Training of Trainers (TOT) on Construction and Supervision of SINIDU Model Biogas Plant for Ethiopia

Trainee's Manual

Prepared for

National Biogas Programme (NBP)

EREDPC/SNV Ethiopia

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Table of Content

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 a biodigester is associated with the selection of the right size, choosing the right site for construction, selecting the construction materials and appliances 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 the effective functioning of a biodigester. It is therefore important that the mason responsible for all the works as mentioned above is 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 do not only cause capital waste but also do a lot of harm and damage to the reputation of biodigester technology and eventually to the desired future expansion of the biogas program. In other words, the satisfied users are the most important 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 get enforced properly. The quality of construction, operation and maintenance of biodigesters is a major concern and supervisors have a vital role to play 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

1.1 Background

Access to modern energy is a key element in rural development. However, despite all attention given to energy issues in Ethiopia in the past, rural communities continue to be deprived of basic energy services. Modern forms of energy are simply not available in rural areas while traditional sources are rapidly being depleted, thereby deepening the rural energy crisis.

Woody biomass represents the principal form of cooking and lighting fuel in Ethiopia's rural areas. An increasing fraction of the population is being confronted with the difficult choice between eating its food poorly cooked and travelling long distances to collect fuel for cooking. The scarcity of fuel wood has led to an increased utilization of dung and agri-residues for cooking, which could otherwise have been used to enhance the nutrient status and texture of the soil and contribute positively to agricultural production.

Biogas offers an attractive option to replace unsustainable utilization of wood and charcoal. It complies with the principles put forward in the country's Energy Policy and Environmental Protection Strategy, and closely meets the terms of the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) as well: it is a local, renewable resource that addresses the basic needs of rural households amongst which energy; it supports decentralised access to household energy; its by-product – bio-slurry – enhances agricultural productivity and promotes organic farming, thus offering opportunities for niche markets and export. On the whole, it ensures environmental sustainability and its use as domestic fuel improves development conditions and opportunities for women and girls. Last but not least, it lends itself to commercial development, hence contributing to the development of the private sector and the technical and human capacity of the Technical Vocational Education and Training Centres (TVETs).

Biogas technology was introduced in Ethiopia as early as 1979. In the last two and a half decades, around 1000 biogas plants were constructed in various parts of the country. Presently, approximately 40 % of these plants are not operational due to a lack of effective management and follow-up, technical problems, loss of interest, reduced animal holdings, evacuation of ownership and water problems. Other reasons for the limited success of the technology in Ethiopia include the adoption of a project-based stand-alone approach without follow-up structure in place, variations in design, and the absence of a standardized biogas technology.

Due to the renewed interest in biogas, and in order to unleash the potential for this bio-fuel in Ethiopia, a feasibility study was commissioned to assess the prospects for domestic biogas in the country. This study led to a formal partnership between the Ethiopian Rural Energy Promotion and Development Centre (EREDPC) and SNV/Ethiopia, and in 2007 a joint EREDPC/SNV team was established to develop a programme implementation document. An extensive stakeholders' consultation process at both regional and national level resulted in more than 120 representatives of the government, non-governmental organisations, and the private and financial sectors gaining awareness about the features and functions required for a national biogas programme (NBP), and providing ample inputs for the development of the programme.

In the process to build the capacity of local artisans especially the masons and supervisors, by imparting them detail technical knowledge and skills on methods of construction and supervisions of the household Biogas Plant, a Training of Trainers (TOT) 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 Demonstration phase is to introduce biogas technology in general and SINDHU biogas plants in particular and to build capacity of stakeholders, especially that of EREDPC and MEA to disseminate the technology including conducting quality training courses on Construction and Supervision of SINIDU (SINIDU) Biogas Plants and within selected private construction cooperatives to construct and supervise SINIDU biogas plants in Ethiopia, according to the quality standards formulated by NDBP.

The following are the specific objectives:

- To familiarize the concerned persons on Biogas Technology, the National Biogas Programme Ethiopia (NBPE) and related issues.
- To acquaint the participants on technological aspects of SINIDU Biogas Plant being introduced in Ethiopia.
- To build skills and enhance knowledge of participants on Biogas Plant construction through on-the-job training.
- To build capacity of participants on imparting training on construction, monitoring, supervision and O&M of Biogas Plants by enhancing training and facilitation skills.
- To enhance knowledge of the participants on promotion of biogas technology and quality control of plant construction as well as operation and maintenance.
- To construct 100 demonstration biogas plants in 4 selected regions.

1.3 Expected Output

The overall output expected from the TOT is the enhanced knowledge and improved skills of the concerned individuals related to dissemination of biogas technology including the internalization of the training process by the individuals as well as by EREDPC and MEA to be able to impart training to masons and supervisors to construct, monitor, supervise, operate and maintain Biogas Plants in Ethiopia. After the training they will be able to conduct further training and engage and train nationally recognized training institutes for biogas plant related technical training courses in Ethiopia.

The following are the specific outputs expected from the TOT:

- The participants will be familiar about the National Biogas Programme Ethiopia.
- The participants will acquire detailed knowledge on biogas technology, its importance and use of Biogas Plant-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 Biogas Plant construction, operation and maintenance
- The participants will know and realize the roles and responsibilities of Masons and Supervisors on promotion and extension of Biogas Plant 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 programme to masons and supervisors).

1.4 Participants

Participants in TOT will include:

- Biogas Experts from the Ethiopian Rural Energy Demonstration and Promotion Centre (EREDPC) (3 persons).
- Biogas experts from Regional Mines and Energy Agencies (MEAs) (8 persons)

- Energy Experts form Woredas (4 persons)
- Representative Dairy Cooperative Debra Zeit (1 person)
- Representatives from 8 Woreda base construction cooperative or enterprises. 1 Supervisor and 1 mason (8 persons)

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 a established training centre. The participants will be provided with theoretical and practical knowledge through classroom sessions and construction of a demonstration Biogas Plant in a household premise near the training centre. The theoretical training and installation of demonstration Biogas Plant will be conducted for 7-8 days.

The on-the-job practical exercises on Biogas Plant construction will be carried out in different locations in the four regional states at the farmers' household premises for 15 days.

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.

Table-1: 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	Presentation
Introduction of Pilot Program on Biogas	a. Evolution of Biogas Pilot Program in Ethiopia b. Program objectives and targets c. Progress/activities undertaken till date	Presentation and Discussion
Introduction to Biogas Technology	a. Biogas in general b. Ideal Conditions for gas production c. Benefits of Biogas d. Use of Biogas	Presentation and Discussion
Overview on Biogas Plant 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 Ethiopia (GGC Model) e. Familiarization on design and drawing of GGC Model of Biogas Plant	Presentation, Discussion and Video show(?)
Selection of Biogas Plant Size, Construction Site and Construction Materials	a. Points to be considered while selecting the size of Biogas Plant (feeding availability vs. family size) b. Quantification of dung based upon cattle numbers c. Hydraulic retention time d. Selection of appropriate size of Biogas Plant based upon dung availability e. Points to be considered while selecting site for Biogas Plant construction (location of plant vs. cattle shed, kitchen, water fetching points etc.) f. Types and quality standards of construction materials	Presentation, Discussion and practical demonstration

	g. Quantity requirements of construction materials	
Laying out and Digging of Pit	a. Methods of laying out of Biogas Plant (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	Presentation, Discussion and practical demonstration
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 wall	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
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	Presentation, Discussion and practical demonstration
Construction of Slurry Pits	a. Site preparation and laying out	Presentation,

	b. Digging of pits c. Stabilizing of the slopes d. Importance of composting and shading of pits	Discussion and practical demonstration
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)	Presentation, Discussion and practical demonstration
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 Biogas Plant (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)	Presentation, Discussion and practical exercises
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	Presentation and Discussion
Training and Facilitation Skills	a. Different tools and techniques of training b. Communication skill c. Facilitation skill d. Adult learning principles e. Planning and organising training sessions	Presentation and Discussion

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 finalisation of design and drawing of SINIDU model of Biogas Plant, 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 Annex-1. 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 (formal/informal)
- Class room deliberations and discussion
- Field demonstration and construction of one demonstration Biogas Plant
- Installation of pilot Biogas Plants by the trainee in the process of on-the-job training
- Sharing of lessons learnt and collection of comments and suggestions
- Closing (formal/informal)

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 and, 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 Ethiopia Rural Energy Development and Promotion Centre (EREDPC).

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1.8.2 Training Sessions

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 Biogas Plant 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 Biogas Plant 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 Annex-1. 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 3-4 members, to install Biogas Plants 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 Biogas Plant.

- 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)
- Commitment of the owner to operate the plant efficiently for a longer run
- Willingness to use both biogas (for both cooking and lighting purposes) and bioslurry
- 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 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.

1.10 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 TO THE NATIONAL BIOGAS PROGRAMME (NBP)

2.1 Background

The development of a biogas sector requires a number of functions to be implemented. These functions will be executed by multiple stakeholders, each of whom will take on responsibilities best suited to its objectives and in agreement with the other programme stakeholders. The Ethiopian Rural Energy Development Centre (EREDPC) at the national level and the Mines and Energy Agencies (MEAs)/Energy Departments at regional level will be the lead institutions. A National Biogas Programme Coordination Office (NBPCO) and regional Biogas Programme Coordination Offices (RBPCO) will be established to ensure the operational management of the programme.

The NBP envisages a first – pilot – implementation phase with construction of 14,000 biogas plants in four regions and development of a commercially viable biogas sector in the country. The lessons learnt from this phase will be used to design strategies for up-scaling the construction of biogas plants covering more areas.

2.2 Objectives of the Programme

The overall goal of the NBP is to improve the livelihood and quality of life of rural households in Ethiopia through the exploitation of market and non-market benefits of domestic biogas such as replacement of unsustainable utilization of wood and charcoal for cooking and lighting; use of the high value organic fertilizer from the bio-slurry; and improvement of health and development conditions for rural households.

The **main objective** of the first phase of the Programme is to develop a commercially viable domestic biogas sector in Ethiopia.

The **Specific objectives** are to:

- attract and strengthen institutions and organizations for the development of a national biogas sector;
- construct 14,000 biogas plants in the four selected regions over a period of 5 years;
- ensure continued operation of the biogas plants installed under the NBP;
- maximize the benefits of all biogas plants installed.

2.3 Description of the Programme

The approach of the NBP will be market-oriented, with the user of the biogas technology in central position. Through private sector competition, potential users will benefit from reduced costs while the private sector can be ensured of growing business opportunities through an increasing demand for biogas technology. The programme comprises eight major components: promotion and marketing, training, quality management, research and development, monitoring and evaluation, institutional support, extension, and gender mainstreaming.

To enable potential users to make an investment decision, they will be provided with full information about the benefits of biogas technology, including financial incentives and benefits, installation and maintenance costs, operational issues, guarantee and after-sales service, Contribution to construction cost, support structure, quality assurance and durability.

The private sector (biogas companies, cooperatives, and biogas appliance and component manufacturers) will be called upon for house-to-house promotion of the technology, construction of the biogas plants and after-sale service provision. A support structure will be developed, which will provide a contribution to construction cost to promote the biogas technology, enable access to microfinance, support promotional and extension activities, and ensure that a minimum level of quality is maintained so as to safeguard the reputation of the biogas technology. Microfinance will make domestic biogas affordable by supplying long-term credits to farmers wishing to purchase the technology at a low interest rate. NGOs, construction cooperatives and private sector companies will assist the biogas users in acquiring micro-credit.

Major outputs of the Programme will include promotional and extension materials; various studies related to biogas adoption, financing and social, economic and environmental impact; standard designs for biogas plants; trained, certified and registered masons; three regional training and resource centres established within existing vocational training institutions; and formation of several construction cooperatives/ companies. This is in addition to the 14,000 biogas plants (with slurry pits and indoor cooking facilities) that will be constructed and a minimum of 7,000 domestic toilets to be attached to the plants.

Biogas Programme activities at central level

Co-ordination at the Government/policy level	• mobilisation of funds; • integration in existing programmes and policies; • monitoring;
Programme co-ordination & administration	• annual plan development; • registration of newly constructed plants; • registration of annual after-sales service (ASS) visits; • channelling of subsidy funds to construction companies; • certification of construction groups and companies; • contracting of organisations for tasks as stipulated in the annual plan; • administration of the National Biogas Programme Office (NBPO); • monitoring and evaluation;
Technical	• selection of appropriate design and development of quality standards for this design; • development of quality standards for plant guarantee and after-sales service; • quality control on construction and after-sales service; • applied research and development on plant design and appliances; • private enterprise development;
Slurry programme	• applied research on appropriate use of the plant's effluent; • developing training and extension methods for these uses; • co-ordination of the training and extension efforts.

Biogas Programme activities at field level

Extension & promotion	• Extension and promotion services at community and household level. Activities include awareness raising, technical advice on digester size and capacity, advice on effluent use, financial advice, …;
Training	• user training on operation and maintenance;
Credit provision	• making the required credit available;
Construction & after sales service	• local construction entrepreneurs skilled in biodigester construction technique by the programme;
Quality control	• quality control on the construction, including the pipe work as well as on the after-sales services provided by the private entrepreneur;.
Administration	• registering new clients and subsidy application.

2.4 Location of the Programme

To promote the uptake of domestic biogas, the first phase of the programme will be implemented in selected *woreda*s in Oromia, Amhara, SNNP and Tigray regional states. The selected *woredas* include:

In Oromiya: Adaà, Dugda Bora, Hetosa, Ambo and Kuyu
In Amhara: Bahir Dar Zuria, Dembia, Gondar Zuria, Fogera and Dangla
In SNNPRS: Dale, Mareko, Meskan, Arba Minch Zuria and Derashe Special Woreda
In Tigray: Hintalo Wajirat, Raya Azebo and Western Tigray

The rationale for starting in these four regions is based on several factors: (i) the four regions have most of the human (> 70 %) and livestock population (~ 70 %); (ii) the loss of vegetative cover as a consequence of severe deforestation, resulting in a huge rural household energy imbalance; (iii) the regions' status with regard to educated human resources and technology adoption experience; (iv) the availability of relatively well-documented information; (v) a woody biomass consumption that exceeds annual increment in more than two-thirds of the *woredas* located in the highland areas in those regions.

2.5 Cost and Financing

The total budget requirement for the implementation of the pilot phase of the National Biogas Programme is € 16.7 million, or ETB 208 million, over a period of 5 years (and without taking inflation into consideration). The budget is stated in Euro, based on the September 2007 exchange rate (1 € = 12.5 ETB).

Proposed contributors to the costs of the NBP include the farmers, the federal government, the regional governments, external donors (Biogas for Africa Initiative) and SNV/Ethiopia. The contributions to construction cost are borne by the federal government (10 %) and external donors (90 %). Through the mobilisation of carbon credits, revenues will be generated that could contribute to the financing of the Contribution to construction cost and future up-scaling of the National Biogas Programme.

2.6 Institutional Arrangement

As an apex organization EREDPC is responsible for monitoring and evaluation of the overall programme activities. It is also responsible for the approval of annual plans and reports.

For the day-to-day coordination of the programme, EREDPC will delegate responsibilities to a semi-autonomous National Biogas Programme Coordination Office (NBPCO). This office will initiate, coordinate, and monitor the activities within the biogas sector, and be responsible for accounting, financial procedures, and staff management. Reporting to EREDPC, the NBPCO will work with both the private and public sectors of the programme stakeholders/partners. Representatives of the main national level programme actors will form a Biogas Sector Steering Committee for advising on policy and programme matters that relate to programme implementation.

SNV-Ethiopia and other local capacity builders will provide technical assistance through advisory services, resource mobilisation and knowledge brokering.

At regional level, the MEAs/Energy Departments will play a role comparable to that of EREDPC, while the regional Biogas Programme Coordination Offices will coordinate, facilitate and monitor day-to-day programme activities; also, they will establish partnerships with the Bureaus of Agriculture and Rural Development (BoARDs) for the promotion of biogas technology through the extension network of the BoARDs at the zonal, *woreda* and *kebele* levels. In a similar way as at a national level, all biogas activities will be periodically monitored and advised by a regional Biogas Sector Steering Committee (RBSSC). Figure in the next page illustrates the institutional arrangements.

2.7 Status of the Programme

A detailed programme implementation document (PID) has been prepared following upon the positive prospects for biogas development in Ethiopia as revealed by the feasibility study. A consortium of several international donors formed in May 2007 in Nairobi – Biogas for Africa – has declared that it considers funding the programme. The four regional governments have made a commitment to integrate the programme in their yearly budget planning. The Association of Ethiopian Microfinance Institutions (AEMFI)has expressed a keen interest to build a long-term partnership with the National Biogas Programme and develop a credit line for domestic biogas.

2.8 Duration and Implementation of the Schedule

A total of 5 years is envisaged to implement the first phase of the programme, starting in 2008 and ending in 2012. Implementation will start with the launching of a demonstration phase, with construction of 100 biogas plants in eight selected *woredas* in the four regions. Up-scaling construction to 100,000 biogas plants is foreseen for a subsequent phase.

Institutional Arrangement of National Biogas Programme, Ethiopia

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.% and, hydrogen sulfide (H_2S) 0-3 vol.%

The mainly component in biogas is methane and it occupies the highest ratio of mixed gas. It also occupies about 90% of the natural gas. Methane (CH_4) is a gas without colour and odour, lighter than air and dissolves in water a little. In atmospheric pressure, Methane can be liquefied at temperature of minus 161.5^oC. Its liquidification process consumes a lot of energy. Therefore both methane and natural gas are not economically viable for liquidification. The main components of liquidified petroleum gas is propane (C_3H_8) and Butane (C_4H_{10}), which can be liquefied at -42.1^oC and -0.5^oC corresponding, in atmospheric pressure. When burning, biogas flame is blue and releasing heat. Biogas combustion normally can be shown as the following equation: $CH_4 + 2O_2 = CO_2 + 2H_2O + 882$ kJ

Heating value (The number of kJ liberated by the complete combustion of one cubic meter of fuel) of methane is 35906 kJ/m^3 or 8576 kcal/m^3. The heat value of biogas consisting of 60% of methane and 40% of CO_2 is: 8576 kcal/m^3 × 0.6 = 5146 kcal/m^3

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 mainly on the percentage of methane and efficiency of the burner or other appliances. Methane is the valuable component under the aspect of using biogas as a fuel. 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 specific gravity of biogas, in which its composition is 60% of methane and 40% of CO_2 is 0.94. Therefore, biogas is lighter than air. Biogas with 60% of methane and 40% of CO_2 has density of 1.2196 kg/m^3.

Hydrogen sulphide and carbon dioxide in the biogas combine with condensed water and form corrosive acid, which corrodes the metal parts of biogas appliances. Therefore, in industrial purposes the hydrogen sulphide and carbon dioxide content must be removed.

3.2 Ideal Conditions for Biogas Production

The process of biogas fermentation is affected by many environmental factors. This document includes the main factors affecting the construction and operation of a digester to guarantee an optimal anaerobic process and expected biogas production. There are many biogas bacteria involved in the process of biogas fermentation, in which methane-producing bacteria are 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 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 are 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 fermentation environment. Therefore an airtight digester is required for digestion. Since methane bacteria are among the most strictly anaerobic micro organisms known, quantities as low as 0.08mg/liter of dissolved oxygen completely inhibit the 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. The ideal temperature in operation of a digester is about 35^{o}C. The yield of biogas reduces significantly when the temperature drops and the fermentation process will stop if the temperature drops under 10^{o}C. There are three temperature ranges in which the methane is produced:

i. Thermophilic

The digestion temperature ranges from 45-60 ^{o}C. Thermophilic digestion can be operated with a high loading rate, consequently a high gas production is obtained. A heating system and insulation are needed.In the case that wastewater must have high quality in output, thermophilic digestion is suggested. The cost of both construction and operation are high.

ii. Mesophilic

Their temperature range goes from 10-45^{o}C. The mesophilic digestions run at a medium gas production, lower than that of thermophilic. The cost is lower as well.

iii. Psychrophilic

Certain special microbes can conduct anaerobic digestion at temperatures below 10°C. At present, it is only operated in laboratory.

iv. Ambient temperature

With the ambient temperature varying seasonally, the digestion temperature always changes instead of keeping constant, resulting in seasonal variations in 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 the 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. The biogas plants in Ethiopia are expected to be operated in mesophilic range, meaning 10°- 45°C.

Tips to enhance the digester heat in the colder periods/regions:

1. Plants should be constructed in a 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 the dome by mixing slurry and other organic dry materials such as straw, leaves and agricultural waste. 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 colder seasons/regions.
4. Even if composting is not done, one should cover the dome portion of the biogas plant to maintain the temperature in the cold season and/or colder regions of the country.
5. Mix dung and water in the morning and let it heat till after noon before feeding the plant, this too will help to maintain the temperature in colder seasons/regions.

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 50 days retention time in the context of Ethiopia.

