Domestic Biogas Implementation Guideline




Department of Renewable Energy
Ministry of Economic Affairs
Thimphu : Bhutan
May 2020

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ACKNOWLEDGEMENTS

This study on the Biogas Implementation Guideline has been prepared by M/s. Norlha Engineering and Management consultancy through Department of Renewable Energy (DRE), Ministry of Economic Affairs (MoEA). This study has been carried out to assess some of the project implementation problems and issues and then to come up with implementation strategies for the benefit of the implementing and executing agencies as well as to the users. However, while carrying out the actual task of developing strategy, guideline has become part of the study. Accordingly, both strategy document as well as guideline has been kept since it is really useful planning and making corrective measures towards development of biogas in the country.

The study attempts to strategize on project management, planning, construction, operation and maintenance and monitoring or evaluation through holistic, market-driven and participatory approaches in the implementation of the Biogas Programme. This report is the outcome of the literature review, consultation meetings and interviews conducted with various stakeholders at the national level as well as with the Dzongkhags, Gewogs and users of Biogas in Monggar, Trashigang, Samtse, Chukha, Wangdue, Paro and Haa.

We would like to acknowledge all the individuals and agencies involved in the preparation of this report. We would like to extend our sincere gratitude to DRE and the committee members for their critical input and assisting in developing the methodology and a comprehensive report. We would like to specifically thank Mr. Chhimi Dorji, Principal Engineer, DRE and Mr. Dorji Gyeltshen, Project Director for guiding the field consultations, providing relevant documents and consistent efforts in shaping the report. We would also like to extend our gratitude to all Dzongkhag Livestock Officers of concerned Dzongkhags for their valuable input and assistance in the field consultations with the users.

This report would not have been produced without the full cooperation and inputs received from key stakeholders of government, non-government organizations and biogas plant users throughout the field consultations.

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ACRONYMS

ADB	Asian Development Bank
BBP	Bhutan Biogas Project
BDBL	Bhutan Development Bank Limited
BSB	Bhutan Standards Bureau
BTN	Bhutan Ngultrum
CDM	Clean Development Mechanism
CSO	Civil Society Organization
DoL	Department of Livestock
DPA	Department of Public Account
DRE	Department of Renewable Energy
EA	Executing Agency
FYM	Farm Yard Manure
FYP	Five Year Plan
GDP	Gross Domestic Product
GGC	Gobar Gas and Agricultural Equipment Development Company
GHG	Green House Gases
GNHC	Gross National Happiness Commission
HRT	Hydraulic Retention Time
kW	Kilowatt
LPG	Liquefied Petroleum Gas
M&E	Monitoring and Evaluation
m3	Meter cube
MoEA	Ministry of Economic Affairs
MU	Million Units
NBIS	National Biogas Implementation Strategy
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
PIU	Project Implementation Unit
PVC	Polyvinyl Chloride
RAA	Royal Audit Authority
RMA	Royal Monetary Authority
SGIA	Second-generation imprest account
SNV	Netherlands Development Organization
SWOT	Strengths Weakness Opportunities Threats
TOE	tonne of oil equivalent
USD	United States Dollar
W	Watt

1. INTRODUCTION

1.1 Background

Biogas was first introduced in Bhutan in the 1980s as a clean and renewable energy source for household cooking to help cut down firewood consumption. However, most biogas technologies have been abandoned due to poor technical design and lack of spare parts, repair and maintenance. To assess the biogas market potential in Bhutan, SNV (Netherlands Development Organization), conducted technical feasibility studies, and ADB subsequently undertook the market assessment studies with SNV. These studies have concluded that there are at least 16,000 households that have the potential to use biogas plants cost-effectively.

Bhutan Biogas Project was initially introduced as a joint programme of Asian Development Bank (ADB), Renewable Energy Division (RED) of erstwhile Department of Energy, Department of Livestock (DoL), SNV and Bhutan Development Bank Ltd. (BDBL) since March 2011. The project was aimed to build capacity in the public and private sectors to construct and operate 1,600 biogas plants in four southern districts in the country namely, Samtse, Chhukha, Tsirang and Sarpang, in the period of March 2011 to February 2014. The pilot project was intended to establish the capacity to enable Bhutan to run a large-scale biogas program in the subsequent phases.

The overall target of the Bhutan Biogas Project over the period March 2011 – December 2017 was 4,600 domestic biogas plants and the progress as of December 2019 was 6,087 Biogas plants installed across all 20 Dzongkhags in Bhutan.

The promotion of biogas in the country has picked up and has been very successful in the 11FYP. With the ever-rising demand for the biogas plants from the public, there will be more roll out programs in the 12 FYP. The biogas has not only benefited the rural communities, it has also helped in GHG emission reduction, maintaining carbon neutral and minimizing usage of imported LPG gas and chemical fertilizers. However, due to resource allocation framework where 50% budget is being decentralized to the local government, the requirement for a new implementing mechanism was felt necessary. Therefore, the Department proposes to streamline all the implementing stakeholders so that the biogas program can be implemented smoothly.

1.2 Energy Situation

Bhutan has aggressively pursued electrification through both off-grid and grid connected solutions, achieving a current electrification rate of 99% overall and 98.4% in rural areas. It is also the most widely used sources of energy for cooking with 94.9 percent households. Electricity generation, though still relatively small in comparison with the rest of the world is growing in importance. In 2018, the total electricity generation was 6,940.58 Million Unit (MU). Domestic consumption of electricity has been marginal but is in increasing trend with access to modern facilities. Still firewood is the main source of primary energy for the people of Bhutan, and it represents the largest slice of energy consumption. More than 60% of population lives in the rural areas where they have access to modern forms of energy mix and fuel wood is easily available from the nearby forests wherein, 70 % of country's land mass is covered with forests.

Bhutan's energy demand is dominated by thermal energy (72%), with only 28% of demand being serviced by electricity (Figure 1). Biomass in the form of fuel wood, biogas and briquettes is the largest source of thermal energy, satisfying 36% of total energy demand. It is followed by diesel, coal and other petroleum products (petrol, kerosene and LPG), which satisfy 16%, 15% and 5% of demand, respectively[1].

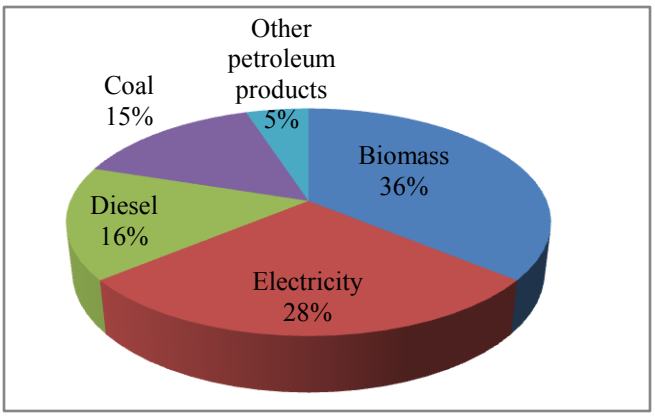


Fig 1: Fuel mix in the economy (TOE)

The energy demand in industry and transport has doubled in the period 2005–2014, making them the fastest growing sectors in terms of energy consumption. Over this period, per capita energy consumption increased from 0.6 TOE per capita in 2010 to 0.69 TOE per capita in 2017, which is indicative of rising industrialization and improving living conditions. While per capita energy consumption is increasing, the energy intensity of the economy as measured by energy consumption per unit of GDP has declined from 3.7 TOE/Bhutanese ngultrum (BTN) to 3.1 TOE/BTN[2].

To assess the biogas market potential in Bhutan, SNV, Netherlands Development Organization, conducted technical feasibility studies, and ADB subsequently undertook the market assessment studies with SNV. These studies have concluded that there are at least 16,000 households that have the potential to use biogas plants cost-effectively. Out of which 6,087 biogas plants are already installed in the field as of December 2019 which is 38% achievement against the potential in the country.

1.3 Status of Biogas

The Biogas Project has immensely benefited farmers in 20 Dzongkhags by successfully installing 6,087 biogas plants as of December 2019 which led to reduction in their daily workload and household expenditure.

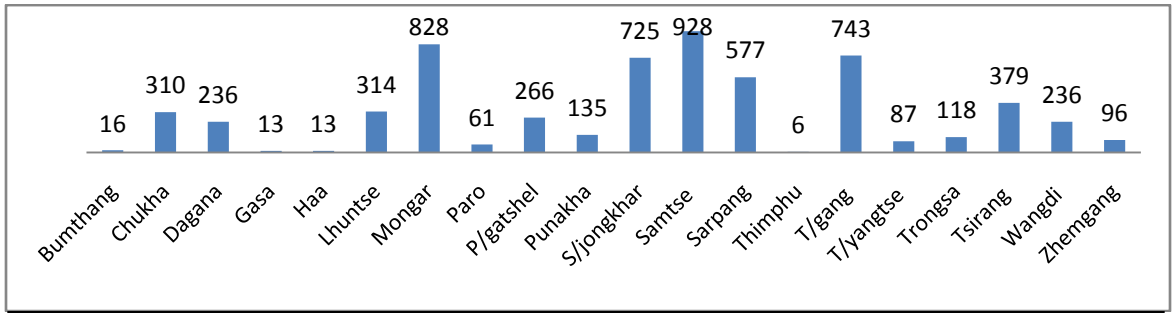


Fig 2: Status of biogas plants

[1] Energy Status of MoEA, 2018
[2] National Statistics Bureau, Year Book 2019

In rural areas, firewood collection is one of the main concerns for farmers and is a difficult task specially at this time when the forest is depleting with more human activities, it is also time consuming and risky for a sustainable environment. As such, biogas introduction have played an important role in enhancing farmers' livelihood and environment.

The installation of biogas costs between Nu. 36,000 to Nu. 48,500 to set up a biogas plant depending on the size of the plant ranging from 4, 6, 8 and 10 cubic metres in the country. In order to ease the burden for the cost of installation of the biogas plant as well as to encourage adoption of biogas by the rural homes. The project has collaborated with the Bhutan Development Bank Limited to provide a loan of Nu. 20,000 to farmers for a biogas plant set up. Besides, farmers can also avail a subsidy amount of Nu 11,700 for all types of plant irrespective of the size of the biogas plants.

A household with biogas can save 2000 kgs of firewood, 2555.5 litres of kerosene, 164.25 kgs of liquefied petroleum gas, 1460 kilowatt of electricity and 5000 kpgs of carbon dioxide in a year. The biogas is also beneficial for human health, environment and agriculture farming. At the moment, biogas in Bhutan is mainly used for cooking. In other countries, it is used for lighting and duel fuel engines as well. As per the results of the biogas user survey 2015, it was found that the users were satisfied with biogas technology with no identification of disadvantages and was considered more helpful by women.

In order to sustain the biogas project, about 3,793 user trainings were conducted for the beneficiaries, awareness promotion was also created to about 3,926 people in the rural areas, 629 masons trained on bio-digester construction as well as to 308 supervisors as of December 2019.

