lamps to be used in biodigesters have to be approved by the concerned quality control authority.

Mixing Device
This device is used to prepare good quality water-dung solution in the inlet tank when cattle dung is used as feeding material. Usually for household biogas digesters, vertical mixing devices are installed. The device should be of good quality, as per the design, and the mixing blades have to be well galvanised. The blade should be properly aligned for the effective mixing.

6. PROPER CONSTRUCTION OF BIODIGESTER

6.1 Plant Layout

Construction works of biodigester starts with the process of layout works. This is the activity carried out to mark the dimensions of plant in the ground to start the digging work. For this purpose, first a small peg has to be stuck in the ground at the centre spot of the digester. Then the following steps should be followed:

- Level the ground and determine the centre line of the digester, outlet tank and inlet pit (generally called as hart-line)
- Select the outer diameter of the pit (digester diameter plus wall thickness) as shown in the drawing under dimension 'C' and mark it in the rope or chord
- Insert a stick or wooden peg in the levelled ground at the centre of the proposed digester pit. With the help of this pole and chord prepared earlier, make a circle, which indicates the area to dig.
- From the centre point where the central line meets with the perimeter line, draw a tangent and measure a length equal to half of the breadth of outlet plus wall thickness on either side of this tangent.
- Draw horizontal parallel lines from the points in either side in the tangent, which will meet the dome. From the centre point where the central line meets with the perimeter line, measure the length of outlet plus wall thickness to decide the outer dimension of outlet
- Check the size diagonally to ensure that the corners are exactly at 90 degrees
- Use coloured powder to mark the dimensions
- Decide the location of slurry pits while laying out plant digester and outlet.

6.2 Digging of Pit

After completion of lay-out work, the work for digging of pit has to be started. Tools like, crow-bar, picks, spade, shovel and basket should be available at the site. The following points have to be followed to dig the pit.

- Digging should be done as per the dimensions fixed during layout
- As far as practical the cutting in ground should be vertical, however, if the soil is cohesion-less and angle of repose needs more slope cutting, scaffolding may be needed. If the water table is high and digging to the required depth is difficult, a deeper pit has to be constructed near the digester pit. Water accumulated in the digester pit has to be drain to this pit through underground pipes. Water should be pumped from this pit.
- Once the depth of digging is equal to the dimension 'E' as shown in the drawing, the work of fixing curvature at the bottom has to be considered while digging
- The pit bottom must be levelled and the earth must be untouched.
- Always ensure that the excavated earth is deposited at least 2 m away from the pit in each side to ease the construction works
- Be careful to avoid accident while digging near the sides as soil may collapse
- Dig the foundation for the manhole (first step of outlet tank) along with the foundation for digester as per the dimensions in the drawing during the layout.
- Now horizontal poles have to be placed in the ground level crossing each other at 90 degree in the centre. Ensure that the poles rest at levelled ground.
- If because of hard rock or under ground water, the right depth can not be achieved, the pit has to be made as deep as possible, while after completion of the structure some protective measure have to be constructed so that the walls of outlet and dome is supported well from outside

6.3 Construction of Digester

After the completion of digging of pit, construction of digester wall has to be started. The central wooden pole and the guide chord have to be used in this case. The following points should be followed while constructing digester and gas holder.

- Soak the brick in water for about 10-15 minutes before use.
- Prepare mortar for brick wall construction in the ratio of 1 part cement to 3 parts sand.
- At the centre of the pit, a straight rod or pipe (the 0.5" GI gas pipe) must be placed in an exact vertical position. At ground-level, a heavy pole or pipe has to be placed horizontally on the centre of the pit. The vertical pipe can now be secured to the horizontal pipe or pole. After securing, the vertical pipe has again to be checked whether it is still in the right position. Now, fix the radius of wall at the floor with the help of a string or chord attached to the vertical pole or pipe. The length of this string or chord can be found on the drawing under the dimension 'F', 1.2 cm has to be added to this length to allow space for plastering. Every brick or stone which is laid in the round-wall has to be exactly F+l.2 cm away from the vertical pipe. After deciding the radius of digester, a circle has to be drawn to decide the circumference of the round wall. Now, the base of round wall (the collar) is constructed. The collar is a thick layer of mortar 2.5-3 cm placed on the untouched earth in the floor of the excavated pit along the circle.
- Place the first brick with the help of guiding string. Go on placing the bricks in circle with the help of this string. Construct the brick wall from one direction only, either clockwise or counter clockwise. The face of brick wall should be maintained inside while constructing the wall. The first row of bricks must be positioned on their sides so that a 4.5" high, 9" wide base is made. It is essential that first row is placed on a firm, untouched and level soil. The next rows of bricks can be positioned on their lengths so that the wall thickness becomes 4.5". It is not necessary to make pillars in the wall but the backfilling between wall and pit-side must be compacted with great care. This backfilling has to bed one in the morning before starting the construction work. Earth should be well compacted by adding water and gentle ramming all along the circumference of the digester. Poor compaction will lead to cracks in round-wall and dome.
- If stone is used for the construction of round wall, the wall should rest against the pit-side as it is difficult to have proper backfilling because of the irregular shape of the outside of the stone wall. The cement mortar used can be 1 cement-4 sand to 1 cement-6 sand depending on the quality of the sand.
- While laying bricks ensure that the space (joints) between them is filled with mortar, properly compacted. The thickness of mortar joint should at least be 10 mm. However it should not exceed 15 mm. Ensure that the mortar joints in two adjacent brick layer never fall in vertical line.
- When the height of round wall reaches 30 cm, place 2 inlet pipes (one for conveying swine manure or cattle dung and the other for human excreta from toilet). These pipes should drain exactly at the opposite side of the manhole opening. The slope of these pipes should at least be 45° with the ground level. Ensure that the lengths of inlet pipes are sufficient enough to construct the floor of inlet at least 15 cm in higher elevation than the level of slurry overflow at the outlet wall.
- The height of the round-wall can be found on the drawing under dimension 'H' when measured from the finished floor. The dung inlet pipe and toilet pipe must be placed in position when the round-wall is 35 cm high. To reduce the risk of blockages, the inlet pipe(s) must be placed as vertically as practical possible.
- Exactly to the opposite of the dung inlet pipe, a 60 cm wide opening must be left in the round-wall which acts as manhole. The digested slurry also flows out to the outlet tank through this opening. The inlet pipe from the latrine should be placed as close as possible with the dung inlet pipe with a maximum distance of 45 degrees from the dung inlet on the dang inlet-centres-manhole line (hart line).
- When the round-wall has reached the correct height, the inside must be plastered with a smooth layer of cement mortar with a mix of 1 cement - 3 sand. The digester floor can be made from bricks or small stones with plaster in cement mortar.

6.4 Construction of Gas Holder (Dome)

When the construction works of round wall as described above is completed than the dome has to be constructed. Before filling the pit with earth to make the mould for the dome, backside of the round wall should be filled with proper compacted back-filling. If this is not done, the pressure of the earth for the mould can lead to cracks in the round-wall. On the vertical centre pipe a mark has to be made at a distance T, as given in the drawing, from the finished floor. Now soil has to be filled in the finished digester up to the marked height. Once the earth filling is completed, the vertical pipe can be removed by pulling it upwards. It has to be replaced by a shorter 0.5" dia. pipe, approx. 0.5 metres length in the earth exactly at the same spot. Now the template should be used to make the shape of the dome. The top of the round wall must be clean when the template is in use. The template can be checked by making sure the top is horizontal and the side exactly vertical. Furthermore, the part of the template that touches the round-wall must be in the same position all over the round wall.

It is important that the earth of the mould is well compacted. If the earth is further compressed after casting the dome, by its own weight and that of the concrete, it can lead to cracks in the dome. When the earth mould has the exact shape of the template, a thin layer of fine sand has to be spread on the mould-top by gently patting it on the surface. Any excess sand or soil that falls on the round-wall has to be removed. The earth used for the mould has to be damp to prevent dry earth from soaking up water from freshly casted concrete. Before starting the casting work enough manpower and construction materials like sand, gravel, cement and water has to be collected on the site. The casting has to be done as quickly as possible and without interruptions as this will negatively affect the quality of the cast. A constant, adequate supply of concrete (mix: 1 cement, 3 sand, 3 gravel) must be made for the mason. No concrete older than 30 minutes should be used.

A special care should be taken to maintain the thickness of dome while casting, i.e. the thickness in and near the edges should be more than the thickness in the centre. For 4, 6, 8 & 10 m3 plant, the thickness in the edge should be 25 cm where as the thickness in the centre should be 7 cm. Similarly, for 15 & 20 m-3 plants, the thickness in the centre should be 8 & 9 cm respectively and the thickness in the age should be 25 cm. The small pipe on the top of the mould must be left in place till the main gas pipe is installed. This is to make sure that the main gas pipe is exactly in the centre.

Already during the casting, the concrete has to be protected against strong sun-light by covering it with jute bags or straw mats. This protection has to be left in place for at least
one week. The day after the casting, the turret must be made.

Any delays can lead to leakage between main gas pipe and dome. Also from the day after the casting onwards, the dome has to be sprinkled with water 3 to 4 times a day which is known as curing.

6.5 Plastering of Digester and Gas Holder

Gas-tightness of the gas-holder is very important for the effective functioning of any biodigester. If the gas stored in the gas-holder escapes through the minute pores, the users will not be able to get gas at the point of application. The whole investment will therefore be wasted if gas holder is not made perfectly gas-tight.

After approximately one week, depending on the temperature the earth of the mould can be removed through the manhole. When all earth is removed, the surface of the gas holder has to be cleaned with scrubbing with water and iron brush. The entire surface of the concrete dome has to be cleaned before starting the plastering. After cleaning the following layers of plastering works have to be applied to make the gas holder perfectly gas-tight.

- Scrubbing and scratching (chiselling)
- 5 layers of dome treatment works:

- Layer-1: Plain cement-water flush (1 part cement and 3-5 parts of water), applied with the help of broom
- Layer-2: 10 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand) applied with plastering trowel
- Layer-3: 3-5 mm thick cement cement-sand punning (1part of cement and 2 parts of sand) with plastering trowel
- Layer-4: Plastering with cement and acrylic emulsion paint mix (1 part paint and 10-12 parts cement) 3 mm thick applied with plastering trowel
- Layer-5: Painting with thick layer of cement- acrylic emulsion paint (1 part of paint and two parts of cement) applied with painting brush (10 cm wide)

A plaster coat must be at least one day old before applying the next layer. While applying the plaster layers, the work must be executed with the greatest care and without interruption in between. Each layer has to be smooth and fine. Curing has to be properly done in each surface before applying another layer. The well functioning of the plant is very much depending upon the gas tightness of the dome and hence, the work of plastering each layer has to be done very carefully and as per the set quality standards.

6.6 Construction of Turret, Manhole and Outlet tank

Turret is constructed to protect the dome-gas pipe. The construction of turret has to be done when the plaster applied in the outer surface of the gas holder sets well. The turret could be square or circular in shape. The size of square should be 20 cm. If it is circular the diameter should be 20 cm. The height of turret should be 40 cm.

To construct the outlet tank which is also called as displacement chamber, excavation has to be done just behind the manhole. It is important to accurately comply with the dimensions of the tank as they determine the useful capacity of the gas holder. The following steps should be followed while constructing this tank.

- The depth of exaction should be inner depth of outlet plus the thickness of plaster plus thickness of concreting (inner depth+1.2+7.5 cm) form the ground level. When excavated at this depth, the level would exactly reach at the top of manhole. The earth in the base of outlet, behind the manhole has to be well compacted otherwise cracks will appear in the outlet floor later on. The inside dimension of outlet chamber can be found on the drawing under length, breadth and depth (A, B and D). The length and breadth of digging should be the inner dimension plus wall thickness plus plaster layer. Ensure that the distance from the floor of the manhole to floor of the outlet should is depth of outlet tank plus concrete thickness (7.5 cm).
- Once the excavation is completed lay concrete on the properly rammed surface. The ratio of mix should be 1:2:4 (cement:sand:aggregate). The concrete surface should be levelled and smooth. In this surface, once the concrete is set, outlet walls have to be constructed. The inner-dimensions of outlet should be as shown in drawing (length and breadth). While fixing the dimensions allow 2.5 cm for plastering (two sides). Lay a first layer of mortar (1 cement to 3 sand) and start constructing wall. Place bricks in the four corners of the tank wall which will ease the construction. The walls have to be vertical and finished with a smooth layer of cement plaster (1 cement to 3 sand). The outer part of the wall has to be compacted well to avoid cracks due to slurry pressure from inside.
- The overflow level in outlet wall should be at least 10 cm in higher elevation than the natural ground level. This is done to avoid the surface run-off from the surrounding areas to enter into the outlet, especially in the rainy season.
- It is better to orient outlet in such a manner that the length is parallel to the hart-line. If there is limitations of land than it can be done in the other way. Always construct the overflow in the longer wall.
- The cover slab for outlet should be casted during the concreting of floor for outlet. The slab could be casted on levelled ground as per the dimensions given for different capacity of plants. Special care has to be given to compact the concrete mix while casting slab as small holes left behind will expose the steel reinforcement to corrosive vapour coming from the slurry in the outlet tank. This vapour will lead to corrosion of reinforcement and in longer run the slab may ultimately collapse. Even if some

holes are created, these should be closed with a layer of plaster. The slab should be cured daily for at least 5 days before it is placed into its location. The slab must be 7.5 thick with proper reinforcement of 2 to 2.5 cm from the bottom. The slab must of size that could be handled by 3-4 people without great difficulty. The outlet cover slabs are very essential to protect people especially the children and animal from falling inside. Furthermore it stops the rainwater entering into the digester and also helps in avoiding excessive vaporisation of slurry in the dry and hot season.

The dimensions of outlet slabs are shown in the following table.