Biodigester size (m^3)	Initial Feeding (cattle dung) (kg)	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 solids) (organic matter) and non-volatiles. Non-volatiles (FS - fixed solids) 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 contains 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 diluted with water and/or urine in a ratio of 1:1.

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). The Carbon/Nitrogen ratio is an important index to evaluate the capacity of materials to decompose. Generally, biogas microbes need the carbon twenty five to thirty times more than nitrogen. Therefore the optimum carbon nitrogen ratio of feedstock is 25/1 to 30/1. Feedstock with a low carbon nitrogen ratio will start fermentation more quickly than that with a 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 for effective digestion. The carbon nitrogen ratio of fresh vegetation is high and this ratio is getting very high in old vegetation, therefore these materials should be mixed in proper proportions in order to start the fermentation process and raise the yield of biogas.

Biogas production varies as per the carbon/nitrogen ratio of the 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	Nitrogen	Carbon	C/N	Moisture*	Total**

	(Source of feed stock)	(% dry wt)	(% dry wt)	(ratio)	(Content %)	(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, an alkaline solution will have pH greater than 7.0 and an acidic solution will show a pH lower than 7.0. Most bacteria prefer light alkali conditions with a pH value in the range of 6.8-7.5. However, methane-producing bacteria still grow in a pH value 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. The HRT is highly determined by the temperature of slurry and the digester volume. The digester volume 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 the HRT depends largely on temperature, retention periods differ from place to place. For the context of Ethiopia the biodigesters are designed with a HRT of 50 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.

The following two diagrammes shows the digestion process during the formation of biogas.

DIAGRAMMES TAKEN OUT

3.2 Design Principles of a Biodigester

The starting point of the design of a biodigester is the quantity of cattle-dung . It is important that the actual amount of cattle-dung reliably available with the household is measured before deciding on the size of a biodigester. The design steps have 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). The total gas production will be equal to the available quantity multiplied by the 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)	Daily dung production per producer (kg)
Cattle dung (cow/ox)	35-40 (0.035-0.040)	10-15
Buffalo	35-40 (0.035-0.040)	15-20
Pig 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, we can now calculate up to which level the amount of available dung will satisfy the family need, based on a gas requirement of 0.3 to 0.4 cum per capita per day.

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 the cylindrical portion of the digester and the diameter of the digester. There is no strict rule for the relative values of H and D, however, in areas with a 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 a 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 to 60% 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 can be calculated.

e. Once the gas storage capacity is calculated, the design of the outlet or displacement chamber has to be calculated. The volume of the outlet is designed to be equal to the volume of slurry displacement in the digester, which in turn is equal to 50-60% 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 to calculate the volume of the displacement chamber as the volume of displaced slurry minus the volume of the inlet pipe up to the overflow level.

f. Once the volume of the displacement chamber is known, the length, breadth and height of the displacement chamber needs 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 domes. Assuming a suitable value within this range, the height of the displacement chamber can be calculated. The length of the 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
- Saving 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 needed quantity of chemical fertilizers, due to the use of bio-slurry
- Reduction on health expenditures due to a decrease in smoke-borne diseases
- Local employment creation
- Private sector development that produces economic goods
- Livestock development

Health Benefits

- Reduction in smoke borne diseases (headache, eye-burning and infection, respiratory tract-infection, etc.)

- Improved household sanitation due to attaching of latrines to bio-digesters, absence of sooth, ashes and firewood in the kitchen
- Decrease in burning accidents

Environmental Benefits
- Preservation of forest
- Increase in soil productivity due to added NPK by using slurry and agricultural residues
- Reduction in green-house gases, especially methane
- Prevention of land-fertility degradation due to the excessive use of chemical fertilizers

Social Benefits
- Extra time for social activities
- Enhanced prestige in the community
- Workload reduction (less time spent on firewood collection and cooking), especially for women and children
- Bright light to help in quality education and household works

3.5 Gas Production

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

Manure	**Gas Production (litres) as per HRT in days**			
	25 days HRT	**30 days HRT**	**35 days HRT**	**50 days HRT**
Pig	58	63	68	77
Cow	30	34	37	43
Buffalo	30	34	37	43
Horse	45	51	56	65
Chicken	60	65	69	78
Human Excreta	50	55	59	65

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

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

3.6 Use of Biogas

Biogas can be used like any other combustible gas, e.g. LPG. Each gas has its own properties which must be observed for efficient combustion. The main influencing factors are:

- gas/air mixing rate
- flame speed
- ignition temperature
- gas pressure, respectively volume of gas flow per time

Compared to LPG, biogas has a lower calorific value and needs less air per cubic metre for combustion. This means, with the same amount of air more gas is required. Therefore, gas jets are larger in diameter when using biogas. About 7 litre of air are required for total combustion of 1 litre of biogas, while for butane it is 31 litres and for propane 24 litres.

The flame speed of biogas is relatively low, lower than with LPG. Therefore, the flow speed must be less to avoid lifting the flame off the burner. The flow speed is defined by the total volume of gas (biogas + air) and the size of the opening the gas is passing through.

The critical ignition temperature of biogas is higher than of diesel. Therefore, when biogas is used in engines, ignition spark plugs are required or partly diesel must be added to the gas (dual fuel) to ignite the fuel and run the engine. Because of its low flame speed, slow turning diesel engines (below 2000 RPM) suit biogas better than fast turning diesel engines (above 5000RPM).

The efficiency of using biogas is 55% in stoves, 24% in engines but only 3% in lamps. A biogas lamp is only half that efficient than a kerosene lamp. The most efficient way of using biogas is in a heat-power combination where 88% efficiency can be reached. But his is only valid for larger installations and under the condition that eh exhaust heat is used profitably. The use of biogas in stoves is best way of exploiting the energy needed by farm households.

Stoves

All gas burners follow the same principle. The gas arrives with a certain speed at the stove. This speed is created by the given pressure from the digester in the pipe of a certain diameter. By help of a jet at the inlet of the burner, the speed is increased producing a draft which sucks air into the pipe. This air is called primary air and is needed for combustion. The air must be completely mixed with biogas. This happens by widening the pipe to a minimum diameter, which is in constant relation to the diameter of the jet.

For biogas under any pressure the relation between the jet diameter and the diameter of the mixing pipe is 1:6. If this relation is observed, mixing will always be perfect. If the relation is higher, it will be very difficult to control the amount of primary air. Therefore, it makes little sense to have adjustable air control devices.

The gas mixes completely with the primary air inside the mixing pipe and the burner head. When the gas mixture leaves the burner head through the orifices the flame speed must be in balance with the flow speed of the gas. If the flame lifts off, the orifices are too small. They should be widened or its number should be increased. If this is not possible the diameter of the jet must be reduced and the diameter of the mixing pipe must be adjusted to maintain a constant relation. Reducing the diameter of the jet means reducing the amount of gas and thus, the amount of heat supplied by the burner. If this should not be the case the amount of primary air must be reduced. This can be done either by closing the air intake holes almost completely or by reducing the diameter of the mixing pipe below the relation 1:6 compared to the diameter of the jet. The length of the mixing pipe, in which the diameter determines the amount of primary air intake, is seven times the diameter of the pipe.

For final combustion the gas needs more oxygen which is supplied by the surrounding. This air is called secondary air. If combustion is perfect, the flame is dark blue and almost invisible in daylight. Stoves with a relation of 1:6 between the jet and the mixing tube work 75% primary air. If too little air is available the gas does not burn fully and part of the gas escapes unused. With too much air supply the flame cools off and thus, prolonging the cooking time and increasing the gas demand.

Modification of LPG Stoves

LPG stoves can be modified to fit the properties of biogas. The efficiency will often not be as good as with a genuine biogas stove. Hence, the geometry of the burner will not be known exactly, modification remains subject to trial and error. The easiest way is to close the primary air inlet completely (e.g. with a metal plate) and then widen the jet according to the wanted heat supply. The air intake might then again be opened very little. When lighting the burner about half of the orifices should bear flames. After a pot is placed on the fire, all orifices will bear flames.

The jets of LPG burners can be widened with a drill. If no definite heat supply is needed, it is better to go step by step instead of spoiling the burner by opening the jet too far. For example, an original 1.2 mm jet should be widened in the first step to 1.4 mm only, in the second step to 1.6 mm until it gives the wanted result. If there is no vice hand, the drill can even be used without a drilling machine when jets are of soft brass metal.

Manufacturing Stoves

Gas stoves are relatively simple appliances which can be manufactured by most blacksmiths or metal works. Gas stoves of mild steel may corrode if the hydro-sulphur content in the biogas is high. This is often the case when biogas is produced from human excreta or pig dung. Therefore, high quality steel or cast iron is advantageous. Clay burners are widely used in China and have proved to render good service. For experimental use, for example in schools, stoves can be made from used food-tins. When manufacturing stoves in an iron mongers workshop, the shape of the burner must be simplified, for example, the diffuser cone is omitted. This is justifiable because the methane content and the gas pressure are changing and full adaptation is not possible for that reason. The stove itself, i.e. the stand for the pots, needs consideration as local food habits have high influence on the design. The stand must be string to allow stirring of even stiffer pap.

Lamps

The principle of a biogas lamp is to heat the mantle until it glows brightly. If the gas-air mixture is correct (diameter of mixing pipe is 6 times the diameter of the jet) the length of the flame in relation to the geometry of the mantle determines the brightness of the light. If the mantle does not burn brightly the mantle might be too long. In this case use a smaller, shorter model.

Approximately 1251/h of biogas are needed to make a short mantle (e.g. No. 3-4) shining brightly. For a longer mantle (e.g. No. 5-6) approximately 180 1/h are required. Therefore, smaller mantles are recommended. If there is a flame visible outside the mantle, too little primary air supply is mostly the reason for that. It shows that the gas burns mainly with secondary air which is only sufficiently available outside the mantle. The solution to the problem is widening the diameter of the mixing pipe. One may theoretically as well reduce the amount of biogas by partly closing the valve, but in most cases there will be not enough heat to make glow brightly.

When gas is supplied from a fixed dome digester the pressure, and thus the amount of gas supplied, reduces steadily. Pressure control devices as known from LPG-bottles help to obtain equal brightness over a longer time.

Instead of importing biogas lamps kerosene pressure (petromax, anchor, butterfly and others) are available on the market which could be modified from portable lamps to stationary wall lamps. In principal, the jet is widened (normally to ø 1 mm) and a new mixing pipe (six times wider in diameter than the jet, normally ø 6 mm) is mounted. Instead of the pressure tank, which serves as well as the bottom stand, a wall holder is mounted,

Refrigerators

For modification of LPG-refrigerators follow the same principle as for others gas appliances. This means that the gas-air mixture must be observed. Because of the low flame speed of biogas the flame is easily blown off by only slight draft. Therefore, the site where the fridge will be placed must be selected carefully.

There is a sensor installed to close the gas supply in case the flame is torn off. The sensor must be bent into proper position, namely directly into the hot zone of the flame. Check the proper function of the sensor before use. If the refrigerator does not cool sufficiently the jet and the mixing pipe must be enlarged.

Other Appliances

Biogas can be used for various activities and requirements common in the project region. There are individual cases of using biogas for chicken hedging, radiator heating, coffee roasting, bread baking or sterilization of medical instruments. If the properties of biogas are observed, there is no limitation to its utilization.

In general, therefore, biogas can be used for three main purposes:

- Cooking
- Lighting
- Running an engine

One ordinary biogas stove with a single burner consumes 350 to 400 litres of gas her hour. In other words, 10 kg of cattle dung will be enough to produce enough gas to burn a stove for one hour. A 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:

- 5.5 kg of firewood
- 1.6 kg of charcoal
- 0.75 litre of kerosene
- 0.45 kg of LPG
- 1.5 to 1.7 kWh of electricity

The following table shows the gas requirements for some appliances.

Appliances		Gas Requirement in m^3/hour
Gas Burner:	5 cm	0.226
	10 cm	0.280
	14 cm	0.420
Mantle Lamp:	Ordinary	0.071
	25 watts equivalent	0.100
	60 watts equivalent	0.195
Gas Refrigerador:	100 litre	0.053
	170 litre	0.067
	225 litre	0.078
Incubator:	per m^3 capacity	0.600
Gasoline engine:	Per kW output	0.569
	Per rated kW	0.398
Diesel engine:	Per kW output	0.700
	Per rated kW	0.563

Operating an engine is not preferable with household biodigesters because of the fluctuations in gas pressure and the presence of other gases than methane that will harm parts of the engine.

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 on 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, in trace amounts, are also essential for plants.

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, garbage, etc. It also provides moisture to the computable biomass.

3.8 Cost of a Biodigester

As far as the costs of a 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 ETB	$4m^3$ Quantity	$4m^3$ Total Cost ETB	$6m^3$ Quantity	$6m^3$ Total Cost ETB	$8m^3$ Quantity	$8m^3$ Total Cost ETB	$10m^3$ Quantity	$10m^3$ Total Cost ETB
I	**Construction Materials**										
1	Stones	m^3	**77**	4	308,0	4,5	346,5	5,0	385,0	6,0	462,0
2	Cement – 50 kg bag	bag	**130**	15	1950,0	18,0	2340,0	21,0	2730,0	25,0	3250,0
3	Gravel 1x2	m^3	**155**	1,5	232,5	1,7	263,5	2,0	310,0	2,5	387,5
4	Coarse sand	m^3	**140**	1	140,0	1,1	154,0	1,2	168,0	1,4	196,0
5	Fine sand	m^3	**140**	1,1	154,0	1,2	168,0	1,3	182,0	1,4	196,0
6	Inlet G.I. pipe 10cm dia, length 2m	piece	**18**	2	36,0	2,0	36,0	2,0	36,0	2,0	36,0
7	Iron bars ø 6 mm	Kg	**10**	10	100,0	12,0	120,0	14,0	140,0	17,0	170,0
8	Binding wire	kg	**10**	0,5	5,0	0,5	5,0	0,5	5,0	0,5	5,0
9	Acrylic emulsion paint	Lit	**35**	1	35,0	1,0	35,0	1,0	35,0	1,5	52,5
	Subtotal 1				**2960,5**		**3468,0**		**3991,0**		**4755,0**
II	**Accessories**										
10	G.I Gas outlet pipe Ø 0.5", 0.6m length	pcs	**40**	1	40	1	40	1	40	1	40
11	GI nipple, Ø 0.5" for connecting main gas pipe and main gas valve + reducing elbow	pcs	**110**	1	110	1	110	1	110	1	110
12	Main gas valve (Ballvalve Ø 0.5")	pcs	**30**	1	30	1	30	1	30	1	30
13	Male-female socket Ø 0.5", G.I. with aluminum thread, for connecting main gas valve and gas pipeline (G.I.)	pcs	**3**	1	3	1	3	1	3	1	3
14	G.I. 90o elbow	pcs	**3**	4	12	4	12	4	12	4	12
15	T-socket Ø0.5" for water trap (aluminum thread inside)	pcs	**3**	1	3	1	3	1	3	1	3
16	*Glue for G.I. connection*	kg	**0**	0,3	0,0	0,3	0,0	0,3	0,0	0,3	0,0
17	Water drain	pcs	**35**	1	35	1	35	1	35	1	35
18	Gas tap	pcs	**30**	1	30	1	30	2	60	2	60
19	Teflon tape	pcs	**2**	4	8	4	8	4	8	4	8
21	G.I. pipe Ø 0.5",	m	**49**	12	588	12	588	12	588	12	588
22	Gas rubber hose pipe Ø 0.5" and 2 clamps	m	**8**	1	8	1	8	2	16	2	16
23	Stoves - single burner	pcs	**400**	1	400	1	400	2	800	2	800
24	Lamp	pcs	**200**	1	200	1	200	1	200	1	200
25	Pressure Manometer	pcs	**60**	1	60	1	60	1	60	1	60
	Subtotal-II				**1527,0**		**1527,0**		**1965,0**		**1965,0**
III	**Labours**										
26	Skilled Labour	No.	**150**	9	1350	10	1500	11	1650	12	1800
27	Unskilled Labour	No.	**25**	22	550	26	650	32	800	35	875
	Subtotal III				**1900**		**2150**		**2450**		**2675**
	Total				**6387,5**		**7145,0**		**8406,0**		**9395,0**
	Overhead, Guarantee and After-sales Services(20%)				1277,5		1429,0		1681,2		1879,0
	Total Cost of Installation				**7665,0**		**8574,0**		**10087,2**		**11274,0**

Note: If brick is used in place of stone, the amount of bricks needed, are:
4 cum plant: 1400, 6 cum plant: 1700, 8 cum plant: 2000, and 10 cum plant: 2400.

b. Operation and Maintenance Cost

The operation and maintenance costs consist of wage and material costs 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 a biodigester is virtually negligible if feeding material does not need to be purchased. However, the annual cost is assumed to be 3-5% of the total investment cost.

c. Financial Viability

One biodigester with 4 cum capacity which costs about ETB 7600 to install, 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 ETB	Total cost saved per day in ETB	Total cost saved per year in ETB	Payback period without subsidy in Years	Payback period with ETB 2400 subsidy in Years
Firewood in kg	6	2	12	4380	1.76	1.2
Charcoal in kg	2	3	6	2190	3.52	2.4
Kerosene in litre	0.6	5	3	1095	7.03	4.8
Electricity in Kwh	1.9	1.75	3.325	1213.625	6.34	4.4

It is clear from the above table that biogas has higher replacement value if it is used to replace firewood. The minimum and maximum savings because of the use of biogas are ETB 1095 for kerosene and ETB 4380 per year. Without any subsidy, the payback period of a 4 cum biodigester is just 1.2 year if used to replace firewood, which is financially very attractive. However, if the biogas is used to replace charcoal, electricity, or kerosene the payback periods are 3.5, 6.3 and 7.03. When subsidy of ETB 2400 per plant is provided, the pay back period reduces to 1.2 year for replacing firewood, 2.4 years for charcoal, 4.4 years for electricity and 4.8 years for kerosene.

3.9. Feasibility of a Biogas Programme in Ethiopia

3.9.1 Technical aspects.

Temperature: Climatic issues will hardly limit the potential for large-scale dissemination of domestic biogas. The temperature is sufficiently high enough throughout the year, with possibly some local short cold spells in the highlands.

Livestock keeping: The current practice of cattle roaming on communal grazing lands and fields outside the cropping season limits the amount of available dung to some extent. In addition, cattle are mostly not well fed and often skinny. The low productivity in terms of milk and meat also reflects negatively on the amount of dung produced. Hence, farmers should rather have a minimum of four heads of cattle to secure sufficient dung availability. Improvement of cattle sheds and floors would improve this situation considerably for most farms.

It is likely that the free grazing practice gradually but increasingly will be replaced by “cut and carry”, stable feeding of livestock, as the traditional practice may just have to high a toll on the environment. Parallel, other cattle breeds would be introduced, improving the situation for biogas.

In view of the cattle stabling customs as well as the poor diet of most cattle in Ethiopia, households should rather have 4 heads of cattle to ensure sufficient available manure (>20 kg / day) to produce a reasonable amount of biogas per day (> $1m^3$ biogas / day). The map indicates that most parts of the studied regions (Amhara, Oromia, SNNPRS and Tigray) have an average cattle population larger than 4 heads per household.

Water: The availability of water is critical. The findings of this mission too indicated that water should not be further away than 20 to 30 minutes. There are definitely many farm locations that meet this requirement, but there will be many that don’t too. Careful and strict selection should avoid disappointment in any future programme. In addition, following the World Vision example, a more integrated approach whereby water harvesting techniques, water wells and a water-carrying donkey become economically feasible, would improve the situation.

The 1998 census would indicate that nearly 64% of the rural population live within 1 km (approx 12 minutes walking) of a water source and 30% of the population lives at a distance of 1 to 4 km from a water source (12 to 48 minutes walking).

Assuming that a proximity of 20 to 30 minutes would be equivalent to a distance of maximally 2 km, and assuming that population shares in the 1 to 4 km segment is distributed evenly, in total 64 + (30/4) = 71% of the rural population would live within 20 to 30 minutes from a water source.

This would not quite match the observations of the mission in some of the visited areas (Amhara, Tigray). In addition, water source yields may reduce significantly during longer dry periods, forcing water carriers to use lower quality water (not a problem for biogas) at even longer distances.

Access to safe water would be another proxy to account for regional variations in water accessibility. For SNNPR and Tigrai region, a rural figure was not available; the share has been calculated assuming 75% of the share of the total would result in the rural access to safe water.

Space: The study team did not visit any farm where the physical space requirement of a biogas plant could have been a limiting factor. Besides, when fixed dome installations would be promoted in stead of floating drum plants, the required amount of place will further reduce.

Track record: There are only few domestic biogas plants in Ethiopia. Although their track record is worrying, their impact on the reputation of the technology would be limited as the technology as a whole is little known.

