CHAPTER V

DESIGN OF THE STUDY

Energy is the engine of growth and key to the prosperity of an economy. The energy potential of a nation has direct relationship with its economic development. The per capita energy consumption of a country is a key indicator of its stage of development. Under the aggravating situation of energy crisis and worsening environmental condition, there arises the need for undertaking planning programs and strategies to minimize energy crisis and to conserve the environment through effective use of available commercial and non-commercial sources of energy and developing renewable sources of energy. This task becomes all the more significant in rural India as more than 70 per cent of her population are living in villages and bulk of them are engaged in agricultural activity and having the practice of burning valuable cattle dung and cutting down valuable trees and plants to obtain fuel wood for cooking. The heavy demand for firewood resulted in deforestation through unauthorized and indiscriminate cutting of trees which otherwise would result in conserving valuable forest wealth and maintaining ecological balance. The scarcity of firewood has lead to increased diversion towards dung cake which deprived farm land of its high value organic manure. Keeping in view of the depleting commercial sources of energy and denudation of forest area and the need to conserve environment, the Government of India has made planned efforts to reduce the consumption of both commercial and conventional non-commercial sources of energy by way of shifting to the consumption of alternative pollution free renewable sources of energy such as solar energy, wind energy, tidal energy and bio-gas. In rural area, bio-gas
technology is the major option at the household level which can mitigate the problem of growing fuel demand and at the same time it can help in no small measure in reducing carbon pollution and enabling efficient waste utilization. Bio-gas is a versatile source of energy with many end uses which reduces the drudgery of rural women. Even though there is much progress in the installation of gobar-gas plants, it is not known as to what extent it has resulted in saving fuel energy, increased manure value of dung and reduced pollution. But the prevailing data base information on the social cost and benefits of bio-gas production is incomplete and inadequate. Most of the economic evaluation studies carried out in the past have either ignored the pollution benefits or unable to make an estimation of these benefits, may be on account of no proper methods for evaluating these benefits. In this regard, the present study has been undertaken in Avinashi taluk of Coimbatore district, a leading taluk in terms of number of gobar-gas plants, so as to incorporate social cost and social benefits in the economic evaluation of bio-gas plants which may give clear picture on the real benefits of gobar-gas plants.

5.1 OBJECTIVES OF THE STUDY

The broad objective of the study is to make a social cost-benefit analysis of bio-gas plants. However, the specific objectives of the study are

1. To analyze the capital cost of gobar-gas plants.

2. To estimate unit cost of gobar-gas by fitting appropriate cost function and to determine its price by cost pricing method.

3. To estimate unit cost of emission reduction in switching over to gobar-gas and to assess pollution abatement benefit per unit of gobar gas.

4. To estimate fuel cost saving in switching over to gobar-gas.
5. To estimate the manure value added due to gobar-gas plant.

6. To estimate the value of labour time saved in cooking and procuring fuel while switching over to gobar-gas.

7. To estimate the value of forest wealth saved in switching over to gobar-gas.

8. To calculate the cost of unutilized capacity and the value of produced gas wasted.

9. To carry out benefit-cost analysis of gobar-gas plants by taking social benefits and costs.

10. To make financial evaluation of gobar-gas plants by incorporating social costs and benefits of gobar-gas.

The first objective would help in ascertaining the capital cost structure of gobar-gas plants. The second to eighth objectives would help in the estimation of various benefits flowing out of gobar-gas plants and the special costs involved in them. The last two objectives would throw light on the economic and financial feasibility of gobar-gas plants with the inclusion of social costs and benefits.

### 5.2 HYPOTHESES OF THE STUDY

For the above objectives, the following hypotheses can be made for testing which may be either confirmed or rejected in the course of analysis.

1. The gobar-gas plants are economically viable and financially feasible projects.

2. The economic viability and financial feasibility of the gobar-gas plants increases with the increase in the size of the gobar-gas plants.