Plant size in M3	Slab size in cm		No. of slabs	Diameter of MS rod	Weight of steel to be procured in kg
	Length	Breadth			
4	145	55	3	8	10
6	145	58	3	8	12
8	155	65	3	8	13.5
10	155	68	3	8	15

For all slabs:

Thickness : 5 to 7.5 cm (2-3")
Cover (bottom) : 2-2.5 cm (1")
Spacing of rods places longitudinally : 15 cm (6")
Spacing of rods in cross section : 30 cm (12")
Concrete ratio : 1 part cement, 2 parts sand and 4 parts aggregate
Curing period : At least 5 days

6.7 Construction of Inlet Tank

After the completion of the construction of outlet tank, inlet is constructed. If the feeding material is cattle dung, then a inlet tank is constructed. This tank is constructed to mix dung and water and make the required paste with solid content about 8-10% in the mix. For plant to feed swine manure, a collection channel and maturation chamber has to be constructed. The following are some of the facts that need to be considered while constructing inlet tank to feed cattle dung into the digester.

- The foundation of the inlet pit should be places in well rammed, hard and levelled surface.
- In this rammed surface first of all the rectangular base of inlet tank is constructed. The height of the base should be decided in such a manner that the floor of inlet tank is at least 15 cm above the outlet overflow level.
- Once the base is constructed, the circular portion of inlet tank has to be constructed where the dung and water is mixed. Prior to the commencement of construction of round wall for the inlet, provisions should be made in the base to house the mixing devise if mixing devise is to be installed. Installation of mixing devise is preferable not only from easy operation point of view but also to improve the quality of mix. To fix the mixing device in position, a pivot should be placed at the centre of the base of inlet. Then the floor of inlet tank is made. In this finished surface, a circular mark with the help of a thread or chord is made of 30 cm radius to decide the inner circumference of the tank.
- The round wall of inlet tank now should be constructed with the brick placed in circular fashion following the mark already made. When the height of circular pit reaches to 45 cm, iron bracket should be fixed to tighten the mixing device. The mixing device should be firmly attached to the structure, easy to operate, effective in mixing process and rust-proof. The steel parts in contact with the slurry need to be galvanised properly.
- The height of inlet from the ground level including the base is recommend to be 90 cm, however in no case it should be more than 100 cm.
- Once the round wall is constructed, one day should be allowed to set the mortar properly. Then both inside and outside of the tank is plastered cement mortar (1 part of cement to 3 parts of sand).
- The bottom of the tank must be at least 15 cm above the overflow level in the outlet wall.

- The position of the inlet pipe in the floor must be such that a pole or rod could be entered through it without obstructions if any de-blocking is needed. If the inlet pipe is not positioned properly, the inlet walls have to be dismantled to insert rod or pole through it.
- In case of toilet attachment to the plant, it is better to construct without siphon or trap as the pan with siphon needs more water to drain the excreta which may result more water inside the digester affecting the hydraulic retention time and total solids in the slurry. It is also not possible de-block the pipe if siphon is placed. The inlet pipe from the toilet should not discharge farther than 45° from the hart-line. Additionally the pan level of toilet should at least be 15 cm above the overflow level in the outlet walls.

For feeding swine (pig) manure into the digester, a channel with proper slope towards the plant should be constructed in the pig-stay. The channel discharges in a maturation chamber of appropriate size. The feeding in this maturation chamber is conveyed to the digester through inlet pipe.

6.8 Fitting of Pipeline and Appliances

The biogas produced in the digester and stored in the gas holder is conveyed through pipeline. If the laying and jointing of pipe is not done properly, the produced gas could not be conveyed effectively to the point of application. The following steps should be followed while laying pipes and installing appliances:

- Prior to starting laying of pipe, the best possible alignment from the plant to the point of application (kitchen) has to be decided. As far as possible such route should be the shortest one and with the minimum risk of damage to the pipeline due to external factors.
- When proper alignment is selected digging of trench has to be started. The slope of trench should be gentle and appropriate so that the laying of pipe therein could be done with required slope.
- First of all the gas valve has to be fitted in position. Attention should be given not to have any fittings rather than a pipe-nipple between the main gas pipe fitted in the dome and the main gas valve to avoid the risk of gas leakage.
- Prior to the laying of pipeline, the length of pipe and required quantity of fittings should be decided in good advance. The pipe has to be cut in pieces as per the requirement by the hexa-blade. The threads in pipe have to be made skilfully. To make threads in pipes, vice and die-sets have to be used in a proper way. The pipe has to be secured in the vice and die-set should be used properly to make the threads. Oil has to be added as lubricant to ease the cutting process. This also helps in making the threads perfectly sharp. When the threads are made and fittings are decided, the work of pipe laying and jointing could be started.
- The pipeline conveying biogas from the plant to point of application is vulnerable to damages by people, domestic animals and rodents and hence, suitable measures have to be adopted for its protection. It is therefore recommended to use galvanised iron (GI) pipes and bury them to a minimum of 30 cm in the ground. However, best quality PVC pipe could also be used if the users prefer it. Fittings in the pipelines must be sealed with zinc putty, Teflon tape or jute and paint. Any other sealing agents such as grease, paint only, soap, clay etc. must not be used. To reduce the risk of leakage, the use of fittings should be kept to a necessary minimum. Unions should not be used.
- The biogas conveyed from the gas holder is saturated with water vapours. This water condenses when it comes in contact with the walls of the pipe. If this condensed water is not drained regularly, it will ultimately clog the pipeline. Hence, a water outlet to drain the water has to be fitted in the pipeline. The position of water drain should be vertically below the lowest point in the pipeline so that water will flow automatically by gravity to the outlet. Water should be drained periodically and therefore the location of water outlet should be conveniently places. The outlet should be protected well in a chamber (30 cm length, 30 cm breadth and 50 cm deep). The cover for this chamber has to be casted during the period of slab casting for outlet tank.
- When the laying of pipe is done correctly from dome to the kitchen, the next step is to fit the gas stoves and lamps. After positioning gas taps correctly, neoprene rubber hose pipe has to be used to join gas tap and gas stove. No other pipe than the approved neoprene rubber hose pipe of the best

quality has to be used for this purpose. As per the requirement of the user, gas lamps have to be fitted. The assembling of different parts of the gas lamp has to be dome with greatest care.

- As soon as there is gas production, the joints and taps must be checked for leakage by applying a thick soap solution. If there is leakage, the foam will either move or break. If so happens, the joints must be sealed properly. The general layout of the pipeline arrangement has been shown in the following sketch.

6.9 Construction of Compost Pits

Compost pits are integral part of the biodigester; no plant is complete without them. A minimum of two composting pits should be constructed near the outlet overflow in such a manner that the slurry can flow easily into the pit. However, at least 100 cm space should be left between outlet wall and compost pit to avoid cracking of the wall of outlet tank. These two pits should be used alternately to fill slurry coming out of digester. The total volume of compost pits must be at least equal to volume of the plant. The depth of the compost pits must not exceed more than 1 metre and the distance between the two compost pits must not be more than 50 cm. The length and width at the top must be more than of the bottom and 10 cm mud has to be added on all sides to raise the height from the ground level to avoid rain water enter the compost pits. The following table illustrates the detail dimensions of compost pits for different plant capacities.

Plant size in m3	**Minimum dimensions of pit in cm**			**Number of pits**	**Total minimum volume of pits in m3**
	Length	**Breadth**	**Depth**		
4	200	100	100	2	4
6	200	150	100	2	6
8	200	200	100	2	8
10	250	200	100	2	10

To make potent and easy-to-use fertiliser, the compost pits should be filled with agricultural residues together with slurry from the plant. It is recommended to construct a shade above the pits to avoid direct sun light. This shade could be used for growing vegetables with vines

7. USE OF BIO-SLURRY AND COMPOSTING

7.1 Use of Bio-slurry

Biogas slurry is one of the end products of the anaerobic digestion in the biogas plants. The mixture of animal / human waste and water put into the biogas plant undergoes a process of anaerobic digestion or fermentation in a biogas digester. During digestion, about 25 – 30% of the total dry matter of animal / human waste will be converted into a combustible gas and residue of 70 – 75 % of the total solids content of the fresh dung comes out as sludge which is known as biogas slurry or slurry only.

Biogas slurry consists of 93% water, 7% dry matter of which 4.5% is organic and 2.5 % is inorganic matter. The percentage of NPK (Nitrogen, Phosphorus and Potassium) content of slurry on wet basis is 0.25, 0.13 and 0.12 while in dry basis it is 3.6, 1.8 and 3.6 respectively. In addition to the major plant nutrients, it also provides micro-nutrients such as zinc, iron, manganese and copper that are also essential for plants but required in trace amounts.

Biogas slurry can be used for varieties of purposes, the main being as the organic fertiliser in farms especially in vegetable and fruit gardens. The following are some of the applications:

- Organic fertiliser in farms
- Organic fertiliser for mushroom culture
- Seed treatment
- As swine supplement feed
- Organic fertiliser to grow algae to increase fish production

Though varieties of uses, the main use of bio-slurry is the organic fertiliser. It can be used wet or dry. The slurry from biogas plant can directly be use in farms mainly mixing it with irrigation water. Wet application is rather cumbersome. Farmers prefer to use dry slurry in their farms. Composting of the slurry is highly recommended for the dry use.

The following table shows the N, P, K values in different types of organic fertiliser (Gupta 1991):

Nutrients	Compost Manure		Farm-yard Manure		Digested Bio-slurry	
	Value Range in %	Average Value in %	Value Range in %	Average Value in %	Value Range in %	Average Value in %
Nitrogen	0.50-1.50	1.00	0.50-1.00	0.80	1.40-1.80	1.60
Phosphorus	0.40-0.80	0.60	0.50-0.80	0.70	1.10-2.00	1.55
Potassium	0.50-1.90	1.20	0.50-0.80	0.70	0.80-1.20	1.00

It can be seen from the above table that digester bio-slurry has better nutrient values in comparison to other organic fertilisers. The effect of compost on crop production depends upon the type and condition of the soil, the quality of the seeds, climate and other factors. However, application of compost will bring the following changes to the soil:

- Improvement of the physical structure of the soil.
- Increased soil fertility.
- Increased water-holding capacity of the soil.
- Enhanced activity of the micro-organisms in the soil.

Effluent compost, if stored and applied properly, improves the soil fertility and increases cereal crop production with 10-30% as compared to FYM. The application of liquid effluent on paddy, wheat and maize has increased the yield by 10, 33 and 37% respectively. Compost application versus non application has given a yield increase of 80% in cauliflower, 67% increase in wheat and 21% in tomato. The most responsive crops to effluent compost are vegetables like root crops (carrots and radish), potatoes, fruit trees and rice (Kharif, India-1988).

Various research studies done in China have indicated that the use of bio-slurry helps in increasing the yields of agricultural productions to a considerable extent. Compared to farm yard manure, application of

digested slurry increased the yields of rice, wheat and maize by 6.5%, 8.9% and 15.2% respectively in China.

7.2 Composting of Slurry

If bio-slurry is composted the nutrient value will be added into it. Digested slurry is an excellent material for fastening the rate of composting of refuse, crop waste and garbage etc. It also provides moisture to the computable biomass. There are several ways of making compost. The widely used method is pit method and semi dried methods of slurry composting. The following steps have to be followed for pit composting of bio-slurry.

- First of all, prepare two compost pits, with volume equal to total plant volume, by the side of biogas plant at least 1 meter away from the plant
- Spread a thick layer of dry materials (15 – 20 cm), such as dry forest litter, waste grasses and straw, leftovers of animals feed and weeds collected from the fields, at the bottom of the pit which will absorb the moisture of the slurry and prevent from leaching of nutrients to the ground water system.
- Let the slurry flow on the dry materials so that the dry material is soaked with the moisture present in slurry.
- Cover the slurry with a thin layer of straw or any dry materials or stable waste. This is done to prevent slurry from drying. This preserves the plant nutrients.
- Next day, let the slurry flow in the pit. If possible spread the slurry equally over the dry materials in the pit and cover it with the same materials as used previously.
- Repeat this process every day till the pit is filled slightly 15 – 20 cm over the ground level and cover it with dry straw/ materials or a thin layer of soil and leave it for a month.
- Provide shade to the compost pit either by making bamboo structure and planting it with the creeping vegetables or by planting fruit trees like banana, fodder trees, green manuring plants or pulses like horse gram. It prevents the evaporation loss of nutrients from the compost pit.
- After a month, turn the compost of the pit and cover it with the same dry materials or a thin layer of soil.
- Turn the compost of the pit again after 15 days and cover it with the same materials as explained earlier. This process of turning will help the fast decomposition of composting materials. The compost thus prepared will be moist and pulverized.
- Start the filling of the second pit after the first pit is filled up. Follow the same procedure in filling the second pit.
- The decomposed slurry compost should be covered with dry materials or a thin layer of soil while the compost is in the pit or stored outside the pit.
- The compost should not be left exposed in the field for longer duration. It should be mixed with the soil as early as possible. This helps in avoiding the loss of nutrients because of excessive evaporation.