3.9.2 Financial aspects.

Handling manure: While the benefits of manure-use as fertilizer are well known to farmers it is only used frequently in some areas in the South of Ethiopia. In most areas the competing value (opportunity costs) as energy and income source is too high to allow the farmers the luxury to use it for the crops. The fact that most of the visited biogas households used the bio-slurry for fertilizing vegetables and other crops shows that farmers will use the organic fertilizer if their energy needs are covered form other sources.

Many farmers visited by the study team, over the whole country, had smaller or larger vegetable gardens on their farm yard. These farmers used their manure (or bio-slurry in the case of biogas households) as manure for their crops. In some areas, however, vegetable growing is more intensive than others; Gurage, for instance, is a typical intensive vegetable growing area, and manure has a high fertilizing value. In other areas (parts of Amhara and Tigray), cattle are using common grazing grounds and manure is less handled by farmers.

Dairy production: Increasingly, farmers embark up on dairy production as a commercial activity. To that extent, dairy cooperatives with transport / refrigeration facilities are popping up. The traditional diet of most (rural) families knows little dairy products (some butter for cooking, “aib”, the local cottage cheese and little “urgu” (local yoghurt) to eat with injerra), promotion aims especially on increasing urban dairy consumption.

Selling dung-cake: As the efficiency of a biogas stove is easily five times higher compared with a traditional (dung-cake) stove, contrary to common believe, biogas would not compete with the commercial value of dung cake as an energy source, as a farmer would be better off converting the dung to biogas rather than burning it directly. Additionally, the farmer would reap the fertilizing benefit of bio-slurry

Fuelwood: The scarcity of fuelwood in most of the visited areas is factual, as is its high and rapidly increasing price. So much so that fuelwood and charcoal are gradually becoming luxury goods for rural households. Besides fuelwood, BLT, dung cake and agricultural residue are increasingly becoming commercial energy sources, traded at markets.

The value of biogas: This value depends directly on the value of the substituted fuels. The table provides the calculated value of 1 m^3 of biogas, based on the fuel price, the substitution ratio (biogas stoves have a significant higher efficiency than traditional stoves) and the assumed fuel mix (the share of the substituted fuel in the total energy supply. The table shows two values; the economic value, taking the full market price of the substituted fuel into account, and the financial value, taking only a share of the market price into account. Thus, the financial value better allows for the fact that rural farmers acquire fuel often by hard labour (often by the women and children) rather than buying it on the market.

Striking in the results is not only the significant difference of Euro 0.20 between the economic and the financial value of biogas, but also that the value of biogas is three times higher in Ethiopia as compared with Vietnam.

Micro credit: With the micro credit facilities modernizing and extending their services, credit is becoming a feasible financing option for biogas in many of the visited areas. Credit terms are not prohibitive, but it has to be taken in mind that there is no experience with biogas credit yet. Hence, micro financing organizations may require assistance in covering the risk initially.

In the past, farmers did have a reputation of being reluctant to take loans. Obtaining credit could be difficult; micro credit facilities were less developed and land could not be used as collateral. The situation has improved since, but the extent to which this reluctance will hamper a biogas credit component would need further study.

Integrated farming practices: Cattle are an integrated part of farming on the highlands of Ethiopia. It is used for draught, transport, wealth management, status and source of fertilizer, meat and -to a lesser extent- dairy. In view of the low level of mechanization and chemical fertilizer usage, for most farmers it will be quite impossible to farm without cattle.

3.9.3 Social aspects.

Role of women: The team did not get the impression that women play a crucial role in making decisions in the household, and certainly not where a financial investment the size of a biogas plant would be concerned.

A more balanced, scientific view, however, could be obtained from Guday Emirie’s dissertation (reference 011); in the chapter on “decision making patterns in the extended family” (5.4.2.1) structure the following can be read:

The dominant family structure is characterized by formal and informal power structures based on the principles of sex, age and relatedness. The gender division of power is primary, with males, except the very young ones) having power over females. Decisions regarding education, marriage of children, *construction of a house, farm work schedules of the household members, hiring farm labourers land allocation and the use of farm inputs are made by the (mostly male) head of the household. Wives make decisions pertaining to child care, food preparation and household management. Male dominance is paramount, but when asked to define who the ultimate decision maker in family matters is, most husbands express that both wife and husband make decisions jointly.*

Obviously, with biogas being a significant investment for the household, whereby a large share of the advantages of the technology benefit women and children in particular, male skewed decision authority is an important potential programme risk.

Integration in farming practice: Biogas will easily find its place in the typical integrated farming set-up of the Ethiopian highlands. Cattle is night stabled, yards allow enough space for placing an installation, vegetable gardens are often adjacent to the yards, distances to the kitchen and the stable can mostly be chosen favourable for biogas.

1.3.3 Awareness on benefits: With the low current penetration of the technology, one cannot expect wide awareness of the benefits of biogas. Information and promotion, hence, shall be a significant component in any programme. Biogas benefits, however, are likely to be very appealing for most households; not only in view of the scarcity of energy and fertilizing sources, but also from a workload, health and sanitation point of view.

Toilet connection: The taboos around handling (products of) human faeces seem not as principally imbedded in culture and religion as can be the case in India or Nepal. Advanced sanitation programmes, as for instance the one from Finnida in Amhara, are making good progress. Nevertheless, households are likely to be reluctant to connect their toilet to the biogas plant. Proper information and extension on the advantages and the risks of toilet connection is the key to a successful programme component, as is the provision of a second inlet pipe that allows the connection at a later stage. Compulsory connection would be ill advised; risking that households avoid using the bio slurry or even the gas. It should be noted that modern sanitation facilities are not quite common place yet in rural Ethiopia.

Health: Biogas installations improve the health situation of families. Most prominently by eliminating indoor air pollution, the main cause of respiratory diseases, and in particular for women and small children who are often close to the cooking fire. Biogas installations further improves the sanitary condition of the farmyard and its direct environment by feeding animal manure directly to the installation and connecting a toilet to the plant respectively. As such, Biogas installations thus contribute to the betterment of the two of Ethiopia's three main diseases in terms of mortality rate.

3.9.4 Institutional aspects.

Political will: The federal Rural Energy Development and Promotion Centre and the regional Bureaux of Energy are very well aware of the domestic energy issue and its ramifications on rural livelihood, agriculture and environment. These government offices are not only mandated to support and coordinate a larger scale domestic biogas programme, they would probably also be best place in terms of knowledge and skill related to domestic energy. The impression from the interviews is that any biogas programme would find eager supporters in these organizations. The team's impression is, however, that the capacity of these organizations, in terms of operating funds, infrastructure and manpower, may be insufficient to effectively support a larger initiative. Hence, programmes should consider an appropriate capacity building component.

At higher level, particularly regarding the Ministry and Bureaux of Finance and Economic Development (MoFED / BoFED), further study will be required to gauge the willingness to co-finance (directly or "in kind") such a large scale programme. The BoFED officials visited showed a good understanding of the issues around rural development, energy and environment.

Indirectly, through the interviews, it transpired that in political circles of the government the awareness of energy and environment, and hence the concern regarding providing basic energy services to rural poor households, is very limited indeed.

Stakeholders: Potential enthusiastic stakeholders from the Government side could include at central level the REPDC and Bureaux of Energy (and agriculture) at regional level. At national as well as regional level a cooperation agreement with the Ministry / Bureaux of Finance and Economic Development will likely be necessary and helpful.

The private sector does not show great presence in rural Ethiopia. For construction and maintenance, any programme would have to invest in establishing (initially small and informal) biogas enterprises. In some areas, linking with Mirte manufacturers or technicians trained for pump and latrine construction (e.g. Finnida) might be a good option. For starting-up, Selam would be a good partner for manufacturing and marketing of appliances as well as applied research and development. Selam would also –at least initially- be well placed to provide biogas mason and technician training.

UNDP-GEF, and the Netherlands Embassy in Ethiopia should certainly be approached with an eventual programme document; both would look favourably at co-financing such initiatives. Biogas would add well to SNV-Ethiopia’s new BOAM initiative, and SNV would be well-placed to channel biogas technical and programme experience from the Asia Biogas Programme to Ethiopia.

3.10 Technical potential.

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 expensive; and
- bio-slurry is appreciated as an organic fertiliser and/or fish feed.

Looking into the above conditions, Ethiopia meets most of the conditions indicated.
To come to a first estimate on the potential for domestic biogas, the number of households with 4 or more cattle is taken at Woreda level. As substrate, manure of other stabled animals (donkeys, horses) would do equally well. However, avoiding an over-optimistic picture, for the calculation only cattle holding is considered.

The availability of manure as substrate for the installation is not the only technical parameter. Equally important, and much more critical in the Ethiopian context, is the availability of water. Practically, in view of the considerable amount of water that has to be fed to the installation, the water source should be within 20 to 30 minutes from the farm yard. In total, the four regions of the study area count together nearly 11.2 million households. 8.7 million households (78%) are keeping cattle. Out of these 8.7 million “cattle holdings”, nearly 5 million (57%) are holding 4 cattle or more.

Country wide, 71% of the rural households live within 20 to 30 minutes walking from a water source. The “high” technical potential for domestic biogas in the 4 regions hence is estimated on some **3.5million households.** On average, 23% of the households in the four visited regions have access to safe water. The “low” technical potential for domestic biogas in the studied area thus would amount to approximately **1.1 million households.**

Region	Area [km2]	House holds [# of hh]	Cattle holdings [# of ch]	Cattle population [#of heads]	% Cattle holdings [%]	Cattle density [head/km2]	Avg cattle holding / hh [head/hh]	cattle holding <4 [# of ch]	cattle holding >4 [# of ch]	share cattle holding >4 [%]	hh water < 30 min [%]	hh access to safe water [# of ch]	Technical potential HIGH [# of ch]	Technical potential LOW [# of ch]
Amhara	148509	3194754	2574836	10275527	81%	69	4.0	1587506	1110264	43%	71%	23%	788,287	255,361
Oromia	328939	4564213	3594072	18575227	79%	56	5.2	799379	2787099	78%	71%	23%	1,978,840	641,033
SNNPRS	112217	2688970	2009680	8815689	75%	79	4.4	1213824	758760	38%	71%	21%	538,720	159,340
Tigray	50182	724964	559334	2665129	77%	53	4.8	284879	290733	52%	71%	26%	206,420	75,591
Total study area	**639846**	**11172901**	**8737922**	**40331572**	**78%**	**63**	**4.6**	**3885588**	**4946856**	**57%**	**71%**	**23%**	**3,512,268**	**1,131,324**

3.12 Impacts of Biogas Technology

Biogas technology can play an important role to improve the quality of life for these rural households where the technology has been introduced. The emphasis of biogas use will be on cooking, as electric energy is far more convenient for lighting. At the end of the programme period, an estimated additional 14 000 biogas plants will be in operation (no failure assumed), annually producing about 8 550 000 m^3 biogas (600 m^3 per plant per year) and 213 750 tons (about 15 ton per plant per year) of digested slurry (8 % dry matter).

Assuming 90 % of the replaced fuel to be firewood and 8 % charcoal, the following amounts are expected to be substituted annually:

- 38 475 tons of fuelwood (by 7.7 million m^3 biogas) since 1 m^3 of biogas will replace about 5 kg fuelwood;
- 1 360 tons of charcoal (by 850 000 m3 biogas) since 1 m^3 of biogas will replace about 1.6 kg of charcoal.

On top of that, the following benefits are expected:

- meeting the energy demand in rural areas by substituting fuelwood as the principle source of energy for domestic cooking (the calorific value of biogas is about 6 kWh/m^3, which corresponds to about 5.5 kg of firewood). The energy payback period of a biogas plant is short. When simple construction materials are used, the main energy used for building a biogas plant is the fuel for making bricks. This energy is normally paid back within one year by a well functioning plant;
- improvement of hygienic conditions, especially of women and children, by eliminating indoor air pollution and by stimulating better management of dung (the stable is cleaned and the dung fed into the digester on a daily basis) and night soil (latrine attachments);
- reduction of the daily workload of women of 14 000 households (wood collection, cooking, cleaning cooking utensils) since operation and maintenance (O&M) activities hardly require extra labour. Biogas does not require constant attention or blowing on the coals, so the user can put a pot on the burner and do other activities while the food is cooked. Introduction of biogas does not necessarily change entrenched traditional patterns in the division of labour. Strategic gender needs are thus not specifically addressed by biogas. However, in many cases the reduction of workload can be considered as a pre-condition to make opportunities available for women to organise and attend meetings, increase skills and awareness through training courses, etc. Biogas does well to fulfil this pre-condition;
- natural resources protection:
    - combat soil depletion: the organic materials that are fed into the plant are used without being destroyed. The nutrients and organic matter (apart from some carbon and hydrogen) will still be available in the plant effluent and can be returned to the soil;
    - reduce deforestation by reducing the consumption of fuelwood;
    - reduce erosion: biogas slurry contributes to sustain the amount of organic matter in the soil, improving infiltration rates and water holding capacity on its turn having a positive effect on reducing run-off and limiting soil erosion;
    - reduce harmful emissions (at local and global level): burning biogas is much cleaner than burning biomass and coal. Apart from being smokeless (health aspect), it basically submits only CO_2 and H_2O to the atmosphere whereas a simmering wood or coal fire gives much more pollution. Burning biogas does not contribute to global warming, because the fodder used to feed the animals uses an equal amount of CO_2 in the ecological cycle. Furthermore biogas is not released in the atmosphere in the natural dung digesting process. This burning of the CH_4 component in the biogas leads to an additional CO_2 equivalent emission reduction;
- micro-economical benefits:
    - energy and fertiliser substitution, e.g. eliminating the need to buy expensive fuelwood and chemical fertilisers;
    - additional income sources;
    - increasing yields in animal husbandry and agriculture by using the full potential of digester effluent as organic fertiliser. If properly stored, treated and applied to the fields, biogas slurry has a higher fertiliser value than ordinary farmyard manure;

- macro-economical benefits:
  - decentralised energy generation;
  - import substitution (fossil fuels and fertilizers);
  - job creation: the programme is expected to generate a fair amount of employment in the regions where it is active, through the staff of biogas companies, by the labour required for the production of appliances and building materials and through the unskilled labour used during the construction of the plants.

All these benefits clearly show the MDG relevance of this biogas intervention by mainly contributing to goal 7, e.g. ensuring environmental sustainability through integrating the principles of sustainable development into country policies and programmes and by reversing the loss of environmental resources. This can be monitored through energy related indicators, such as: the proportion of land area covered by forest; GDP per unit of energy use (as proxy for energy efficiency); carbon dioxide emissions (per capita); the proportion of population using solid fuels and the % of renewable energy used versus the total energy consumption. (UNDP, 2004, *Guidelines for annual reporting on MDG 7 for Uganda*)

3.12 Program Integration

Biogas Technology 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 of fuel wood collection and cooking in a 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 is functionally integrated 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 is 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.

3.13 Conditions for large-scale dissemination of domestic biogas in Ethiopia

	Condition	Score	Remark
Technical	Even daily temperatures over 20^{o}C throughout the year	++	Average maximum temperatures range in the 20s throughout the year. On the plateau, however, night temperatures may drop to 10^{o}C or slightly lower during the rainy season
	At least 20kg of fresh animal dung available per plant per day	++	As argued earlier, under the current holding regime sedentary farmers would need at least 4 cattle. Large parts of the plateau have an average cattle holding of 4 or more per household.
	Availability of water required to mix with fresh dung in a 1:1 ratio	+/-	Water availability is very area dependent, and in most parts of Ethiopia recurrent droughts have to be taken in consideration.
	Sufficient space for biogas plant in the compound of potential users	++	Compound space is not an issue in rural areas; farmers have yards of reasonable size.
	History of proper performing biogas installations	+/-	60% non-functioning is not a good track record, but up to 750 plants nation wide is not a large amount either.
Financial	Traditional practice of using of organic fertilizer	+	Traditionally, dung is used as fertilizer. Unfortunately, energy shortage increasingly force households to use dung as energy source instead
	Scarcity of traditional cooking fuels like firewood	++	Fuelwood is scarce to the extent that its use is considered a luxury in large parts of the country
	Potential users have access to credit	+	All visited regions have good, albeit recent, micro credit facilities. There is, however, no experience yet with biogas credit
	Livestock farming is the main source of income for potential households	++	Farming integrates cropping and livestock. Hence, livestock may not be the main source of income, but it is an indispensable part of it
So	Role of women in domestic decision-	_ _	Traditionally, domestic decision making is male skewed. The decision for an

	making process and life		investment in a biogas installation would definitely be within the male domain.
	Biogas plant can be integrated into normal working routine at the farm	++	In view of the integrated farming system, biogas will fit seamlessly in most situations in the highlands, where cattle are night-stabled.
	Awareness of effects of biogas technology among potential users	-	In view of the low penetration of new technologies in general and biogas in particular, man farmers may not be very aware
	Willingness among potential users to attach a toilet to the plant	+/-	Handling (products of) night soil definitely is a sensitive issue. However, there are some good examples.
Institutional	Political will of the Government to support a national biogas programme	+	At REDPC and BoE level, the political will is certainly there. The MoFED and BoFEDs, however, have not been consulted in this detail yet
	Willingness of (potential) stakeholders to get engaged in biogas programme	++	Both from government side (REPDC, BoEs, BoAs) as well as NGO side (UNDP-GEF, Selam, RNE, SNV-Ethiopia) the team met with considerable enthusiasm.
	Availability of organizations having access to potential users	+	The government's agricultural extension network reaches down to kebele level, but habitats are much dispersed.

Score	*Condition*
++	*Fully met*
+	*Met*
+/-	*Doubtful*
-	*Not yet met*
--	*Falls short*

4. BIODIGESTER DESIGN/DRAWINGS AND CONSTRUCTION STEPS

4.1 Types of Biogas Plant

There are different designs of household biodigesters being in use today. Broadly, they can be classified as: fixed dome plants and floating drum plants. The following are some of the models being used in different parts of the world.

PHOTOS TAKEN OUT

Flooding drum models (India) **Floating drum Model (Nepal)** **Janatha Fixed Dome (India)**

KT 1 Fixed Dome, Vietnam **Chinese Fixed Dome** **Plastic Bag digester**

GGC Model Fixed Dome, Nepal **Deenbandhu Fixed Dome, India**

Vacvina Digester, Vietnam **CAMARTEC Biogas Plant – Tanzania, Rwanda, Ethiopia**

4.1 Selection of Type of Biodigester

To successfully achieve anticipated objectives of biogas programme, it is imperative that the best suited model/design of biogas plant is selected for the wide-scale dissemination. Varieties of models/designs of biogas plants are being used in different countries in the world with successful track records. Based upon the performance of the existing plants and experiences from other biogas countries, attempts were made to select the best model for the wide-scale dissemination of the biogas technology in the country.

The following factors have been considered to evaluate the suitability of biogas plant assuming that the adaptability of any biogas plant in a given context depends mainly upon these factors.

a. Climatic and geo-physical parameters
   - Ambient temperature
   - Geo-physical conditions of the soil
   - Condition of ground water-table

b. Technological Parameters
   - Structural strength against different load conditions (structural durability)
   - Methods of construction/supervision
   - Time and effort in quality control
   - Methods of operation and maintenance
   - Applicability/adoptability of the design in different geographical context for mass dissemination
   - Prospects for sharing of technical information and know-how

c. Affordability of potential farmers to install biogas plant
   - Availability of construction materials
   - Availability of human resources (skilled and unskilled) at the local level
   - Cost of installation, operation and maintenance
   - Transportation facilities

d. Purpose of the use of the products from biogas plant
   - Use of gas for cooking, lighting and/or operating a duel-fuel engine
   - Use of slurry as organic fertiliser

e. Performance of existing models, if any, in the local and/or regional conditions
   - Existing physical status and functioning
   - User's level of satisfaction

f. Quality and quantity of available feeding materials
   - Type of feeding materials (cattle dung, pig manure, human excreta etc.)
   - Availability of water for mixing
   - No. of cattle/pig per household

Based upon above mentioned criteria the Nepalese GGC model with some modification to suit the Ethiopian context has been selected. This model is locally named as SINIDU model.

4.2 Different Components of a Fixed Dome Biodigester

There are 6 main parts of the biodigester: inlet (mixing chamber), digester (digestion chamber), gas holder (storage chamber), outlet (displacement chamber), gas conveyance and application system (pipes and appliances) and slurry compost pit(s). The mix of dung and water (mixed in inlet or mixing chamber) 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 pig-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)

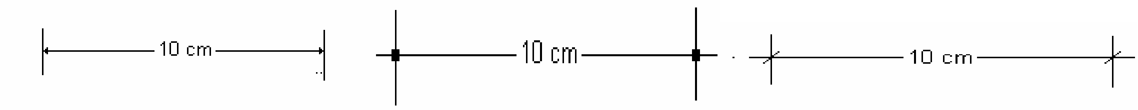
4.3 Drawing Reading

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 whereas 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.