1.4 Benefits of Biogas

As per the best practice, an average biogas plant serving a household of 5 to 6 people generates the following benefits:

a) Farmers with 2 cows can generate sufficient biogas to meet daily basic cooking and lighting needs of the small family in a house;

b) Saving of traditional cooking fuel such as firewood (2000 to 3000kg/year) or kerosene (300 to 350liters/year);

c) Reduction of workload 1.5 to 3 hours per day per household;

d) Reduction of green house gasses up to 5 ton of CO_2 equivalent per year;

e) Reduction of indoor air pollution 3 persons per household less exposed;

f) Toilet attachment up to 65% of all biogas households have latrines connected to the biogas plants;

g) Potential increase of agricultural production or saving on the use of chemical fertilizer (biogas plants produce very high quality organic fertilizer-bio slurry up to 40%); and

h) Improved household and environmental sanitation and less pollution to ground water.

The direct benefits of the biogas are increased access to modern household cooking and heating, reduced greenhouse gas emissions, and reduced deforestation. The indirect benefits include: a reduction in adverse health effects from indoor air pollution resulting from firewood smokes, a reduction in time spent collecting firewood, and an improvement of crop yields through the use of organic by-product from the biogas plants.

1.5 SWOT analysis

In order to determine the major issues, SWOT analysis was undertaken in terms of Strengths, Weaknesses, Opportunities and Threats, then to come up with proper strategies to overcome the issues as follows.

Strengths	**Weaknesses**
a) Due to success of project, there is support from the Royal Government to upscale the project; b) Well written advocacy document as references for construction, operation and maintenance of the plants; c) Availability of trained and experienced people working for the project; d) Well established financial subsidy and credit system from the financial institute and the donor agencies; e) Cooperation from farmers for installation of biogas plants and willingness for investment; f) Availability of dedicated project office with proper linkages from the Dzongkhag and Gewog livestock offices; g) Established links with the suppliers, manufacturers and technical experts. h) Well established systems in place in terms of application procedure and approval process.	a) Awareness and advocacy created to the farmers are not adequate; b) Availability of low quality biogas appliances in the market; c) High cost of construction materials and lack of labour; d) In adequate gas production especially during winter months; e) Inconsistent stock of cattle in the rural homes which leads to uncertainty of biogas plant production; f) Lack of inadequate number of trained masons or technicians in the villages; g) Inadequate number of staff in the project office as well as in the Dzongkhags or Gewogs to cover the plants that too biogas is not their actual responsibility; h) Lack of regulatory framework in the biogas sector.
Opportunities	**Threats**
a) Government's more focus on conservation of energy and preservation of forests; b) Importance given by the Government on production of organic vegetable; c) There is raising cost of import on fossil fuels for cooking, heating and other requirements; d) Emphasis on import substitution for local products as well as for fuels; e) Increasing importance on sanitation and hygiene in the rural homes; f) Lot of problems with the waste from urban as	a) Changes in the Government policies, directives and decision will have adverse impact on the biogas project; b) Risk of rural people not taking interest in biogas projects due to availability of other sources of energy; c) Loss of confidence on biogas plants by rural people if there is no sustainability and reliability; d) Price fluctuation of construction materials posses risk to the biogas plant construction; e) Extreme winter weather conditions in some

well as in the rural areas; g) With the shift in the lifestyle of the people living in the rural homes, more people are using LPG for cooking which increases expenditure; h) Support from the donors and financial institutions on collateral free loans and subsidy from the government.	parts of the country which is not favourable for biogas plants; f) Due to rough terrain, some of the remote areas are not accessible by road for transport of materials; g) Lack of readily available appliances or spare parts in the locality.

Deductions from SWOT Analysis

a) The market is characterized as immature for biogas plants;
b) Numerous awareness programmes are conducted for both the supervisors as well as rural people on the benefits biogas but is not enough;
c) Since there is issue of affordability for installation of biogas plants for most of the farmers, subsidy and credit plays a critical role;
d) Except for cooking purposes, the use of biogas for other benefits such as slurry for agriculture manure, fish feed and other usage are yet to pick up;
e) There is immense benefit to forest conservation and substitution of import on LPG and other fossil fuels;
f) There is acceptability of farmers for biogas but there are still rooms to explore appliances for the biogas plant so as to make it available;
g) If there is some way to re-design or adopt different modalities for those colder regions, it would scale up biogas plant in the country;
h) There is need to establish proper supply chain for the supply of biogas appliances specially for maintenance point of view;
i) Proper operation and maintenance need to be re-emphasized through proper trainings and workshops to the rural homes to make it long term sustainable.

2. PROJECT LEVEL MANAGEMENT STRUCTURE

Bhutan Biogas Project is managed and implemented by Project Implementation Unit (PIU) under the Department of Livestock (DoL) supported by ADB under the framework of Energy for All Partnership Programme. The Department of Renewable Energy (DRE) under the Ministry of Economic Affairs is the Executing Agency (EA). SNV provides technical assistance while BDBL supports credit and subsidy administration. The DRE, as the EA, is responsible for overall planning and renewable energy policy support for this component. A high level Bhutan Biogas Project Steering Committee chaired by the Director (DRE) and members from DRE, DoL, BDBL, SNV Bhutan and the Department of Public Accounts under the Ministry of Finance has been established to provide policy direction and oversee the program implementation.

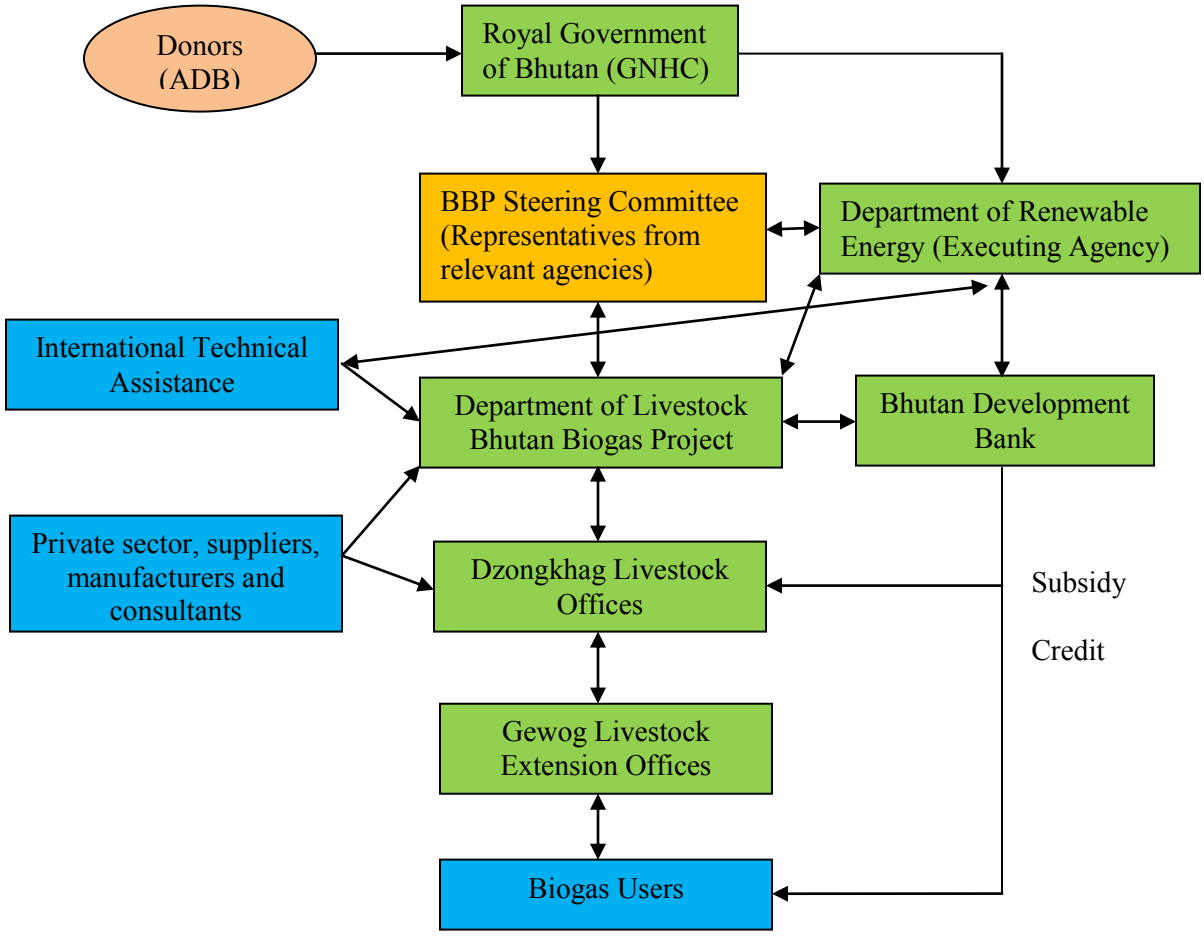


Fig 3: Project Management Structure

2.1 Assessment

The Department of Renewable Energy (DRE) is responsible for monitoring and evaluation of the overall biogas program activities in the country. It is also responsible for the approval of annual plans and reports. For the day-to-day coordination of the program, DRE delegates responsibilities to the Bhutan Biogas Project Office. This office initiates, coordinates, and monitors the activities within the biogas sector, and it is responsible for accounting, financial procedures, and staff management. The project office reports to the Steering Committee and to the Royal Government (DRE, DOL and Other agencies). It works in coordination with both the private and public sectors of the program stakeholders/partners. Representatives of the main national-level program actors form the Biogas Sector Steering Committee for advising on policy and program matters that relate to program implementation.

SNV-Netherlands Development Organization used to provide capacity building and training to the project office, DoL extension officers, private sector participant including masons and other service providers. It also used to act as technical advisory service for the project. At the national level, project office plays a major role while in the Dzongkhags, Dzongkhag Livestock Office carries out coordination, facilitation and monitoring of day-to-day program activities. In terms of

fund support for the project, BDBL is taking the role of financial institution to manage the fund provided by ADB earlier. It also carries out standard procedures for acquiring of fund from the donor and then disbursement of the fund in terms of subsidy and credit. Then there is role of Gewog extension office for supervision and monitoring during the construction and afterwards. There is also involvement of consultants to provide technical support during the initial stages of the project as well as to develop standard documents and systems. Manufacturers and suppliers also play a role for supply of biogas items for the construction of the project. At last farmers have a major role to take decision on the choice of plant size with advice with the livestock office and to mobilize resources for the plant.

Overall, there is no problem with the existing set up and everything is working well except that there is no proper documentation with defined roles and responsibilities of the stakeholders being involved in the project. Without the proper roles and responsibilities, there are cases of limited collaboration and coordination amongst the concerned stakeholders besides Department of Livestock and Department of Renewable Energy.