8. TECHNOLOGY PROMOTION AND QUALITY CONTROL

8.1 Motivation and Technology Promotion

a. Public and Political Awareness

Popularisation of biogas technology has to go hand in hand with the actual construction of biodigesters in the field. Without the public awareness of biodigester technology, its benefits and pitfalls, there will be no sufficient basis to disseminate the technology at grassroots level. At the same time, awareness within the government is essential. Since impacts and aspects of biodigester technology concern so many different governmental institutions (e.g. agriculture, environment, energy, etc.) it is necessary to identify and include all responsible government departments in the dissemination and awareness-raising process. To raise awareness of the people the following activities has to be carried out:

- Develop and distribute different IEC (information, Education and Communication) materials in local language such as: posters, pamphlet, and leaflets that contain information on biogas, its benefits, costs, services, installers, and subsidy and loan provisions.
- Develop and distribute IEC materials on effective storage, handling and utilization of bio-slurry including composting methods,
- Develop video cassettes on promotion and extension of biogas and slurry applications and broadcast them from TV/local cable.
- Disseminate information on biogas through radio, local FM stations and cinema halls.
- Organize orientation training to the potential users, staff of government line-agency offices, NGOs workers, school teachers and workers of local organizations.
- Organize exhibition and demonstration.
- Motivate biogas plant construction companies to concentrate in cluster area construction and organize effective promotion campaign.

b. Motivation

Motivation is a vital component of any program like biogas that is aimed at a wider section of the population. This especially relevant for rural areas of Lao PDR where the means of communication are not as well developed as in the urban areas. The exact nature of motivation strategy must, however, be responsive to the specific needs of the area and situation. In the context of biodigester program in Lao PDR, motivation plays an important role when the technology is being introduced in an area for the first time. Developing an effective motivation strategy becomes even more critical in areas where people developed unfavourable attitudes towards the technology because of various reasons. Similarly, in areas where the general awareness among the people on biodigester technology is low or not existent, there is a strong need to actively publicize it. The following could be some strategies for motivation in the context of Lao PDR.

i. Reliance on 'demonstration effects'

A successful biodigester is assumed to be a sufficient stimulus for motivating others to install biodigester. Demonstration effect can be an effective means to promote a technology in progressive areas close to urban or semi urban centres with well-developed communication systems. It is, therefore, recommended that biodigester program in the provinces be initiated from semi-urban settlements close to the towns. In these areas providing accurate and complete information to the people whenever asked should be given priority. Technology demonstration becomes essential especially in these areas where there is a need to change the existing negative attitude about biodigester technology.

ii. Motivation through governmental officials

It is rather awkward to recommend that the concerned government offices in the provinces hire motivation staff focusing solely on biodigester programme. However, various government agencies working in the fields of agriculture, women development, social sensitization, health, education and other functional areas could be effective vehicle to work as motivation agents. The agriculture and livestock divisions and other government offices in the provinces could be effective partners of PBPO in this case.

Although biodigester is not their core activity, these agencies can integrate the technology with their routine programs. For example, biodigester activites could be integrated with 'women's workload reduction program' of the Women Union.

iii. Use of local Resource Persons

Another prominent strategy for motivation is the utilization of local resource persons by providing fixed incentives. Some contract persons in the communities could be mobilized as agents to inform PBPO regarding potential beneficiaries. Awareness generation and motivation could then be undertaken by PBPO.

iv. Use of local leaders

Local leaders could be mobilized in biodigester program as motivation agents. Such leaders could either exist already in the village or may be identified and trained by PBPO. The village heads, schoolteachers and other influential persons in the community could play an important role in selecting and motivating beneficiaries.

v. Use of Village Institutions

Existing village institutions in Lao PDR, such as farmers' cooperatives, women's group, youth union, labour union could effectively be used as motivation tools. PBPO should create such structure at the village level to organize and sustain the participation of the people, especially women, in the program. These groups should not focus on biodigester exclusively but for all programs the communities.

vi. Use of Educational Institutions

The use of educational institutions for promoting biodigester technology is one of the best possible options. School children could play the role of motivation worker.

vii. Involvement of Women in Biodigester Program

In the rural area of Lao PDR women has traditionally shouldered the responsibility of managing the domestic energy requirements for their families. They thus have an intrinsic and symbolic relationship with the surrounding natural resource system. Cooking fuels are derived predominantly from biomass resources like wood and crop residues. Women carry out fuel wood collection in majority of the cases in rural areas.

The role of women in biodigester program in Lao PDR could be enhanced by involving village women in the program as decision makers and by employing women staff as motivators. Women Unions can play an effective role in mobilizing women in the program. Women should be involved in planning process as decision makers for adopting the technology and selecting appropriate site for biodigesters. As primary users, women should be made familiar with the function of the biodigester; proper method of feeding dung and water; the procedure for removing water from the pipeline; methods of cleaning stove components; and minor repairs like replacement of washer.

In light of the potential role of women in the biogas program, it should be well understood that:

- Motivation is most effective when local village women can be used for motivating others to adopt the technology; and
- Involvement of women would be high if undertaken through village level institutions, however, instead of creating new institutions; focus should be on utilizing existing institutions.

8.2 Programme Focus

Program focus could be on individuals or on the institutions. In the first case program may focus more on the individual beneficiary, rather than the community or a village. It is the individual farmer's responsibility to approach PBPO or the construction agency if they want to install biodigesters. Similarly, in case of any problem/defect with a biodigester, the onus of informing the implementing agency lies with the beneficiary. This approach works well where the implementing agency relies largely on 'demonstration effect' for creating awareness about the technology. The main advantage of focusing on

the individual beneficiary is that a farmer is likely to get a biodigesters installed only if he/she genuinely requires it and not for reasons such as availing the subsidy. Thus the beneficiary has a stake in his/her device and is likely to maintain it better.

In the second case, emphasis is given on creating local level institutions or strengthening the existing ones, and utilizing them for the biodigester program. While it is known that ultimately biodigesters have to be installed and maintained at the level of households, yet there are several advantages in creating village level institutions and implementing the program through them. Firstly, motivation and beneficiary identification are easier if an institution comprising members of the local communities are involved in the process. It is also easier to get women's participation in the program if there is an institution operating at the local level. Secondly, the task of developing and managing local repair and maintenance network is simpler if an institution already exists. However, creating and ensuring the sustainability of such institutions require large investment in terms of time and efforts. It is feasible to create these if they can be involved in number of other development program.

In the case of Lao PDR the combination of the two approaches will be best suited. Program should target to focus on individual as well as village level institutions based upon the specific site conditions. However, the existing institutions should be strengthened rather that creating the new ones.

8.3 Private Sector Development

Private sector development should be viewed as a means to develop a more productive and efficient economy and to increase the economic participation of the population. In the case of production and use of biogas and bio-slurry in Lao PDR, the objective should be to let the biodigester sector develop by using the internal forces of demand and supply and by reducing external driving forces such as centrally planned production targets and subsidization in the long run. However, the immediate or short term driving force should be external driving force like subsidy. A condition for a successful privatization process should be that there are checks and balances between countervailing powers, because that dismisses the government sector from the need to intervene.

The PBPO should provide a conducive environment for the private sector entrepreneurs to function effectively. Strengthening and capacity building of provide sector is the main pre-requisite for the promotion and extension of the technology. Private sectors are the main vehicle to penetrate the program to the needy communities. The private sector should be provided with a clear-cut mandate to participate in biodigester program.

8.4 Support Services/Incentives to be provided to Potential Farmers

A package of technical and financial incentives has been developed to promote biodigester technology among the rural masses in Lao PDR. Some of the means to be created to extend financial assistance are subsidy for the beneficiaries and motivation incentives for the motivators. In addition to this, institutional credit from banks, co-operative societies etc. will to be made available to the beneficiaries to facilitate the users to adopt the technology. The financial mechanism influence the program coverage, beneficiary profile, follow up and maintenance and most importantly, sustainability of the program. The following incentives are being provided/proposed to be provided by BPP.

a. Subsidy

A flat rate subsidy of Euro 100 per digester has been proposed to motivate the farmers to install biodigester. The subsidy structure has been designed to cover the substantial part of the installation cost, more than one third of the cost of construction for smaller biodigesters. This type of flat rate subsidy will encourage small farmers to install biodigesters. Most people in Lao PDR cannot afford biodigesters if they have to incur the full cost. Since the program will have substantial environmental and health benefits, especially for women, the subsidy is justified. Subsidy will be transferred to the user through the bank or MFI if a biodigester loan has been taken or through the construction company for cash plants upon completion of the Handover/Acceptance Protocol for the biodigester.

b. Credit through Bank

Financing biodigesters through commercial and development banks is quite an established practice in other countries. A designated lead bank can coordinates loan facilities. At the central and provincial levels in Lao PDR banks working in the grassroots sector could be motivated and mobilised for overall coordination on this sector.

c. Credit through village level institutions

In the wake of increasing unit cost and difficulty in obtaining bank loans, it is increasingly important to mobilize other sources of finance at the village level. This can be promoted through village level funding institutions. Organizations, which have strong grassroots presence and those implementing their programs through village level institutions, could be able to initiate village level credit mechanisms.

d. Technical Backstopping

With a view to enhance knowledge of users on proper operation of biodigester and minor repair & maintenance works to ensure that the installed biodigesters function with out any trouble, different training programs are proposed by the program. One day operation and maintenance training for the users will be organised immediately after the installation of biodigesters. Likewise, follow-up/refresher user's training will also be conducted from time to time based upon the demand of the users. Technicians from BPP will frequently visit the biodigester to assess the performance and solve minor problems, if any. The users can lodge request/complain in BPP for required technical assistances.

e. Guarantee and After-sale-services

Guarantee duration for the construction work is 24 months (???) since the hand over date. After sale service requires the biodigester company or mason teams to thoroughly monitor the biodigester upon the owner's request and sign on Guarantee Certificate granted to household by the company or mason-team on hand over date.

If the biodigesters have any trouble, and the company or mason team do not sent a technician for trouble shooting or for operation instruction to household heads then household heads can inform BPP by telephone or letter. As soon as the BPP receives the information, this office must re-act immediately to the trouble.

For every biodigester constructed, US$ 10 (?????) will be deposited by the construction company or mason team on a special BPP bank savings account. This amount, with interest, will be repaid to the company or mason team if there are no problems with the plant after the warranty period has expired. If the company or mason team does not execute any necessary repair work, BPP will use the deposit amount to repair the biodigester systems and will terminate the contract with that company or team.

f. Research and Development

Research and development activities will be focused on the following 3 points:

- Research to improve the existing biodigester model, including improving design, better materials, installation and construction technique, operation techniques, method to maximize the use of biodigester and biodigester slurry in order to improve quality of biodigesters and cut costs.
- Research and build up biodigester development strategy including marketing and promotion and the support to companies.
- Measure and evaluate the effect of biodigester dissemination on individual households as well as on the communities.

8.5 Role of Local Government COunterpart in Promotion

a. **General Promotion**

  - Organise media programs on local radio, village information workshops, pre-construction trainings and involvement of others to introduce biodigester technology in their programmes/projects.

- Placard promotional posters and distribution of leaflets.

b. **Investigation for potential clusters/farmers**
   - In cooperation with district agricultural extension network prepare list of potential biodigester users per district which will be basis for considering locations to implement the programme.
   - Select communes consisting of many villages and have potential biodigester users of more than 10 households/commune
   - The presence of NGO's active in agricultural and/or sanitation related activities needs to be given priority

c. **Individual Promotion and marketing to potential biodigester users**
   - Issue promotion documents made available by the BPP to potential biodigester users
   - Arrange farmer's visit to biodigester plant models wherever possible.

d. **Registration for biodigester plant to Programme**

i. Conditions for households to be subsidized by the Programme
   - Have stable animal husbandry development of family size, with regular dung source of 20 to 120 kg /day.
   - There is enough space suitable for a biodigester.
   - Farmer is ready to cover expenses for construction of biodigesters and upgrade toilets, kitchens, breeding facilities, compost pits as a synchronous complex.
   - Commit to cooperate with biodigester technicians to participate in biodigester trainings, supervising, testing, operating and maintaining the biodigester in accordance with programme technical requirements.

ii. Approach to potential biodigester users for registration
   - Give further explanation to households regarding biodigester technology and programme assistance/support (technical assistance, subsidy of Euro 100, construction of high quality digesters by experienced masons).
   - Investigate if household conditions meet programme requirements.

iii. **Facilitate the households to sign construction contracts with mason teams/installer**
   - Programme officers recommend programme approved companies or mason teams to households for them to consider.
   - Households sign construction contracts with company/mason team.

e. Provide quality support services/incentives on time

8.6 Quality Control

The quality of construction and after-sale services will be monitored closely by the BPP as mentioned earlier. This is to ensure that the biodigester is functioning properly and investment of the farmers is not wasted.

a. Importance of Quality Management

Non-functioning and poorly functioning biodigesters cause not only capital waste but also do a lot of harms and damages to the reputation of biodigester technology and eventually to the desired future expansion biogas program. The satisfied users are the main and effective extension media for the promotion of the technology and vice-versa. To safeguard the quality of biodigesters, it is important that effective quality control mechanisms be formulated and enforced properly. The quality on construction, operation and maintenance of biodigesters has to be major concern. Supervisors have to play vital role in this regard. The quality is basically related to the following aspects:

- Quality of the design
- Quality of the construction
- Quality of the operation and maintenance by the users
- Quality of after-sale-services on behalf of the installers

The objective of the quality management mechanism should be to encourage installers to comply with the quality standards on the above four aspects. The quality enforcing system generally consists of the following:

- Companies and mason teams who wish to corporate with the BPP and benefit from the subsidy scheme, will be required to seek recognition from the BPP office. Such recognition is subject to a series of strict conditions such as:
- approval of standard design and sizes of biodigesters;
- trained, certified and registered masons for the construction of biodigesters;
- construction of biodigesters on the basis of detailed quality standards;
- provision of BPP approved quality biodigester appliances (pipes, valve, stove, water trap, lamp);
- provision of proper user training and provision of a user instruction manual;
- provision of one year guarantee on appliances and two years guarantee on the civil structure of the biodigester, including an annual maintenance visit during the guarantee period;
- timely visit of a technician to the biodigester in case of a complaint from the user;
- proper administration.

The task of quality management will carried out by BPP and its local government counterpart with technical back-stopping supports from head office. The quality management system will also grade/categorise the installers in different levels based upon their compliance to quality standards.

The rate of installation of biodigester will be increasing year by year. This increases calls for more effective quality management system in place.

b. Quality Control Visits

Quality control visits are important to check the compliance of the quality standards. Visits to all the biodigester will not be possible because of the resource constraints. Therefore, random sampling or stratified random sampling methods will be used to select the biodigesters for control visits. The number of biodigester will be at least 25% of the total number installed in the initial year, which can gradually reduced to 10% in the years to come. Before the visit, the following points should be clear:

- Purpose of Quality control visits
- Frequency of visits
- Reporting and documentation methods
- Corrective actions

The following four basic principles of quality control should be given due care:

- Reliability
- Uniformity
- Impartiality
- Transparency

Standard formats are needed to collect data and information from the respective site of biodigester. These includes:

- Quality control of under-construction biodigester
- Quality control of biodigester before filling dung/pig manure (Biodigester construction completion report)
- Quality control of After-sale-services

c. Responsibility of Quality Control (QC) activities for Biodigesters

- Trained and certified Biodigester Supervisors (BSs) will be responsible for supervising, testing construction works, and other activities such as acceptance, operation and maintenance and after sale services.