There are four different types of projections when it comes to technical drawings; 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, an 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, since without dimensions the subject cannot be constructed in the correct proportion. The lines that indicate measurements of the subject in the drawing are called dimension lines. Dimension lines can be drawn in different styles such as:



4.4 SINIDU model of Biodigester

The National Biogas Programme will adopt a model which fulfils the following criteria:

- reliable, durable and user-friendly: the digesters should have an estimated lifetime of over 20 years with a minimum of maintenance;
- replicable: with local available material and local skilled manpower, the digesters must be able to be constructed nation wide;
- adapted to local conditions (climatic and soil conditions, water levels, quality and quantity of feeding material, etc.);
- the cost of the digesters should be as low as possible without affecting the durability.

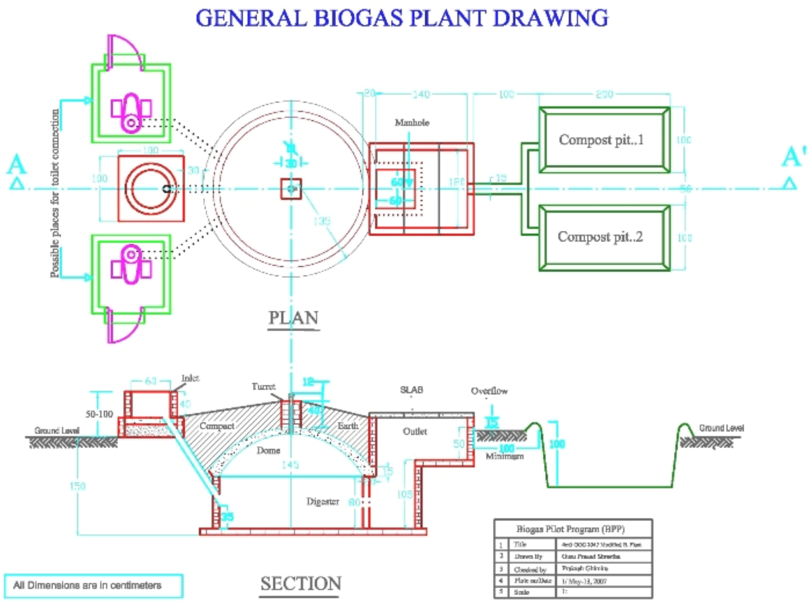
The fixed dome plant, on which the programme will focus and which is most suitable for the Ethiopian conditions, comprises a closed digester with a fixed, non-moving gas space and a compensating tank. The gas is stored in the upper part of the digester. Gas production increases the pressure in the gas space of the digester and pushes the slurry into the compensating tank. When the gas is extracted, a proportional amount of the slurry flows back into the digester.

The main advantages are as follows:

- a long life span (no moving and steel parts);
- its total cost is less than that of a floating gasholder plant;
- can be built below ground level: saving space and easier to insulate and protect the digester;
- provides opportunities for skilled local employment;
- the long-lasting technology will enable Banks to make loans available with sufficient recovery time;
- the technology will have less failure and risk resulting in high consumers confidence.

The disadvantages are as follows:

- they require more skilled masons in order to keep the plant gastight with risk of heavy gas losses if the construction is not properly done;
- prices vary very much with the location and transport affects the prices as the Ethiopian residences are much scattered;
- gas pressure fluctuates substantially depending on the volume of gas stored and the



height of the slurry level in the outlet chamber.

Initially only one design fixed dome plant will be approved, be it in different specified sizes and materials (bricks or rocks according to availability). Other proven designs can be admitted later on if there would be a demand for a new design and if all conditions for the smooth implementation of the programme are in place.

In this first phase, SINIDU model plants of 4, 6, 8 & 10 m^3 will be constructed. If the design and size of a plant other than mentioned above is chosen, the subsidy is not allowed. The size of the plant is selected on the basis of the available dung and not on the family size. Therefore, in order to decide on the plant size, it is necessary to collect dung for several days to determine what the average daily dung production is.

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 volume 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

The construction of SINIDU model biogas plant consists of the following steps:

- 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/stone 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
- 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
- Orienting the users on simple operation and maintenance activities

5. BIODIGESTER SIZE, CONSTRUCTION SITE AND CONSTRUCTION MATERIALS

5.1 Selection of Correct Size of Biogas Plant

SINIDU biogas plant is fixed dome design plants. 4, 6, 8 and 10 m3 biodigesters of this model are eligible for obtaining subsidy from the Government of Ethiopia under the National Biogas Programme (NBP). 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: 50 days*

The size and dimensions of the biodigesters have been decided based upon 50 days retention time and 60% gas storage. This means that the fresh feeding fed into the digester should remain inside it for at least 50 days before it comes out through outlet. Likewise, the plant should be able to store 60% 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 pig 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 (mainly cattle dung).

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 may pass 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 problems in operation. The important points 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 then only the size is determined by the gas demand which is usually taken to be 0.33-0.40 cum gas per person per day.

5.2 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/pig manure, plant must be as close as possible to the cattle shed or pig sty.
- To mix dung and water or flush pig 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.

5.3 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/Stones
Brick plays a very important role in construction especially for SINIDU 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.

In areas where bricks are expensive and not available, stones can be used for construction of the SINIDU model biogas plants. Stones to be used in the construction should be best locally available. When hitting one stone with another, stones should not break. When the stone is scratched with a pointed object like iron nails, there mark should not be more than 1mm. If the stones are dirty it should be washed. Before use, stones must be soaked for few minutes in clean water.

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 Ethiopia. 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.

Gas Pressure Gauge
U-shaped pressure gauge (manometer) made up-of a transparent plastic or glass tube and filled with coloured water or a clock-type digital or analogue pressure meter has to be installed in the conveyance system to monitor the pressure of gas. Whatever may be the type this device should best among those available in the local market and should meet set quality standards, if any.

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. 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 locations of the digester, outlet tank and inlet pit and draw a straight line in which the centres of inlet, digester and outlet will be located (generally referred as hart-line).
- Decide the reference level. It is better to assume the levelled ground level as the reference level. The top of the dome (outer) should exactly be in this level.
- Insert a stick or wooden peg in the hart-line to mark the centre of the proposed digester pit. Select the outer radius of the pit (digester diameter plus wall thickness plus plaster thickness plus space for a footing projection of at least 10 cm) for brick walls as shown in the drawing under dimension ‘Rp’ and mark it in the rope or chord. For stone masonry, this 10 cm will also be used as the wall thickness as stone wall could not be constructed with 10 cm thickness. With the help of this peg and chord prepared earlier, make a circle, which indicates the area to dig.
- From the centre point where the central line (hart-line) meets with the perimeter of the digester, draw a tangent and measure a length equal to half of the size of manhole (half of 60 = 30cm) plus wall thickness plus plaster thickness. Now, measure size of manhole plus wall thickness plus plaster thickness in the hart-line to decide the positioning of manhole. Mark the manhole ensuring that the inner size is 60 cm x 60 cm.
- To decide the location of outlet, take half the breadth of outlet plus wall thickness plus plaster thickness and mark the points in either side of the centre point where the central line meets with the perimeter line (extension of line drawn for manhole). From the centre, measure the length of outlet plus wall thickness plus plaster thickness to decide the outer dimension of outlet lenthwise.
- 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 ‘Dp’ as shown in the drawing, the work of levelling and ramming the base has to be done. 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 (outlet passage) 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. The vertical pole will guide the construction of digester wall.
- 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/stone in water for about 10-15 minutes before use.
- Prepare mortar for brick/stone 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, as mentioned earlier, 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 'Rd'. Plaster thickness (1.5 to 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 at a distance of (Rd+plaster thickness) from the vertical pipe. After deciding the radius of digester, a circle has to be drawn to decide the inner 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.
- The construction of round wall should be started from the side of manhole. First a space of 60 cm plus plaster thickness has to be marked and then construction of wall started. Place the first brick/stone with the help of guiding string. Go on placing the bricks/stones in circle with the help of this string. Construct the wall from one direction only, either clockwise or counter clockwise. The face of wall should be maintained inside while constructing the wall. If brick masonry, the first row of bricks must be positioned on their sides so that a **5 cm** high, **20 cm** wide base is made. It is essential that first row is placed on a firm, untouched and levelled 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 be done 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-3 sand to 1 cement-4 sand depending on the quality of the sand.
- While laying bricks/stones 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 (for 4 and 6 cum plants) and 35 cm (for 8 and 10 cum plants), place 2 inlet pipes (one for conveying 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 60° 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. To reduce the risk of blockages, the inlet pipe(s) must be placed as vertically as practically possible.
- The height of the round-wall can be found on the drawing under dimension 'Hc' when measured from the finished floor. The construction of round wall should be continued till the height is Hc+floor

thickness which is usually 7-10 cm. If the foundation is constructed before the round wall, the height of round wall should be equal to Hc.

- 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 30 degrees from the dung inlet on the dang inlet-centres-manhole line (hart line).
- Now the digester floor has to be constructed. For this, a flat soling of broken bricks or stones should be done in the compacted floor. After properly ramming the stone layer, a thick layer of plaster in cement mortar (1:4) has to be applied and finished properly. In areas where the bearing capacity of soil is low or water table is relatively higher, the floor has to be constructed with plain cement concrete (1:2:4) prior to the construction of round wall.
- 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.

6.4 Construction of Gas Holder (Dome)

When the construction works of round, wall as described above, is completed than the spherical (dome-shaped) gas holder has to be constructed. The gas holder is constructed with plain cement concrete with the help of an earthen mould prepared by filling excavated earth. Before filling the pit with earth to make the mould for the dome, backside of the round wall should be filled with proper compacted earth-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 which is used for constructing round wall, a mark has to be made at a distance ‘Hall’ plus 2.5 cm (the thickness of inside plastering coats), 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. 1 metre 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 earthen 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. The earth used for the mould has to be damp to prevent dry earth from soaking up water from freshly casted concrete.

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. 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 in between. Such interruption will negatively affect the quality of the cast. A constant, adequate supply of concrete (mix: 1 cement, 2 sand, 3 gravel) must be made for the mason. No concrete older than 30 minutes should be used. The top of the wall has to be applied with cement-water slurry before starting the concreting work.

The concreting of dome should be started from the top of manhole where a 15 cm thick beam has to be casted to accommodate he foundation for the outlet wall. 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 and 6 m3 plants, the thickness in the edge should be 15 cm where as the thickness in the centre should be 7 cm. Similarly, for 8 & 10 m3 plants, the thickness in the edge should be 20 cm where as the thickness in the centre should be 7 cm. For 15 & 20 m3 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. 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: 15 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand) applied with plastering trowel
    - Layer-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 parts cement) 5 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 well set before applying the next layer. Interval of one day for the third and fourth coat is good for gas-tightness. 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 day after the casting, the turret must be made. Any delays can lead to leakage between main gas pipe and dome. The construction of turret has to be done when the concrete in the outer surface of the gas holder sets well. The size of the turret should be decided based upon the size of stone and brick. It could be square or circular in shape. The size of square should be at least 20 cm. If it is circular the diameter should be 20 cm. The height of turret should be at least 40 cm. Turret could be constructed of concrete if there is some leftover mortar prepared for dome casting.

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 flooring (Ho+7.5 to 10 cm) form the ground level. When excavated at this depth, the top level of flooring 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 (Lo, B0 and Ho). 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 finished floor of the outlet is equal to height ‘Hop’ in the drawing.

- Once the excavation is completed, compact the floor and lay broken stones or brick bats (broken bricks) on the floor. After properly compacting the stone or brick floor, lay a thick layer of course cement-sand mortar (1:4). The finished surface should be levelled and smooth. In this surface, once the mortar is set, outlet walls have to be constructed. The inner-dimensions of outlet should be as shown in drawing (Lo and Bo). While fixing the dimensions allow 1.5-2 cm for plastering (in each side). Lay a first layer of mortar (1 cement: 3 sand) and start constructing wall. First, place bricks in the four corners of the tank wall and fix a rope to guide the brick work by tying it with the bricks in either side. The walls have to be vertical and finished with a smooth layer of cement plaster (1 cement: 3 sand). The outer part of the wall has to be compacted well to avoid cracks due to slurry pressure from inside. There is no need of plastering the outside of the outlet tank walls.
- The overflow level in outlet wall should be 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 shorter wall.
- The cover slab for outlet should be casted during the concreting of gas-holder. 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 more than 5.5 cm thick with proper reinforcement of 2 cm from the bottom. The slab must be 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	164	62	3	8	12
6	174	68	3	8	14
8	184	72	3	8	16
10	204	78	3	8	18

For all slabs:

Thickness	: 6 to 7.5 cm (2.5-3”)
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

Usually inlet is constructed after the completion of the construction of outlet tank; however, it can be constructed simultaneously. If the feeding material is cattle dung, then an 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 pig 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, if it is to be installed. 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 wall should be 60 cm. The overall height of inlet tank including the base is recommended to be 90 cm. In no case, the height of inlet from the ground level should be more than 100 cm.
- Once the round wall is constructed, enough time should be allowed to set the mortar properly. Then both inside and outside of the tank is plastered with 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 pan 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 30° from the hart-line. Additionally the pan level of toilet should at least be 20 cm above the overflow level in the outlet walls.

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 biogas 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 in the case of GI pipes. 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. However, best quality PVC pipe could also be used to minimise the cost. The joint between two pieces of PVC pipes should be properly sealed with sealing agents. Fittings in the pipelines must be sealed with zinc putty, Teflon tape or jute and paint in case of GI and best quality liquid rubber gasket in case of PVC pipes. 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 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 as mentioned earlier.
- 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 placed. 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 done with greatest care.
- Now the pressure gauge has to be installed. U-shaped pressure gauge (manometer) made up-of a transparent plastic or glass tube and filled with colored water or a clock-type digital or analog pressure meter has to be installed. In case of manometer, one end of U pressure gauge is joined to the gas pipeline and the other end is attached to an empty bottle exposed to the atmosphere. When the gas pressure in the digester is zero, the surface of colored water in two branches of pressure gauge is leveled in the middle of the water column. When biogas enters the pressure gauge, the colored water level in closed branch drops down, whereas the water level in other branch increases. A difference between levels of these two colored water columns shows the gas pressure in cm of water columns. Pressure gauge is also a safety valve to prevent gas overflow. When gas pressure in the digester surpasses the designed value, the water in the one branch of pressure gauge is pressed into the bottle and the gas escapes outside. When the gas pressure in the digester drops to the normal level, the water stored in the bottle will flow back into the pressure gauge. Clock-type pressure meter is easy to install and read. It can be directly fitted in the gas pipeline with a tee junction. A gas pressure gauge has to be fixed near the point of application of the gas.
- As soon as there is gas production, the joints and valves (taps) must be checked for leakage by applying a thick soap-water solution. If there is leakage, the foam applied in the joints will either move or break. If so happens, the joints must be sealed properly.

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 two compost pits must be at least equal to volume of the plant. The depth of the compost pits must not exceed 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

However, the dimensions in most cases will be governed by the availability of land. Keeping the volume and height constant, length and breadth of pit could be decided as per the site conditions.

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

6.10 Finishing Works and Instructions to Users

Once the construction works are completed, the sites should be cleaned and cleared properly. 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 as per 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 the following aspects of operational activities has to be given to the users:

- Initial Filling of Plant
- Daily feeding of Plant
- Use of Main valve
- Checking leakages
- Use of Water drain
- Cleaning of outlet
- Composting/ maintaining compost pits
- Oiling of gas tap
- Cleaning of gas stove
- Cleaning of gas lamp
- Breaking of scum layer
- Reading of pressure gauge and adjusting of gas flow as per the reading

6.11 Conclusion

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 and 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.

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 bio-digester. During digestion, about 25 – 30 % of the total dry matter of animal/human waste will be converted into a combustible gas and the 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.

Biogas slurry consists of 93 % water and 7 % dry matter of which 4.5 % is organic and 2.5 % inorganic matter. The percentage of NPK (Nitrogen, Phosphorus and Potassium) content of the slurry on wet basis is 0.25, 0.13 and 0.12 while on 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 a variety of purposes, the main one being 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 pig supplement feed
- Organic fertiliser to grow algae to increase fish production

As organic fertiliser, it can be used wet or dry. The slurry can be used directly by mixing it with irrigation water. Wet application is rather cumbersome, therefore farmers prefer to use dry slurry in their farms. For the dry use, composting of the slurry is highly recommended.

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 (%)	Avg. Value (%)	Value Range (%)	Avg. Value (%)	Value Range (%)	Avg. Value (%)
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 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, the climate and other factors. However, application of compost will bring the following changes to the soil:

- Improvement of the physical soil structure.
- 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 soil fertility and increases cereal crop production with 10-30 % compared to farm yard manure (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.

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, garbage, etc. It also provides moisture to the computable biomass. There are several ways of making compost. The widely used method is the pit method and semi dried methods of slurry composting. The following steps have to be followed for pit composting of bio-slurry.

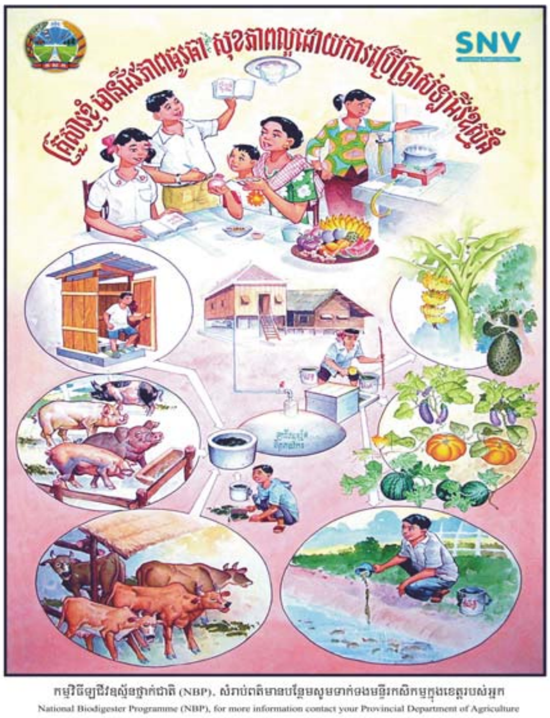
- First of all, prepare two compost pits with a combined volume equal to the total plant volume, by the side of the biogas plant and at least 1 meter away from the plant
- Spread a thick layer of dry materials (15 – 20 cm), such as dry forest litter, waste grasses and straw, leftovers of animals feed and weeds collected from the fields, at the bottom of the pit which will absorb the moisture of the slurry and prevent the leaching of nutrients to the ground water system.
- Let the slurry flow on to the dry materials so that the dry material becomes soaked with the moisture present in slurry.
- Cover the slurry with a thin layer of straw, stable waste or any other dry material. This is done to prevent slurry from drying and preserves the plant nutrients.
- Next day, let the slurry flow into 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 15 – 20 cm above 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 have to be carried out:



- Develop and distribute different IEC (information, Education and Communication) materials in local language, such as: posters, pamphlets 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 DVDs on promotion and extension of biogas and slurry applications and broadcast them on local TV.
- Disseminate information on biogas through radio and local FM stations.
- Organize orientation trainings to the potential users, staff of government line-agency offices, NGO workers, school teachers and workers of local organizations.
- Organize exhibitions and demonstrations.
- Motivate biogas plant construction companies to concentrate on cluster area construction and to organize effective promotion campaigns.

b. Motivation

Motivation is a vital component of any program like biogas that is aimed at a wider section of the population. The exact nature of the motivation strategy must however be responsive to the specific needs of the area and situation. 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 Ethiopia.

i. Reliance on 'demonstration effects'

A successful biodigester is assumed to be a sufficient stimulus for motivating others to install a biodigester. The 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 the biodigester program in the districts be initiated from semi-urban settlements, close to the towns. In these areas, providing accurate and complete information to the people whenever asked for, should be given priority. Technology demonstration becomes essential, especially in these areas where there is a need to change the existing negative attitude towards biodigester technology.

ii. Motivation through government officials and NGO personnel

It is rather awkward to recommend that the concerned government offices or NGOs in the districts hire motivation staff focusing solely on the biogas programme. However, various government agencies and NGOs working in the fields of agriculture, women development, social sensitization, health, education and other functional areas could be effective vehicles to work as motivation agents. Some government offices at the district level could be effective partners of the biogas programme in this case. Although biogas is not their core activity, these agencies can integrate the technology within their routine programs. For example, biodigester activities could be integrated with a 'women's workload reduction program'.

iii. Use of local Resource Persons

Another prominent strategy for motivation is the utilization of local resource persons by providing fixed incentives. Some contact persons in the communities could be mobilized as agents to inform potential beneficiaries on the biogas programme.

iv. Use of local leaders

Local leaders could be mobilized as motivation agents. Such leaders could either exist already in the village or may be identified and trained by the programme. 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 Ethiopia, such as farmers' cooperatives, milk collection centres, women's group, youth unions, labour unions could effectively be used as motivation tools. Biogas Programme Offices should link up with such structures at the village level to organize and sustain the participation of the people, especially women, in the program.