2.2 Stakeholders and their roles & responsibilities

Following stakeholders have been identified for their role in promoting and implementing Biogas Project in Bhutan.

a) BBP Steering Committee

The BBP Steering Committee shall consist of representatives of the main national level actors in the programme, to coordinate and guide developments in the biogas sector and to look after the policy and programme matters related to programme implementation. The steering committee shall mainly be responsible to:

a) Coordinate the activities of the project;
b) Approve the annual plans and budgets for the project with recommendations from the project office;
c) Approve partner agencies during the implementation of the programme;
d) Advocate within their respective organizations and towards international partners;
e) Set and endorse sector wide quality standards and guidelines;
f) Plan and coordinate biogas related research and development;
g) Analyze policy issues and advise on policy matters (such as subsidy, price, taxation, R&D etc);
h) Decide on programme related matters which are deviating from the approved plan;
i) Mobilize funds and liaise with donors;
j) Monitor progress and evaluate the programme.

b) Department of Renewable Energy

The Department of Renewable Energy (DRE) under the Ministry of Economic Affairs has the mandate to serve as the central coordination agency and the focal point of Royal Government of Bhutan on all matters related to renewable energy development. The department aims to broaden

the energy supply mix by exploring and promoting emerging clean and renewable energy sources and technologies.

a) The department shall support in formulation of enabling policy and standards for the promotion of Biogas in Bhutan;
b) Act as a link between Royal Government represented by GNHC and the external agencies working towards biogas programme;
c) Seek external funds in coordination with GNHC for the project implementation;
d) Carry out coordination among the donor agencies, implementing agency and other biogas stakeholders;
e) Provide technical advice and instruction to the implementing agency as well as other stakeholders who are interested to install the biogas;
f) Carry out planning and progress reporting to government agencies and others whenever required.

c) Department of Livestock

The project implementation unit under the Department of Livestock shall be the central coordinating agency for implementation of biogas project across the country. Specifically, the PIU shall be responsible for the following:

a) Responsible for the proper implementation of the programme;
b) To carry out day to day management and coordination of all programme activities;
c) Administration and management of the project;
d) Prepare report and submit to project stakeholders including DRE, donors and the Royal Government;
e) Work closely with different sections of society, private and the public;
f) Develop annual plans and budgets in accordance with the objectives and submit for approval to the Steering Committee and monitor their implementation;
g) To carry out contracting of suppliers and others during the implementation of the project in line with the annual plan;
h) To administer subsidy and credit including follow up;
i) Selection of appropriate design and development of quality standards;
j) Quality control on construction and after sales service;
k) Application of research and development on the plant design and appliances;
l) Development of curricula for the relevant trainings;
m) Conducting training of trainers courses and its management;
n) Developing national and local promotional material (disseminate biogas information);
o) Coordination of the training and extension efforts.

d) Department of Public Accounts

The Department of Public Account (DPA) under the Ministry of Finance is an agency with a sound government accounting system with professional finance personnel. So they will be responsible for the following:

a) To provide policy direction and to oversee the project's implementation;
b) Efficiently manage the Government Fund through proper cash management;
c) Receive all grants and loans made to budgetary bodies by a foreign government or any other body or person including recoveries of loan principals and other receipts;
d) Approve the opening and use of bank accounts by all budgetary bodies.

e) Bhutan Development Bank Limited

Since majority of the farmers living on subsistence farming, it is obvious that there is no adequate cash in to make the necessary investment for a biogas plant. Therefore, to increase the access of biogas to relatively small farmers, the access to reasonable credit is an essential part of the programme and the participation of financial institute makes a key role. Accordingly, Bhutan Development Bank Limited is selected for providing credit facility to the farmers as well as to ensure smooth flow of subsidy due to its long term experience in rural banking as also its coverage level in the rural areas. Following are its roles and responsibilities:

a) Coordinate and liaise with donor/funding agencies;
b) Come up with standards for the subsidy as well as credit for the biogas project;
c) Plan and make necessary arrangements for disbursing of subsidy and the credit as per the rules and regulations framed for the project;
d) Assessment and approval of potential biogas households for the subsidy and the credit;
e) Prepare progress report and submit to relevant agencies;
f) Coordination with relevant stakeholders and monitoring of the fund.

f) Dzongkhag Livestock Office

The actual implementation of the project in the field lies with the Dzongkhag Livestock Office and also to coordinate project activities with the Gewog extension office. Their role determines the actual installation of the biogas plants as well as for monitoring of the plants. So following are some of the responsibilities of the Dzongkhag Livestock Office.

a) To sensitize farmers about the importance of biogas plant, its benefits and supports provided by the Government for installation;
b) To coordinate with the gewog extension office for the feasibility and potential of the biogas plants in the respective locations;
c) To compile list of potential biogas plants in the Dzongkhag and send to the project office for approval;
d) To assist Gewog extension office on the technical aspects of the biogas plant feasibility study;
e) Coordination during installation of the biogas plant in terms of monitoring, supervision and certification on the completion of the plant;
f) Coordinate and provide after services to the rural homes for the biogas plants in collaboration with the project office;
g) Carry out any other activities that may be required at the Dzongkhag and Gewog level.

g) Gewog Livestock Extension Office

The Gewog Livestock Extension Office plays a critical role in the success of biogas plant installation as well as for proper functioning of the plants. They are also in close contact with the rural homes and will be easier for them to monitor the plants. Thus their roles and responsibilities are as follows:

a) To coordinate with the Dzongkhag Livestock Office and the project office as and when required;
b) Participate in the sensitization activities of the farmers about the importance of biogas;
c) To carry out feasibility study for potential of the biogas plants in the respective locations;
d) To assist rural homes for the application of biogas plants as per the prescribed norms as well as to apply for subsidy and credit facility;
e) To carry out monitoring, supervision and certification of the biogas plants;
f) Coordinate and provide after services in terms of technical assistance during operation of the biogas plants.

h) Masons

Masons are the ones who get involved during the construction of the biogas plants and also during repair and maintenance. So their role is also important for the success and proper functioning of the biogas plants. Accordingly, following are the roles and responsibilities of the masons:

a) To provide necessary information on the benefits of bio-digester to the users and motivate them for installation;
b) Select proper size of bio-digester based upon the availability of feeding materials;
c) To carry out plant layout after studying the feasibility of the location;
d) To carry out construction of the biogas plants with assistance from labour provided by the rural homes;
e) Ensure quality standards of construction materials and appliances;
f) Follow strictly the design and drawing as provided during the construction of the bio-digesters;
g) Comply with the construction manual specifications;
h) Ensure timely completion of the work;
i) Report to supervisor if any required regularly;
j) To assess the work completion and certification in coordination with the Gewog Livestock supervisor;
k) To carry out repair and maintenance as and when required for the plant.

i) Biogas Users

Since the biogas plant beneficiaries are the ones who should take care of their own plants. They have important task to manage and maintain proper functioning of the biogas plants. Accordingly, their responsibility lies in the following:

a) To take a lead in the installation of the biogas plant and seek assistance from the Gewog extension office or the Dzongkhag Livestock Office;

b) To mobilize resources for the construction of the biogas plant such as labour and materials;
c) To carry out regular feeding of dung to the digester with the required amount based on the size of the biogas plant;
d) To monitor and check the proper functioning of the biogas plants frequently;
e) If encountered any problems, report to the concerned technical identified person for their services.

3. PROJECT APPLICATION PROCESS

BBP project implementation is well defined with five stage application process. The process involves expression of interest from the household for validation of construction of the biogas plant by the project representatives. This process takes approximately 4 to 10 week's time. However, there is no real-time tracking or monitoring system to understand the number of applications in the pipeline. Also the information about the project is scattered and not updated on timely manner. The standard procedure for the application is as follows:

a) The Dzongkhag Livestock office and the Gewog Livestock Extension Office together make awareness to the people about the possible opportunities available for biogas plant;
b) Those interested will have to fill up the form (Form-02(a)) with assistance from the Gewog Livestock Extension Officers. The form itself suffices for subsidy application process but the credit portion depends on the individual households;
c) The application forms are submitted to the Dzongkhag Livestock Office and to the Biogas Project Office;
d) Once the applications are approved on the basis of budget availability, the potential sites are visited in order to carry out suitability of the site for the biogas plant;
e) If the sites are found to be feasible, then it is given to go ahead with the plant.

It is found that most of the beneficiaries do not have any difficulties in the application process, neither the Dzongkhag Livestock Office have faced any problem during the approval process of the biogas plant. The only limitation is that applicants have to be screened out based on the availability of budget.

3.1 Standard Application Process

Standard application process for adoption of biogas plant have to be instituted which will enable both applicant and the project office for proper management as well as to maintain quality standards. Accordingly, following are the detailed implementation process.

a) Conducting of field survey. During the field survey, form-02 (a) is used to collect the following information to make concrete decisions.
    i. Household details
    ii. Land information for construction of biogas plant
    iii. Information on water and sanitation

iv. Information on livestock (cattle, sheep, goat, yak, buffalo, pigs, poultry etc.), quantity of dung collection, type of dairy shed, loans if any from which financial institute, type of subsidy received or not and purpose.

All these observations give a complete picture of the household which helps project office to make better planning and its entire development though the observations.

b) At the same time another survey is also conducted by using form-02(b). This survey collects information on the following:
   i. Household information such as details of house type, sources of information, number of people in the house, school going children, those working in service etc.
   ii. Income and expenditure such as sources of income, average income and expenditure, household assets and land.
   iii. Energy use and expenditure such as type of energy used for cooking or lighting, source of energy, cost per unit of energy and quantity used in winter and summer.
   iv. Use of fertilizer and expenditure in terms of type of fertilizer and its usage, source and cost, usage in winter and summer.
   v. Health, sanitation and environment, type of health problems, dumping of cattle dung or household waste, toilet and where they defecate.
   vi. Household task, average time spent on each task and who does those tasks.

Then based on the feasibility of the household as per the survey, installation of biogas plant is determined for each household.

c) Consultation meeting and advocacy is conducted with the villagers and the concerned Gewog Administration to convince them for construction of such biogas plants.

d) Then based on the approval of the biogas plants, masons are trained to carry out construction of biogas plants. Those trained mason along with labour arranged by the households carry out construction after the procurement of construction materials.

4. PROJECT IMPLEMENTATION MECHANISMS

The overall implementation of the project is carried out through central project office established within the Department of Livestock, Ministry of Agriculture and Forests along with Department of Renewable Energy as the Executing Agency. The project office is supported by the Dzongkhag Livestock Office and the Gewog Livestock Extension offices located in various Gewogs. Actual implementation of the project is carried out by the concerned Dzongkhags and the Gewogs while the Project Office provides coordination and planning, sensitization, project management and technical assistance.

During the initial phase of the project, technical assistance was provided through SNV (Netherland Development Organization) to assist the project in capacity building. Further to provide policy direction, guidance and decision making, project steering committee was also formed. The funding arrangement for the project was initially provided by ADB amounting to USD 1,451,100 besides the funding source from SNV and RGoB. Then to ensure effective administration of credit and subsidy components, separate imprest accounts and statements of

expenditures has been established and maintained by the RMA and BDBL. The government has established a first-generation imprest account at RMA and a second-generation imprest account (SGIA) for the BDBL.

It was initially targeted to install 1600 family size household biogas plants benefiting about 10,000 people with the cost of the biogas plant ranging from Nu.25,000 to Nu,40,000 depending on size ($4m^3$ to $10m^3$) and location of the plants. There is also subsidy arrangement of Nu.11,700 per biogas plant irrespective of size and location with contribution from farmers ranging from Nu.10,000 to Nu. 25,000 depending upon size of the plant. There is also arrangement for collateral free loan from BDBL at 10% interest rate.

5. TECHNICAL STANDARDS AND SPECIFICATIONS

A bio-digester is a structure constructed under the ground, made with cement, brick/stone, sand and pipes and appliances to decompose organic material and produce biogas to supplement conventional fuel sources. Bio-slurry is used to apply as organic manure in the farms. By feeding the recommended amount of cattle dung and water every day in the digester, clean gas is produced which is used for cooking and lighting purposes.