- Trained and certified Companies or Biodigester Masons Teams (BMTs) will sign assignment contracts with the BPP before starting their construction works and will be responsible for construction quality and after sale service within 24 months since the date of Acceptance.
- Users will be responsible for direct supervising, testing construction works and tightening of the whole plant system.

d. QC activities to construction works of biodigesters

- ***Training:***
  - BPP will select suitable and responsible Biodigester Supervisors (BS) and Biodigester Masons (BM) from that province for training.
  - BPP will organise trainings for BSs and BMs, provide them necessary background knowledge and skills on biodigester so that they can perform well programme activities. These activities will be largely contracted out to a recognised Training Institute (STEA/TRI???).

- **BSs tasks in the construction:**
  - Select suitable households to register with the Programme for technical and financial assistances.
  - Help users select suitable designs and sizes, locations for biodigesters.
  - If required, assist users in obtaining a biodigester construction loan with a recognised financial institution.
  - Help users prepare materials and accessories, tools as per required technical standards for the biodigesters.
  - Introduce trained and certified BMs to the users for their selections and construction agreements.
  - Help and provide document to users instructing construction supervising procedure in order to assure construction and installation quality.
  - Supervise BMTs during construction and installation works in order to control construction quality. Any BMTs who violate seriously construction requirements will be reported to the BPP for final solution or stop BM jobs, revoke certificates, cancel construction contracts and inform users**.**
  - Instruct biodigester users to prepare feedstock as per quality requirements before operating plants.
  - Instruct biodigester users on methods to apply feedstock and start up the biodigesters according to technical requirements.
  - Carry out Test and Acceptance jobs in cooperation with users and BMs and sign Certificate of Acceptance. The plant code will be mentioned in the Certificate of Acceptance for programme management.
  - Register the plant into programme management file.
  - Supervise, follow up, support Companies and BCTs, solve complains from biodigester users if required.

- ***Quality Control types:***

  <u>QC for the first batch of construction work</u>
    - Area of QC: Plants constructed in a province (about 25-50% of total quantity/province)
    - Quality Control under construction plants
    - Done by provincial BS.
    - Scope of work: assist and check the construction, commissioning, Testing and Acceptance work. Make sure that the BMs are qualified enough to carry out their activities.
    - Form: QC under construction

  <u>Quality Control of completed biodigester</u>
    - Done by provincial BS.

- Scope of work: within a year after date of acceptance, district BS will check current operation status of the plant and check BM' warranty responsibilities.
- Form: QC construction completed.

Quality Control - Acceptance

- Done by provincial BS.
- Area of work: whole plants of the balance batch construction work.
- Scope of work: QC on plant quality for Acceptance.
- QC form: Certificate of Acceptance

Complaints

- Done by provincial BS
- Area of work: all complaints from users which have not yet been solved by BMs.
- Scope of work: check current operation status of the plants and fix all troubles to have the plants working normal.
- QC form: QC completed plants

e. Quality Standards Tolerances

To facilitate effective monitoring for ensuring quality, some standards have been developed. The quality standards are basically related to the following aspects:

- Quality standards related to the design of biodigesters
- Quality standards for the construction of biodigesters
- Quality standards for the operation and maintenance of biodigesters (after-sale-services on behalf of the installers and routine O&M on behalf of users)

Most of the quality standards developed for the construction of biodigester allows certain tolerances and all the supervisors should know about these tolerances.

The quality standards, monitoring formats for filled and non-filled biodigester and observation checklist for filled biodigester have been given in the Annex.

9. OVERVIEW ON OPERATION AND MAINTENANCE

9.1 Finishing Works and Instructions to Users

The sites should be cleaned and cleared after the construction works. The remains of construction materials have to be dumped properly in disposal areas. The top of the dome has to be filled with soil which acts as an insulation to protect the plant. The outside portion of outlet walls and base of the inlet should be filled with soil and compacted. Proper drainage system should be constructed to avoid rain water entering into the biodigester.

After the completion of the entire construction work the mason has to provide proper orientation to the users on plant operation and minor maintenance. Importance of daily feeding to required quantity, operation of different appliances, major points to be remembered while operating the plants etc. should be explained to the users before leaving the construction site. Information on operation and maintenance activities have to be given to the users:

9.2 Operational Activities

The following are major operational activities carried out in the biodigesters to make it function efficiently for a longer period.

a. Feeding of biodigester (Initial and Daily Feeding)
b. Use of Main valve
c. Checking of gas leakages
d. Use of Water drain
e. Cleaning of overflow opening in outlet
f. Use gas tap
g. Use of gas stove
h. Use of gas lamp
i. Composting/ maintaining compost pits
j. Breaking of scum layer

9.2.1. Feeding of Biodigester

Once the construction of biodigester is completed, it has to be filled with required quantity of feeding (cattle dung and/swine manure mixed with water) up to the zero level in the digester (level of bottom of outlet). As the quality of dung required to carry out initial feeding of the digester is quite much (as shown in table below), the farmers should be informed in advance to collect and store cattle dung/swine manure from the day they decide to install biodigester. As the preparatory works for construction and the actual construction will take about 20-25 days quite a lot quantity of dung will be stored in this period of time. The farmer may collect the dung from neighbouring households.

Once the initial feeding is done, the user has to feed the biodigester daily with the required quantity of feeding as prescribed. The quantity of dung to be fed is mainly determined by the size of the plant and the hydraulic retention time (HRT). HRT is the time needed for the full digestion of feeding materials inside the digester which mainly depends on:

- Type of feeding material (Carbon/nitrogen ratio)
- Total Solid percentage in the feeding material
- Temperature in the digester
- pH Value of the feeding

The HRT for Lao PDR context to digest cattle dung/swine manure is taken as 45 days. The feeding material that enters into the digester from inlet should remain in the digester for 40 days to release all the gas inherited by it. HRT is therefore the time needed by the slurry to traverse from one side of the digester to the opposite side assuming the flow is laminar.

Before feeding cattle dung to the plant, it needs to be properly mixed with equal amount of water in order to maintain required Total Solid (TS) of 6% - 10%. In the case of swine manure, the ratio can be 1:2. Human excreta can also be fed by attaching toilet to the biodigester. However, precautions such as controlling excessive water and avoiding the use of chemicals while cleaning toilet has to be taken to avoid the possible risk to the functioning of the plant. The following table shows the total quantity of feeding materials needed for initial and daily feeding of the digester.

Biodigester size	Initial Feeding (cattle dung or pig manure)	Daily dung feeding (kg)	Water to mix with dung (litre)	Use of Biogas Stove (hour)	Use of Biogas Lamp (hour)
4	1500	20-40	20-40	3.5 to 4	8-10
6	2300	40-60	40-60	5.5 to 6	12-15
8	3000	60-80	60-80	7.5 to 8	16-20
10	3800	80-100	80-100	9.5 to 10	21-25

Points to consider while feeding the plant

- Collect the dung that is fresh and do not contain straw or other materials
- In the case of swine manure, do not use much water for pressure washing; flush the manure with broom and water ensuring the ratio of manure and water not more than 1:2.
- Remove the unwanted materials such as remains of fodder, soil, stone etc. if any, from the dung/manure before mixing it water or flushing it to the maturation pond. Put straw, remains of fodder and other organic matters in the compost pit – do not leave it near the inlet pit unattended.
- It is better not to feed the biodigester when the gas is being used
- Do not wash the inlet tank with soap or detergent. Do not use much water to clean it.
- For feeding cattle dung, ensure that the ratio of dung and water by volume is 1:1.
- Do not use the dried or very old cattle dung/swine manure to feed the plant.
- It is advisable to feed a new plant with the digested slurry (50-60 kg) from near-by biodigesters, if any.

Benefits of proper feeding

- It enables the plant to function correctly with optimum biogas production benefiting the users to the expected extent.
- It becomes easier to operate and maintain a plant as correct feeding minimises the risks of technical problems. It minimises the cost incurred in maintenance of biodigester components.
- As the plant is likely to be an example of success and benefit, it will have a good impact on the neighbours, which helps in promoting the technology and creating market for biogas.
- The installer will have satisfied users. They will have better reputation in the sector. It will help them to grow their business.
- The risks of formation of scum layer, dead volume in the base and entry of slurry in pipeline are reduced to a great extent.
- Plant functions trouble-free for longer period of time.

Liquid content in slurry can be tested using a rod. Dip the rod in the slurry in outlet tank. If solid contents of the slurry do not bond or glue to the rod properly, it can be concluded that more water is used to feed the plant. If the solid contents stick in the rod and moves slowly by gravity, then the ration is correctly maintained. In contrary, if the solid content sticks heavily without any movement, feed contains less water than required.

9.2.2. Use of Main Gas Valve

The Main Gas Valves is a vital and important component of biodigester fitted just near the turret between dome gas pipe and the pipeline. It prevent loss of valuable gas due to the leakage in the in the pipeline.

This valve eases the repair of leakage in the pipeline. Since, leakage in the main gas valve will directly threaten the functioning of the plant, the users should realise the importance of this valve. The users should close the main gas valve as soon as cooking job is done. Failing to do so will lead to problems such as:

- In-sufficient or no gas available for cooking
- Slurry in the pipe line

Since, some carbon particles will be deposited in the smooth surface of the ball main gas valve if the valve is half-opened. This will cause some wear and tear of the nylon washers causing leakage of gas in long run. Therefore the user(s) should fully open and the close main gas valve at all times.

9.2.3. Checking of gas leakages

There is always risk of gas leakage through the joints in the pipeline and appliances. To avoid the excessive leakage, it is important to check the leakage routinely. The checking of gas leakage should be started from the dome gas pipe. The potential areas of leakages are joint between dome gas pipe and the nipple just before the main gas valve, joint between main gas valve and the pipeline, any joints in the pipeline, joints between gas taps and pipeline and joint between pipeline and gas lamp. There may be leakages from the appliances too. Soap and water solution should be used to check the leakage. Soap or detergent should me mixed with water to make foam or bubbles. This foam is applied in the joints. If there is leakage, the bubbles in the foam will either break or move. Coloured smoke can also be sent to pipeline through rubber-hose pipe to check leakage. The escaping of coloured smoke from the joints is easily visible if there is leakage. Moreover, the pipe near the joint turns to black if there is leakage. Burning of matches or fire in the joint is not the right way to check leakage.

9.2.4. Use of Water drain

The biogas conveyed from the gas holder is saturated with water vapours. This water condenses when it comes in contact with the walls of the pipe. If this condensed water is not drained regularly, it will ultimately clog the pipeline and block the flow of gas. The flame starts burning yellow initially and in the long run if much water is accumulated the gas stove does not burn at all. Hence, a water outlet to drain the water is fitted in the pipeline. The main purpose of water drain is to trap the condensed water and collect in it ensuring the regular flow of gas from the pipeline. After some time this water drain is filled with water which needs to be released out periodically. The general procedure of operating water drain is:

i. Lift the cover-slab of the drain pit
ii. Turn the water releasing nut anti-clockwise until water flows out.
iii. Wait till the accumulated water flows out completely.
iv. Close the nut once gas starts coming out instead of water.
v. Tighten the nut carefully.

9.2.5. Cleaning of Overflow Opening

Digested slurry flows out of the displacement chamber (outlet tank) through this overflow opening located at opposite side of the dome in the shorter wall of the outlet tank. This opening is prone to clogging due to dried slurry. This dried slurry has to be removed from time to time to facilitate the continuous flow of slurry. If some portion of the opening is blocked with dried slurry, it will increase the volume of the outlet tank. Increase in volume of outlet will pose serious problem in the functioning of biodigester as it will result in serious complications. One of these complications is the problem of slurry in the pipeline.

Therefore, the users should maintain the overflow level clean from dried slurry at all time. Regular inspection of this opening is therefore necessary.

9.2.6. Use of Gas Tap

Gas tap is fitted at the end of the pipeline to regulate the flow of gas to the stove as per need. This helps in optimisation of the use of the gas. Biogas conveyed to the point of application will have high pressure at the time when the level of slurry in outlet is up to the overflow level (gas is fully stored in the gas holder). The pressure gradually decreases with the use of gas. This means that the rate of gas flow varies in as per the pressure. Efficiency of the stove varies in different pressure and gas flow rate. To maintain the

optimum efficiency of stove, pressure and gas flow rate needs to be adjusted to the required level. This function is done by gas tap.

There are high chances of leakage of gas trough the gas tap when the washer gets wear and tear during the course of its use. Leakage may also be encountered if the washer is too dry. The need to change or oil the washer should carefully be monitored.

9.2.7. Use of Gas Stove

The gas produced in the biodigester is used with the burning of the gas stove. Gas tap regulates the flow of biogas depending upon the pressure inside the biodigester. Where as in the gas stove atmospheric pressure is regulated with the help of an adjusting ring installed at the burner pipe containing 2 holes of 8 mm diameter. The ring and the gas tap should be adjusted for high efficiency of stove. The ring should be adjusted in such a way that the flame is blue, divergent and it burns with clear hissing sound. If the flame is convergent and long, the efficiency of stove will be very low.

Biogas stoves with single burner generally consumes about 350 to 400 litre of gas per hour.

The user(s) should follow the following steps for operating the stove efficiently:

i. Ensure that the items to be cooked are ready near the stove.
ii. Cover the holes in the burner pipe completely with regulating ring.
iii. Burn the match or lighter before opening the gas valve and take it in one hand.
iv. While with the other hand open the gas tap slowly and lit the stove.
v. Place a cooking pot on the stove.
vi. Adjust the regulating ring in the stove until the flame burns bluish, short and the sound is clearly audible.
vii. Ensure that the flame burns concentrated in the bottom of the pot with out escaping outside.
viii. Lowered the flame as soon as the food is simmering.
ix. Ensure that the stove is burned in closed room as burning in open will have considerable heat lost.
x. Ensure that the burner holes are not closed and the burner cavity is not filled with liquids that escape while cooking.
xi. Never close the primary air intake fearing gas leakage from it.