3. Gobar-gas users are adopting optimum plant size for producing the gas.

4. There is optimum utilization of plant capacity in the production of gobar gas.
5.3 CONCEPTS OF THE STUDY

5.3.1 BIO-GAS AND GOBAR-GAS

Bio-gas is a water saturated gas mixture containing about 65-75 per cent of methane (CH₄), 20-30 per cent of carbon dioxide (CO₂), 5-10 percent of Hydrogen (H₂), 1-2 per cent of Nitrogen (N₂), 419mg/m³ of hydrogen sulphide (H₂S), 0.9mg/m³ of Chlorine (Cl) and 0.5mg/m³ of Fluoride (F). It is a clear, colourless and odourless inflammable gas produced during anaerobic fermentation of organic matter such as cowdung, human night soil, crop residues like leaves, stems and straws and kitchen wastes with the help of methanogenic bacterial activity under the optimum temperature of 30°C in the absence of oxygen. The methane gas produced from cow dung is commonly called as gobar-gas. Methane gas serves as a convenient fuel that can be used for cooking, lighting and operating engines.

5.3.2 SLURRY

It is a fermentable mixture of water and organic matter cowdung mixed in a 1:1 ratio so that the total solid concentration ratio is 8-11 per cent by weight. It is the fermentation material fed into gobar-gas plant to produce combustible methane gas.

5.3.3 GOBAR-GAS PLANT

Gobar-gas plants are structures in which cowdung slurry is fed, anaerobically digested and gobar-gas is produced and stored. It consists of digester and a gas holder. The digester is a cube shaped or cylindrical waterproof fermentation tank with an inlet into which slurry is fed and outflow pipe to lead the sludge out into a drainage pit. The gas holder is normally an airproof steel container that, by floating like a ball on the
fermentation mix, cuts off air to the digester and helps for anaerobiosis and collects the gas generated. The gas holder is fitted with an gas outlet.

5.3.4 EMISSION AND EMISSION FACTOR

Emission refers to the discharge of substances in the process of fuel combustion which are not the constituent of natural air, known as pollutants. In the combustion process, fuels may emit greenhouse gases such as carbon dioxide (CO$_2$), nitrogen dioxide (N$_2$O), methane (CH$_4$), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and SF$_6$, acidifying gases such as nitrogen oxide (NO$_x$), sulphur dioxide (SO$_2$) and ammonia (NH$_3$) and ozone precursors such as nitrogen oxide (NO$_x$), non-methane volatile organic carbons (NMVOC), carbon monoxide (CO) and methane (CH$_4$). Total emissions of all gases are calculated by adding up emissions of each green house gases calculated in CO$_2$-equivalents taking their specific global warming potential (GWP), gases contributing to acidification in potential acid equivalents (PAE) and ozone precursor gases in non-methane volatile organic carbon (NMVOC) equivalents by taking their tropospheric ozone forming potentials (TOPF). CO$_2$ equivalent of each green house gases is obtained by multiplying emission factor of each pollutant gas with its GWP. The GWP factors for CO$_2$, CH$_4$ and N$_2$O gases are 1, 21 and 310 respectively. Similarly emissions of each acidifying gases in terms of PAE is calculated by multiplying emission factor of each pollutant gas with a gas specific conversion factor. The PAE conversion factors for NO$_x$, SO$_2$ and NH$_3$ are respectively 1/46, 1/32 and 1/17. The emission factor for a pollutant gas is defined as mass of pollutant emitted per mass of fuel burned. The emission factors of different pollutants for fuel wood, crop waste, cow dung cake and gobar-gas are presented in Table 5.1.
TABLE - 5.1

EMISSION FACTORS FOR DIFFERENT TYPES OF FUELS

(Units of measurement not specified are in g/kg)

<table>
<thead>
<tr>
<th>Fuel Type &amp; measurement unit of emission factor</th>
<th>CO₂</th>
<th>CO</th>
<th>CH₄</th>
<th>PM₁₀</th>
<th>SOₓ</th>
<th>NOₓ</th>
<th>N₂O</th>
<th>NH₃</th>
<th>NM</th>
<th>VOC</th>
<th>HCL</th>
<th>H₂S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel wood</td>
<td>1705</td>
<td>80</td>
<td>9.00</td>
<td>9.0</td>
<td>0.34</td>
<td>2.34</td>
<td>0.070</td>
<td>1.2</td>
<td>23.5</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop Waste</td>
<td>1266</td>
<td>75</td>
<td>300kg/TJ</td>
<td>7.4</td>
<td>0.29</td>
<td>1.74</td>
<td>4kg/TJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow Dung</td>
<td>1060</td>
<td>83</td>
<td>300kg/TJ</td>
<td>20.0</td>
<td>6.00</td>
<td>7.00</td>
<td>4kg/TJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gobar-gas g/m³</td>
<td>1668.53</td>
<td>-</td>
<td>6.45</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20.82</td>
<td>-</td>
<td>-</td>
<td>0.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.3.5 CAPITAL INVESTMENT IN GOBAR-GAS PRODUCTION