5.1 Assessment

The selection of biogas plant model was selected based on the availability of construction materials, degree of building complexity, durability and maintenance demand, ease of use, appropriateness for construction in both hilly and plain areas and cost, Nepalese Model of biogas plant popularly known as GGC Model was adopted.

However, several technical modifications were made to the original design to suit the local context of Bhutan as follows:

a) The gas storage capacity of the biogas plant has been increased to 60% of the total daily production as contrary to 35% in the original design. This modification has been made based upon the cooking pattern of the people. This design ensures gas availability as per the requirement;
b) The HRT has been adjusted to 50 days keeping in view the climatic condition of project districts in Bhutan;
c) The size and relative location of outlet tank has been designed to ensure the required pressure of gas at the point of application;
d) The overflow level has been modified to ensure the flow of bio-slurry by gravity to the slurry compost pit;
e) The orientation of outlet tank has been changed for smooth hydraulic flow of the digester slurry;
f) The thickness of masonry wall has been changed to suit the size of brick available in the local market

There are not many issues and problem regarding the technical specifications as the project has carried out adequate testing and piloting in different regions of the country. However, in some cases, people are having issue over the large space being occupied by the plant, so if the current

design could be modified to suit small places in the general rural homes. In certain areas, there is need of different design of biogas system for colder climate since the present system is not feasible especially during cold winter season.

5.2 Standard to determining plant size and daily feedstock

The size of the biogas plant depends on the quantity, quality & kind of available biomass, average daily feed stock and expected hydraulic retention time of the material in the biogas system. The following points should be considered.

5.2.1 Sizing the digester

The size of the digester, i.e. the digester volume Vd, is determined on the basis of the chosen retention time RT and the daily substrate input quantity Sd. Vd = Sd × RT [m3 = m3/day × number of days], Where, Vd is in m3; Sd in m3/day or L/day; RT in Days; Biomass/Organic material in kg and Water in L.

The retention time, in turn, is determined by the chosen/given digesting temperature. For an unheated biogas plant, the temperature prevailing in the digester can be assumed as 1-2 degree Kelvin above the soil temperature. For a plant of simple design, the retention time should amount to at least 35 days.

Substrate input (Sd) = biomass (B) + water (W) [m3/d], in most biogas plants, the mixing ratio for dung (cattle and/or pigs) and water (B: W) amounts to 1:1.

5.2.2 Average daily feedstock

Generally, 20 to 40 kilograms of feedstock complimented with 20 to 40 liters of water per day with a hydraulic retention time of 40 days will require a 4-cubic meter plant; Table 1 below gives some relevant data about the different sizes of biogas plants.

Sl.No	Plant capacity (m^3)*	Daily gas production (m3)	Fresh dung required per 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

Table 2: Plant size and average daily feedstock

5.3 Standard components of biogas plant

The biogas plant is also commonly known as a bio-digester, bioreactor or anaerobic reactor. Principally, a biogas plant should have three essential components which are as follows[3]:

Digestion Chamber: Anaerobic reaction or digestion of organic matter by methanogenic bacteria takes place in the digestion chamber which needs to be airtight.

Inlet: An inlet structure is used as a medium to feed organic matter into the digestion chamber.

Outlet: An outlet structure is required to remove the digested organic matter, i.e., the effluent from the digestion chamber. The elevation of outlet level is always maintained lower than that of the inlet structure such that one way flow of digested slurry (effluent) can be maintained.
Any design that satisfies the above three criteria can produce biogas provided that organic matter is fed into the chamber and the ambient temperature is favorable for bacteria to decompose organic inputs.

The main components of biogas plant are mixing pit (inlet), digester, gas holder, outlet tank also known as hydraulic or expansion chamber, gas pipes, appliance system and compost pit. A urine collection tank is also constructed in some plants.

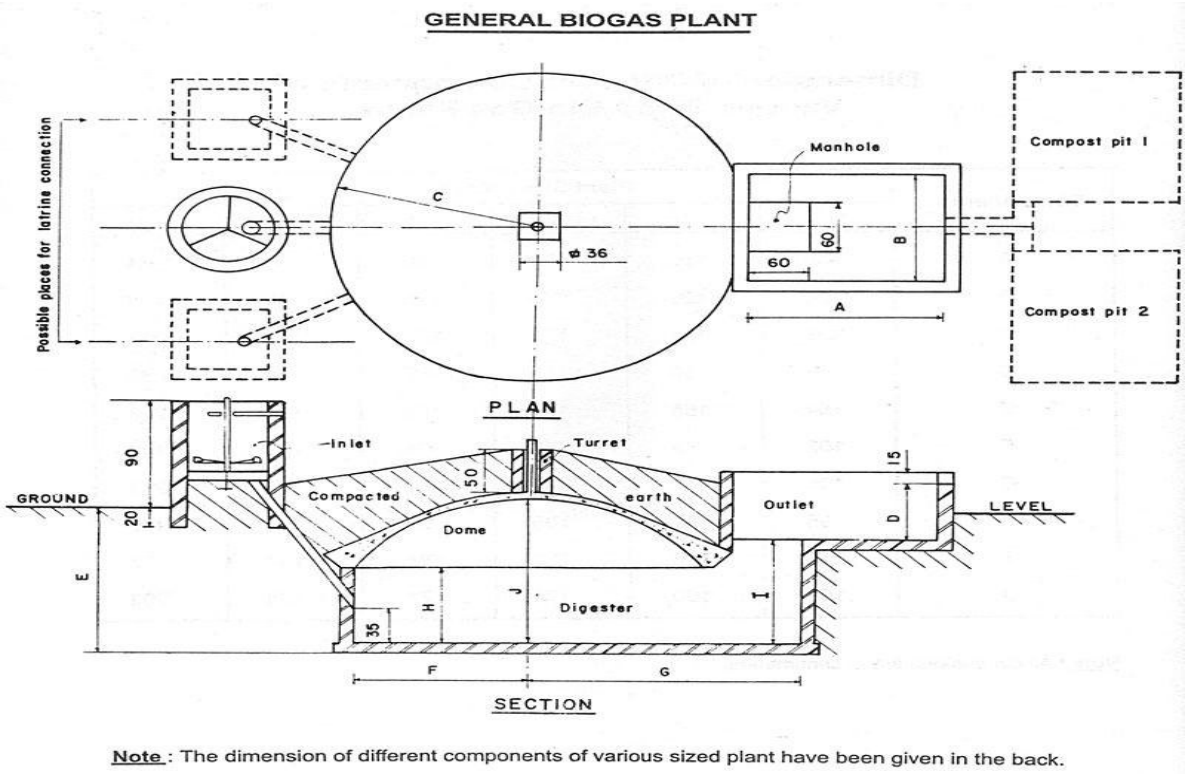


Fig 3: General Biogas Plant

[3] Advanced Biogas Technology Training organized by Centre for Energy Studies, Institute of Engineering, Pulchok, Lalitpur, Nepal

Components	Note	Dimension per size in cm			
		$4m^3$	$6m^3$	$8m^3$	$10m^3$
Length of outlet	A	140	160	170	190
Breadth of outlet	B	120	130	140	160
Radius of pit	C	140	160	175	200
Height of outlet	D	50	55	60	62
Depth of pit (excavation)	E	160	170	180	190
Radius of digester	F	110	130	145	155
Radius of digester +Main hole	G	203	219	140	252
Height of digester wall	H	80	85	90	95
Height of outlet passage	I	105	110	115	123
Inner height of digester and dome	J	145	155	165	175

Table 3: Dimensions of various plant sizes

5.4 Standard construction materials

Digesters can be constructed by using bricks/stones round wall and outlet, dome with plain concrete and slabs with reinforced concrete, inlet with either stones or bricks. A brief description regarding the specifications for some of the construction materials is provided in the appendix to assist with the selection of the best quality materials.

Cement: The cement to use in the plant construction must be of high quality Portland cement from a brand with a known reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls to protect the cement from absorbing moisture before use.

Sand: Sand for construction purpose must be clean. Dirty sand has a very negative effect on the strength of the structure. If the sand contains 3% or more impurities by volume, it must be washed. The quantity of impurities especially mud in the sand can be determined by a simple test using a bottle and clean water. For the test, the bottle is half-filled with sand, filled with clean water, and then stirred vigorously. Allow the bottle to sit stationary to allow the sand to settle. The particles of sand will settle first while mud particles will settle last. After 20-25 minutes, compare the thickness of the mud layer to the sand inside the bottle are; the percent of mud should be less than 3% of the overall volume. Coarse and granular sand can be used for concrete work however fine sand is necessary for plastering work.

Gravel: Gravel size should not be too big or too small. Individual gravel diameter should not be greater than 25% of the thickness of concrete product where it is used. As the slabs and the top of the dome are not greater than 7 cm thick, gravel should not be larger than 2 cm in size. The gravel must be clean, if dirty, it should be washed with clean water.

Water: Water is mainly used for preparing the mortar for masonry, concrete and plastering work. It is also used to soak bricks/stones before using them. Water is also used for washing sand

and aggregates. It is advised not to use water from ponds and irrigation canals for these purposes, as it is usually too dirty. Dirty water has an adverse effect the strength of the structure; hence, water to be used must be clean.

Bricks: Bricks must be of the best quality locally available. When hitting two bricks together, the sound must be crisp or clean. They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. This will prevent the bricks from soaking moisture from the mortar after being laid in place.

5.5 Plant layout specification and standards

Construction work starts with the process of layout works. This is the activity carried out to mark the dimensions of the plant in the ground to start the digging work. The site layout is marked on the ground surface with wooden stakes, rocks, chalk or other materials. First a small peg has to be stuck in the ground at the centre spot of the digester. Level the ground and determine the centre line of the digester, outlet tank and inlet pit and define the reference level. The top of the dome (outer) should exactly be at this level. Select the outer radius of the pit (digester diameter plus wall thickness plus space for a footing projection of at least 10 cm and mark it on the rope.

The circumference can be marked by rotating the end of the cord in circular fashion. Suitable arrangement must then be marked for the inlet tank, inlet-pipe(s), outlet-chamber, compost-pits and gas piping. Insert a stick or wooden peg in the leveled ground at the centre of the proposed digester pit. With the help of this pole and chord prepared earlier, make a circle, which indicates the area to dig. From the centre point where the central line meets with the perimeter line, draw a tangent and measure a length equal to half of the breadth of the outlet plus the wall thickness (for outlet chamber) and half of the size of the manhole (30 cm) plus its wall thickness, on either side of this tangent. Mark the manhole ensuring that the inner size is 60 cm x 60 cm. Draw horizontal parallel lines from the points in either side in the tangent, which will meet the dome. From the centre point where the central line meets with the perimeter line, measure the length of the outlet plus the wall thickness to define the outer dimension of the outlet. Check the size diagonally to ensure that the corners are exactly at 90 degrees. Decide on the location of slurry pits while laying out plant digester and outlet. Once the site layout is marked, the supervisor should review the selected location again to ensure the best site has been chosen and will not interfere with other activities normally performed at the planned biogas plant.