9.2.8. Use of Gas Lamp

Biogas produced in the household biodigester is used for lighting too. Different types of biogas lamps are available in the market. The Chinese model is widely used. Usually this model is supplies with a battery operated starter. The lamp is lit with switching of the starter. It is very easy to operate. Attention should be given to install this switch out of the reach of the children.

The Chinese biogas lamps consume about 150 to 175 litres of gas per hour. Regular inspection is necessary to check the clogging of jet nozzle. Mantle should be changes when it gets punctured or broken.

9.2.9. Composting of Slurry

If bio-slurry is composted the nutrient value will be added into it. Digested slurry is an excellent material for fastening the rate of composting of refuse, crop waste and garbage etc. It also provides moisture to the computable biomass. There are several ways of making compost. The widely used method is pit method and semi dried methods of slurry composting. The following steps have to be followed for pit composting of bio-slurry.

- First of all, prepare two compost pits, with volume equal to total plant volume, by the side of biogas plant at least 1 meter away from the plant
- Spread a thick layer of dry materials (15 – 20 cm), such as dry forest litter, waste grasses and straw, leftovers of animals feed and weeds collected from the fields, at the bottom of the pit which will absorb the moisture of the slurry and prevent from leaching of nutrients to the ground water system.

- Let the slurry flow on the dry materials so that the dry material is soaked with the moisture present in slurry.
- Cover the slurry with a thin layer of straw or any dry materials or stable waste. This is done to prevent slurry from drying. This preserves the plant nutrients.
- Next day, let the slurry flow in the pit. If possible spread the slurry equally over the dry materials in the pit and cover it with the same materials as used previously.
- Repeat this process every day till the pit is filled slightly 15 – 20 cm over the ground level and cover it with dry straw/ materials or a thin layer of soil and leave it for a month.
- Provide shade to the compost pit either by making bamboo structure and planting it with the creeping vegetables or by planting fruit trees like banana, fodder trees, green manuring plants or pulses like horse gram. It prevents the evaporation loss of nutrients from the compost pit.
- After a month, turn the compost of the pit and cover it with the same dry materials or a thin layer of soil.
- Turn the compost of the pit again after 15 days and cover it with the same materials as explained earlier. This process of turning will help the fast decomposition of composting materials. The compost thus prepared will be moist and pulverized.
- Start the filling of the second pit after the first pit is filled up. Follow the same procedure in filling the second pit.
- The decomposed slurry compost should be covered with dry materials or a thin layer of soil while the compost is in the pit or stored outside the pit.
- The compost should not be left exposed in the field for longer duration. It should be mixed with the soil as early as possible. This helps in avoiding the loss of nutrients because of excessive evaporation.

9.2.10. Breaking of Scum Layer

It is likely that a scum layer is formed in the digester because of the inert materials that float in the surface, like straw, hard or dried dung etc. This layer obstructs the flow of gas from digester to gas holder. The gas produced in the digester could penetrate this layer to reach the gas holder and flows out of the manhole opening to the outlet. If the feeding is done properly, this problem never arises. However, if scum layer is formed this should be broken. This could be done by stirring the slurry inside the digester with the help of a rod or bamboo inserted through manhole.

Never enter into the plant to break scum. Entry into the digester should be avoided when there is slurry in the digester. Even after emptying the plant, allow 24 hours aeration as precautionary measure.

9.3 repair and maintenance of biodigester

The following are commonly needed repair and maintenance activities in the biodigesters to ensure continual functioning.

a. Maintaining top-filling over dome
b. Cleaning and lubricating of main gas valve
c. Cleaning and lubricating of gas tap
d. Cleaning / repairing of gas lamp
e. Cleaning / repairing of water drain and drain pit
f. Repairing pipe joints to check leakages
g. Cleaning of stove
h. Changing of rubber hose pipe

9.3.1. Maintaining Top-filling over dome

To maintain constant temperature during day and night and provide enough counterweight against the gas pressure inside the biodigester, the top of dome has to be filled with at least 30 cm of earth layer. Since, the top of the dome is exactly at the ground level, it has to be covered with compacted earth from all

sides. The filling is prone to erosion due to rain; hence it should be maintained properly. Necessary measures to protect erosion should also be taken.

9.3.2. Cleaning and lubricating of main gas valve

If the main valve is difficult to operate due to stiffness, it indicates the need to lubricate and clean it immediately. Otherwise the chromium coated ball and 'O' ring along with the washers will be worn-out leading to major gas leakage. This problem should be fixed as soon as possible otherwise – delay may lead to changing of valve. Since, the valve is the expensive item; it is difficult to change it frequently. Hence, prevention is always better than cure. The following steps have to be followed to keep the valve in condition:

i. Disconnect the pipe line through the union.
ii. Remove "C" lock, washer, "O" ring and valve ball. Using lock pliers, (lubricate or replace if necessary)
iii. Unscrew the knob screw by a screwdriver
iv. Pull out the pin,
v. Check the "O" ring of the pin, (lubricate or replace if necessary)
vi. Check the surface of the valve ball for any carbon deposits or uneven surface. (clean or lubricate if necessary)
vii. Assemble in the sequence provided in the diagram below
viii. Check the leakage after repair using shampoo/soap/detergent foam.

9.3.3. Cleaning and lubricating of gas tap

If the gas tap develops faults, such as leakage, difficulties in operation, blockage etc. it indicates that the gas tap needs cleaning, lubricating or repair.

The following steps needs to be followed:

i. Close the main gas valve.
ii. Unscrew the gas tap retainer anti-clockwise till it is fully opened and pull out the retainer Clean and lubricate the piston.
iii. Check the 'O' ring fitted in the piston, lubricate or change it as per its condition.
iv. Check the holes in the cylinder (clean all the holes with a needle file)
v. Assemble the gas tap.
vi. Check the leakage through gas tap using shampoo/soap/detergent foam.

9.3.4. Cleaning/repairing of gas lamp

Gas lamp needs routine repair and maintenance for faultless operation for long period of time. Dismantling of a biogas lamp should be done carefully to clean its components. The following steps are generally followed:

i. Close the main gas valve.
ii. Unscrew the reducer bush in the lamp
iii. Unscrew the back nut and take off the reflector.
iv. Unscrew the carborendom by turning anti clockwise
v. Inspect the nozzle, clean and be-block it if necessary
vi. Assemble in the sequence
vii. Check the performance.

9.3.5. Cleaning/repairing of water drain and pit

As other appliances water drain pit should be inspected from time to time. Any foreign materials deposited in the drain pit should be removed. The surrounding of the pit should be cleaned to ensure that rain water does not enter into it.

The water drain should also be inspected to check for the functional status. The nylon washer and water release screw holes should be checked. The following steps should be followed:

i. Close the main gas valve.
ii. Unscrew the water releasing screw,
iii. Check the hole in the water releasing screw - de-block the blockage, if necessary
iv. Check the condition and thickness of the nylon washer- replace it, if necessary
v. Assemble the parts correctly

vi. Check for gas leakage using shampoo/soap/detergent foam.

9.3.6. Repair pipe joints to check leakage

All the pipe joints should be checked using shampoo foam thoroughly. At the time of inspecting leakage in the pipe line, main gas valve should be opened and the gas tap closed. If any leakage is detected, it should be repaired immediately.

Steps to repair leakages from pipe joint are as follows:

i. Close the main gas valve.
ii. Open the leaking joint using pipe wrench turning it in anti clock wise direction,
iii. Check the thread for possible damage - repair as necessary
iv. Apply at least 5 layers of Teflon tape or zinc putty over the threads
v. Re-fit the dismantled joint properly
vi. Check for leakage using shampoo foam.

9.3.7. Cleaning of stove

During cooking, foods and liquid spill out from the cooking pot and block the flame port and primary air holes. This leads to loss in efficiency of stove causing excessive gas use. This also creates problems such as insufficient gas for next food items. To avoid such problem, stove should be cleaned periodically

The following are the steps to clean gas stove:

i. Pull out rubber hose from the nozzle of the stove.
ii. Pull out burner cap and clean all the 20 flame ports,
iii. Check the burner cup for deposit of dirt and clean it,
iv. Check the nozzle for possible blockage and de-block it as necessary
v. Check the primary air hole for possible blockage and de-block it as necessary
vi. Check regulator ring for free movement.
vii. Install the stove and check the performance.

9.3.8. Changing of rubber hose pipe

Rubber hose pipe develops cracks due to heat and wear & tear due to longer use. The ends of rubber hose pipe where stove nozzle and gas tap cylinder is fitted expands in diameter causing leakage. Therefore, it should be checked for cracks and leakage of gas from the area where the gas tap cylinder and stove nozzle is fitted. If there are cracks the rubber hose needs to be replaced and the expanded ends should be cutoff.

Steps to inspect rubber hose pipe:

i. Pull out the rubber hose from the gas tap and the stove,
ii. Bend or twist the rubber hose at several places and observe for cracks
iii. If cracks are observed change the rubber hose
iv. Check the ends of rubber hose if the ends are enlarged, cut off the portion that is expanded. Remember that the internal and external diameters of rubber hose pipe should be 9 mm and 12 mm.

9.4. Common O & M Problems, their Causes and Potential Solutions

Problem	**Cause**	**Potential Solution**
Stove does not burn even after gas production	More CO2 in gas	Escape some gas daily for about a week. When CO2 finishes, stove will burn.
	Defective fitting of pipe and appliances	Check if the pipe and appliances are fitted properly. Ensure that the main valve is open, gas tap is open and air intake in stove works properly
Enough gas in plant but stove and lamp does not burn	More CO2 during initial digestion	Escape some gas daily for about a week. When CO2 finishes, stove will burn.
	Clogging of gas pipe, gas tap or gas jet due to dirt	Be-block the pipeline. Clean/un-clog the tap and jet

	Clogging of pipeline due to water or slurry from digester	Drain water through outlet Check the size of outlet tank and if it bigger than recommended, lower the height of overflow opening
Less gas production than anticipated	Improper feeding (less or more quantity, irregular, more water, low temp. in digester)	Correct the feeding practice and do as recommended; Do not use more water to clean inlet tank; Do not use much water in toilet; Mix dung and water properly
	Leakage of gas from gas holder and conveyance system	Check if there is leaked from main valve, pipeline and appliances with the use of soap water solution. If no leakage found then, check if gas is leaked from dome. Close the main gas valve; do not use gas for one or two days. Check the slurry level in outlet. If it is gradually decreasing, there must be leakage from dome. Empty the plant and apply treatment measures.
	Formation of scum layer in top or accumulation of sludge in bottom	Do not use other materials than the recommended for feeding; Stir slurry in digester with pole or rod to break the scum. Correct the water dung ratio.
	Use of chemicals in cleaning toilet	Avoid using chemicals in toilet; Use brush and water only to clean; Empty the plant if chemical is used, and fill with fresh dung; Do not use dung from cattle which is given strong antibiotics. Do not use soap/detergent to clean inlet.
The flame is not strong and blue, it is pale and yellow	Clogging of gas tap and burner holes with dirt or accumulation of cooked items	Clean the gas tap, oil it. Clean the burner holes with needle boil it in water. Clean the secondary air mixing chamber.
	Water or little slurry is accumulated in pipeline	Use water outlet to drain water. Clean the slurry.
	No or very little gas in plant	Close the main gas valve and allow time for gas production
	Primary air intake is blocked or not operated properly	Use primary air intake properly. If the hole is blocked, de-block it.
The stove burns with long and weak flame	Improper mixing of primary air	Adjust the primary air intake until the flame becomes strong
	Clogging of some of the holes in the burner cap	Clean the burner cap and de-block the holes with needle.
The flame 'lifts off' or flame is too big	Excessive flow of gas, high gas pressure	Reduce the gas flow. Reduce air supply.
The flame extinguishes or flame is too small	Less flow of gas, not enough pressure	Increase the gas flow. Check for blockages. Wait for some time till enough gas is produced.
Often slurry inters into the pipeline	Not enough feeding	Feed as per recommendation
	Not enough time left for accumulation of gas	Ensure that plant get free time to accumulate gas. Stop continuous use of gas for longer duration.

	Mixing of chemicals in slurry in digester	Avoid chemicals to clean toilet or inlet tank. Do not mix other materials such as urea while feeding plants Separate the dung of animal who is given hard medicine and do not use it Avoid cleaning of inlet with soap/detergent
	Gas is leaked from gas holder or main gas pipe or main gas valve	Use the main gas valve regularly. Check the leakage and stop it. If problem still persists, call the technicians
	The outlet is oversized or the pressure height is more than recommended	Lower the height of outlet, with repositioning overflow outlet at lower level
	Suction due to vacuum in pipeline	Close the gas taps first before closing the main gas valve.
Slurry does not flow out of overflow opening	Lesser and irregular feeding	Feed the plant as recommended
	Cracks in digester wall and/or outlet wall	Check the cracks in digester and outlet walls; if found repair it.
	Blocking of overflow opening	Check the overflow opening regularly and clean it as needed

9.5 Guarantee and After-sales services

9.5.1 Guarantee

Guarantee is enforced to ensure that the installer provides required after-sale-services and safeguards the interest of the users leading to good functioning plants in operation with satisfied and positive users. Satisfied user's are the best motivators and technology promoters.

- Upon the completion of the construction and commissioning of biodigester company/mason has to provide guarantee certificate to the users
- 1 year guarantee on appliances and 2 years on the civil structure of the biodigester is provided.
- The guarantee provision includes at least 2 visits with a 1 year interval, starting 6 months after the completion of the biodigester
- For every plant constructed, US$ 10 (???) will be deposited by the construction company or mason team on a special BPP bank savings account. This amount, with interest, will be repaid to the company or mason team if there are no problems with the plant after the guarantee period has expired.
- If the company or mason team does not execute any necessary repair work, BPP will use the deposit amount to repair the biodigester systems and will terminate the contract with that team and the money will be used to hire another mason/company to carry out the task.