Capital refers to that part of nation’s output that takes the form of new structures, producer durable equipment and changes in inventories. Capital asset is a producer’s means of production. Fixed capital investment denotes the financial commitment made in fixed capital assets to create production capacity on permanent or fixed basis. As such capital investment here refers to all those financial commitments made in the installation of gobar-gas plant such as cost incurred towards construction of digester, purchase of gas holder and value of cow dung used for initial filling. Since the gobar-gas plants are installed at different time periods, the present value of fixed capital investment has been calculated for each of the plants to the reference time of January 1, 2000 and adopted in the present study. It has been computed by using the formula:

\[ C_K = C (1+r)^n \]
Where $C_k =$ Present value of the gobar gas plant calculated to the reference period.

$C =$ Construction cost of gobar-gas plant.

$r =$ Prevailing market rate of interest in 2000.

$n =$ Elapsed time in between the time of investment and the reference time of January 1, 2000.

5.3.6 FIXED COST

Fixed costs also called as overhead costs are those costs that are incurred as a result of the use of fixed factors or inputs in the production of gobar-gas. They remain fixed at any level of output during production period. They will not change with the change in the volume of gas produced. In the present study it includes annual rental value of land, annual interest on fixed capital and capital depreciation per annum in the production of gobar-gas.

5.3.7 DEPRECIATION OF CAPITAL

It is the decline in the value of a given fixed capital asset as a result of use, wear and tear, rusting and corrosion, accidental damage and time obsolescence. In the present study, depreciation has been computed for fixed capital assets such digester structure, gas holder, pipe lines and end use equipments. It is calculated by taking the formula,

$$D = C_k \left[ \frac{r_c}{1 - (1 + r_c)^{-t}} \right]$$

Where $D =$ Depreciation of fixed capital goods

$r_c =$ Market rate of interest at the reference time of 2000 (12 per cent).

$t =$ Expected time of the good in the reference time period.
5.3.8 INTEREST ON FIXED CAPITAL

Interest expenses refers to the interest calculated for the present value of barrowed capital or owned capital either at the actual rate of interest or imputed rate of interest as the case may be with the reference to the base period. Interest has been calculated by using the formula,

\[ i = C_K (1+r_c)^t \]

Where \( i \) = interest amount on fixed capital

\( C_K \) and \( r_c \) are as defined earlier.

5.3.9 RENT FOR THE LAND

Rent is the payment made for the land which is used for the installation of gobar-gas plant. It is either the actual rent payment made or the opportunity cost incurred in using the land.

5.3.10 OPERATIONAL COST

Operational or production cost in economics (\( C_p \)) refers to the expenses incurred in organizing any business activities. In the present study, it encompasses all those direct and indirect expenses in the production of gobar-gas and its by-products. The direct costs include the annual cost of cow dung and water used in the gobar gas plant, the annual labour cost involved in operations such as collection of cow dung, preparation of slurry and the removal of sludge slurry and the maintenance cost incurred towards upkeep of the plant. The maintenance cost includes the cost of painting gas holder, labour cost in defrosting the gas lines, repairing and white washing of the digester structure. The indirect cost may in the form of social cost. The value of generated gas wasted per annum
or more precisely the value of unused potential capacity of the gobar gas plant per annum is the tangible social cost of gobar-gas plant.

5.3.10.1 VARIABLE COST

Variable costs are those costs which vary with the change in output of gobar-gas. In the present study it includes cost of dung, labour cost in operation, maintenance cost, cost of water used for preparing slurry and cost of unused potential of gobar-gas plant or value of generated gas wasted. It is nothing but the operational cost minus maintenance cost.

5.3.11 COST OF UNUTILISED CAPACITY AND VALUE OF GAS WASTED

The unutilized capacity is defined as the difference between the potential gas production capacity of the plant and actual production of gas made. The cost of unutilized capacity is defined by the formula,

$$C_{UUC} = (G_p \cdot C_u) - (G_p \cdot C_U)$$

$$C_{UUC} = (365 \cdot V \cdot \eta_p \cdot C_u) - (G_p \cdot C_U)$$

Where, $C_{UUC}$ = Annual cost of unutilized capacity of the gobar gas plant

$V$ = Volume (size) of gobar-gas plant.