5.6 Digester chamber specification and standards

The digester foundation is placed using gravel as aggregate then filled with concrete or pain cement. The foundation should be 15 cm thick and at the center of the pit, a straight rod or pipe (0.5" GI gas pipe) must be placed in an exact vertical position. The vertical pipe will be used during the construction as a field-expedient guide to ensure symmetry of the biogas plant. At ground level, a rigid pole, pipe or cord is placed horizontally across the diameter of the pit. The vertical pipe is secured to the horizontal pipe, pole or cord. After securing, the vertical pipe should be checked to ensure it is still in the plumb/vertical position. A string or wire is attached

to the vertical pipe as per the drawing and add one cm length to this length to allow space for plastering. Every stone that is laid in the round-wall will be exactly F+ 1 cm away from the vertical pipe. After the foundation has cured for at least two days, the round wall is constructed in such as way that the first two rows of bricks must be positioned side by side so that 23 cm (9") wide base is made. It is essential that first row be placed on a firm, untouched and level foundation. Subsequent rows of bricks are positioned on their lengths so that the wall thickness is maintained at 23 cm (9") wide. Backfilling should be done no sooner than 12 hours following brick course placement to allow mortar to cure. Earth should be well compacted by adding water and gentle ramming along the circumference of the digester. Poor compaction will lead to cracks in round-wall and dome. The cement mortar used can be 1 part cement to 4 parts sand (1:4) up to 1 part cement-5 parts sand (1:5) depending on the quality of the sand. The feedstock inlet pipe (and toilet pipe, if installed) must be placed in position when the round-wall is 30-36 cm high. To reduce the risk of blockages, the inlet pipe(s) must be placed as vertical as practically possible and opposite of the main feedstock inlet pipe, a 60 cm wide opening must be left in the round-wall that serves as a manhole. The digested slurry will flow to the outlet tank through this opening. Additional inlet pipes should be placed as close as possible to the main feedstock inlet pipe with a maximum distance of 45 degrees from the inlet-center-manhole line. When the round-wall has reached the correct height, the inside must be plastered with a smooth layer of cement mortar with mix of 1:3 cement-sand.

5.7 Technical standard and specification for dome construction

Once the digester chamber is completed, then the spherical (dome-shaped) gas holder has to be constructed using plain cement concrete with the help of an earthen mould prepared by filling excavated earth. Before filling the pit with earth, backside of the round wall should be filled with proper compacted earth-back-filling, if 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 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'' diameter pipe, approximately 0.5 m length, in the earth exactly at the same spot. Now the template should be used to make the shape of the dome. The template can be checked by making sure that 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. Any excess sand or soil that falls on the round wall has to be removed.

When the earth mould has the exact shape of the guide, a thin layer of fine sand is spread on the mould-top by gently patting it on the surface. The sand layer will prevent the earth from adhering to the cast. The earth used for the mould needs to be damp to prevent dry earth from soaking up water from freshly casted concrete. Before start of the cast work, sufficient labor and construction materials like sand, gravel, cement and water must be staged on the site and ready for use. The casting must be done as quickly as possible and without interruptions as this will negatively affect the quality of the cast. A constant, adequate supply of concrete (mix: 1 cement, 3 sand, 3 gravel – 1:3:3) must be made for the mason. No concrete older than 30 minutes should

be used and special care should be taken to maintain the thickness of the dome while casting, i.e. the thickness near the outer edge should be greater than the thickness at the center. In the case of 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.

A continuous application of mortar along the sand mould is necessary as the bricks are placed. Brick dome should be placed continuously and use a mortar mix of 1:4 cement to sand. Once the bricks for the dome have all been placed, the exterior is covered with 1:3 cement to sand plaster. 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. During the casting, the concrete has to be protected against strong sunlight by covering it with wetted burlap, jute bags or straw mats. This protection has to be left in place for at least one week. After the casting, turret must be made with brick, 36 cm square and 50 cm tall and plastered with 1:3 concrete. Following completion of the dome (from the day after the casting onwards), the structure must be sprinkled with water 3 to 4 times a day during the curing period (up to one week). Gas-tightness of the gas-holder is very important for the effective functioning of any bio-digester. After approximately one week, depending on the temperature, the earth of the mould can be removed through the manhole, and then the surface of the gas holder has to be cleaned by scrubbing it with water and an iron brush.

The entire surface of the concrete dome has to be cleaned before starting the plastering on the clean surface of the dome interior. Plastering can be done by scrubbing and scratching, first plain cement-water flush (1 part cement and 3-5 parts of water), applied with the help of a broom; second 10 mm thick plastering with cement sand mortar (1 part of cement and 3 parts of sand) applied with a plastering trowel; third 3-5 mm thick cement - sand punning (1part of cement and 2 parts of sand) with a plastering trowel; fourth plastering with cement and acrylic emulsion paint mix (1 part paint and 10 parts cement) 3 mm thick applied with a plastering trowel; and finally painting with thick layer of cement- acrylic emulsion paint (1 part of paint and two parts of cement) applied with a painting brush (10 cm wide). A plaster coat must be well set before applying the next layer. An interval of one day for the third and fourth coat is good for gas-tightness.

5.8 Technical standard and specification for outlet Chamber

The outlet chamber excavation and manhole is completed concurrently with the digester vessel and the manhole shares a common foundation with the digester vessel. It is important to accurately comply with the dimensions of the tank, as they determine the useful capacity of the gas holder.

The depth of excavation should be the inner depth of outlet plus the thickness of plaster plus the thickness of flooring (D+2+7.5 cm) from the ground level. When excavated at this depth, the top level of flooring would exactly reach the top of the manhole the earth in the base of the outlet, behind the manhole, has to be well compacted, otherwise cracks will appear in the outlet floor

later on. The length and breadth of digging should be the inner dimension plus the wall thickness plus the plaster layer. Ensure that the distance from the floor of the manhole to the finished floor of the outlet is equal to height as per the drawing. Once the excavation is completed, compact the floor and lay broken stones or brick bats (broken bricks) on the floor and apply proper compacting with stone or brick floor followed by thick layer of course cement-sand mortar (1:4). The finished surface should be leveled and smooth.

In this surface, once the mortar is set, outlet walls have to be constructed. While fixing the dimensions, allow at least 2 cm for plastering (in each side). Lay a first layer of mortar (1 cement: 3 sand) and start constructing the wall by placing bricks/stones in the four corners of the tank wall and fix a rope to guide the brick/stone work by tying it with the bricks/stones in either side. The walls have to be vertical and finished with a smooth layer of cement plaster (1 cement: 3 sand).

5.9 Technical standard and specification for outlet slabs

The cover slab for the outlet should be cast during the concreting of the gas-holder. The slab should be cast on leveled ground as per the dimensions given for different plant capacities. Special care has to be taken to compact the concrete mix while casting the slab, as small holes left behind will expose the steel reinforcement to corrosive vapor coming from the slurry in the outlet tank. This vapor will lead to corrosion of the reinforcement and in the longer run the slab may 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 outlet cover slabs are very essential to protect people, especially the children, and animals from falling inside. Furthermore, it stops the rainwater from entering into the digester and also helps in avoiding excessive vaporization of slurry in the dry and hot season. The dimensions of outlet slabs are shown in the table below:

Plant size (m3)	Slab size (cm)		No of slabs	Diameter of MS rod (mm)	Weight of steel (kg)
	Length	Breadth			
4	115	52	3	8	10
6	125	62	3	8	12
8	145	65	3	8	14
10	155	68	3	8	16

Table 4: Dimensions of outlet slabs

The concrete slabs for the outlet chamber should be constructed at the same time of dome casting. It should be easy to make the additional concrete at this time and the slabs will be well cured before they are placed on the outlet. The slabs must be 8 cm thick with proper reinforcement (re-bar) 2.5 cm from the bottom side. The number and size of slabs must be designed so that they could be handled by 3-4 people without great difficulty. Installing re-bar loop handles on the slabs may be useful for the occasional handling of the slabs.

5.10 Technical standard and specification for inlet tank

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 placed in well rammed, hard and leveled surface. In the rammed surface, a rectangular portion of the inlet tank has to be constructed and 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 device if mixing device is to be installed. 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 and on the finished surface, a circular mark with the help of a thread or cord of 30 cm radius is made 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 galvanized properly and the height of inlet from the ground level including the base is recommend to be 90 cm. However in no case it should be more than 100 cm and once the round wall is constructed, enough time should be allowed to set the mortar properly. Even if a mixing device is not installed, the inlet pit should be round in shape as this is a more economical use of material and easier for hand mixing. 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 and 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.

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. The toilet inlet pipe should enter the digester tank no more than 45 degrees from the centerline of the main inlet pipe. Additionally the pan level of toilet should be at least 15 cm above the overflow level in the outlet walls.

5.11 Standard for laying of gas pipeline

The gas pipe conveying the gas from the plant to point of user is vulnerable to damages by people, domestic animals and rodents. Only light quality PVC pipe should be used which must be, where possible, buried 30 cm below ground level. Fittings in the pipeline must be sealed with zinc putty, Teflon tape or jute and paint. Any other sealing agent, like grease, paint only, soap etc. must not be used. The use of fittings, especially unions, should be kept to a minimum to

reduce the risk of leakage. No fittings should be placed between the main gas valve and the dome gas pipe while the pipe size, inside diameter should be between 6 and 1 cm. However the pipe size is determined by the size of the digester, (amount of gas produced) and amount of gas required in the house. A water drain or trap is installed in the pipeline and the position of the water drain should be vertically below the lowest point of the pipeline so that the water will flow by gravity to the trap. The drain must be easily accessible and protected in a well-maintained drain pit since water will be removed periodically by opening the drain. Other biogas appliances should be mounted and connected to the galvanized iron pipe. All joints and taps must be inspected for leakage by applying a thick soap solution and observing for foam movement.

5.12 Technical standard and specification for compost pits

A minimum of two compost pits should be constructed near the outlet overflow in such a manner that the slurry can flow easily into the pit. There should be at least 1m space between outlet wall and compost pit to avoid cracking of the wall of outlet tank.

The two pits should be used alternately to fill slurry coming out of digester and the total volume of the pits must be at least equal to volume of the plant. The earth excavated from the compost pits is used for backfilling of the inlet and outlet chamber and for top filling on the dome. 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. 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. It is recommended to construct a shade above the pits to avoid direct sun light. The following table illustrates the detail dimensions of compost pits for different plant capacities.

Plant size (m3)	Minimum dimensions of pit (cm)			No of pits	Total minimum volume of pits (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

Table 5: Dimensions of compost pits for different biogas plant capacities

6. QUALITY CONTROL

Quality control is important since even if the design is correct and the workmanship is excellent but if the construction materials used for the bio-digester is not of good quality, then the digester will not function properly.

6.1 Assessment

The decision for adoption of biogas plant is generally made at the rural household level as per the existing practice in Bhutan. Although adequate number of biogas plants are already in operation across the country but still majority are not aware of the technology. Only few of the rural households have developed interest and are using the technology. A well functioning plant with satisfied users, which is a prerequisite for its adoption, is the only reliable means to develop and maintain people's confidence in the technology. Poorly installed biogas plants result in inefficiency and mal-functioning systems which lead to capital loss, frustration among owners, promoters and the donors as well. This will also damage the reputation of biogas technology causing negative impact on its adoption. The only precaution to take against such a possibility is to ensure that desired quality is maintained for each plant that is being constructed.