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 areas of Ethiopia, women have traditionally shouldered the responsibility of managing the domestic energy requirements for their families. Women carry out fuel wood collection and 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.

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

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;
- 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

The programme focus could be on individuals or on institutions. In the first case, the program may focus more on the individual beneficiary, rather than the community or a village. It is the individual farmer's responsibility to approach the district biogas programme office or the construction agency if they want to install a biodigester. Similarly, in case of any problem with a biodigester, the responsibility of informing the implementing agency lies with the beneficiary. This approach works well where the implementing agency relies largely on the ‘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 biodigester 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 put 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, 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 a local repair and maintenance network is simpler if an institution already exists. However, creating and ensuring the sustainability of such institutions requires a large investment in terms of time and efforts. It is feasible to create these if they can be involved in a number of other development programmes.

In the case of Ethiopia, a combination of the two approaches will be best suited. The programme should target to focus on individual as well as village level institutions based upon the specific site conditions. However, existing institutions should be strengthened rather than creating 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 Ethiopia, the objective should be to let the biogas 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, 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.

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 Ethiopia. One of the means to be created to extend financial assistance is a subsidy for the beneficiaries. In addition to this, institutional credit from banks, co-operative societies etc. will be made available to the beneficiaries to facilitate the users to adopt the technology. The financial mechanism influences the program coverage, the beneficiary profile, the follow up and maintenance and most importantly, sustainability of the program. The following incentives are proposed to be provided by the biogas programme:

a. Subsidy

A flat rate subsidy of **Euro 193 (ETB 2400)** per digester has been proposed to motivate the farmers to install a biodigester during the initial phase of the programme. The subsidy structure has been designed to cover a substantial part of the installation cost, e.g. about one third of the construction cost for smaller biodigesters. This type of flat rate subsidy will encourage small farmers to install biodigesters, since most people in Ethiopia 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.

b. Credit through Bank

Financing biodigesters through commercial and development banks is quite an established practice in other countries. A designated lead bank can coordinate loan facilities. At the central and district levels in Ethiopia, banks working in the grassroots sector could be motivated and mobilised for overall coordination of this sector.

c. Credit through village level institutions

In the wake of 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. This could for example be linked to other initiatives, such as milk collection centres.

d. Technical Backstopping

With a view to enhance knowledge of users on proper biodigester operation and minor repair & maintenance works to ensure that the installed biodigesters function without any trouble, different training programs are proposed by the program. One day operation and maintenance trainings for the users will be organised immediately after the installation of biodigesters. Likewise, follow-up/refresher user's training will also be conducted based upon the demand of the users. Technicians from the biogas programme will frequently visit the biodigester to assess its performance and solve minor problems, if any. The users can lodge requests/complaints in the biogas programme for required technical assistances.

e. Guarantee and After-sales-services

Guarantee duration for the construction work is **36 months** since the hand over date. After sales service requires the biodigester company or mason teams to thoroughly monitor the biodigester upon the owner's request. It requires them as well to sign on the Guarantee Certificate granted to the household by the company or mason-team on the hand over date.

If the biodigesters have any trouble, and the company or mason team does not send a technician for trouble shooting or for operation instruction to household heads, then household heads can inform the biogas programme by telephone or letter. As soon as the biogas programme receives the information, this office will react immediately to the problem.

For every biodigester constructed, Euro 16(ETB200) will be deposited by the construction company or mason team on a special biogas programme 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 the necessary repair work though, the biogas programme will use the deposit amount to repair the biodigesters 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: design, materials, installation and construction techniques, operation techniques, methods to maximize the use of the biodigester and the slurry, in order to improve the quality of biodigesters and to cut costs.
- Research on and improve on the biodigester development strategy, including marketing and promotion and the support to companies.
- Measure and evaluate the effect of biodigester dissemination on individual households and 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 involve other players to introduce biodigester technology in their programmes/projects.
  - Placard promotional posters and distribute leaflets.

b. **Investigation for potential clusters/farmers**

  - In cooperation with the district agricultural extension network, prepare lists of potential biodigester users per district which will be the basis for deciding on locations to expand the programme to.

- o Select communes consisting of many villages and having more than 10 potential biogas households/commune
- o Communes with the presence of NGO’s active in agricultural and/or sanitation related activities need to be given priority

c. **Individual Promotion and marketing to potential biodigester users**

- Issue promotion documents made available by the biogas programme to potential biodigester users
- Arrange farmer’s visit to biodigester plants wherever possible.

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

i. Conditions for households to be subsidized by the Programme

- Have a stable animal husbandry development of family size, e.g. regular dung source of 20 to 120 kg /day.
- Have relatively easy access to an extra amount of water to mix with the dung;
- Sufficient space to build a biodigester.
- The farmer is ready to cover expenses for construction of biodigesters and upgrade toilets, kitchens, and compost pits as a synchronous complex.
- Commit to cooperate with biogas technicians to participate in biodigester trainings, supervising, testing, O&M of 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 193**, 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/construction companies**

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

e. Provide quality support services/incentives on time

8.6 Quality Control

8.6.1 Concept of Quality in Biogas Programme

In general, quality is the degree of compliance of a process or its outcome with a predetermined set of criteria, which are presumed essential to the ultimate value it provides. Quality is doing the right things in right way. A product or process that is reliable, and that performs its intended function is said to be a quality product. Quality is the extent to which products, services, and processes, are free from defects, constraints, and items which do not add value for customers. The quality of a product or service refers to the perception of the degree to which the product or service meets the customer's expectations. In technical usage, quality can have two meanings:

- o the characteristics of a product or service that bear on its ability to satisfy stated or implied needs.
- o a product or service free of deficiencies.

In the case of NBP, the quality is basically related to the following aspects of biogas programme implementation:

- **Quality of the design of biogas plant**: The biogas plant should be cost-effective; users’ friendly; easy to construct, operate and maintain.
- **Quality of training and capacity building activities**: Correct training need assessment; proper selection of training participants, proper selection of facilitators, suitable training contents, session plans and scheduling; appropriate training methods; effective practical sessions; effective evaluation of training; timely follow-up of the evaluation findings.

- **Quality of promotion and extension works**: Potential customers should fully be aware and understand all the benefits and costs. They should be provided with factual data and information and should be aware of their roles and responsibilities for quality control.
- **Quality of the construction** (including selection of construction materials and appliances): Strict adherence of set quality standards on site selection, selection of construction materials and appliances and construction.
- **Quality of the operation and maintenance** by the users and technical backstopping from the installer: Effective training to users', timely follow-up visits by the installer.
- **Quality of after-sale-services** on behalf of the installers: Strict adherence of terms and condition of after-sale-service provisions including timely actions to the complaints from users, routine visits and problem-solving.
- **Quality of financial and administrative procedures and practices**: Proper utilisation of fund, timely disbursement of subsidy amount, proper book-keeping, less-lengthy procedures, fast, friendly and useful customer services.

If the biogas plant does what is anticipated by the programme personnel and what the user wants it to do, then it is a quality plant. That's meeting the anticipated requirements. Hence, qquality is the performance excellence of biogas plant as viewed by all stakeholders. Thus, if the installed biogas plant:

- has the right dimensions, configuration and features,
- does what it's supposed to do,
- is reliable and durable,
- is delivered on-time, and
- is well-supported; then

It is quality biogas plant.

8.6.2 Quality Control in Biogas Programme

Quality Control refers to the operational techniques and the activities used to fulfil and verify requirements of quality. QC is the planned process of identifying established technical specifications for the project and exercising influence through the collection of specific (usually highly technical and standardized) data. The basis for decision on any necessary corrective action is provided by analyzing the data and comparing it to system specifications/requirements. At NBP, it implies all those planned or systematic actions necessary to provide adequate confidence that the biogas plant is of the type and quality needed and expected by the stakeholders.

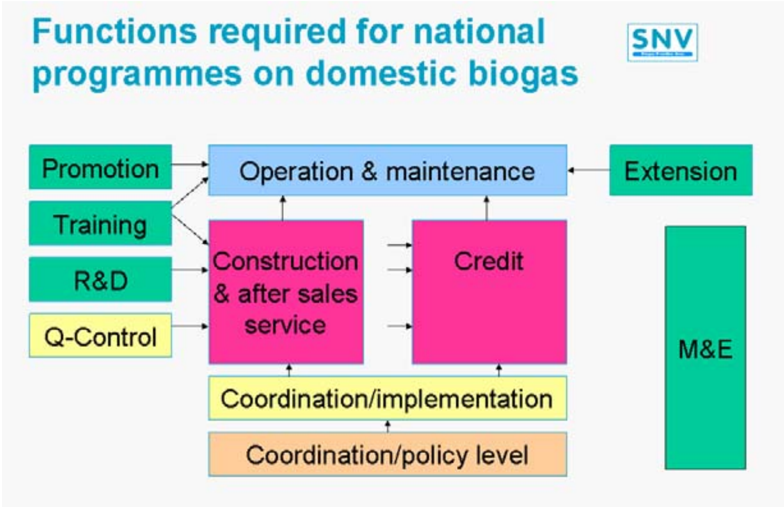
The objective of the quality control is to encourage stakeholders to comply with the set quality standards. Quality Control is all the means by which the frequency of defects in a biogas plant is reduced. It includes quality planning, quality measuring and quality analysis.

In biogas programme, quality control is involved in developing systems to ensure biogas plants are designed and constructed to meet or exceed users' requirements. As with cost control, the most important decisions regarding the quality of a biogas plant are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of insuring conformance to this original design and planning decisions.

8.6.3 Need for QC System in Biogas Programme

The following figure illustrates the general functions required for any national programmes on domestic biogas within the framework of SNV. The concept of quality is associated with each and every function. Quality control is increasingly important concern during biogas programme implementation. Defects or failures in constructed biogas plants can result in costs.

Even with minor defects, re-construction may be required and facility operations impaired. Increased costs and delays are the results. The structured QC system is therefore important for the following main reasons:



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

8.6.4 General Approach of Quality Control

The basic objective of quality control in NBP is to ensure that the installed biogas plants meet the set quality standards and they function optimally without any major problems for the anticipated duration of time. Quality will be the prime concern of the programme. Effective quality control not only helps in ensuring the compliance of quality standards but also provides learning opportunity for the programme personnel.

While enforcing quality control systems NBP will make sure that the following four basic principles are considered:

- Reliability of the information collected
- Uniformity (consistency) of the information collected and analysed
- Impartiality (neutrality) while collecting information
- Transparency when dealing

Before the visit, the following points should be clear to the technicians:

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

8.6.5. Quality Standards

Quality standard is a framework for achieving a recognized level of excellence within the programme. These are stipulations of measurable physical properties or characteristics, which materials, equipment or constructed items must have as a minimum. Achievement of a quality standard demonstrates that the programme activities have met the requirements laid out by a quality control authority. In general, quality standards are the benchmarks of levels of service or design specification.

Standards, as a rule or principle, are used as a basis for judgment or comparison – whether the installed biogas plant fulfills the basic requirements. These are statistics that measure changes or deviations and provides impetus to analyze whether any deviation will have detrimental effects on functioning. It helps in identifying the level of accuracy in complying the set criteria.

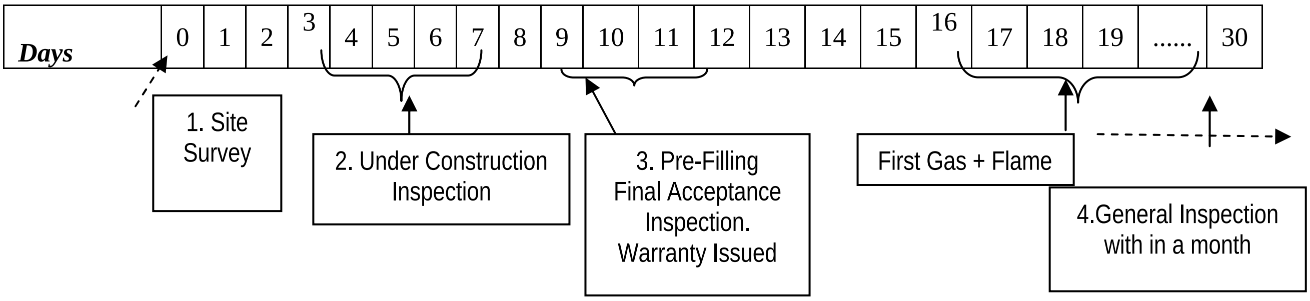
To facilitate effective monitoring for ensuring quality, standards have been developed as given in the following table. The quality standards are basically related to the following aspects:

- Quality standards related to location and size of biodigesters
- Quality standards related to the design and 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)

These standards have been categorised under three different groups keeping in view their importance. The **critical standards** are those which need to be followed strictly and no compromise should be allowed. Failure to comply with these standards will have serious adverse effect on the end product and on the programme as a whole. The **major standards** are very important for the smooth functioning of the biogas plants and failure to comply these standards results in serious problems with the functioning. The **minor standards** are also important for the successful operation of biogas plant however, these can sometimes be manipulated based upon the site conditions. Still care should be provided to adhere with these standards.

8.6.6 Quality Control Visits

QC visits are the main tools to monitor the quality of works being carried out at the field level. The following diagram illustrates proposed timeline of such QC visits.



As shown in the diagram, four visits are generally necessary during the process of the installation of biogas plants. Among these four, the second (inspection of biogas plant during construction) and third (inspection of biogas plant immediately after the completion of construction prior to the feeding) are mandatory. The first (site survey) and fourth (general inspection) could be optional depending upon the need. Besides these visits, at least one visit should be made to monitor the quality of after-sale-services within a year from the date of plant operation.

The scope of work during the QC visit includes assisting and checking the construction and providing feedback to mason. The purpose is also to make sure that the masons are qualified enough to carry out their activities. General process for QC visits will be as follows:

- The mason/mason’s team submits the details on under-construction as well as completed biogas plants to the Woreda technician
- The Woreda technician selects the biogas plants to be inspected from the list of under-construction and completed plants on the basis of random sampling
- Field visit schedule is prepared
- Site verifications are carried out using the standard formats
- The filled forms are signed by three parties (mason, owner and the Woreda technician)
- Necessary feedback and suggestions is given to the mason through the Woreda technician based upon the analysis of the data and information
- The mason follows/acts upon the feedback and suggestions immediately

- Regional Biogas Offices selects some plants on random sampling basis (under-construction, construction-competed and operational) and carries out validation of data and information collected by Woreda technicians.
- The data and information are entered into computer database in NBP and feedback are provided to Woreda through regional biogas offices.

8.6.7 Tolerances

Tolerance is the degree to which the set quality standard can vary or deviate without jeopardising the functioning of the biogas plant. In NBP case, tolerance is the permissible limit of variation in the physical dimensions of biogas plant. Dimensions of biogas plant may vary within certain practical limits without significantly affecting functioning of the final product. Tolerances are specified to allow reasonable leeway for imperfections and inherent variability without compromising performance. Tolerances are fixed based upon the anticipated degree of precisions to ensure effective operation of biogas plants. Most of the quality standards developed for the construction of biodigester allow certain tolerances. The following table shows the maximum tolerance limits for some of the dimensions. Details are given in annex under the heading Quality Standards.

	Description	**Tolerances**
1.	Inner Diameter of digester	± 2%
2.	Total inner height of digester	± 5cm
3.	Height from floor to bottom of inlet pipe	± 5cm
4.	Height from floor to bottom of outlet tank	± 5cm
5.	Height between bottom of outlet tank and top of manhole	± 2cm
6.	Length and Breadth of Outlet tank	± 5cm
7.	Height of outlet tank up to the bottom of over flow opening	± 5cm
8.	Thickness of slab	± 1cm
9.	Height of inlet from the ground level	± 5cm
10.	Height of turret	± 5cm
11.	Size of turret	± 5cm
12.	Height of top filling over dome	± 5cm

8.6.8 Reward and Penalty Mechanisms

The disadvantage or painful consequences resulting from an action or condition that is against the set quality standards are referred to as ‘penalty’ whereas something given or received in recompense for full compliance of the quality standards is a ‘reward’. Penalties are imposed when the quality of works and the final products are of inferior quality than the anticipated whilst rewards are awarded when the product fully meets or even exceeds the expected level of quality.

The quality control system in NBP proposes reward provision to encourage those doing exceptional works. The following reward mechanism will be practiced:

- Mason or Mason’s Team who construct biogas plants with minimum or no defects will be awarded as ‘best mason/mason’s team of the year’. The best mason(s) will be provided with certain amount of cash prize. He/she will also be involved as a trainer for new mason’s training.

- The best mason’s team will be rewarded with technical, financial and institutional supports to establish a biogas plant construction company.

- The Woreda and Regional supervisors who do outstanding job will be awarded as ‘best supervisor(s) of the year’ and awarded with certain intensive. The best supervisor(s) will be given opportunity for exposure visits or participation in any national/international training/workshop/seminar on biogas technology.

- The woreda/regional biogas office doing the outstanding job will be rewarded with ‘best woreda/region of the year’. The Woreda/region personnel will be given opportunity for exposure visits or participation in any national/international training/workshop/seminar on biogas technology.

Likewise, the following ‘penalty mechanisms’ will be practiced to ensure the quality while constructing and supervising the construction of biogas plants:

- Poor quality work, the defaults, will surface in the database, through the NBP QC reports and through QC on QC reports. The mason(s) and supervisors will be warned on such defects based upon the severity of the defects. Repeated offenders against the quality standards will be removed from the programme and the defects will be corrected by utilising the money deposited by the mason’s team to become eligible for participating in NBP activities.

- If certain mistakes are commonly made, this should be addressed at the new technical training and at annual refresher trainings for masons and supervisors.

- If the Regional/Woreda office seems to fail in their role of quality inspectors, the supervisors should be provided with a warning. Supervisors who, after a first warning, commit the same mistakes again will be removed from the programme;

- On a monthly basis the Woreda have to report on the complaints they have received from the users and the action they have taken. If a user claims that he has registered a complaint and this is not reported by the Woreda/Region, NBP as to investigate an possible take sanctions.

8.6.9 Roles and Responsibilities of Stakeholders

a. Role of Biogas Plant Owners

The biogas plant owners are the most important stakeholders in the quality control of biogas plants during construction as well as operation and maintenance phases. They are responsible to:

- Participate in pre and post construction training.
- Prepare construction sites and collect materials according to the instruction of the mason and/or district biogas technician.
- In consultation with the district biogas technician and the mason, set the construction schedule and deadlines.
- Provide required unskilled labour for the digging work and to assist the masons during construction.
- Constantly monitor the work of mason.
- Operate the plant as stipulated in the operation manual.
- Carry out routine repair and maintenance works as per maintenance manual.
- Report problems to the mason and/or district technicians.
- Lodge complaints in Woeda/regional offcie if the mason does not respond to the call for problem solving.

b. Role of Woreda Offices

The woreda office appoints a full-time technician for biogas programme. **The Woreda technician** is responsible for the protection of farmers against incompetent and/or careless masons. It is done through quality control during the construction on randomly sampled plants and completion control of all plants. During these visits the supervisors will methodically inspect the plant using a detailed inspection form. The supervisor will ensure that no plant is handed over to the user if he/she is not completely satisfied that the completed plant, including pipeline and appliances, will function as it is supposed to. The above described control mechanism is also laid-down in the construction contract signed by the district technician.

The detail tasks of district technician are:

- Select suitable households to register with the Programme for technical and financial assistances with the help of commune technician.
- Help users select suitable designs, sizes, locations for biodigesters and required construction materials as per the quality standards.
- If required, assist users in obtaining a biodigester construction loan with a recognized financial institution.
- Help users purchase/prepare accessories and tools as per required technical standards for the biodigesters.
- Introduce trained and certified mason's team/mason to the users for their selections and construction agreements.
- Help and provide document to users instructing construction supervising procedure, including their roles during and after the construction works, in order to assure construction and installation quality.
- Supervise masons during construction and installation works in order to control construction quality. The plants to be visited are selected randomly from among the under-construction plans. Data and information are recorded in the standard Construction Monitoring Form (given in Annex). Masons are instructed to correct any deviations from the standards. Any mason who violates seriously the construction requirements are reported to the Regional Office for final actions such as stopping mason's jobs, revoking certificates, cancellation of construction contracts etc**.**
- Submit the filled Construction Monitoring Form to Regional Office/NBP for entering the data and information into the database.
- Instruct biogas plant users to prepare feedstock as per quality requirements before operating plants.
- Visit all the completed plants for filling Construction Completion Report (also known as Acceptance Report) (given in Annex). This visit is made after the completion of construction works but before the initial feeding of the biogas plant. Measurements of various key components are taken and crossed checked with the standard. Test and Acceptance jobs are carried out in cooperation with users and mason. The data and information is filled and Construction Completion Report is signed by the three parties (technician, mason and the user). The plant code is mentioned in the Construction Completion Report for programme management. Plant owners are instructed to feed the biogas plant only if the quality standards are met. Any rectification needed is carried out by the mason in an agreed timeframe.
- Submit the Construction Completion Reports from fields to Regional office/NBP for entering the data and information into the database and register the plant into programme management file.
- Instruct biogas plant users on methods to apply feedstock and start up the biodigesters according to technical requirements.
- Supervise, follow up, support masons' team, solve complains from biodigester users if required.
- Carry out checking of current physical status and functioning of the plant and the warranty responsibilities at least once in a year during the warranty period in randomly sampled biogas households. Biogas Plant Performance Monitoring Form (given in Annex) will be used during this visit.
- Submit the Biogas Plant Performance Monitoring Form from fields to Regional Offcie/NBP for entering the data and information into the database.
- Report PNBP authorities if the mason/masons' team violates the term and conditions set out in warranty provision.
- Act upon the feedback from Regional Office/NBP in the agreed timeframe.

c. Role of Regional Office

The Regional Biogas Office will assign a pat-time Project Director, a part-time Project Administrator and full time technical supervisor(s). The number of technical supervisors will depend upon the targeted number of biogas plants and the geographical spread of the Regional State. The following are the major responsibilities of Regional in Quality Control.