9.5.2 After-sales-services

- The aim of after-sale-services is to have good functioning plants in operation with satisfied and positive users, leading to farmer-to-farmer motivation
- After sale service requires the biodigester company or mason teams to thoroughly monitor the plant upon plant owner's request and sign on Guarantee Certificate granted to household by the company or mason's team on hand over date.
- After sales service is an integral part of the product delivered by the mason teams or biodigester companies.
- Target group: users (men and women)
- The after sales service include:
  - Give proper instruction to the user on the operation of the plant
  - Carry out maintenance works as required
- The instruction of the user will include the following aspects of plant operation and maintenance:

- proper feeding of the plant;
- proper use of biogas;
- regular simple maintenance like cleaning of the burner, changing the mantle of the lamp and the use of the water trap;
- proper use of the plant effluent;
- cooking habits and cooking environment.

- The above mentioned topics are all equally important for an effective use of the plant and its outputs and for the overall impact of the biodigester programme.
- Proper after-sales service will keep the plants in good function which is a precondition for the promotion of biogas.
- If the biodigesters have any trouble, and the company or mason team do not sent a technician for trouble shooting or for operation instruction to household heads then household heads can inform PBPO by telephone or letter. As soon as the PBPO receive the information, this office must re-act immediately to the trouble.

9.5.3 User's Training

Training for biodigester user before construction work:

- Participants: biodigester household members who directly operate and maintain biodigesters daily
- Training duration: 1 day
- Scheduled program:
  - Introduction to biodigesters and benefits: 0,5 day
  - Discussion, sharing and feedback: 0,5 day
- Training facilities and materials:
  - Training materials: prepared by BPP.
  - Audio/video facilities.
- Arrangement: BPP will be responsible for organising trainings for users at villages and inter-village level.

- Contents of Training for biodigester user before construction work:
  - Importance and Benefits of biodigester technology
  - Cost of installation and operation and maintenance
  - Support services and incentives being provided for potential users to install and operate and maintain the biodigester
  - Processes of installation

Training for biodigester user after construction work:

- Participants: biodigester owner after sometimes of plant operation
- Training duration: 1 day
- Scheduled program:
  - Information update: 0,5 day
  - Discussion: 0,5 day
- Training facilities and materials:
  - Training materials: prepared by BPO.
  - Audio/video facilities
- Arrangement: PBPO will be responsible for organize trainings for users at villages and inter-village level.
- Contents of Training for biodigester user after construction work:
  - Potential problems and likely solution as related to operation and maintenance of biodigesters
  - Activities for proper operation of biodigesters
  - Methods of simple repair and maintenance works
  - Discussion on Existing problems, if any
  - Promotional activities on-behalf of satisfied users

10. ROLE OF STAKEHOLDERS, SUPERVISOR AND A MASON

10.1 Role of Different Stakeholders

There are different stakeholders at central and provincial levels to implement various activities related to technology, promotion, extension and dissemination at various levels. The following are major activities needed to be carried out for effective promotion, extension and dissemination of biodigester technology:

- Sector Coordination
- Operational Issues
- Promotional Activities (Information dissemination, Marketing of the product, publication and distribution of promotional materials)
- Capacity Building and strengthening including Training of Trainers, Training Masons and supervisors, training of users etc.
- Energy Planning
- Subsidy Administration
- Subsidy Channelling
- Credit Administration
- Credit Channelling
- Biodigester Construction
- Biodigester Maintenance
- Quality Control
- Research and Development
- Program Management
- Program Implementation
- Monitoring and evaluation

The major potential stakeholders in the dissemination of biodigester technology in Lao PDR are:

- The existing/potential users:
    - Invest in the biogas installation,
    - Carry out operation and minor maintenance activities perfectly
    - Share their views to other potential users to motivate them for installation of biodigester. A satisfied user can be a very good motivator of the technology.

- Government offices at the centre, provinces and districts:
    - Coordinate the activities
    - Integrate biodigester related activities in their routine activities

- Biogas Pilot Programme
    - Technical, financial backstopping services/advices to provincial counterparts
    - Monitoring and evaluation of the activities
    - Research and development
    - Subsidy administration
    - Coordination of activities
    - Networking and lobbying
    - Capacity building and strengthening

- Provincial Biodigester Counterpart Offices
    - Implement the activities as stipulated in the implementation document and provincial guidelines.
    - Capacity building and strengthening,
    - Quality control of construction and after-sales services
    - Registration of completed plant (updating of database)
    - Registration of guarantee
    - Research and development
    - Program management
    - Program implementation and monitoring and evaluation.
    - Promotion and extension

- INGOs/ NGOs/ CBOs/ Functional groups/ clubs working at the grassroots level in the fields of agriculture, forestry, rural development, women development, health & sanitation and environmental management:
    - Promotion and extension of the technology
    - Organise community level workshops/seminars
    - Organise and conduct users training
    - Facilitate operation and maintenance activities
    - Distribute promotional posters, leaflets etc.
    - Capacity building of the local users to operate biodigesters optimally
    - Integrate biodigester program with their routine programmes
    - Be instrumental in penetrating rural needy communities

- Local government bodies at the provinces, districts and communes:
    - Dissemination of information,
    - Motivating the potential users
    - Bridging the users and local counterpart

- Financing institutes including commercial and development banks, cooperatives and micro-associations, community level saving-credit groups:
    - Improve access to the credit if the users need it
    - Promotion and motivation

- Educational institutions/schools
    - Include the topic of biodigester technology in their curriculum
    - Make the student aware of the technology and develop students as information disseminator
    - Organise and conduct training and research activities.

- Media (radio stations, FM transmitting stations, newspapers, TV stations:
    - Transmit success stories, interview of satisfied farmers
    - Help in popularising the technology by disseminating information on subsidy and other incentives being provided by the government.

- Civil society groups and village key-informant-persons:

- Motivate the farmers by disseminating factual information related to the benefits of biodigester technology.

- Private Sector companies/mason's group/local artisans and craftsmen:
  - Marketing of the product/demand collection.
  - Biodigester construction, repair and maintenance
  - After-sales-services
  - Instructions/orientation to the users
  - Subsidy channelling
  - Quality control of construction and ASS
  - Work as the main vehicle to penetrate the program to the needy communities.

10.2 Responsibilities of a Mason

The mason's role is vital in successful installation of biodigesters. The following are some of the major responsibilities of a mason:

- Select proper size of bio-digester based upon the availability of feeding materials
- Ensure that the quality standards of construction materials and appliances are properly complied with.
- Follow strictly the design and drawing as provided to them during construction of bio-digesters.
- Comply with the Construction Manuals while installing the biodigesters.
- Provide necessary information on benefits of biodigester to the users and motivate them for biodigester installation
- Provide the users with minimum requirement of knowledge and skill to operate various components of bio-digester
- Ensure timely completion of the work
- Report progress and difficulties, if any to supervisors regularly
- Do not allow untrained masons to take lead responsibly in constructing biodigester
- Work as extension worker and promoter of the technology in their areas of influences
- Provide regular follow-up and after-sales services to the users to ensure trouble-free functioning of completed plants

If the concerned mason/plumber strictly follows the instruction as described in this construction manual, during the construction phase, the biodigester will function properly with anticipated efficiency. The owner will get the return of his/her investment. This will encourage his/her relatives and neighbours to install biodigesters. However, if the biodigester function poorly, nobody will be motivated to install it. Poor quality plant will harm the reputation of biogas technology will have serious negative effect on promotion and extension. The masons therefore should be well aware that good quality plant will help increasing the rate of installation with the demonstration effect which ultimately benefits himself, the farmer and the country as a whole.

10.3 Responsibilities of a Supervisor

The supervisor has a very important role to play in effective promotion and extension of biodigester technology at the grassroots level. Some of the major responsibilities are highlighted below:

- Select proper size of bio-digester based upon the availability of feeding materials

- Ensure that the quality standards of construction materials and appliances are properly complied with
- Ensure that the mason follow strictly the design and drawing as provided to them during construction of bio-digesters
- Ensure the masons to comply with the Construction Manuals while installing the biodigesters
- Provide necessary information on benefits of biodigester to the users
- Ensure that the users are provided with minimum requirement of knowledge and skill to operate various components of bio-digester
- Report progress and difficulties, if any to higher authority regularly
- Ensure timely completion of the work without overloading the users
- Do not allow untrained masons to take lead responsibly in constructing biodigester
- Work as extension worker and promoter of the technology in their areas of influences

- Carefully monitor the work of mason and Provide necessary advice and feedback to masons as and when needed
- Fill plant completion forms and ensure that all the quality standards are met.
- Correct the drawbacks if any at sites
- Receive comments and complains from the users and pass them to concerned authorities

Remember,

- The role of Supervisor is:
  - 'Quality Controller'
  - 'Coach' or 'mentor'
  - 'Problem solver at site'
  - 'Bridging person' between field level personnel and management personnel
  - 'Promoter' and 'Extension worker' to popularise the technology

These roles are very important roles for the successful dissemination of the technology

10.4 Follow-up Plan for the Participants after the Training

1. Organize and conduct village level workshops in potential clusters and prepare the list of potential biogas households
2. Make household visits to the households as listed in form-1 and identify the suitability/feasibility of the particular households to install biodigester
3. Based upon the data and information collected, identify the most feasible households to install biodigester
4. Prepare schedule of activities related to the installation of biodigesters in household as identified from the process as mentioned above
5. Facilitate signing of contract between the company/mason's team and the households to install biodigester
6. Facilitate the signing of construction contact between the company/mason's team and BPP

7. Facilitate the commencement of construction works in the households as per the schedule of activities as finalized in step-4
8. Carry out monitoring visit during construction of biodigester for quality control and provide on-the-spot feedback to the mason. Enter the data and information collected from the field in the computer database and prepare the monitoring reports.
9. Upon the completion of the construction work, carry out the monitoring visit to fill the construction completion report
10. Ensure that the guarantee certificate has been given to the biodigester owners upon the completion of the construction works
11. Prepare the activity report and submit to BPP
12. Prepare the list of biodigester households for subsidy payment and submit it to the BPP
13. Organize and conduct users training to ensure effective operation and maintenance of biodigesters
14. Carry out routine visits to biodigester households to monitor the performance of biodigesters and provide instructions/feedback to the owners
15. Supervise the work of masons who are installing biodigester as part of their on-the-job practical training and qualify/disqualify them for receiving training completion certificate

Annexes:

Annex-1(a)

Training Schedule (Session Plan) – Phase 1: Theoretical Training

Session No.	Time Schedule	Session Topic
	Day-1	
	08:00-10:00	Registration and Opening ceremony
	10:00-10:15	Tea break
1	10:15-12:15	Introduction, Objectives, Expected Outputs, Detailed-Schedule and Pre-test
	12:15-13:30	Lunch
2	13:30-14:00	Introduction of Biogas Pilot Program (BPP) in Lao PDR
3	14:00-15:30	Introduction to Biogas Technology: General and Ideal Condition for Gas Production, Design Principle of Biodigester, Cost and Benefits of Biodigester including Use of biogas and bio-slurry
	15:30-15:45	Tea break
4	15:45-16:45	Significance in biodigester technology in Lao PDR
	16:45-17:00	Recapitulation and discussion
	Day-2	
5	8:00-08:30	Introduction to Biogas Technology: Functioning and types of biodigesters
6	08:30-10:00	Video show or Visits to biogas plant to familiarise the plant components and discussions
	10:00-10:15	Tea break
7	10:15-12:15	Design/Drawings of GGC model Biodigester
	12:15-13:30	Lunch
8	13:30-14:30	Biodigester Construction methods and steps
9	14:30-15:00	Selection of Construction Site
10	15:00-15:30	Selection of biodigester size
	15:30-15:45	Tea Break
10	15:45-16:45	Selection of Biodigester Size continues
	16:45-17:00	Recapitulation and discussion
	Day-3	
11	8:00-09:00	Quality Standard of Construction Materials and appliances
12	9:00-10:00	Construction of Biodigester: Lay out of biodigester (theory and practice)
	10:00-10:15	Tea break
12	10:15-11:15	Lay out of biodigester (practice)
13	11:15-12:15	Construction of Biodigester: Trench digging and foundation works (Theory and practical demonstration)
	12:15-13:30	Lunch
14	13:30-15:30	Construction of Biodigester: Construction of digester (Theory and demonstration)
	15:30-15:45	Tea Break

14	15:45-16:45	Construction of Biodigester: Construction of digester (practical demonstration)
	16:45-17:00	Recapitulation and discussion
	Day-4	
15	08:00-10:00	Construction of gas holder: Making mould for casting gas holder
	10:00-10:15	Tea break
15	10:15-12:15	Construction of gas holder: Concreting of gas holder
	12:15-13:30	Lunch
15	13:30-15:30	Construction of gas holder: Concreting of gas holder continues
	15:30-15:45	Tea Break
15	15:45-16:45	Construction of gas holder: Plastering and treatment of gas holder (Theory and demonstration of making plastering coats)
	16:45-17:00	Recapitulation and discussion
	Day-5	
16	08:00-10:00	Construction of Turret, Manhole, Inlet and Outlet tanks
	10:00-10:15	Tea break
17	10:15-12:15	Installation of Pipeline and appliance and construction of slurry pit
	12:15-13:30	Lunch
18	13:30-15:30	Quality standards
	15:30-15:45	Tea Break
18	15:45-16:45	Quality standards continue.
	16:45-17:00	Recapitulation and discussion
	Day-6	
19	08:00-09:00	Technology Promotion and Quality Management: Importance and Process
20	09:00-10:00	Introduction to Promotion and Quality control forms and formats
	10:00-10:15	Tea break
21	10:15-12:15	Overview on O&M of biodigester: Routine Operational and Minor Maintenance Activities
	12:15-13:30	Lunch
22	13:30-14:30	Potential problems and likely solutions
23	14:30-15:30	Guarantee, After-sales services and User's Training
	15:30-15:45	Tea Break
24	15:45-16:45	Role of Mason and Supervisors and other Stakeholders
	16:45-17:00	Recapitulation and discussion
	Day-7	
25	08:00-09:00	Participatory Discussion/Recapitulation of the overall learning
26	09:00-10:00	Formulation of future plan of action
	10:00-10:15	Tea break
27	10:15-11:15	Post Test and Training Evaluation
	11:15-12:15	Closing
	12:15-14:00	Lunch and Departure