Until now, Bhutan does not have any agency capable enough to implement programmes for controlling the quality of biogas plant construction and use of standard biogas appliances. Although some kind of quality control checks are carried out during the initial phase of site survey at the time of construction, acceptance inspection after the completion of the plant, first operation of the plant and during general inspection at the end.

6.2 Parameters to consider for Quality Control

Brief descriptions on some of the important parameters for quality control are:

6.2.1 Designs

The design of dome digester is GGC model and is eligible for subsidy from the Government under the Bhutan Biogas Project. During the construction of the plant, the technical requirements of the design have to be complied along with the dimensions mentioned in the drawings for each parts of the plant, i.e., fermentation chamber, gas chamber, inlet and outlet, must be maintained within the allowable tolerance limit.

6.2.2 Decision on the Size or Capacity

Installation of a correct size of biogas plant is important both for economic efficiency and trouble free operation. Many of the existing plants are under-sized and hence are not adequate for the family. The main criteria to decide on the correct size of plant are the cooking and lighting requirements of a family along with the number of cattle heads for the availability of feeding materials. A plant size of 4 to 6 m3 capacity biogas produces 0.8 to 2.4 nr of gas per day which is sufficient to cook for a family of 6 to 8 members. On an average, about 0.3 m3 of gas is needed per person per day for cooking, and biogas lamps consume 0.10 m3 to 0.15 m3 of gas per lighting hour (Karki and Dixit, 1984). A thumb rule of 6 kg of dung in 24 hours per m3 of gas production can be used to estimate required amount of dung as per the size of a digester.

6.2.3 Site Selection

Following are the factors to be considered in selecting the appropriate site for plant construction. The site should be exposed to the sun, close to the animal shed and water source. It should also be close to the kitchen to minimize the cost of gas delivery pipe. It should be at least 10 m away from underground water sources to avoid pollution. As far as possible, plant construction should not be encouraged if the water source is located at a distance of more than 20 minutes' walk. The site should be also facilitate easy construction, minimize construction cost, easy operation and maintenance and should guarantee plant safety among others.

6.3 Quality checks for Construction Materials

Even if the approved design and trained masons are used, the actual construction work could still suffer due to the use of the poor quality construction materials such as cement, sand, bricks, water and aggregates.

Cement: Cement should be of high quality Portland cement from a brand with good reputation. Cement containing impurities may lead to poor quality structure. Cement should be fresh (not more than six months old), without lumps and should be stored in a dry and cool place.

Sand: Sand should be clean and should not contain soil or other materials. Dirty sand will have very high negative effect on the strength of the structure. Sand containing more than 3 percent dirt or soils should not be used. Preferably, sand should be washed with clean water before mixing it with cement.

Gravel/Aggregates: The size of the gravel should not be very big or small and it should not be bigger than 25% of the thickness of the concrete product where it is used. Since the thickness of concrete layer of the foundation and the outlet slabs is not more than 7.5cm, the maximum size of the gravel should be 2cm or ¼ size of the size of thickness of the concrete layer. If gravel is mixed with soils, it should be washed in clean water.

Water: Water is needed to prepare mortar for masonry work, concreting and plastering. It is also required for washing the aggregates, bricks and the stones used for construction. To ensure the quality of construction, clean water should be used for masonry work. Water from ponds and irrigation canals containing sediments and colloidal materials should not be used for masonry work.

Bricks/stones: Bricks plays an important role in the construction of GGC model biodigesters. Bricks should be of high quality available in the market, well burnt, straight, and regular in share and sizes and should not be broken. In areas where bricks are not available or expensive, stone can be used. Stones should be also of good quality as such when one stone hits another, it should not break. If stones are dirty, it should be washed before use.

Use of Trained Mason: Masons to be used for the biogas construction should be the one who have undergone training for the biogas construction including site selection.

6.4 Critical Stage of Construction

Although every stage of the construction is important, the following stages are considered critical. Once a faulty structure is established, it will be very difficult to rectify it and sometimes, the whole structure needs to be demolished. These stages should be carefully noted and corrected on time to save the wastage of the scarce resources as well as to keep up the popularity of the technology among users and potential users.

Locating the Central Point: Special attention has to be paid for fixing the central point of the bio-digester, if the central point is not properly located, the plant size will differ which leads to malfunctioning of the plant. Therefore, before excavating the pit for the construction of the plant, the central point should be well located and the same reference point should be used to locate other points in the course of construction.

Dome Casting: Casting of dome is a critical stage of construction. After construction of the digester wall, the plant is filled with soil up to its highest point in such a way that it should take a shape of a dome. A thin layer of sand is spread over the desired shape of dome so that the soil can be removed easily after casting the dome. Cement, sand and gravel are used at the ratio of 1:4:8 for dome casting. Concrete work needs to be completed in one day and curing of the dome should be done properly. A simple method of curing is to cover the dome with well soaked gunny bags for at least seven days.

Back Pilling: The gap between the wall of the structure and outer excavated part should be carefully filled with sufficient amount of soil. Then, it should be rammed well for compaction. Digester walls may show cracks if the back fill is not sufficiently compacted.

6.5 Quality assurance on appliances and accessories

Among various appliances, the biogas users need gas stove (burner), lamps and accessories like main stopcock, gas tap and other fittings. These appliances, mainly the burners and lamps, are imported from India. The quality of biogas accessories available in the market vary widely. Some of the materials available in the nearest market are too expensive or last for only a short period. The users have to replace them very frequently. This is the reason for importing the main gas valve from other countries. The companies/suppliers that produce or use such standard appliances need to provide a one year guarantee services to users. If there is a malfunction in these appliances within the guarantee period, the suppliers are required to replace them free of charge.

6.6 Quality monitoring during commissioning

After construction, the plant is loaded with a mixture of dung and water. For example, if cow dung is used, one part of water should be mixed to one part of fresh dung for achieving the desired consistency of the slurry. Depending upon the season and ambient temperature, it may take from one week to about 4 weeks for the production of combustible gas in the digester. Addition of effluent from operating plants have been found to reduce the gas generation time.

The gas first generated has high CO_2 content and does not burn. Therefore, the initial gas volume needs to be vented to release excessive CO_2. Regular feeding of digester with recommended amount of input mixture has to be continued till the gas starts burning smoothly. Regular feeding of inputs in required quantity and regular use of the gas will ensure trouble -free operation of the bio-digester.

Firsthand knowledge on operation procedures of biogas plants is provided to the users by the masons at the time of plant construction. Following their instructions, the users operate their plants for six months. Then, there is need to provide users' training for the benefit of users. Various problems can be encountered during initial plant operation phase. The training or during demonstrations shall cover different aspects of plant operation including technical problems and their possible solutions, proper utilization of digested slurry, advantages and disadvantages of biogas plants and after-sale-services.

7. OPERATION AND MAINTENANCE

Once the biogas plant starts its operation, it is necessary to carry out maintenance daily, monthly or yearly as necessary. Although, there are not much of operational issues in the field but few households are having problems in securing materials for maintenance as it is not readily available in the locality. Some of the minor problems are leakage from tank and pipe which causes possible damage to the stove. Further, some of the rural people are not trained to carry out minor maintenance and when there is need to carry out certain maintenance, they have to wait for the officials to come and check the plant which is time consuming.

As the number of biogas plants keep on increasing year by year, it would be difficult for the Dzongkhag or Gewog Livestock officers to go and check every household. So there is need of either additional people to carry out such routine maintenance or have to train people in the locality. On the other hand, there is insufficient budget provision at the Dzongkhag or Gewog level to carry out routine maintenance of those plants which are already in operation. In addition to that as of now, majority of the plants have not faced any serious maintenance issues but as the age of the plants get old, there will be need of more maintenance in future.

It is recognized that optimal functionality of plants will contribute significantly to the achievement of scale. Satisfied biogas users are the best advocates for further upscale as word of mouth among farmers forms the basis for many to go for the biogas decisions at the household level. The good reputation of working technology is considered to be the best guarantee. The aim of proper operation and maintenance is to ensure all biogas plants remain operational in their lifetime in order to safeguard the investment and maximize the user’s benefit and return on investment. Therefore, operation and maintenance forms an integral part of the plant. So there is need to adopt practical and well functioning operation and maintenance system, timeliness in response and action, and to make availability of appliances or spare parts.

7.1 General rule

Rule	Justification	Additional notes
Initial charging (loading) of the biogas plant with fresh manure should be done after 4 days after construction has been completed	Minimum period required for plant curing.	Premature charging of the plant, may lead to weakness in structure and hence its breakage.
The biogas user should ensure that the plant is filled to capacity before he/she starts using the gas.	Incomplete filling may lead to an interruption in the digestion process	Bio-slurry should overflow from the expansion chamber through the slurry canal
The very first gas produced should be vented unused from the water drain valve.	Existence of too much air may not enable the ignition of the gas.	Sometimes, it may take several days of venting before the gas ignites.
When the biogas plant is in use, feeding should be done on a daily basis.	Ensures that gas is produced consistently.	Reduces on the common complaint of "insufficient gas production".
The biogas user should always endeavor to keep the area around the biogas system clean.	Ensures good hygiene and sanitation for the environment	Biogas technology is eco-friendly

7.2 Common Problems in Plant Operation

A properly installed biogas plant with regular maintenance provides trouble-free services to the user for years. It is important to educate the users on O&M of the plants. Some of most common problems in the course of day-to-day operation are:

Leakage from Pipe Line: The low quality plumbing materials and their fittings have been the main cause of gas leakage from the joints of the delivery pipes. When low quality pipes such as thin walled PVC pipes are used for gas delivery, they tend to burst frequently. Compared to GI pipes. PVC pipes are more affected by temperature differences and degrade faster.

Leakage from Main Gas Valve: Leakage from the main gas valve is one of the most common and serious problems. The valves found in the market are not durable and need to be changed frequently. Several products which have already been tested are proved to be inefficient in this regard.

Slurry in the Pipe Line: Entry of slurry into the gas pipe has been a problem in appreciable number of biogas plants. To solve this problem, some slurry should be taken out from the outlet and the gas pipe should be disconnected and cleaned thoroughly.
Carbon Deposition in the Gas Burner: Carbon collected in the burner jets blocks the flow of gas when kitchen appliances are not regularly cleaned after use. To overcome this problem, the cooking stoves should be cleaned daily after use.

Lamps: So far as cooking is concerned, the users are satisfied with the performance of biogas stoves and burners. No major problems have been reported. Compared to biogas stoves, the biogas lamps have more problems in terms of frequent gas leakage and breakage of glass and mantles.

Over-sized Plants: The users generally tend to install larger size plants than they require or can feed with the amount of dung available. In many cases, plant sizes do not correspond to the number of cattle that the user possesses, or more specifically, the amount of dung available and hence the plants are underfed. Construction of such over-sized plants results in added financial burden to the user without any additional benefit.

Moisture in Drain Pipe: Water vapour together with the gas condenses in the pipe line. After a lapse of time, water accumulates inside the pipe and thereby restricts the flow of gas. To drain this water, a moisture trap is installed at the lower level of the gas pipe. Sometimes, gas also leaks from the drain pipe as the gasket of the stop cock gets loosened. In such cases, a rubber disk is attached to the gasket and tightened.