- Select suitable and responsible Biogas Technicians (BTs) and Biogas Masons (BMs) through Woreda offices for training based upon a set selection criteria. A public announcement will be made to collect applications from interested persons.
- With support from NBP, organize training programmes for BTs and BMs, provide them necessary background knowledge and skills on biodigester so that they can perform programme activities as anticipated. These activities can largely be contracted out to a recognized Training Institute, if feasible.
- With support from NBP organize training programmes (pre and post construction) for the (potential) users in which they will be oriented on their roles during construction and post construction operation and maintenance through woreda offices.
- Select at least 5% of the under-construction plants and 10% of the competed plants on random sampling basis to validate the data and information filled in the forms by the Woreda.
- Validate the data and information from the field.
- Facilitate woreda technicians for checking of current physical status and functioning of the plant and the warranty responsibilities. Plant monitoring form (given in Annex) has to be used during this visit. Regional office will validate at least 5% of the forms filled by woreda technicians selected on random sampling basis.
- Provide feedback to woreda technicians on the outcome of the analysis of data and information entered into the database. Ensure that the feedbacks are acted upon in the stipulated timeframe.
- Collect data and information in biogas users including existing fuel use situation to provide baseline data for calculating Emission Reduction and evaluate the impact of the programme. Form-2 given in annex shold be filled at any time during the construction period. Filling of this form could be combined with QC visits.

d. Role of NBP

Given the limited resources (human and financial) and time, NBP is not in a position to visit targeted number of under-construction or completed biogas plants to ensure the compliance of quality standards by the masons. The role of NBP should be to build the capacity of provincial and district biogas technicians to internalise the quality control process. To ensure this to happen, NBP personnel should:

i. train the Regional/Woreda technicians
ii. accompany them to the field to monitor their works at the field level and provide necessary back-stopping services at site
iii. ensure that the provincial technicians are building capacity of district technicians to effectively carry out the quality control activities through transferring of their skills and knowledge

Capacity building of local masons, Woreda technicians, Regional offices and other stakeholders involved in biogas sector is crucial for the sustainability of the programme. Knowledge and skills of biogas technicians and masons are vital in ensuring the quality of construction, operation and maintenance. QC activities should begin from the very beginning of these training programmes. To ensure effective learning from training the following issues should be considered:

- Proper selection of training participants
- Proper selection of facilitators
- Suitable training contents, session plans and scheduling
- Appropriate training methods
- Effective practical sessions
- Effective evaluation of training
- Timely follow-up of the evaluation findings

The NBP should facilitate the Regional Offices to formulate selection criteria for the participants and ensure that these criteria are adhered to. For example the selection criteria for masons could be:

- Formal education of at least up to 5th standard. Should be able to read technical drawings and other instructions provided to them from time to time
- At least 2 years of experience in construction works as a mason or plumber. Previous experience in biogas plant construction would be an added advantage.
- Be a permanent resident of the Regional State
- Have good reputation in community – should be a trusted person
- Good interpersonal and communication skill
- Receptive to community's need and willingness to support them
- Age between 20 to 40 years
- Good health

Likewise, NBP should monitor the training programme to evaluate the overall effectiveness of such programmes.

e. Role of Mason and Mason's Team

Companies and/or mason's teams, who wish to corporate with the NBP and benefit from the subsidy scheme, will be required to seek recognition from the NBP 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 NBP 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 administrative system in place.

The activities of the Mason depends to a large extent on his/her interest and initiatives. The masons/ masons' team assigned for the construction of biogas plant will have the following responsibilities:

- Construct the biodigesters according to the NBP quality standards
- Complete the construction works including fitting of pipes and appliances within a stipulated timeframe.
- Instruct the biogas plant users on the proper feeding procedures of biogas plants and on the proper use of biogas and bioslurry.
- Provide warranty on the construction within .... months period with effect from the data of completion as mentioned in the completion report.
- Repair and maintain biogas plants and solve any technical and operational problems in accordance with the conditions described in the warranty certificate.
- Visit the biogas plant at least twice a year during the warranty period to check the plant and appliances even if no complaints are lodged by the users.
- Involve in marketing, participate in pre-construction and post construction training to users and initial feasibility visits to potential and interested farmers.

8.6.10 Data and Information Management

NBP will install database-oriented software in order to keep track of the construction of biodigesters both quantitatively and qualitatively. This software will be used to monitor the biodigester dissemination progress, monitor the construction process, control the quality of the construction, keep track of the trained professional involved in the construction and monitor their after sale service and finally keep track of some financial data.

The software is intended to replace the existing system and to extend this system by providing statistical tools.

The software will be designed to be easy to use for non-experienced computer users by providing simple and intuitive data entry forms. Moreover, the software will provide an extensive list of reports that will provide statistical data in multiple languages; giving NBP and Regional Office users extended monitoring capabilities.

The database system users can be assigned several roles. Typically, the NBP Supervisor can also be NBP Translator for instance.

- The Software will be developed using MS Access 2003
- The Software must be easy to use and must remind the user of the forms on which the data is collected.
- The Software must support several concurrent users accessing the same data.
- The Software must be able to display data both in local language and English depending on the user preferences, **including data retrieved from the database**.

9. OVERVIEW ON OPERATION AND MAINTENANCE

Proper operation and maintenance (O&M) of the different components of a biogas plant is very important for its efficient and long-term functioning. The users have a major responsibility of carrying out operational and minor maintenance activities as anticipated. It is therefore, necessary to orient users on these activities upon the completion of the construction works.

9.1. Operational Activities

After the completion of the entire construction work, the site surrounding the biogas plant should be cleaned and cleared. The remains of construction materials have to be dumped properly in safe 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 properly. Proper drainage system should be constructed to avoid rain water entering into the biodigester. Moreover, the mason has to provide proper orientation to the users on plant operation and minor maintenance. Importance of daily feeding of 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.

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
k. Reading of pressure gauge and adjusting of gas flow as per the reading

9.1.1. Feeding of Biodigester

Once the construction of biodigester is completed, it has to be filled with required quantity of feeding (cattle dung and/pig manure mixed with water) up to the zero level in the digester (level of bottom of outlet). As the quality of dung required for 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/pig manure from the day they decide to install biodigester. As the preparatory works for construction and the actual construction will take some days, quite a lot quantity of dung will be stored in this period of time. The farmer may collect the dung from neighbouring households. The initial feeding material should contain slurry with high bacteria population; therefore, it is recommended that digested-slurry from existing biogas plants, if any, be added to the initial feeding as starter or seeding matter.

Before putting any slurry in the digester, ensure that all the valves are open. Once the filling is done up to zero level, new slurry should not be added until the combustible gas is produced.

Once gas production starts, 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 Ethiopia context to digest cattle dung/pig manure is taken as 50-55 days. The feeding material that enters into the digester from inlet should remain in the digester for 50-55 days to release most of 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%. 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 pig 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 with water. 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 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.

9.1.2. 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 gas-pipeline. It prevents the risk of loss of valuable gas due to leakage in pipeline and appliances. This valve eases the repair of 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 and slurry in the pipe line.

Some form of carbon particles will be deposited in the smooth surface of the ball of main gas valve if the valve is half-opened. This will cause some wear and tear of the nylon washers which may increase the risk of leakage of gas in long run. Therefore, the main gas valve should fully be opened and closed during the time of operation.

9.1.3. 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 gas leakage. Soap or detergent mixed with water is vigorously shaken 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 passed 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.

9.1.4. 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.

9.1.5. Cleaning of Overflow Opening

Digested slurry flows out of the displacement chamber (outlet tank) through the 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 accumulation of slurry. This accumulated 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.

9.1.6. Use of Gas Tap

Gas tap is fitted in 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. The rate of gas flow varies 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 dry. The need to change or oil the washer should carefully be monitored.

9.1.7. 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. 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.

9.1.8. 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 supplied 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. The following points have to be considered while operating a biogas lamp:

The glass-cover should be pre-treated with boiling in hot water before it is placed in position. The holes in clay-part (carborendum) should be checked any blockages regularly. While operating the lamp, one should ensure that the heat is reasonably far from any materials that catch fire easily.

9.1.9. 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 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.

9.1.10. 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 can not penetrate this layer to reach the gas holder and thus, 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. For this the slurry should be removed for several days. Even after emptying the plant, allow 24 hours aeration as precautionary measure. Before entering, presence of harmful gases or sufficient oxygen should first be checked. Flames should be avoided near or within the digester. When one person enters the digester, another person should be constantly watching from outside to ensure the safety.

9.1.11. Use of Pressure Gauge

Pressure gauge is fitted in the gas-pipeline near the point of application of biogas to monitor the pressure of gas that flows to the appliances. When the needle of the pressure gauge indicates higher pressure, then the gas tap should be adjusted to allow less gas to flow to the stove or lamp and vice versa. Importantly, when the indicator shows full pressure, gas has to be used otherwise there is chance of gas leakage to atmosphere, which should not happen from the environmental point of view. Likewise, when the gas pressure is very low, one has to stop using the gas to avoid slurry in the pipeline. If the pressure is less than 15 cm water column, it is not preferable to use gas anymore.

9.2. 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 stop leakages
g. Cleaning of stove
h. Changing of rubber hose pipe

9.2.1. 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.

9.2.2. 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 cleaning. Otherwise the chromium coated ball and rubber washer usually called 'O' ring will be worn-out leading to gas leakage. This problem should be fixed as soon as possible – delay may lead to changing of valve. Since, the valve is an expensive item; it is difficult to change frequently. Hence, prevention is always better than cure. The following steps have to be followed to repair and maintain the main valve:

i. Disconnect the pipe line through the union.
ii. Remove lock, washer 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.

9.2.3. 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.

9.2.4. Cleaning/repairing of gas lamp

Gas lamp needs routine repair and maintenance for faultless operation. Dismantling of a biogas lamp to clean its components, should be done carefully. 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 clay part (carborendom) by turning anti clockwise very carefully
v. Inspect the nozzle, clean and be-block it if necessary
vi. Assemble in the sequence
vii. Check the performance.

9.2.5. Cleaning/repairing of water drain and pit

As for 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.

9.2.6. 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 or sealing agent over the threads
v. Re-fit the dismantled joint properly
vi. Check for leakage using shampoo foam.

9.2.7. 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 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.

9.2.8. 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.

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

Problem	**Cause**	**Potential Solution**
Biogas is not produced even after 10-15 days	No bacterial activity inside the digester	o Ensure that the first feeding is done with fresh cattle dung. o Mix bio-slurry from existing plant as seeding agent. Wait for a month and see if gas production starts. If not, then empty the digester, and refill plant with fresh cattle dung.
	Leakages in dome (gas storage), or in pipes and appliances	o Check the main gas valve if it has leakage. o Close the main gas valve and see if the slurry level rises in outlet tank or not. If the level rises, then there is leakage from either pipeline or appliances. Check for leakage and correct it. o If the slurry level does not rise even after closing of main valve, there may be leakage in dome. o Wait for a month and see if gas production starts. If not, then empty the digester, check leakages from dome and refill plant with fresh cattle dung.
Stove does not burn even after gas production	More CO_2 in gas	Escape some gas daily for about a week. When CO_2 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 do not burn	More CO_2 during initial digestion	Escape some gas daily for about a week. When CO_2 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
The digested slurry coming out of outlet has strong foul smell	The digestion process is not as anticipated may be because of: o Short-circuiting of feeding in the digester o More quantity of water added o There is no bacteria in digester	o Ensure that the inlet pipe discharges just opposite to outlet opening. o Ensure water dung ratio 1:1 while mixing dung to feed into the digester o Stop any adverse activities that kill bacteria such as use of chemical to clean latrines attached to biogas plant.
More time needed to cook food	Efficiency of flame is not as anticipated due to heat lost or defective stove	Ensure that the primary air intake is adjusted properly to produce strong blue flame that concentrates in the bottom of cooking pot. Ensure that the stove is properly maintained and used. Ensure that the area of cooking is not windy and open. Locate stove in closed space to avoid heat lost.

9.4. Guarantee and After-sales services

9.4.1 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. The user's should know that:

- 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, **Euro 16 (ETB 200)** will be deposited by the construction company or mason team on a special 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, biogas programme 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.

9.4.2 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 handing over date.

- 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 to 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. 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 biogas programme office by telephone or letter. As soon as the office receives the information, it must be re-acted immediately to solve the problem.

9.5 User's Training

Training for biodigester user before construction work

- Participants: biodigester household members who will operate and maintain the biodigester on a daily basis
- 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 biogas programme office.
  - Audio/video facilities.
- Arrangement: the biogas programme office will be responsible for organising trainings for users at village 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 some time 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 biogas programme office.

    - Audio/video facilities
- Arrangement: the biogas programme office will be responsible for organizing trainings for users at village and inter-village level.
- Contents of Training for biogas user after construction work:
    - Potential problems and likely solution as related to O&M 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 district level 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 and Channelling
- Credit Administration and Channelling
- Biodigester Construction and Maintenance
- Quality Control
- Research and Development
- Program Management and Implementation
- Monitoring and evaluation

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

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

- Government offices at the central and district level:
  - Coordinate activities
  - Integrate biodigester related activities in their routine activities

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

- Regional/Woreda Biogas Programme Offices
  - Implement the activities as stipulated in the implementation document and Woreda guidelines.
  - Capacity building and strengthening,

- Quality control of construction and after-sales services
    - Registration of completed plants (updating of database)
    - Registration of guarantee
    - Research and development
    - Program management
    - Program implementation, 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 user training
    - Facilitate operation and maintenance activities
    - Distribute promotional posters, leaflets etc.
    - Capacity building of the local users to operate biodigesters optimally
    - Integrate the biogas programme with their routine programmes
    - Be instrumental in penetrating to rural needy communities

- Local government bodies at the provincial, district and communal level:
    - Dissemination of information,
    - Motivating potential users
    - Linking the users to local counterparts

- 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 biogas technology in their curriculum
    - Make the student aware of the technology and develop students as information disseminators
    - Organise and conduct training and research activities.

- Media (radio stations, newspapers, TV stations):
    - Transmit success stories, interview 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 biogas technology.

- Private Sector companies/mason groups/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 for the programme to penetrate to the needy communities.

10.2 Responsibilities of a Mason

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

- Select the proper size of a 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 while constructing biodigesters.
- 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 a minimum requirement of knowledge and skill to operate the various components of a bio-digester
- Ensure timely completion of the work
- Regularly report on progress and difficulties, if any, to supervisors
- Do not allow untrained masons to take lead responsibility in constructing biodigesters
- 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 the construction manual, during the construction phase, the biodigester will function properly with anticipated efficiency and 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 functions poorly, nobody will be motivated to install one. Poor quality plants will harm the reputation of biogas technology and will have a serious negative effect on promotion and extension. The masons therefore should be well aware that good quality plants will help to increase the rate of installation through the demonstration effect which will ultimately benefit 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 masons strictly follow the design and drawing during the construction of bio-digesters

  - Ensure the masons comply with the Construction Manuals while installing the biodigesters
  - Provide necessary information on the benefits of biodigester to the users
  - Ensure that the users are provided with a minimum of knowledge and skills to operate various components of the bio-digester
  - Regularly report progress and difficulties, if any, to higher authorities
  - Ensure timely completion of the work without overloading the users
  - Do not allow untrained masons to take the lead responsibility in constructing biodigesters
  - Work as extension workers and promoters of the technology in their areas of influences
- Carefully monitor the work of masons and provide necessary advice and feedback to masons when needed
- Fill plant completion forms and ensure that all the quality standards are met.
- Correct the drawbacks if any
- Receive comments and complaints from the users and pass them on to the concerned authorities

Remember,

- The role of a 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 and identify the suitability/feasibility of the particular households to install a biodigester
3. Based upon the data and information collected, identify the most feasible households to install a biodigester
4. Prepare a schedule of activities related to the installation of biodigesters in households as identified from the process mentioned above
5. Facilitate the signing of a contract between the installer and the households to install a biodigester
6. Facilitate the signing of construction contract between the installer and the biogas programme
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 visits during the construction of biodigesters 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 monitoring reports.

9. Upon completion of the construction work, carry out a 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 work
11. Prepare the activity report and submit it to the biogas programme office
12. Prepare the list of biodigester households for subsidy payment and submit it to the biogas programme office
13. Organize and conduct users training to ensure effective operation and maintenance of biodigesters
14. Carry out routine visits to biogas households to monitor the performance of biodigesters and provide instructions/feedback to the owners
15. Supervise the work of masons who are installing biodigesters as part of their on-the-job practical training and qualify/disqualify them for receiving a 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 Ethiopia
3a	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
3b	15:45-16:45	Introduction to Biogas Technology: Significance in biodigester technology in Ethiopia; Functioning and types of biodigesters
	16:45-17:00	Recapitulation and discussion
	Day-2	
3c	8:00-09:00	Video show or Visits to biogas plant to familiarise the plant components and discussions
4	09:00-10:00	Design/Drawings of GGC model Biodigester
	10:00-10:15	Tea break
5	10:15-12:15	Biodigester Construction methods and steps
	12:15-13:30	Lunch
6	13:30-14:00	Selection of Construction Site
7	14:30-15:30	Selection of biodigester size
	15:30-15:45	Tea Break
8	15:45-16:45	Quality Standard of Construction Materials and appliances
	16:45-17:00	Recapitulation and discussion
	Day-3	
9	8:00-09:00	Construction of Biodigester: Lay out of biodigester (theory and practice)
	9:00-10:00	Lay out of biodigester (practice)
	10:00-10:15	Tea break
	10:15-11:15	Construction of Biodigester: Trench digging and foundation works (Theory and practical demonstration)
	11:15-12:15	Construction of Biodigester: Construction of digester (Theory and demonstration)
	12:15-13:30	Lunch
	13:30-15:30	Construction of Biodigester: Construction of digester (practical demonstration)
	15:30-15:45	Tea Break
	15:45-16:45	Construction of gas holder: Making mould for casting gas holder
	16:45-17:00	Recapitulation and discussion
	Day-4	
	08:00-10:00	Construction of gas holder: Concreting of gas holder
	10:00-10:15	Tea break
	10:15-12:15	Construction of gas holder: Concreting of gas holder continues

	12:15-13:30	Lunch
	13:30-15:30	Construction of gas holder: Plastering and treatment of gas holder (Theory and demonstration of making plastering coats)
	15:30-15:45	Tea Break
	15:45-16:45	Construction of Turret, Manhole, Inlet and Outlet tanks
	16:45-17:00	Recapitulation and discussion
	Day-5	
	Construction works in the field (whole day, making mould and casting concrete for gas holder.	
	Day-6	
	08:00-10:00	Installation of Pipeline and appliance and construction of slurry pit
	10:00-10:15	Tea break
10	10:15-12:15	Technology Promotion and Quality Management: Importance and Process
	12:15-13:30	Lunch
11	13:30-15:30	Quality standards
	15:30-15:45	Tea Break
	15:45-16:45	Quality standards
	16:45-17:00	Recapitulation and discussion
	Day-7	
11a	08:00-10:00	Introduction to Promotion and Quality control forms and formats
	10:00-10:15	Tea break
12	10:15-12:15	Overview on O&M of biodigester: Routine Operational and Minor Maintenance Activities
	12:15-13:30	Lunch
12a	13:30-14:30	Potential problems and likely solutions
12b	14:30-15:30	Guarantee, After-sales services and User’s Training
	15:30-15:45	Tea Break
13	15:45-16:45	Training and Facilitation skills
	16:45-17:00	Recapitulation and discussion
	Day-8	
14	08:00-09:00	Role of Mason and Supervisors and other Stakeholders Participatory
	09:00-10:00	Discussion/Recapitulation of the overall learning and Formulation of future plan of action
	10:00-10:15	Tea break
	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 SINIDU Model of Biodigester – 2008