$\eta_p$ = Production efficiency of bio-gas plant.

$C_U$ = Price of bio-gas in terms of its unit cost

$G_p$ = Annual potential gas production capacity of the plant.

$G_p$ = Actual quantum of gobar-gas produced per annum.
The value of gobar-gas wasted is the difference between the value actual quantum of gas generated \((G_p C_u)\) and the value of actual quantum of gas used for various end uses \((G_u C_u)\). As the gas produced in the study area is used only for cooking needs, the value of gobar-gas wasted \((G_{vw})\) is estimated by the formula,

\[
G_{vw} = (G_p C_u) - (G_u C_u)
\]

\[
G_{vw} = [(G_p C_u) - \{(t_{CG} \eta_B)(C_u)\}]
\]

Where \(t_{CG}\) = Annual time of cooking in hours.

\(\eta_B\) = Sum total of cooking burner capacities

The annual value of unused potential of the plant is the difference between the annual value of potential gas production capacity of the plant and value of actual quantum of gas used per annum for cooking which is the sum total of annual cost of unutilized capacity of the plant and annual value of generated gas wasted.

### 5.3.12 BENEFITS OF GOBAR-GAS

The benefits flowing out of bio-gas plants may be in the form of primary benefits and secondary benefits. The primary benefits include the value of gas generated and the value added to the manure by the gobar-gas plant. The valuation of these benefits involves the monetary estimation of the quantity of gas obtained and monetary estimation of the value added to the manure in terms of its quality, quantity and increase in fertilizer nutrients. The secondary benefits include value of labour time saved in cooking and procuring wood, value of fuel saving in switching over to gobar-gas, employment generated, value of forest wealth saved in terms of value of fuel wood and the value of emission reduction in switching over to gobar-gas.
5.4 SCOPE OF THE STUDY

The study highlights the relative economic and financial feasibility of different type of gobar plants in varying sizes. The findings of the study will reveal the economic and financial prospects in the adoption of bio-gas plants. The study is made in Avinashi revenue block area and as almost all household which adopted gobar gas have installed only KVIC plants for fuel, the present study is only with reference to KVIC type gobar gas plants installed in this area. The study has been conducted for the crop year 1999-2000. The interview has been made in the month of April 2000.

5.5 METHODOLOGY

The importance of a study lies to a great extent in the method followed in the selection of statistical unit, collection of data and in the method adopted for their analysis. While deciding the validity of the result of a study, a clear understanding of the methods followed in the study is considered important. Detailed pictures of the methods adopted are given below.

5.5.1 SELECTION OF THE STUDY AREA

Coimbatore district is the forerunner in the installation of biogas plants in India and Avinashi block happens to be topper in the country in terms of the number of gobar-gas plants installed and a leading block in the successful implementation of gobar-gas programme. Avinashi block is a backward area in the dry belt wherein most of the people own cattle and relay on the agricultural occupation and consume mostly conventional source of fuel energy. Hence Avinashi block is purposively selected for the study.
5.5.2 SELECTION OF VILLAGES

The statistical unit for the study is revenue villages. A sample of twenty villages has been considered adequate to select sizeable number of respondents. From the list of villages obtain from Avinashi Panchayat Union Office, the villages are randomly selected by following simple random sampling method. The selected villages are:

1. Ayyampalyam  
2. Chinnaolapalayam  
3. Kanagakulam  
4. Karukampalayam  
5. Karakutaipalayam  
6. Kuppandapalayam  
7. Kuttapalli  
8. Naduvangery  
9. Nadupalayam  
10. Nallakattipalayam  
11. Puduunjampalayam  
12. Periyaolapalayam  
13. Pongai, G. Pudur  
14. Pothampalayam  
15. P. Thamaraikulam  
16. Pulipar  
17. Raothampalayam  
18. Thaneerpandal  
19. Thulukamuthur  
20. Vadugapalayam.

After selecting the villages, it is confirmed that the selected villages represent the general geographical and other condition of the selected block.