Gas Formation during winter: During the winter season, microbial activities decrease as a result of the decrease in the atmospheric temperature which affects the rate of gas production. To overcome this problem, various methods have been tried but no effective solution has been found as of yet. For example, the slurry was warmed in the sun during the day time and was then fed into the digester in the late afternoon. Another method tried was to insulate the digester by covering it with a thick layer of straw which was then covered with a plastic sheet. These methods were found useful to raise the temperature of the digester to some extent but no appreciable difference in gas production was noticed.

7.3 Do's and Don’ts for maintenance of biogas plants

Do's:

1. Decide the size (capacity) of biogas plant matching the availability of feed material and requirement of gas for various needs.
2. Select the site for biogas plant which is nearer to the points of use (say kitchen) and also nearer to the cattle shed, as far as possible.
3. Install biogas plant in an open space where sun rays are freely falling during day time.
4. Install biogas plant strictly as per the approved drawings and specifications with trained masons.
5. Install the biogas plant below ground level as per the drawings.
6. Do back filling by filling up the gap between the outer surface of the digester and the portion of the earth cutting, firmly compacting with sand/soil and also putting some water as per the construction manual.
7. Initial feeding to biogas plant should be done after curing as prescribed.
8. Feed biogas plant with cattle dung and water in 1:1 proportion, making it a homogeneous mixture after thorough mixing.

9. Remove straw pieces of sticks, *etc*. from the slurry (mixture of dung and water) before feeding.
10. Maintain proper slope in the pipeline and fix water remover (water tap) at the lowest point.
11. Break the scum formed on the surface of the slurry by inserting a long bamboo throughout and stirring the slurry.
12. Use ISI marked burners and lamps to get maximum efficiency.
13. Close the main gas cock in the night after the use of gas is over.
14. Test the burning of the gas at the burner.
15. Use soap solution for testing leakage of gas in the dome/gas holder.
16. Put the burners on a raised platform in the kitchen.
17. Adjust the air shutter to get blue flame to get maximum heat.
18. Use lighter or light the match before opening the gas tap.
19. Cover the inlet and outlet tank openings of fixed dome models with wooden plank, stone or reinforced cement concrete slab.
20. Keep the kitchen ventilated.

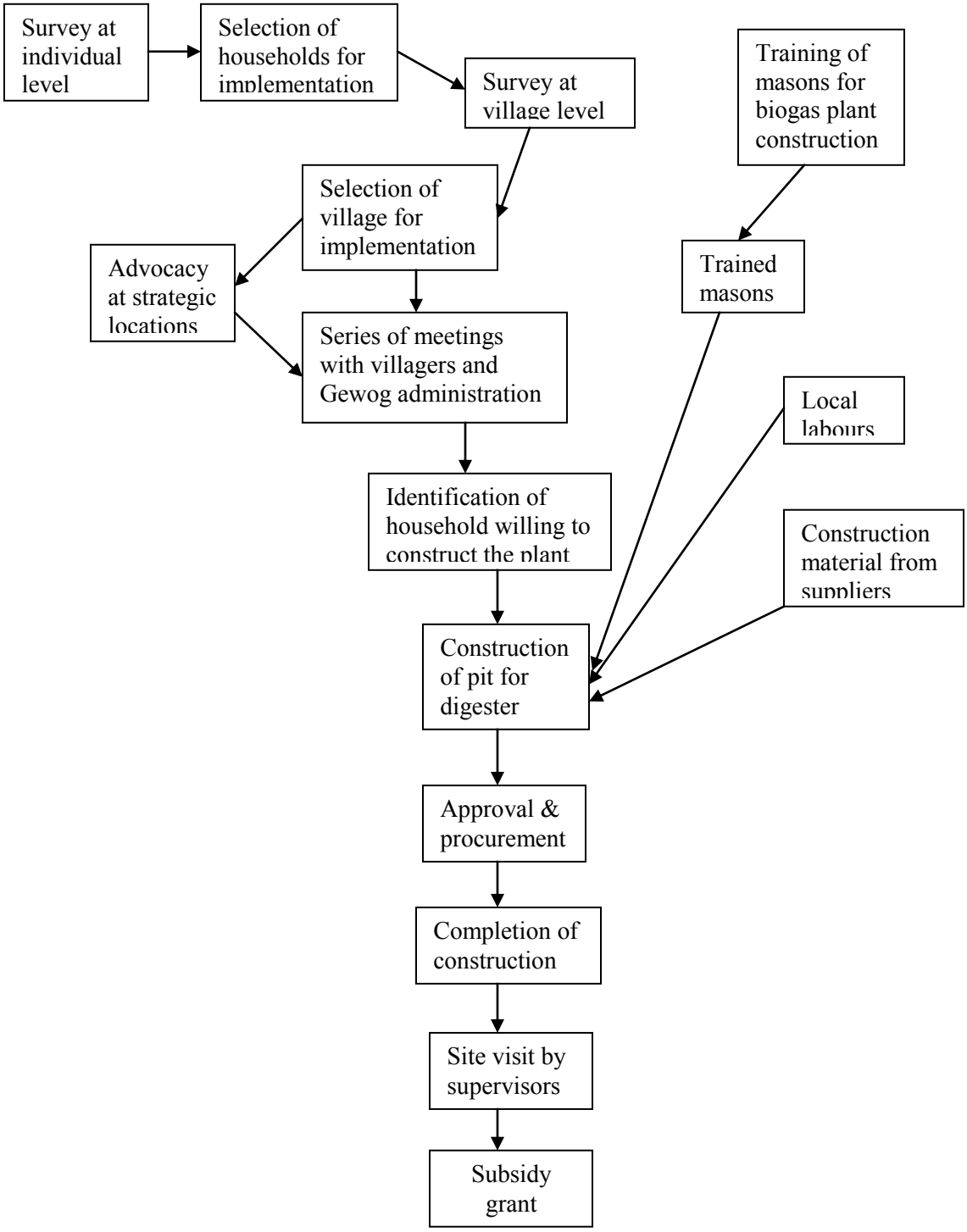
Don’ts

1. Don't recommend much higher capacity simply because there is enough dung, when the use of gas is less. Don’t suggest a smaller plant because there is less feed material when gas required is much higher.
2. Don't select a site far-away from cattle shed and also kitchen to avoid operational inconveniences.
3. Don't install biogas plant under a tree or under any other shade.
4. Don't introduce any change in the design and/or specification of biogas plant at field level suggestions if any regarding modifications should be referred to BBP.
5. Don't install biogas plant above ground level.
6. Don't do back filling loosely
7. Don't start initial feeding without proper curing.
8. Don't add either more water or less water to make a homogeneous mixture with cattle dung for feeding.
9. Don't allow soil or sand particles to entire the digester along with the slurry.
10. Don't lay the pipeline in such a way that condensed water gets accumulated in any portion of the pipeline which disturbs the smooth flow of gas.
11. Don't allow accumulation of scum of the surface of the slurry in the digester.
12. Don't use burners and lamps which are not approved by ISI since they may not give maximum efficiency.
13. Don't leave the gas taps near the burner open after use.
14. Don't test burning of gas at the main gate valve on the dome/gas holder.
15. Don't use fire for testing the leakage in the gas holder.
16. Don't put burners on the ground in the kitchen.
17. Don't make the air shutter tight or too loose. In both the cases, there would be incomplete combustion and thus wastage of gas.
18. Don't open gas tap and start searching for lighter and match box.
19. Don't keep the outlet tank open since cattle, children may accidentally fall.
20. Don't inhale biogas since it may be hazardous.
21. Don't allow the gas holder to rust which brings down its life.

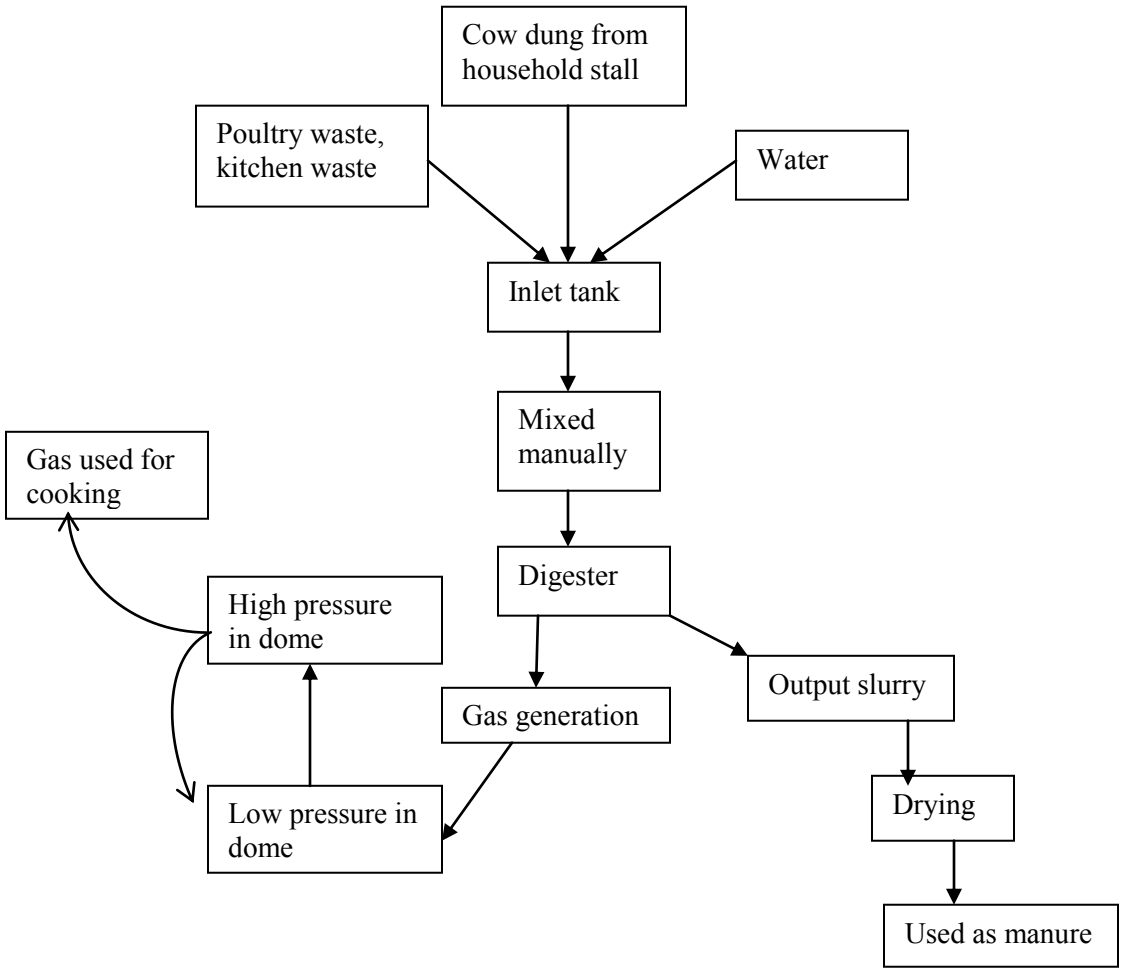
Appendix 1: References

a) First Annual Progress Report, March, 2012, PIU
b) Biogas technology: a training manual for extension
c) Project Completion Report, December 2017
d) Biogas Market Study in Bhutan, December 2009
e) National Energy Efficiency & Conservation Policy, 2019
f) Alternative Renewable Energy Policy, 2013
g) Energy Efficiency Roadmap, 2019
h) Progress report on Biogas, BDBL, 2017
i) Evaluation of Bhutan Biogas Project, SNV
j) Construction manual, Bhutan Biogas Project
k) Operation and Maintenance guideline, Bhutan Biogas Project
l) Report on Macroeconomic Impacts of Sectoral Energy Efficiency Initiatives in Bhutan, DRE, 2016
m) Challenges and an Implementation Framework for Sustainable Municipal Organic Waste Management Using Biogas Technology in Emerging Asian Countries, September 2019
n) Biogas for rural communities, Center for Technology Alternatives for Rural Areas, Indian Institute of Technology Bombay, May 2011
o) Socio-Economic and Environmental Impact of Biogas Programmes, Kerala Research Programme on Local Level Development Centre for Development Studies, Thiruvananthapuram, Kerala, India, May 2004
p) Feasibility of a Biogas Programme in Bhutan, SNV, December 2008
q) Biogas as a Renewable Source of Energy in Nepal, Theory and Development, Alternate Energy Promotion Center, Ministry of Population and Environment, Government of Nepal, December 2015
r) Evaluation of Bhutan Biogas Project (BBP – 2011-2016), Niras
s) Bhutan Biogas Project Promotion Brochures
t) Implementation Plan, National Programme on Domestic Biogas in Rwanda, September 2006