Annex-1(b)

Activity Schedule – Phase 2 (Practical on-the-job Exercise)

Date	Activities	Monitoring Indicators
1st Day	• Finalisation of households based upon the set criteria, household visits, selection of construction sites	• Households should comply with the selection criteria
2nd Day	• Supply of construction materials • Plant Layout	• Construction materials should meet the quality standards • The dimensions should be as given in the drawing
3rd Day	• Starting of digging of pit	• Digging depth and circumference has to be as per the layout plan
4th Day	• Digging completes	• The depth of digging should be as per the drawing
5th and 6th Days	• Construction of round wall	• The centre of digester should carefully be fixed and central pole should tightly be secured. The pole should be vertical. • Radius of digester – as per drawing • The distance between the centre of the pole to end of chord or string should be equal to radius of digester plus 15 mm. • Mortar ratio – 1:3 • Length and height of collar – 15 and 3 cm respectively • Bricks/stones should be soaked in water before using • Each brick/stone has to be laid by matching its side (rise) with the chord/string fixed on the centre pole. • Joints between brick/stones should be well compacted. Joints in adjacent layer should not fall in a vertical line. • The lowest point of inlet pipe should be 30 cm above the collar • The walls should be plaster with smooth surface – mortar ration 1:3 (cement: sand) • The cavity in the back of the wall should be filled properly
7th Day	• Preparation of earthen mould for dome concreting	• Care should be provided to fill in the earth to avoid damage to the round wall • Proper compaction of soil is important • Use of correct size of template is necessary • Proper use of template is essential • The finished surface of the mould should be sprinkled with water and covered with a thin layer of sand before concreting.
8th Day	• Concreting of gas holder	• The mix of mortar should be 1:2:3 (cement:sand:aggregate) • The work of concreting should start from on edge and continue to the opposite edge via the top • The depth of concrete should be as per drawing

	• Casting of outlet cover (slab)	• Freshly laid concrete should be properly compacted • The mortar should be used within 30 minutes from its preparation • Concreting works should be done uninterruptedly • Dome gas pipe should be correctly placed in the centre of the dome • The finished surface should be properly cured for at least five days. • Outlet cover should be casted as per instruction in construction manual
9th Day	Construction of turret and Outlet	• Turret has to be constructed as shown in the drawing • The base of outlet tank should be prepared with broken bricks and a thick layer of plastering • The length, breadth and height of outlet should be as per the drawing • The overflow opening should be in the longer wall parallel to the hart-line • The walls should be vertical and plastered with 1:3 mortar • The overflow opening should be built slightly higher than the ground level (as per the drawing) to avoid water entering into the outlet during rainy season.
10th Day	Construction of inlet (maturation chamber)	• The foundation of the inlet pit should be places in well rammed, hard and levelled surface. • In this rammed surface first of all the rectangular base of inlet tank is constructed. • The height of the base should be decided in such a manner that the floor of inlet tank is at least 15 cm above the outlet overflow level. • Height of inlet should not be more than 1m from the ground level • The drain from pigsty should facilitate easy flow of feeding to the digester
11th Day	Digging for pipe trench Pipe laying and installation of Appliances and Finishing Works	• The alignment for pipe trench should be the shortest and safe. • The depth of pit should be at least 30 cm. • Avoid to many joints • Water drain pit must be constructed at the lowest point of the pipe line where it is easy accessible. When finished, the inside dimension must be 40 X 40 cm and the height 50 cm. To avoid rain water entering into the drain pit the walls must be at least 5 cm above ground level. For easy operation of the water drain must be installed 30 cm below the ground level. The drain pit slab has to be of 66 X 66 cm and easy to handle by 1 person. • To avoid gas leakage Teflon tape must be used on every joins. • One must minimise using unnecessary fittings

		and unions in the pipe line. • No unnecessary fittings should be used in between the reducer of dome gas pipe and the main valve. • To prevent it from damage the pipe line must be buried 1 foot where possible.
12th Day	Plastering of gas holder (1st , 2nd and 3rd layers)	• The inner surface of dome should be chiselled and clean well with water before starting plaster work • First, the surface should be flushed with cement-water solution • Then, a layer of plaster (1:3), 12 cm thick has to be applied. • Then, a thin layer (5 mm) of cement-sand punning (1:2) has to applied once the second layer is set • The surface of plastering and punning should be smooth and fine.
13th Day	Plastering of dome (4th and 5th layers)	• For 4th layer, 1 part of Acrylic emulsion paint has to be well mixed with 10-12 parts of cement by volume adding required quantity of water to make fine paste • This paste should be applied evenly through out the surface of dome (5 mm thick) • For fifth layer, 1 part of Acrylic emulsion paint has to be well mixed with 2 parts of cement by volume adding required quantity of water to make fine paste • This paste should be applied evenly through out the surface of dome (2 mm tick) with the brush
14th Day	Construction of Slurry pits Construction Works Completes	• The compost pit must be minimum 1 m away from the outlet where the slurry can flow into the pit easily. 2 compost pits equivalent to the plant volume must be made. • The depth of the compost pits must not exceed more than 1m and the distance between the two compost pits must not be more than 50 cm. • The length and width at the top must be more than of the bottom and add 10 cm mud on all sides to raise the height from the ground level to avoid rain water enter the compost pits. • Cover the entire dome with at least 30 cm thick layer of soil • Clean the site properly
15th Day	Sharing of difficulties and lessons learnt and closing of the training program	• Participants discuss on the problems and lessons learnt during the course of training

Annex-2

Quality Standards for the Installation of Modified GGC Model of Biodigester – 2006

SN	Standards	Tolerances	Type of Default
	Standards in Household, Size and Site Selection		
1	One biodigester per household	Separate kitchen per biodigester.	Critical
2	Construction site not far from kitchen	Distance from kitchen not more than 20 meters.	Minor
3	Construction site not far from cattle shed or pig sty	Distance from cattle shed or pig sty not more than 20 meters.	Minor
4	Components of the biodigester adequately far from existing structures or trees	Plant components should be at least 2 m away from existing structure or trees.	Major
5	Enough space for biodigester construction as per drawing	Enough space to orient the plant location and slurry pits.	Major
6	Correct size of plant based upon the availability of feeding materials	At lease 5 kg of dung available per cubic meter capacity of biodigester.	Critical
7	No plant fed with night-soil only	Inlet tank should be constructed and used	Critical
8	Approved model of biodigesters	Modified GGC plant as per the design and drawing	Critical
	Standards on Construction Materials and Appliances		
9	Good quality bricks	Best quality locally available. Well baked, regular in size, free from cracks and broken parts.	Major
10	Good quality sand	Not contain more than 3% impurities as determined by bottle test.	Major
11	Good quality cement	Fresh, free from lumps, best locally available.	Major
12	Good quality aggregate	Angular, of regular size not more than 2 mm and free from dust or impurities.	Major
13	Good quality MS Rod	Free from heavy rust and at least 8 mm diameter.	Major
14	Good quality acrylic emulsion paint	Approved by the quality control authority.	Major
15	Good quality inlet pipe	PVC, concrete or Polyethylene pipe 10 cm diameter.	Major
16	Good quality water	Clean and free from suspended particles.	Major
17	Good quality dome gas pipe	The size bigger than 15 mm diameter with the elbow properly sealed in the workshop. Length - 60 cm.	Major
18	Good quality main gas valve	Approved by the quality control authority.	Major
19	Good quality pipes and fittings	½" GI or 20 mm PVC pipe of best quality locally available.	Major
20	Good quality water drain	As approved by the quality control authority.	Major
21	Good quality gas tap	As approved by the quality control authority.	Major
22	Good quality connecting pipe	Either neoprene rubber hose or good quality	Major

		plastic pipe as approved by the quality control authority.	
23	Good quality gas stove	As approved by the quality control authority.	Major
24	Good quality gas Lamp	As approved by the quality control authority.	Major
25	Good quality mixing devise (optional)	As approved by the quality control authority.	Minor
	Standards on Construction		
26	Only trained masons carry out the construction work	The mason registered in BPP office after successfully completing the required training courses on biodigester construction	Critical
27	Correct cement, sand, aggregate ratio	For all masonry works and plastering, the ratio is 1:3 (cement:sand). The ratio of concreting in dome (gas holder) is 1:2:3 (cement:sand:aggregate).	Major
28	Biodigester appropriately placed under the ground	The depth of digging as per drawing. Maximum allowable deviation by ±5 cm from the standard. If because of high water table or rocky strata the depth is not adequate proper justification to be provided. In this case, proper stabilisation measures are provided around the structure.	Major
29	Correct diameter of the digester	The diameter of the completed biodigester not to differ by ±1% from the standard.	Major
30	Accuracy plum of digester wall	Vertical wall with plum not differed by ±1 cm	Major
31	Correct height of the position of the bottom of the inlet pipe	The height of bottom of the inlet pipe from the collar not to differ by ±2 cm from the standard.	Major
32	Correct height of the manhole	The height of manhole at the top of the opening not to differ by ±2 cm from the standard.	Major
33	Correct height – top of manhole to floor of outlet	The height between top of manhole to the floor of outlet not to differ by ±2 cm from the standard.	Major
34	Proper plastering of inside of the digester	The finished surface is properly finished and smooth.	Major
35	Digester floor smooth and levelled	The finished surface is smooth and the level difference not to differ by ±0.2%.	Minor
36	Proper back-filling in the outside of the wall of digester	The space between natural soil and the digester wall is filled with soils and compacted well. The height of back-filling is at least equal to 45 cm from the top of the dome.	Major
37	Correct diameter of the gas holder	The diameter of the gas holder of the completed biodigester not to differ by ±1% from the standard.	Major
38	Correct height of the gas holder	The height not to differ by ±2% from the standard.	Major
39	Correct positioning of the dome gas pipe	The location of the dome gas pipe to be at the centre. Maximum allowable deviation is 2% of the diameter of the digester.	Major
40	Proper plastering inside the gas-holder	Gas holder is treated with 5 layers of plastering as indicated in the construction manual. The finished surface is smooth and free from cracks.	Critical
41	Proper top-filling over gas holder	The height of top-filling is at least equal to 45 cm	Major

		from the top of the dome.	
42	Proper length, breadth and height of outlet tank	The length, breadth and height of outlet tank not to differ by ±2% from the standard.	Major
43	Proper volume of outlet tank	The volume of outlet tank not to differ by ±5% from the standard.	Major
44	Proper plumb of the outlet walls	The plumb of the finished surface not to be more than ±0.25 cm 'in' or 'out'.	Major
45	Outlet floor properly finished	The floor is smooth, properly plastered and the level difference not to differ by ±0.2%.	Minor
46	Properly casted outlet slabs	The thickness of the outlet slab not to differ by ±0.05 cm. The length and breadth of each panel not to differ by ±0.2 cm from the standard.	Major
47	Proper size of overflow opening	The length and height of overflow opening not to differ by ±2 cm from the standard.	Major
48	Correct positioning of outlet tank	The centre line of outlet, manhole, digester and inlet pipe is located in one straight line. The deviation not to differ by ±2 cm.	Major
49	Proper backfilling against the outlet walls	The outside of the outlet walls is properly compacted with rammed soil to prevent soil erosion.	Major
50	Correct height of inlet tank	The height of inlet tank not to differ by ±5 cm from the standard.	Major
51	Correct positioning of the inlet pipe	The inlet pipe is placed at the near end to the digester so that inserting of pipe or pole is possible. It discharges exactly at the hart line (imaginary line that joins centre of digester, manhole and outlet tank).	Major
52	Proper finishing works of inlet tank	The plaster surface is smooth and free from cracks.	Major
53	Positioning of the inlet chamber	The floor of the inlet chamber is at least 15 cm higher than the bottom of overflow opening in the outlet tank.	Major
54	Correct positioning of collection chamber for maturating swine manure	Swine manure and urine flow by gravity to the collection chamber.	Major
55	Positioning of the collection chamber	The floor of the collection chamber is at least 15 cm higher than the bottom of overflow opening in the outlet tank.	Major
56	Correct positioning of inlet pipe from the latrine attached to biodigester	The inlet pipe discharges within the location of 30% from the hart-line	Major
57	Correct positioning of the pan level	The pan level of the latrine is at least 20 cm higher than the bottom of overflow opening in the outlet tank.	Major
58	Correct sizes of turret	The length, breadth and height (diameter in the case of circular turret) of the turret not to differ by ±2 cm from the standard.	Minor
59	Correct fitting of main gas valve	No fittings in between elbow in the dome gas pipe and the main valve. The joint is properly sealed with Teflon tape and good quality adhesive.	Critical

60	No unnecessary fittings in the pipeline	Pipeline contains minimum joints as required. No unions are used.	Major
61	Proper burial of pipeline	The pipeline is buried to at least 30 cm where possible. It is protected well with clamps and covers where burial is not possible.	Major
62	Water drain able to drain the whole quantity of condensed water	The profile of pipeline is maintained properly so that the whole quantity of accumulated water is easily drained.	Major
63	Water drain protected in a well maintained chamber	The size of the chamber is such that it is easy to operate water drain and rain water does not enter into it. The pit is provided with a good cover.	Major
64	Correct fitting of gas tap	The gas tap is placed in convenient place and the joint is sealed with Teflon tape and good adhesive.	Major
65	Correct fitting of gas stove	The connecting pipe from gas tap to the stove is correctly fitted to avoid the gas leakage.	Major
66	Correct fitting of gas lamp	The gas lamp is located in safe and convenient place. The joint is sealed with Teflon tape and good adhesive.	Major
67	Proper construction of slurry composting pit	2 compost pits at least equal to the volume of biodigester are constructed as per the standard dimensions	Major
68	User's instructed on operation and minor repair works	At least one member from the user's household is provided with proper orientation on operation and minor maintenance of biodigester	Major
69	Provision of instruction book let	Instruction booklet is provided to the users	Critical
70	Guarantee and After-sale-service provisions	Guarantee Certificates of 2 years in structural part and 1 year in pipeline and appliances is provided by the installer to the users	Critical

Annex-3

Forms and Formats

Form 01

Biogas Pilot Programme

LIST OF POTENTIAL CUSTOMERS OF PROVINCE: .....