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 (toilet) only	Inlet tank should be constructed and used	Critical
8	Approved model of biodigesters	SINIDU model plants as per the design and drawing	Critical
	Standards on Construction Materials and Appliances		
9	Good quality bricks/stones	Bricks: Best quality locally available. Well baked, regular in size, free from cracks and broken parts. Stones: Best locally available. Should not break when two stones are hit together. When scratched with pointed object, the mark should not be more than 1 mm deep.	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 cm 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 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 pressure meter	As approved by the quality control authority.	Major
23	Good quality connecting pipe	Either neoprene rubber hose or good quality plastic pipe as approved by the quality control authority.	Major
24	Good quality gas stove	As approved by the quality control authority.	Major
25	Good quality gas Lamp	As approved by the quality control authority.	Major

26	Good quality mixing devise (optional)	As approved by the quality control authority.	Minor
	Standards on Construction		
27	Only trained masons carry out the construction work	The mason registered in NBP office after successfully completing the required training courses on biodigester construction	Critical
28	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
29	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
30	Correct diameter of the digester	The diameter of the completed biodigester not to differ by ±2% from the standard.	Major
31	Accuracy plum of digester wall	Vertical wall with plum not differed by ±1 cm	Major
32	Correct height of the position of the bottom of the inlet pipe	The height of bottom of the inlet pipe from the floor not to differ by ±5 cm from the standard.	Major
33	Correct height of the manhole	The height of manhole at the top of the opening not to differ by ±5 cm from the standard.	Major
34	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
35	Proper plastering of inside of the digester	The finished surface is properly finished and smooth.	Major
36	Digester floor smooth and levelled	The finished surface is smooth and levelled.	Minor
37	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.	Major
38	Correct diameter of the gas holder	The diameter of the gas holder of the completed biodigester not to differ by ±2% from the standard.	Major
39	Correct height of the gas holder	The height not to differ by ±5cm from the standard.	Major
40	Correct positioning of the dome gas pipe	The location of the dome gas pipe to be at the centre. Maximum allowable deviation is 5 cm of the diameter of the digester.	Major
41	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
42	Proper top-filling over gas holder	The height of top-filling is at least equal to 40 cm from the top of the dome.	Major
43	Proper length, breadth and height of outlet tank	The length, breadth and height of outlet tank not to differ by ±5cm from the standard.	Major
44	Proper volume of outlet tank	The volume of outlet tank not to differ by ±5% from the standard.	Major
45	Proper plumb of the outlet walls	The plumb of the finished surface not to be more than ±1 cm ‘in’ or ‘out’.	Major
46	Outlet floor properly finished	The floor is smooth, properly plastered and levelled.	Minor
47	Properly casted outlet slabs	The thickness of the outlet slab not to differ by ±1 cm. The length and breadth of each panel not to differ by ±2 cm from the standard.	Major
48	Proper size of overflow opening	The length and height of overflow opening not to differ by ±5 cm from the standard.	Major
49	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 ±5 cm.	Major

50	Proper backfilling against the outlet walls	The outside of the outlet walls is properly compacted with rammed soil to prevent soil erosion.	Major
51	Correct height of inlet tank	The height of inlet tank not to differ by ±5 cm from the standard.	Major
52	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
53	Proper finishing works of inlet tank	The plaster surface is smooth and free from cracks.	Major
54	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
55	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
56	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
57	Correct sizes of turret	The length, breadth and height (diameter in the case of circular turret) of the turret not to differ by ±5 cm from the standard.	Minor
58	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
59	No unnecessary fittings in the pipeline	Pipeline contains minimum joints as required. No unions are used.	Major
60	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
61	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
62	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
63	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
64	Correct fitting of gas stove	The connecting pipe from gas tap to the stove is correctly fitted to avoid the gas leakage.	Major
65	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
66	Correct Fitting of gas-pressure meter	The pressure meter is installed near the point of application of gas.	
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
	Quality Standards on O&M		
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

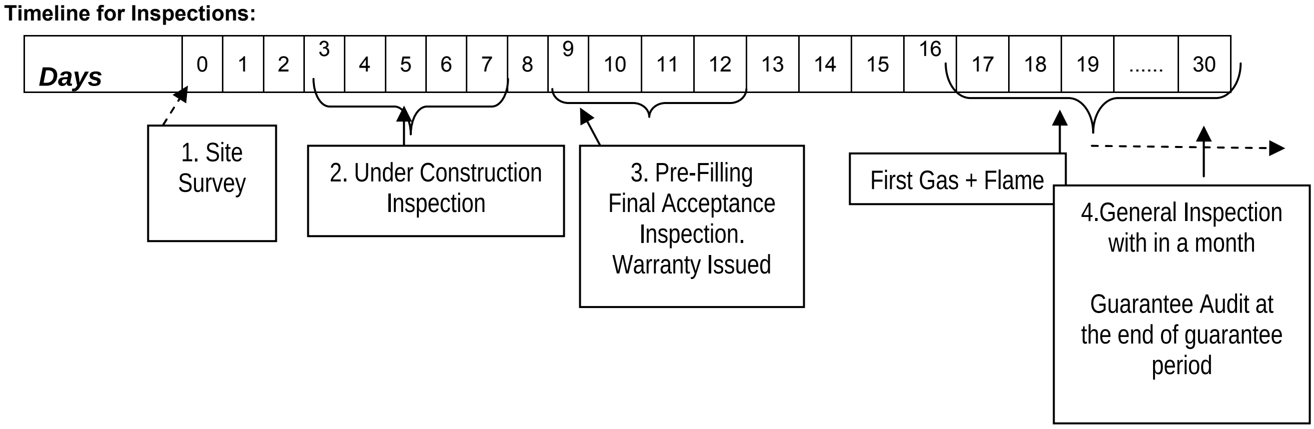
Quality Control Log Book

1.	Biodigester ID	Serial Number:………………………………
2.	Householder	Name:……………………………… Telephone Number:……………………………ID Card No. …………..
3.	Address	Village:………………….. Commune.:…………………. District:…………………..…… Regional State:………….
4.	Mason	Name:………………………………… NBP Registration Number:……………………………..
5.	Biodigester Size	..........................m^3
6.	Construction Period	Started: …………… Completed: ....…………

Quality Control Status

Form	**Title**	**Completed By**	**Checked (name, date)**	**Data Entered (name, date)**
2	Site Survey for Potential Households	Signed:……………. Name:………………….. Position:……………………Date:……………		
2 a	Baseline Survey Form	Signed:……………. Name:………………….. Position:……………………Date:……………		
6	Quality Inspection Form - *During Construction*	Signed:……………. Name:………………….. Position:……………………Date:……………		
9	Quality Inspection Form - *Final Acceptance (Before Filling)*	Signed:……………. Name:………………….. Position:……………………Date:……………		
11	General Monitoring Inspection Form	Signed:……………. Name:………………….. Position:……………………Date:……………		
	Warranty Certificate	Signed:……………. Name:………………….. Position:……………………Date:……………		
10	Warranty Audit (Monitoring before the maturation of warranty period)	Signed:……………. Name:………………….. Position:……………………Date:……………		

Timeline for Inspections:



Form 01

National Biogas Programme

LIST OF POTENTIAL CUSTOMERS OF WOREDA: ....

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									
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Form 2(a)

National Biogas Programme

Survey form for Potential households

Code No.......... ..

General Informatio

Regional State: ....; District: ....; Commune: ....; Village: ....

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

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

Date of survey ....

Land information

Enough land area available for construction: yes/no

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 Riel

Do you owe a bank? : Yes: [ ] No: [ ]

Survey officer
(Full name and signature)

Biogas Household head
(signature)

Form 6

National Biogas Programme

Quality Inspection Form – Under Construction

Date of Inspection:…………

			Auditing (QC on QC)
A.	**General Details** **Plant Code No: ……….**		
1.	a) Name of Owner :………………………….……..…(b) Tel No:……………….(c) ID Card No…….. b) Address: Village.:………......…Commune:………………… District:…………………..…… Regional State:………………..		
2.	Date of Commencement of the Construction	………………………………(dd/mm/yy)	Pass □ Fail □
3.	Name + Registration Number of Mason on site	Name:……………………………….. Regd. Number:………………	Pass □ Fail □
4.	N0. of households using the biodigester?	a)1 □ b) 2 □ b) 3 □	Pass □ Fail □
B.	**Biodigester Feeding**		
1.	Biodigester Size	....m^3	Pass □ Fail □
2.	No. of Cattle and Pig	Cattle: Adult……. Calf………. Total………. Pig: Adult……. Calf………. Total……….	Pass □ Fail □
3.	Total dung production	…………kg	Pass □ Fail □
4.	Is dung being collected for the initial feeding?	a) Yes □ No □ b) Quantity collected:……..kg	Pass □ Fail □
5.	Provision of toilet attachment	a) Yes □ No □	Pass □ Fail □
C.	**Location of Biodigester Site**		Pass □ Fail □
1.	Is Biodigester location suitable?	a) Yes □ No □ b)Comment:………	Pass □ Fail □
2.	Distance from:	a)Kitchen: …m b)Animal Shed: …m c)Structure: ……m d)Tree: ……m e) Drinking Well:…..m f) Main road ....m	Pass □ Fail □
3.	Flood/stagnant water problem	a)Yes □ No □	Pass □ Fail □
D.	**Bricks**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Shape	Good □ Fair □ Bad □	Pass □ Fail □
2.	Sound	Good □ Fair □ Bad □	Pass □ Fail □
3.	Drop test	Good □ Fair □ Bad □	Pass □ Fail □
4.	Are they the best locally available?	Yes □ No □	Pass □ Fail □
E.	**Sand**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Bottle test	…………..…% impurity	Pass □ Fail □
F.	**Gravel**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Cleanliness	Good □ Fair □ Bad □	Pass □ Fail □
2.	Maximum size	…….……. mm	Pass □ Fail □
3.	Shape	Good □ Fair □ Bad □	Pass □ Fail □
G.	**Cement**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Quality of Cement	Good □ Fair □ Bad □	Pass □ Fail □
2.	Brand name		Pass □ Fail □
3.	Lumps	Yes □ No □	Pass □ Fail □
H.	**Emulsion Paint**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
4.	Quality of Paint	Good □ Fair □ Bad □	Pass □ Fail □
5.	Brand name	……………………. □	Pass □ Fail □
H.	**MS Reinforcement rod**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Diameter	……… mm	Pass □ Fail □
2.	Condition of Rods (not too rusted etc)	Good □ Fair □ Bad □	Pass □ Fail □
I.	**Construction**	**Pass □ Fail □ Action:…………………………………..**	Pass □ Fail □
1.	Layout of plant made correctly?	Yes □ No □	Pass □ Fail □
2.	Diameter of digester	a)………cm (Standard = ………cm)	Pass □ Fail □
3.	Depth of excavation	a)………cm (Standard = ………cm)	Pass □ Fail □
J.	**Overall Quality**	**Pass □ Fail □**	Pass □ Fail □
1.	What is the quality of construction of the digester and dome (if completed)?	Good □ Bad □ Not Complete □ Comment:…………	Pass □ Fail □
2.	What is the quality of construction of the outlet tank (if complete)?	Good □ Bad □ Not Complete □ Comment:…………	Pass □ Fail □
3.	What is the quality of construction of the inlet (if complete)?		Pass □ Fail □
4.	Overall Quality of Workmanship	Good □ Fair □ Bad □ Comment:………………….	Pass □ Fail □
K.	**Financing**	**Pass □ Fail □**	Pass □ Fail □
1	Do the users know the cost of biogas plant and their contribution?	Yes □ No □	
2	Do the users know about the credit and subsidy mechanisms?	Yes □ No □	

L	Items to be Fixed by Mason	Overall Comments	Signature of Inspector Signature of Mason	Comment: Signature of QC

Signature of the user:	**Inspector**

Form 9

National Biogas Programme

Quality Inspection Form – *Final Acceptance (Before Filling)*

Date of Inspection:…………

A. Biodigester Details			
1. Biodigester ID	Serial Number:……………………..		
2. Name and Address of Owner	Name…………………………………ID Card No:………. Village:…………….. Commune…………….District…………………………. Regional State…………………………		
3. Name of Mason	Name………………………………… Regd. No. …………………….		
4. Biodigester Size	....m³		
5. Construction Period	a)Started: ..………… b)Completed: ....……… c)Total Days: ………..		
6. Reason if longer than 30 days	…………………………………………………………………………………………		
7. Is there a toilet at the customer's house?	Yes □ No □		
8. Is the toilet connected to the biodigester?	a)Yes □ No □ b) Will connect later		
9. Total quantity of Dung available for Feeding per day	………… kg		
To be filled by PBPO Supervisors		**Auditing (QC on QC)**	
B. General Construction Quality **Pass □ Fail □** **Action:**…………………………………..			
1. Site suitable for Biodigester	Yes □ No □	Pass □	Fail □
2. Top filling over dome	Good □ Fair □ Bad □	Pass □	Fail □
3. General quality of workmanship	Good □ Fair □ Bad □	Pass □	Fail □
4. Total quantity of cement used	…….. bags	Pass □	Fail □
D. Inlet **Pass □ Fail □** **Action:**…………………………………..		Pass □	Fail □
1. Type of inlet	Mixing chamber □ Channel for pig manure □	Pass □	Fail □
2. Finishing	Good □ Fair □ Bad □	Pass □	Fail □
3. Inlet floor vs. bottom of overflow opening *(use flex pipe)*	well above □ just above □ below □	Pass □	Fail □
E. Digester and gas holder **Pass □ Fail □** **Action:**…………………………………..		Pass □	Fail □
1. Finishing of floor and walls	Good □ Fair □ Bad □	Pass □	Fail □
2. Plastering inside the digester and gas holder	Good □ Fair □ Bad □	Pass □	Fail □
1. Inlet pipe position in the digester	Good □ Fair □ Bad □	Pass □	Fail □
F. Outlet **Pass □ Fail □** **Action:**…………………………………..		Pass □	Fail □
1. Floor and wall finishing	Good □ Fair □ Bad □	Pass □	Fail □
2. Backfilling against the wall	Good □ Fair □ Bad □	Pass □	Fail □
G. Toilet (if connected) **Pass □ Fail □** **Action:**…………………………………..		Pass □	Fail □
1. Position of Pan level vs. bottom of overflow opening	well above □ just above □ below □	Pass □	Fail □
2. Pipe Provisions for future attachment	Yes □ No □	Pass □	Fail □
3. Positioning of inlet pipe in the digester	Good □ Fair □ Bad □	Pass □	Fail □
H. Pipes and Accessories **Pass □ Fail □** **Action:**…………………………………..		Pass □	Fail □
1. Quality of dome gas pipe	Good □ Fair □ Bad □	Pass □	Fail □
2. Quality of main gas valve	Good □ Fair □ Bad □	Pass □	Fail □
3. Type of gas pipe	PVC □ Flexible plastic □ GI □ (dia Φ: …)	Pass □	Fail □
4. Total length of gas pipe	…..m		
5. Quality of gas pipe	Good □ Fair □ Bad □	Pass □	Fail □
6. Unnecessary fittings	Yes □ No □	Pass □	Fail □
7. Depth of pipe trench	……… cm Not buried □	Pass □	Fail □
8. Sealing agent	Good □ Fair □ Bad □	Pass □	Fail □
9. Quality of stove	Good □ Fair □ Bad □	Pass □	Fail □
10. Number of burners	1 □ 2 □ 3 □	Pass □	Fail □
11. Location of stove	Appropriate □ Not Appropriate □	Pass □	Fail □
12. Quality of connecting pipe	Good □ Fair □ Bad □	Pass □	Fail □
13. Quality of gas tap	Good □ Fair □ Bad □	Pass □	Fail □
14. No. of lamps	1 □ 2 □ 3 □	Pass □	Fail □
15. Quality of lamp	Good □ Fair □ Bad □	Pass □	Fail □
16. Location of lamp	Appropriate □ Not Appropriate □	Pass □	Fail □
17. Quality of gas pressure gauge	Good □ Fair □ Bad □	Pass □	Fail □
18. Positioned of water drain at lowest point in pipeline?	Yes □ No □	Pass □	Fail □
19. Water drain pit constructed correctly?	Yes □ No □	Pass □	Fail □
20. Water drain pit cover ok, and in place?	Yes □ No □	Pass □	Fail □
I. Gas Tightness and Water Tightness *(if used)* **Pass □ Fail □** **Action:**…………………………			
1. Gas Tightness *(if done)*	Pass □ Fail □	Pass □	Fail □
2. Any gas leaks under pressure?	(a) No leaks □ (b) Gas Leaks from	Pass □	Fail □
3. Water Tightness *(if done)*	Pass □ Fail □	Pass □	Fail □
J. Compost Pit			
1 Compost pits constructed?	None □ One □ Two □	Pass □	Fail □
2 Total volume of pits (approximate)	……………… Cum m		
K. Financial			
1. What was the actual overall total cost of your plant including your contributions?	………………US$	Pass □	Fail □
2. Credit taken from	Not taken □ Bank □ MFI □ Other:………	Pass □	Fail □
3. How long did it take to arrange the loan?	a)……… days b) Not Applicable □	Pass □	Fail □
4. What is the interest rate and repayment period of the loan?	a)…% per month b) Period……..months	Pass □	Fail □
5. How much subsidy did you receive?	No subsidy □ Euro ………..		
6. Did anyone get any training on how to use the biodigester?	Yes □ No □	Pass □	Fail □
7. Have you received Biodigester O& M Manual?	Yes □ No □	Pass □	Fail □
8. Have you received guarantee certificate?	Yes □ No □	Pass □	Fail □

Items to be Fixed by Mason		Signature of Inspector: …………………………..	Comments :
		Signature of Mason …………………..	Signature of QC Supervisor…………………

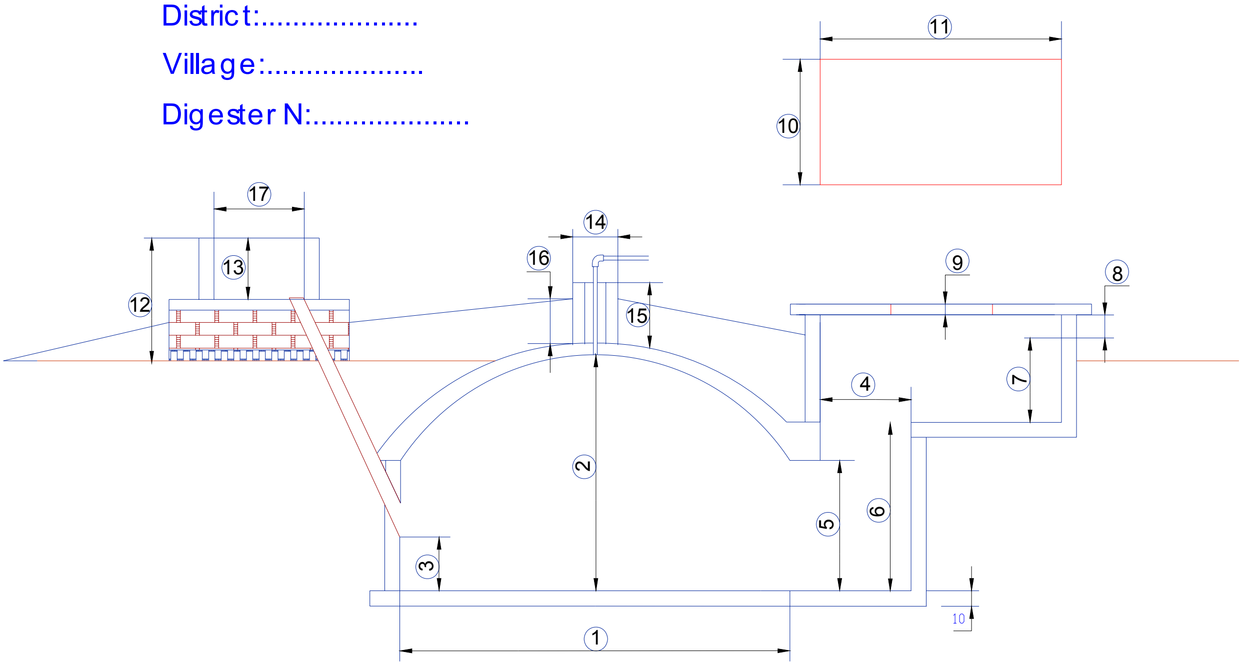
Approved for feeding □	**Not Approved for Feeding □**
Approved by PBPO Officer	Name:…………………………………Signature:…………………. Date:……………..
Agreed by the Mason	Name:…………………………………Signature:…………………. Date:……………..
Witnessed by the User	Name:…………………………………Signature:…………………. Date:……………..

Final Measurement of Various Components (if inspection is made before filling the plant)

District:....................

Village:....................

Digester N:....................