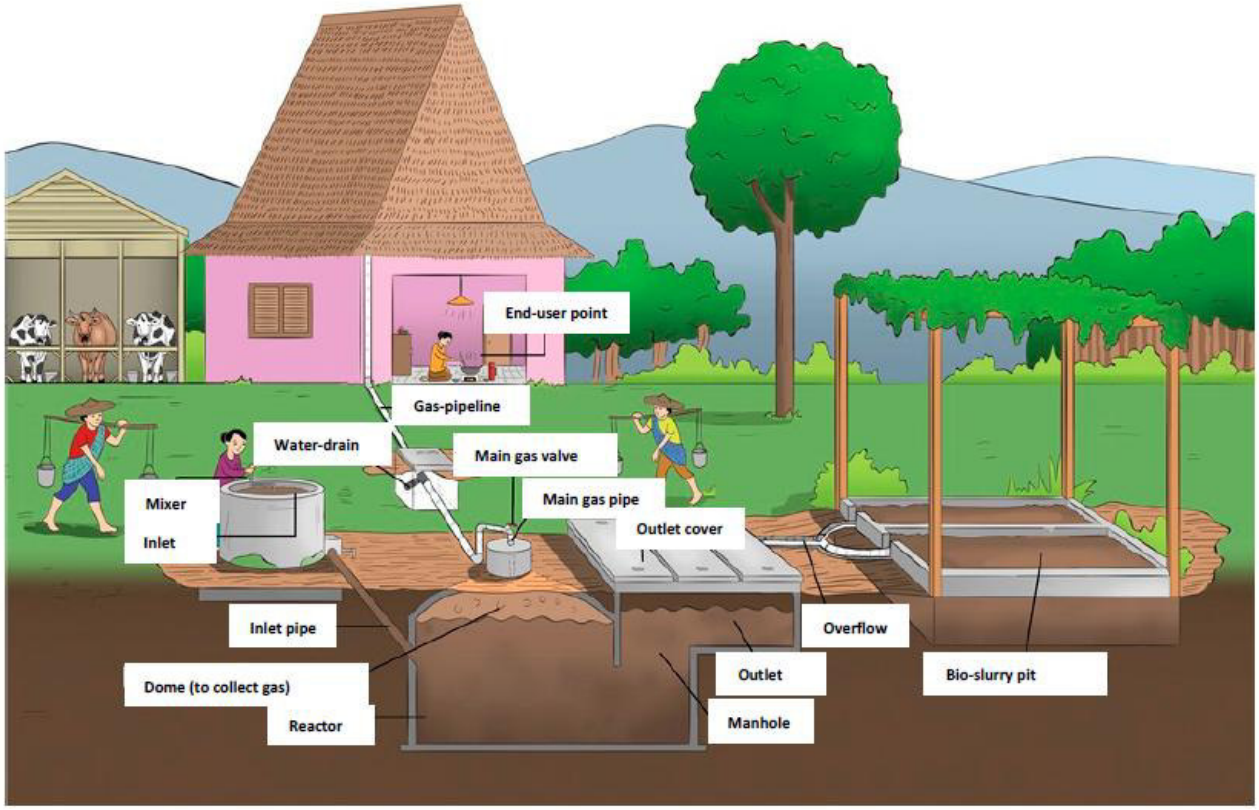
Appendix 2: Procedure for construction of biogas Plant



Appendix 3: Daily Operation of individual biogas Plant



Appendix 4: Biogas plant layout and operation



Appendix 5: Bill of Quantities and the cost as per size of digester

Bill of Quantities and the cost as per size of digester

Sl.No.	Particulars	Unit	Cost	4m3		6m3		8m3		10m3	
I	**Construction materials**			Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
1	Brick	Nos	8	1000	8000	1200	9600	1400	11200	1600	12800
2	Cement -50kg bag	Bag	300	13	3900	16	4800	20	6000	23	6900
3	Gravel 1x2	m3	1500	1.3	1950	1.5	2250	1.7	2550	2	3000
4	Coarse sand	m3	1950	0.8	1560	0.9	1755	1	1950	1.1	2145
5	Fine sand	m3	1950	1.1	2145	1.2	2340	1.3	2535	1.4	2730
6	Inlet PVC pipe 10cm dia, length 2m	Piece	350	2	700	2	700	2	700	2	700
7	Iron bars 8mm dia	Kg	50	10	500	12	600	14	700	17	850
8	Binding wire	Kg	40	0.5	20	0.5	20	0.5	20	0.5	20
9	Acrylic emulsion paint	Litre	300	1	300	1	300	1	300	1.5	450
II	**Accessories**										
1	G.I Gas outlet pipe 0.5" dia, 0.6m long with elbow	Piece	450	1	450	1	450	1	450	1	450
2	GI nipple, Ø 0.5" for connecting main gas pipe and main gas valve	Piece	250	1	250	1	250	1	250	1	250
3	Main gas valve (Ball valve Ø 0.5")	Piece	200	1	200	1	200	1	200	1	200
4	Male-female socket Ø 0.5", G.I. with aluminum thread, for connecting main gas valve and gas pipeline (G.I.)	Piece	25	1	25	1	25	1	25	1	25
5	G.I.90" elbow	Piece	30	4	120	4	120	4	120	4	120
6	T-socket Ø0.5" for water drain and stove (aluminum thread inside)	Piece	30	2	60	1	30	1	30	1	30
7	Water drain	Piece	300	1	300	1	300	1	300	1	300
8	Gas tap	Piece	150	1	150	1	150	2	300	2	300
9	Teflon tape	Piece	60	1	60	1	60	1	60	1	60
10	Gas pipe, G.I. or PVC pipe Ø 0.5”	m	250	12	3000	12	3000	12	3000	12	3000
11	Rubber hose pipe Ø 0.5” and 2 clamps	m	700	1	700	1	700	2	1400	2	1400
12	Stoves – single burner	Piece	700	1	700	1	700	2	1400	2	1400
13	Pressure meter/Manometer	Piece	700	1	700	1	700	1	700	1	700
III	**Labour**										
1	Skilled labour per day	No	500	9	4500	10	5000	11	5500	12	6000
2	Unskilled labour per day	No	300	19	5700	22	6600	24	7200	28	8400
	Total				**35990**		**40650**		**46890**		**52230**
	Overhead (15%)				5398.50		6097.50		7033.50		7834.50
	Total				**41388.50**		**46747.50**		**53923.50**		**60064.50**

Appendix 6: Field visit Schedule

Dates	Field Visit
First group	
22/2/2020	Thimphu-Bumthang
23/2/2020	Bumthang – Monggar
24/2/2020	Interview and consultation with the Monggar Dzongkhag
25/2/2020-26/2/2020	Visit to Rural homes, interview and survey
27/2/2020	Monggar-Trashigang
28/2/2020	Interview and consultation with the T/gang Dzongkhag
29/2/2020-1/3/2020	Visit to Rural homes, interview and survey
2/3/2020	Trashigang-Monggar
3/3/2020	Monggar-Bumthang
4/3/2020	Interview and consultation with the Bumthang Dzongkhag
5/3/2020	Visit to Rural homes, interview and survey
6/3/2020	Bumthang-Wangdue
8/3/2020	Interview and consultation with the Wangdue Dzongkhag
9/3/2020	Visit to Rural homes, interview and survey
10/3/2020	Wangdue-Thimphu
Second group	
23/2/2020	Thimphu-Haa
24/2/2020	Interview and consultation with the Haa Dzongkhag, site visit, survey and consultation
25/2/2020	Haa-Thimphu
26/2/2020	Thimphu-Chukha
27/2/2020-28/2/2020	Interview and consultation with the Chukha Dzongkhag, site visit, survey and consultation
29/2/2020	Chukha-Samtse
2/3/2020	Interview and consultation with the Samtse Dzongkhag,
3/3/2020-5/3/2020	Site visit, survey and consultation
6/3/2020	Samtse-Pling
7/3/2020	P/ling-Thimphu

Appendix 7: List of Consultations

Sl.No	Name and Designation	Agency
	Central Level Agencies	
1	Mr. Ugyen Lhendup, Chief Program Officer	Bhutan Trust Fund for Environmental Conservation
2	Mr. Tshering Penjore	UNDP
3	Mr. Raj Kumar, WASH Officer	SNV, Bhutan
4	Mr. Tsheten Dorji, Chief, Conservation and Sustainable Livelihood Division	RSPN
5	Mr. Tenzin Khorlo, Chief	National Environment Commission
6	Mr. Thinley Dorji, Chief	Waste Management Division, NEC
7	Mrs. Ugyen Tshomo, Environment Officer	Waste Management Division, NEC
8	Mr. Jamyang Phuntsho, Asst. Program Officer	Tarayana Foundation
9	Mrs. Tshering Pem, Finance Officer	Bhutan Development Bnak Limited
	Dzongkhag and Gewog Level	
1	Mr. Sherab Tenzin, Dzongkhag Livestock Officer	Chukha Dzongkhag
2	Mr. Karma Dorji, Dzongkhag Livestock Officer	Samtse Dzongkhag
3	Mr. Sangay Phuntsho, Extension Supervisor	Darla Gewog, Chukha Dzongkhag
4	Mr. Dil Pardhan, Livestock Extension Officer	Samtse Gewog, Samte Dzongkhag
5	Mr. Ugyen, District Livestock Officer	Wangdue Dzongkhag
6	Mr. Tenzin Dorji, District Livestock Officer	Monggar Dzongkhag
7	Mr. Khamsum Wangdi, Livestock Supervisor	Monggar Gewog, Monggar Dzongkhag
8	Mr. Naina Singh Tamang, District Livestock Officer	Trashigang Dzongkhag
9	Mr. Loden Jimba, District Livestock Officer	Paro Dzongkhag
10	Mr. Jambay Dorji, District Livestock Officer	Bumthang Dzongkhag