No.	Full Name of household head	Address			Quantity of domestic animals				Requested loan
		District	Commune	Village	Pig	Buffalo	Cow	Chicken	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Form 02

Biogas Pilot Programme

Survey form on potential households

General Information

Province: .....; District: .....; Commune: .....; Village: .....

Name of household head: ..... Telephone No: .....

Number of people in family: Adult: ☐ Children (age <16): ☐ Total: ☐

Date of survey: .....

Land information

Total land area: ..... m^2 Land area for biodigester: ..... m^2

Groundwater level in dry season ..…m Flooding problems in wet season: yes / no

WATER AND SANITATION INFORMATION

Sanitary works		Running water sources		General sanitary			
Simple Pit latrine		River			Good	Fair	Bad
Improved latrine		Lake/Pond		Kitchen			
No latrine		Deep Tube well		Latrine			
Drainage system		Shallow Tube well		Water Source			
		Dug-wells		Drainage System			
		Piped Water Tap		Household wastes disposal			
		Canal					

Animal husbandry development activities

Number of domestic animals:

Animal Type	Pig		Cattle		Buffalo	
	Adult	Calf	Adult	Calf	Adult	Calf
Quantity						

Daily dung volume: ..... kg/day

Credit demand

How much do you want to loan from a bank to build biodigester:

..... Thousand Kip

Do you owe a bank? : Yes: ☐ No: ☐

Survey officer
(Full name and signature)

Biogas Household head
(signature)

Form 03

Quality Control of a Non-filled Biodigester
Questionnaire to be filled during the Visit to Under-construction Biodigester

ID No	Parameters	Responses
1	Sample No	
2	Name of the Installer	
3	Address of the Installer	
4	Name of Mason	
5	Registration no. of Mason	
6	Name of the Biodigester Owner	
7	Name of the Household Head	
8	Name of the Respondent	
9	Relation with Plant Owner	
10	Address: Commune	
11	District	
12	Province	
13	Biodigester Size	4/6/8/10 cum
14	Date of Commencement of the Construction	
15	Date of Completion	
16	If construction time longer than 30 days, reason	
17	One Biodigester per household	Yes/No
18	Use for owner-household only	Yes/No
19	No. of People using the gas	……. persons
20	No. of Cattle	…. Adult, ….. calf, …….. total
21	No of Swine/pig	…. Adult, ….. calf, …….. total
22	Quantity of available cattle dung	…… kg
23	Quantity of feeding expected	…… kg
24	Cattle dung/swine manure being collected for the initial feeding	Yes/No
25	Toilet constructed in the house	Yes/No
26	Toilet attached to the Biodigester	Yes/No
27	Provision for future attachment	Yes/No
	Financing	
28	Total cost of Installation	USD…….
29	Subsidy amount	USD…….
30	Subsidy received	Yes/No
31	Subsidy through	Bank/Company/Mason/other
32	Loan taken	Yes/No
33	If yes, taken from	**Bank/MFI/Local money lenders**
34	Bank service	Good/satisfactory/poor
35	Duration of loan process	…… days
36	Facilitating/intermediating agency	none/ ……
	Observation	
	Location of the Biodigester	
37	Distance from Kitchen	……m
38	Distance from cattle shed/pig sty	……m

39	Distance from the nearest structure	……m
40	Distance from the nearest tree	……m
41	Distance from well/water source	……m
42	Ground water problem	Yes/No
43	Flood/stagnant water problem	Yes/No
	Bricks	
44	Best locally available	Yes/No
45	Shape	Good/fair/bad
46	Sound	Good/fair/bad
47	Drop test	Good/fair/bad
48	**Sand** – Bottle test	…….% impurity
	Gravel	
49	Cleanliness	Good/fair/bad
50	Maximum size	……. mm
51	Shape	Good/fair/bad
	Cement	
52	Total quantity used/purchased	…… bags of …kg
53	Brand name	
54	Lumps	Yes/No
	Paint	
55	Total quantity used/purchased	……. litres
56	Type	Acrylic emulsion/……
57	Brand name	
	MS Reinforcement rod	
58	Diameter	……. mm
59	Quantity purchased	……. kg
	Digester and gas holder	
60	Finishing of floor	Good/fair/bad
61	Diameter of digester	……. cm
62	Height of dome	……..cm
63	Overall height from bottom centre to top of dome	……..cm/not yet complete
64	Height from manhole floor to inlet pipe	……..cm/ not yet complete
65	Height of manhole up to top of opening	……..cm/ not yet complete
66	Height of manhole up to floor of outlet	……..cm/ not yet complete
67	Dome gas pipe in the centre	……..cm/ not yet complete
68	Plastering inside the gas holder (according to the construction manual)	Good/fair/bad/ not yet complete
69	Top filling over dome	Good/fair/bad/ not yet complete
	Outlet	

70	Inner length	……..cm/ not yet complete
71	Inner breadth	……..cm/ not yet complete
72	Height of tank up to the bottom of overflow opening	……..cm/ not yet complete
73	Height and length of overflow opening	……..cm/ not yet complete
74	Accuracy plumb walls	Yes/No/ not yet complete
75	Floor and wall finishing	Good/fair/bad/ not yet complete
76	Floor level difference	…….%/ not yet complete
77	Top of wall difference	…….%/ not yet complete
78	Backfilling against the wall	Good/fair/bad/ not yet complete
79	Thickness of slab	…….. cm/ not yet complete
80	Slab as per dimension	Yes/No/ not yet complete
	Inlet	
81	Type	Mixing tank for cattle dung/channel for swine manure
82	Finishing	Good/fair/bad/ not yet complete
82	Height of inlet pit	…… cm/ not yet complete
84	Inlet floor vs. bottom of overflow opening	sufficiently above/just above/below/ not yet complete
85	Type of inlet pipe	PVC/Concrete/Other
86	Inlet pipe position	……. degree in hart-line
87	Easy to insert rod	Yes/No
88	Diameter of inlet pipe	…… cm
	If toilet Attached,	
89	Position of Pan level vs. bottom of overflow opening	sufficiently above/just above/below/ not yet complete
90	Type of inlet pipe	PVC/Concrete/Other
91	Positioning of inlet pipe	……. degree in hart-line
92	Diameter of inlet pipe	…… cm
93	Pipe Provisions for future attachment	Yes/No
94	If not, the reason	
	Appliances	
95	Brand name of dome gas pipe	
96	Quality of dome gas pipe	Good/fair/bad
97	Brand name of main gas valve	DTW/….
98	Quality of main gas valve	Good/fair/bad
99	Type of gas pipe	PVC/Flexible plastic/GI ……Φ
100	Quality of gas pipe	Good/fair/bad
101	Brand name of water drain	DTW/……
102	Quality of water drain	Good/fair/bad
103	Brand name of gas tap	DTW/…..
104	Quality of gas tap	Good/fair/bad
105	Brand name of stove	DTW/……
106	No. of stoves	1/2/3
107	Quality of stove	Good/fair/bad
108	Expected duration of stove-use	……. hour/day
109	Quality of connecting pipe	Good/fair/bad

110	Brand name of lamps	Chinese/…….
111	No. of lamps	1/2/3/4
112	Quality of lamp	Good/fair/bad
113	Expected duration of lamp use	……. hour/day
	Condition of Pipeline	
114	Sealing agent	Good/fair/bad
115	Unnecessary fittings	Yes/No/ not yet complete
116	Pipe buried where possible	Yes/No/ not yet complete
117	Depth of trench	…… cm/ not yet complete
118	Pipe protected against damage	Yes/No/ not yet complete
119	Water drain able to drain condensed water	Yes/No/ not yet complete
120	Drain pit properly maintained	Yes/No/ not yet complete
	Instructions to User	
121	User properly instructed	Yes/No/ not yet
122	If yes, by whom	Mason/supervisor/……
123	Who was instructed	Male member/Female member
124	Instruction booklet provided	Yes/No/ not yet
125	Remarks, if any	
	Form Filled by (Officer from BPP)	
	Seconded by (The user)	
	Agreed by (The company/installer/mason)	

....., *date .....month ..... 200 ...*

Form 04

Activity report

Date: Month……/Quarter....., 200.....

Items	Activities	Unit	Plan	Result	Descriptions
A	***Promotion and Marketing***				
A.1	Promotion activities				
a	Public Media				
b	Deliver brochures, leaflets, posts				
A.2	Investigate potential customers				
A.3	Promotion activities to customers				
A.4	Registration for Biodigesters				
B	***Construction and Maintenance***				
B.1	Construction of biodigester				
B.2	Maintenance				
C	***Training***				
C.1	Biogas technician				
C.2	Biogas mason				
a	Biogas experienced mason				
b	Biogas fresh mason				
C.3	Biogas user				
C.4	Related officers				
D	***Comprehensive application extension***				
D.1	Model design				
D.2	Biogas newsletter				

Petition:

.....

.....

.....

.....

Date: …… month……200…

Prepared by……
(Full name + signature)

Reviewed by:……..
(Signature + stamp)

Form 05

LIST OF BIODIGESTER USERS FOR SUBSIDY PAYMENT

Period: From ……/……/200… to ……/……/200…

No.	Name	Address			ID No.	Plant code	Date of acceptance
		District	Commune	Village			
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Date: …… month……200…

Prepared by……
(Full name + signature)

Reviewed by:……..
(Signature + stamp)

Form-06

BIODIGESTER CONSTRUCTION COMPLETION REPORT

General

Serial No:……..

Name of Plant Owner:…….

Name of Household Head: …….

Address: Village…….....

District……

Province…….……

No. of family Members sharing the kitchen: ……..

Size of Plant: 4/6/8/10 cum

Name of Mason Responsible:…….

Name of Company:……..

Date of Start of Construction: ……

Date of Completion of Construction:……

Feeding Materials

No. of Adult Cattle:…….

No. of Adult Pig:……..

Total Quantity of Dung Produced:…… kg/day

Total Quantity of Dung Fed: :…… kg/day

Toilet constructed: Yes/No

Latrine Attached to biodigester: Yes/No

Provision of future attachment: Yes/No

Location of Plant

Distance from Kitchen:……

Distance from Cattle shed/Pig Sty:……

Distance from dug well/tube well:……..

Ground water problem: Yes/No

Ease in Dung Feeding: Easy/Moderate/Difficult

Safe from erosion, vandalisms etc.: Yeas/No

Quality of Construction

Total Quantity of Cement used:……Bags

Gas Stoves Brand:…….. Installed No:…….

Gas Lamp Brand:……... Installed No:…….

Main Gas Valve Brand:……

Water Outlet Brand: …….

Gas tap Brand:…….

Type of Dome Gas Pipe:……

Type of Gas Pipe:

- GI 13 mm, Flexible Plastic
- 13 mm, PVC 17 mm,
- Other (specify)……

Length of Pipeline: …….. metre

Depth of Pipe trench:…….

Sealing Agent(s): Teflon Tape, …….

……

Quality of plaster inside the digester: good/fair/poor

Quality of plaster coats inside gas holder: good/fair/poor

Thickness of Outlet slab: ……

Quality of Outlet slab: good/fair/poor

Quality of water drain pit: good/fair/poor

Quality of workmanship in general: good/fair/poor

No of composing pit: 0/1/2

Total volume of Compost pit: …….

Condition of the surrounding: clean/dirty/very dirty

Symmetry of inlet pipe, digester, manhole and outlet maintained: Yes/No

Overall Comments:

……

……

……

Measurement of Different Components

1.	Inner Diameter of digester:	.....	cm
2.	Total inner height of digester:	.....	cm
3.	Height from digester floor to inlet pipe:	.....	cm
4.	Length of manhole floor:	.....	cm
5.	Height of manhole up to top of opening:	.....	cm
6.	Height of manhole up to the floor of outlet:	.....	cm
7.	Height of outlet up to the bottom of over flow opening	.....	cm
8.	Height of overflow opening:	.....	cm
9.	Thickness of slab:	.....	cm
10.	Breadth of outlet:	.....	cm
11.	Length of outlet:	.....	cm
12.	Height of inlet from the ground level:	.....	cm
13.	Inner height of the inlet chamber:	.....	cm
14.	Size of turret:	.....	cm
15.	Height of turret:	.....	cm
16.	Height of top filling over dome:	.....	cm

Form 07

Biogas Pilot Programme
Biodigester Monitoring Form

Name of Biodigester Owner	Mr/Mrs……..……..…….
Address	Commune: ……..……..…… District: ……..…… Province: ……..……
Name of user(s) consulted during visit	1. ……..……..…….. 2. …….……..
Size of Biodigester	4 / 6 / 8 / 10 cum
Visited by	1. ……..……..…….. 2. ……..……..
Date of Visit	……..
Purpose of Visit	1. ……..……. 2. ……..…….. 3. ……..……..
Main activities carried out at the site during the visit	1. ……...……..……. 2. …….. 3. ……..……..
Existing problems reported by the user(s), if any	1. ……..……. 2. ……..…….. 3. ……..……..
Instruction given to the users	1. ……..……. 2. ……..…….. 3. ……
User's level of satisfaction	Fully satisfied/Partly satisfied/Not-satisfied
Reason for not satisfying fully	…….. ……..
Comments on Overall Condition and functioning of the biodigester	……..……. …….. ……..…….. ……..
Recommendation for follow-up	……..……. …….. …….. ……..……..

Signature:……. Date: ……..