5.5.3 SELECTION OF HOUSEHOLDS

A sample of size 200 gobar-gas adopted households is considered adequate while considering the total population of gobar-gas households and the resources at the disposal of the researcher. Therefore in each selected villages ten households have been randomly selected from the list of gobar-gas households furnished by the respective village extension workers. The decision making individuals in these households have been identified and interviewed.
5.5.4 COLLECTION OF DATA

The present study is an empirical research based on survey method. The data collection was done with the help of a well structured and pre-tested interview schedule. Pre-testing was done with a sample of ten respondents selected from non-sample units. After pre-testing, refinement was made in the interview schedule wherever necessary. Data was collected by personal interview with the respondents. In order to get good response, proper rapport was established with sample farmers with the help of village extension workers. The objectives of the study were explained to them in order to alleviate the misunderstanding if any and to get fairly accurate information. Even though no respondent maintain proper record account, yet they were able to recollect and furnish fairly accurate information. To ascertain the reliability of the information provided by the respondents, necessary cross checks were made during the enquiry. Women members of the household were also contacted to get the details of energy consumption and time spent on cooking etc. The personal information such as age, education, size of the family, income, assets, community, occupation etc., were also collected in order to maintain homogeneity of units in the analysis of the economics of gobar-gas plants. Besides this, information regarding the capital costs at the time of installation and costs and outputs on operation were collected. After collection of data, an exploratory deskwork was done. These data were edited and analysed systematically with appropriate statistical tools.

5.5.5 METHOD OF ANALYSIS

The economic viability of gobar-gas plant has been analysed in terms of cost-benefit analysis and financial feasibility of investment on gobar gas plants has analysed in terms of net present value criteria, pay-back period and break-even point. For making
these analyses, monetary valuation of gobar gas produced, manure value added, labour
time saved in cooking and procuring fuel, fuel saved, employment generated, forest
wealth saved and benefits of emission reduction has been made.

5.5.5.1 VALUE OF GOBAR GAS

The valuation of gobar-gas has been made in terms of unit cost of producing the
gobar gas by adopting the cost pricing method. Value of gobar-gas produced (Pp) is the
product of the quantum of gas produced in m³ (Gp) and the unit cost of producing the
same (Cu).

5.5.5.2 UNIT COST OF GOBAR-GAS

For estimating unit cost of gobar-gas, the method suggested by Rubab and
Kandpal with modification has been used. As the capital cost has been valued for the
reference period of 2000, the average inflator/deflator value found in their cost function
has been dropped and in the present study a cost function of the form

\[ C_K = aV^b \]

relating the present value of capital cost (Ck) to the daily gas production capacity (V) has
been used. The cost of unit volume (one m³) of gobar-gas has been calculated by
dividing the total annual production cost by the total annual production of gas. The
following mathematical expression is used for obtaining unit cost of gobar-gas (Cu).

\[ C_U = \frac{a(e \cdot \lambda) + \mu_p}{365 \cdot \eta_p \cdot V^{1-b}} \]

Where \( \mu_p = \left[ \frac{C_o}{C_K} \right] \), the fraction of capital cost required for annual operation and
maintenance
\[ \lambda = \text{the recovery factor for a discount rate of } r \text{ and useful plant life of } t. \text{ It is calculated by using the formula, } \lambda = \frac{1}{\left[ \frac{1}{1 + r} \right]^{t} + \left[ \frac{1}{1 + r} \right]^{t-1}} - 1 \]

\[ \epsilon = \text{the fraction of capital cost (C_k) to be amortized on gobar-gas produced. It is given by the following mathematical expression} \]

\[ \epsilon = \frac{365 \cdot V \cdot \eta_p \cdot P_{gf}}{(365 \cdot V \cdot \eta_p \cdot P_{gf}) + (365 \cdot V \cdot d_u \cdot \omega_M)} \]

where \( \omega_M \) is the value added to the manure per kg of dung when passing through gas plant.