SN	Component	Dimention		Deviations with in tolerance?	Tolerances
		Actual	Standard		
1.	Inner Diameter of digester:				± 2%
2.	Total inner height of digester:				± 5cm
3.	Height from floor of the digester to bottom of inlet pipe				± 5cm
4.	Length and breadth of manhole floor:				± 2cm
5.	Height of manhole (height of round wall):				±5cm
6.	Height of manhole up to the floor of outlet:				± 2cm
7.	Height of outlet up to the bottom of over flow opening				± 5cm
8.	Height of overflow opening:				± 2cm
9.	Thickness of slab:				± 1cm
10.	Inner Breadth of outlet:				± 5cm
11.	Inner Length of outlet:				± 5cm
12.	Height of inlet tank/chamber from the ground level:				± 5cm
13.	Inner height of the inlet chamber:				± 5cm
14.	Size of turret:				± 5cm
15.	Height of turret:				± 5cm
16.	Height of top filling over dome:				± 5 cm
17.	Inner diameter of inlet				± 2cm

Optional Information

L. User Training and knowledge **Pass (min 20/28 correct) □** **Fail □**

Action:………………………

1.	How much dung must you feed into the plant each day?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
2.	How much water must you feed into the plant each day?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
3.	What determines the quantity of gas production?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
4.	When should you **close** the main gas valve?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
5.	How do you check for gas leaks?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
6.	What should you do if there is a problem?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
7.	How do you drain water from the gas pipes?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
8.	How often should you drain water from the gas pipes?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
9.	What must you always check and do at the outlet tank?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
10.	How do you light the stove? (ask user to do for you)	a)…………..	b) Pass □	Fail □	Pass □	Fail □
11.	With the gas tap, how should you make the flame look and sound?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
12.	How can you ensure the efficient burning of the stove?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
13.	How do you light the lamp? (ask user to do for you)	a)…………..	b) Pass □	Fail □	Pass □	Fail □
14.	How can you save gas so that you have longer time for use?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
15.	How do you make compost?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
16.	What can you build over compost pits to improve compost?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
17.	What can you do to improve the safety of your family around the biodigester?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
18.	What can you do to improve the safety of your family in the kitchen with the new gas stove and lamp?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
19.	How can you estimate the quantity of gas inside the gas holder?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
20.	What should you do if the digester is always full (more gas than you need)?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
21.	What is the use of the gas pressure meter	a)…………..	b) Pass □	Fail □	Pass □	Fail □
22.	How do you avoid the scum formation in the biogas plant?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
23.	If the gas stops because of a scum layer forming inside the digester, how would you fix it?	a)…………..	b) Pass □	Fail □	Pass □	Fail □
24.	What should be taken care while emptying the biogas plant?	a)…………..	b) Pass □	Fail □	Pass □	Fail □

Form-10

National Biogas Program

Form for Plant Monitoring before the maturation of Warranty Period

(Form for Mason/Supervisor)

(This evaluation shall be filled about one week before the end of warranty period and should be done on-site accurately and high responsibility. Any points do not comply with the real figure or condition leads to cause penalty and compensate on the own expenses.)

General Information:	**To be filled by the Mason**
Name of Owner	……………..……….
Name of Mason	…………………………….
Date of Visit	…/……/200…
Address	Village…………. Commune…..………. District…….…….. Regional State……………
Biodigester Size:	4/6/8/10/15 cum
Plant Completed Date	..…/…..../200….
End of warranty Period Date	…../…..../200….
Plant Code	………………………….
Visited by (Mason)	……………….…….
Name of user(s) consulted during visit	1. ……………..……………… 2. ……………..…………..……
Number Animal	Cow....... Pig……Buffalo...........
Feeding per day	..............Kg
Plant Structure	
Condition of mixing tank	Good ☐ Fair ☐ Damaged ☐
Condition of turret main Condition of main gas valve	Good ☐ Fair ☐ Damaged ☐ Good ☐ Fair ☐ Damaged ☐
Condition of outlet tank	Good ☐ Fair ☐ Damaged ☐
Condition of Water drain Chamber	Fine☐ Minor problems☐ Major problems☐
Condition of Top filling	Enough ☐ Not enough ☐ filling ☐
Gas Pipe System and Appliances	
Leakage in pipe line	Yes ☐ No ☐
Condition of Pressure gauge	Proper ☐ Not Proper ☐
Functioning Pressure gauge, usual pressure in:	Close main valve for10-20 min. and check) – ask the users
- early morning	………………
- Noon	………..……
- late evening	……………..
No. of Gas Stoves	1 / 2 /3
Functioning of Gas Stove(s)	Fine☐ Minor problems☐ Major problems☐
No. of Lamps	1 / 2 / 3 / 4 / 5
Functioning of gas lamps	Fine☐ Minor problems☐ Major problems☐
Functioning of Water trap	Fine☐ Minor problems☐ Major problems☐
Functioning of gas taps	Fine☐ Minor problems☐ Major problems☐
Use of Gas Stove	………………… hours per day total
Use of Gas Lamp	…………………. hours per day total
Enough gas to cook/light	Yes ☐ No ☐
How often not enough gas	Daily ☐ Some times in a week ☐ sometimes in a month ☐
Reason for insufficient gas	Less feeding ☐ problems with plant ☐ longer hours of gas usage ☐ others …… ☐ Very Often ☐ Some times ☐ Never ☐
How often too much gas What the users do if too much gas	Flare it ☐ Use it for something ☐ Let it escape ☐
Slurry Management	
No. of Slurry pit	0/ 1/ 2
Size of slurry pit	Enough ☐ Small ☐ Very Small ☐
Compost hut	Constructed ☐ Not constructed
Condition of compost hut	Good ☐ Fair ☐ Poor ☐
Use of liquid slurry	Yes ☐ No ☐
Use of semi-liquid slurry	Yes ☐ No ☐
Use of compost	Yes ☐ No ☐
Overall Situation	Properly Managed ☐ Fairly managed ☐ Poorly managed ☐
Documentation present:	
- User manual	Yes ☐ No ☐
- Slurry booklet	Yes ☐ No ☐
- Form no. 9	Yes ☐ No ☐
- T-shirt	Yes ☐ No ☐
- other document	Yes ☐ No ☐
ASS and Repairing record:	**description:** (copy from the guarantee certificate backside)
1st visit: - Date	……..../……./200
- Works done	………………………………………
- Cost of Repair works	USD..
2nd visit: - Date	……..../……./200

- Works done	………………………………………
- Cost of Repair works	USD…………
3rd visit : -Date	……../……./200
- Works done	………………………………………
- Cost of Repair works	USD………………….
No of Visit from PBPO staff	1/ 2/ 3/ 4
Did any members attend user training?	Yes ☐ No ☐
User's level of satisfaction	Fully satisfied ☐ Partly satisfied ☐ Not-satisfied ☐
Reason for not satisfying	o …………………………………… o …………………………………… o ……………………………………
User's view on current performance	No problems ☐ Ok but some problems ☐ Plant not functioning ☐
Existing problems reported by the user(s), if any	1. …………………………………. 2. …………………………………. 3. ………………………………….
Overall condition of plant	Good ☐ Fair ☐ Poor ☐
Comments on Overall Condition and functioning of the plant	……………………………………….. ……………………………………….. ………………………………………..
Recommendation for follow-up action including the deadline	……………………………………….. ………………………………………..
Recommendation for Release of Guarantee amount	Yes ☐ No ☐

Signature of Mason: …………………
Date: ……/……../200…

Signature/Finger Print of Plant Owner: ………..….
Date: ……/……../200…

Form 11

National Biogas Program

BIODIGESTER MONITORING FORM

Inspection date:……………………

Household Details		
1.	Biodigester ID	Serial Number:……………………..
2.	Householder	Name:……………………………… Telephone Number:…………………………………
3.	Address	Village/commune:…………….. District:…………………… Regional State:……………………
4.	Biodigester Size	...........................m^3
5.	Date of Visit	....
6.	User Visited	……………………………………………………………*(Name and position in house)*
7.	Purpose of Visit	Regular QC Check □ User Problem Reported □ Other: ……………………
8.	User's General Satisfaction	Very Happy □ Quite happy but some problems □ Disappointed with System □
9.	User's view on current performance?	No problems □ Ok but some problems □ Plant not functioning at all □ Problems Reported:
10.	Average Duration of Gas Use?	a) Use of Gas Stove: ………………… hours per day total b) Use of Gas Lamp: …………………. hours per day total c) Do you have enough gas for cooking and/or lighting? a) Yes □ No □ d) If no, how often do you not have enough gas? Daily □ Some times in a week □ sometimes in a month □ e) If no, what you think is the reason for insufficient gas? Less feeding □ problems with plant □ longer hours of gas usage than anticipated □ others .... □ f) How often do you have too much gas? …………times/mth g) What do you do if there is too much gas? Flare it □ Use it for something □ Let it escape □
11.	Do you use the Bioslurry?	a) Yes □ No □ b) If Yes, how, and is it effective?: …………………………………………………. b) If No, why not?: ………………………………………………………………………………………..
12.	General Condition of Plant (from Inspector)	Very Good Condition □ Satisfactory Condition □ Poor Condition □ Comments:
13.	Any problems found by inspector?	No, working fine □ Some small problems □ Major problems □ Problems Found:
14.	Repair Actions by Inspector during Visit:	
15.	Condition of Plant after Actions:	No problems □ Ok but some problems □ Plant not functioning at all □ Problems Remaining:
16.	Instructions given to the User:	
17.	Follow-up Actions Needed (+ dates):	

Inspector	**User**
…………………………………………	…………………………………………
Name:………………………………… Date:……………	**Name:………………………………… Date:……………**
Organisation:……………………… Position:…………………..	

Form-2(b)

National Biogas Programme

Baseline Survey Form

Instructions:

- Conduct this survey with each new customer, some time before construction is complete
- ALSO do this survey for 1-2 additional households, close to the potential Biogas customer

A. General Household Information		
1. Address: a) Village:…………………………….. b) Commune:……………………………………………. c) District: …………………………………………. d) Regional State: …………………………………………….	2a) Name(s) of householder: ………………………………… b) ☐ Male ☐ Female c) Main occupation: …………………………………	3a) Name of interviewer: …………………………………… b) Date: ……………………..
4. Condition of the house: a) Building material: ☐ Concrete ☐ Brick ☐ Wood ☐ Thatched ☐ Others................................. b) Roofing material: ☐ Tile ☐ Iron ☐ Thatched ☐ Others...		
5.a) Number of people in household:	5.b) Number of people between 10 and 60 years old:	
5.c) Number of children below 10 years old:	5.d) Number of people above 60 years old:	
B. Income and Expenditure		
6. Main source(s) of income (Rank from the most to the least important in numerical order, start from 1 which is the most important): ☐ Rice farming ☐ Livestock ☐ Business, specify:………………………… ☐ Small trade ☐ Others, specify:...		
7. Income and expenditure	Amount Per Month in Dry Season	
Household Income (estimate average):	a)…………………………US$	
Total Household Expenditure (estimate average):	a) ……………………..……..US$	
8. Household Assets	How many in the Household?	Estimated Value?
Television	a)……………………………..	b)………………..US$
Motorbike	c)……………………………..	d)………………..US$
Car	e)……………………………..	f) ………………..US$
Stereo	g)……………………………..	h)………………..US$
Tractor	i)……………………………..	j) ………………..US$
Diesel Generator	k)……………………………..	l) ………………..US$
Other: ………………………………………………..	m)…………………………..	n) ………………..US$
9. a) Do you have any agricultural land: ☐ Yes, Owning ☐ Yes, Renting ☐ No b) If 'Yes', how many ha: ☐ Rice field:………………..(ha) ☐ Other:………………..(ha)		

B. Energy Use and Expenditure					
Energy Type	Main Use Cooking, Lighting etc	Where from? Market, Forest etc	Cost? …….US$ per ….. (or hours/day if free)	Quantity Used in Dry Season?	Quantity Used in Wet Season?
10. Firewood	a)	b)	c)	d)	e)
11. Charcoal	a)	b)	c)	d)	e)
12. LPG	a)	b)	c)	d)	e)
13. Kerosene	a)	b)	c)	d)	e)
14. Electricity	a)	b)	c)	d)	e)
15. Diesel (non-transport)	a)	b)	c)	d)	e)
16. Diesel (transport)	a)	b)	c)	d)	e)
17. Petrol for Transport	a)	b)	c)	d)	e)
18. Other: …………………	a)	b)	c)	d)	e)
C. Fertilizer Use and Expenditure					
Fertilizer Type	Main Use Rice, Vegetables etc	Where from? Market, Animals etc	Cost? …….US$ per ….. (or hours/day if free)	Quantity Used in Dry Season?	Quantity Used in Wet Season?
19. Animal Dung	a)	b)	c)	d)	e)
20. Chemical Fertilisers	a)	b)	c)	d)	e)
21. ……………	a)	b)	c)	d)	e)

D. Health, Sanitation and Environmental Conditions
22) Has anyone in this household had a serious respiratory problem in the last 6 months? ☐ Yes ☐ No
23) Has anyone in this household had a serious eye infection or problem in the last 6 month? ☐ Yes ☐ No
24) How often the children in the households get diarrhoeal diseases? ☐ Quite Often ☐ Some times in 3-4 months ☐ Very rare
25) How often does someone in the household get sick? ………………..times per month
26) How often is there a problem with bad smell from animal or household wastes? …………………….. times per month
27) Where is the cattle dung and household wastes dumped? ☐ In wet pit or lagoon ☐ In semi wet areas ☐ In dry areas (this info is needed for CDM)
28) Where do you defecate? ☐ In private latrine ☐ In open spaces surrounding the house ☐ In open spaces far from house

D. Household Tasks		
	Minutes per Day (estimate average)	Who usually does this? (eg: Husband, Mother, Daughter, Son etc)
29. Collecting Firewood	a)	b)
30. Cooking Breakfast	a)	b)
31. Cooking Lunch	a)	b)
32. Cooking Dinner	a)	b)

33. Cooking Animal Feed	a)	b)
34. Cleaning cooking vessels		
35. Collecting water		
36. Collecting the feed/fodder and feeding the cattle		
37. Other Cooking: ……………………….	a)	b)
38. Do all the children above 6 in the household go to school?	□ Yes all □ Only the boys □ Only the girls □ None	
Thank you very much!		

<u>Form 04</u>

National Biogas Programme

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 Biogas plants				
B	***Construction and Maintenance***				
B.1	Construction of biogas plant				
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

National Biogas Programme

LIST OF BIOGAS PLANT 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-3

National Biogas Programme

Biodigester Construction Contract

Woreda:……………………. Plant serial no.:…………………….

1. Party A: National Biodigester Supported Household.
   Head of Household Name:………………………………………………………
   Address:……………………………………………………………………….
   Tel: ....
   ID document type and number:………………………………………………….
2. Party B: Regional Biogas Programme Coordination Office (RBPCO).
   RBPCO Director Name:…………………………………………………………
   Address:………………………………………………………………….
   Pphone no.:…………………………………………………………………
3. Party C: Biodigester Mason.
   Biodigester Mason Name:…………………………………………………...
   Address:……………………………………………………………………….
   Tel:...
   ID document type and number:………………………………………………….

All parties agree to participate in the construction of a biodigester at the premises of Party A, upon the following conditions:

Article 1. Scope of work
To construct a biodigester, according the quality standards set by the National Biodigester Programme, **sized ……….m^3** at the premises of Party A.

Article 2. Obligations
Party A. The Biodigester Household

- Prepare the construction site and material according the instructions of Party C.
- In consultation with Parties B and C, set a deadline for the start of the work.
- Provide adequate labour for the digging work and to assist the Biodigester Mason during the construction. OR, agree the mode of payment and pay the mason if the labour is arranged by the mason.
- Pay for the construction work as agreed in Article 3.
- '*Party A transfers all rights, credits, entitlements, benefits or allowances arising from or in connection with any greenhouse gas emissions reductions arising from the operation of the biodigester (Emission Reductions), and agrees to take all necessary action requires to ensure the transfer of those Emission Reductions to the National Biodigester Programme.*

Party B. Regional Biogas Programme Coordination Office (RBPCO).

- Conduct a survey at the premises of Party A to determine the conditions for biodigester construction and advise Party A accordingly.
- Provide Party A with an information sheet containing required building material quantities, cost of appliances, cost of skilled labour, and cost of warrantee and participation fee.
- Assures that Party C, the Biodigester Mason, is trained, experienced and certified in his profession.
- Give full essential technical support to Parties A and C.
- Monitor the quality of the construction work through sample construction inspections.
- Conduct a Plant Completion Inspection. If the plant is considered by the RBPCO Supervisor to be complete and fit to function without problems, it will be handed over to Party A. Party A will receive a signed a stamped Completion report from Party B.
- Guarantees the provision of Euro 193 subsidy upon completion of the biodigester.
- Provision of user training on biodigester operation and bio-slurry application.
- Deposits the warranty fee, paid by Party A, at warrantee savings account and enforce Party C to repair plant the plant if so required under the warrantee conditions.. Within two years if the plants have no any problem, Party B has to release the warranty fees to Party C.
- Issue a warrantee certificate, on behalf of Party C, to party A

Party C. The Biodigester Mason

- Constructs the biodigester according to the National Biodigester Programme quality standards.
- Completes the construction work, including pipefitting and appliances connection, within 20 calendar days. If there delays due to reasons beyond the influence of the mason such as high ground water or rocky soil, a new completion date will be determined in consultation with Party A and B.
- If Party C, due to illness or other personal reasons, is unable to complete the work in time, he will contact Party B for consultation on how to complete the assignment within the agreed period.
- Instructs the biodigester user (Party A) on the proper filling procedure of the biodigester and on the proper use of the biodigester appliances.
- Will work in a responsible manner and therewith minimise the risks of accidents.
- No claims can be made by Party C to Parties A or B in relation to injuries sustained during the construction process.
- After completion, leaves the construction site in a fit to be seen state.
- Provides warranty on the construction within a 24 months period since the completion date mentioned on the completion report.
- Repair the biodigester if any technical problem occurs, in accordance with the warrantee conditions described in the warrantee certificate.
- Visits the biodigester at least once a year during the 2 year warrantee period to check the plant and appliances, also if no complaints have been lodged by Party A.

Article 3. Cost and Payment
The cost of construction materials, sand, gravel, cement, reinforcement rods, GI pipe, will be paid by Party A directly to the supplier. Party A will also make sure these materials will be at the construction site in time. Party C will advise Party A on the required quality and quantity of these materials.

The cost of the skilled labour, amounting to Euro…..........., will be paid directly by Party A to Party C upon completion of the construction.

Party A will pay Party B:

Item:	Number	Cost per Item	Total Cost
Pressure Gauge			
Dome gas pipe			
Water drain			
Stove incl. tap			
Lamp			
………………..			
Warrantee fee			
Participation fee	-	-	15

Party A has to fulfil all financial obligations to Parties B and C upon completion of the construction including the pipefitting and the installation of the appliances.

Article 4. Construction Starting and Completion Date
The construction will start on ………..(day)/………(month)/……..(year) at the latest.
The construction will finish on ………..(day)/………(month)/……..(year) at the latest.

Article 5. Unilateral Termination of construction contract and compensation:
Each party has right to terminate the construction contract unilaterally and can request for compensation when the other party offend contract provisions.

The offending party has to compensate all expenses which the other party had paid for the lost, unless otherwise stated.

Article 6. Complain and dispute settlement:
All complains and disputes will be considered and settled by both parties base on mutual interest. If both parties can not reach final agreement then the matter will be brought before Civil Court for final.

This contract is made in 3 copies of the same value and become effective since the signing date.

Date:………….(day)/………….(month)/………………..(year)

Party A: Head of Household
Full name + Thumb Printing or signature --

Party B: RBPCO Director
Full name + signature --

Party C: Biodigester Mason
Full name + signature --

PLANT DRAWING

Components	Symbol	Dimension per size in cum			
		4 m^3	6 m^3	8 m^3	10 m^3
Length of Outlet	Lo (A)	140	160	170	190
Breadth of Outlet	Bo (B)	120	130	140	160
Height of Outlet	Ho (D)	50	55	60	62
Radius of digester	Rd (F)	110	130	145	155
Radius of pit	Rp (C)	132	152	167	177
Height of digester wall	Hc (H)	80	85	90	95
Depth of pit (excavation)	Dp (E)	165	175	185	195
Height of Dome	Hdom	65	70	75	80
Radius of curvature of dome	Rdom	126	156	178	190
Inner height of digester and dome	Hall (J)	145	155	165	175
Height of maximum slurry displacement	Hd	25	25	25	28
Height of outlet passage	Hop (I)	105	110	115	123
Thickness of concrete in dome (side – centre)		15 - 7	15 – 7	20 – 7	20 – 7
Size of manhole		60 x 60	60 x 60	60 x 60	60 x 60
Inner Diameter of inlet tank		60	60	60	60
Height of inlet tank		60	60	60	60