It is obtained by the equation, \( \omega_M \) is

\[ \{0.73(1.2(\eta_{P_R} + 0.016P_N + 0.0145P_P + 0.01P_K) - \{M_{R_L} + 0.01P_N + 0.006P_P + 0.012P_K}\} \]

\[ \eta_p = \text{the average yearly gas production efficiency.} \]

\[ d_u = \text{Quantity of fresh dung in kg to produce one m}^3 \text{ of gobar-gas} \]

\[ P_{gf} = \text{Price of gobar-gas in terms of fuel wood price. It is calculated by the formula,} \]

\[ P_{gf} = \frac{Q_b \cdot \eta_b}{Q_f \cdot \eta_f} \cdot P_f \]

Where \( Q_b \) is the caloric value of bio-gas per m\(^3\)

\[ \eta_b = \text{the thermal efficiency of gobar-gas} \]

\[ Q_f \] is the caloric value of fuel wood per its kg weight.

\[ \eta_f = \text{the thermal efficiency of fuel wood.} \]

\[ P_f \] is the price of fuel wood per kg.
5.5.5.3 MANURE VALUE ADDED

The value added to the manure, the other primary benefit of gobar-gas plant is estimated by taking the difference between the value of gobar-gas manure (slurry manure) and farm yard manure. Adopting the estimate used by Bhavani with regard to the quantity of manure produced and their fertilizer (NPK) content and the slurry-dung ratio adopted by Pathania and Sharma and using the prices of manure and fertilizer, the value added to the manure by gobar gas plant (AMV) has been estimated by the formula,

\[ \Delta MV = Q_d \left\{ 0.73(1.2(A/ra + 0.01P_n + 0.0145P_p + 0.01P_k)) \right\} - \left\{ M_{vd} + 0.01P_n + 0.006P_p + 0.012P_k \right\} \]

where, \( Q_d \) is the quantum of dung used in the gobar gas plant in kg per annum.

\( M_{VS} \) and \( M_{Vd} \) are respectively the value of slurry manure per kg and farm yard manure per kg.

\( P_n, P_p \) and \( P_k \) are respectively per kg price of nitrate, phosphate and potash fertilizers.

5.5.5.4 VALUE OF LABOUR TIME SAVED

It is the value of difference between the labour time involved in cooking with the replaced fuel namely firewood and labour time taken in cooking with gobar-gas. It is estimated by taking the formula,

\[ \text{Value of labour time saved in cooking (VLts)} = \frac{(t_{cf} - t_{cg})}{8} \cdot W \]

Where \( t_{cf} \) and \( t_{cg} \) are the time taken annually in cooking with fire wood and gobar gas measured in hours respectively.

\( W \) is the wage rate per mandays of cooking labour.
5.5.5.5 FUEL COST SAVING IN SWITCHING OVER TO GOBAR-GAS

It is the difference between the value of gobar-gas and other fuels used for cooking and the value of fuels used before the adoption of gobar gas. It is estimated by the formula,

\[ S_{cg} = [(f_b \cdot C_u) + (f_{wb} \cdot P_w)] - (f_w \cdot P_w) \]

Where, \( S_{cg} \) is the annual fuel cost saving in switching over to gobar-gas.

- \( f_b \) is the annual quantum of bio-gas used in m\(^3\)
- \( f_{wb} \) is the annual quantity of fuel wood used after adopting gobar gas in kg.
- \( f_w \) is the annual quantity of fuel wood used before installation of gobar-gas.
- \( P_w \) is the price of fuel wood per kg and
- \( C_u \) is per m\(^3\) cost of gobar-gas.

5.5.5.6 VALUE OF EMPLOYMENT GENERATED

It is the monetary value of annual man days of labour employed in the operation of the gobar gas plant at the existing wage rate. The value of employment generated per annum in gobar-gas plant \((N_v)\) is

\[ N_v = \frac{h_o \cdot W}{8} \]

Where \( h_o \) is the total hours of operation of the gobar-gas plant per annum and

- \( W \) is the wage rate for labour engaged in the operation of the plant

5.5.5.7 VALUE OF FOREST WEALTH SAVED

It is the monetary value of fuel wood replaced by the gobar-gas. It is calculated by the formula

\[ \text{Value of forest wealth saved, } S_{fw} = (f_w - f_{wb})P_w \]
5.5.5.8 BENEFIT OF EMISSION REDUCTION

Benefit of emission reduction is measured in terms of negative cost of abatement of emissions in switching over to gobar gas from fuel wood. The unit cost of abating emissions has been calculated as the ratio of incremental cost of the measure to the emissions abated. The total cost of abatement of emission in domestic cooking (TCea) is measured by the difference between the annual cost of cooking in using gobar-gas and the annual cost incurred in cooking with fuel wood before adopting gobar gas. It is given by the formula,

\[ TC_{ea} = [C_b + (f_b \cdot C_u)] - [C_w + (f_w \cdot P_w)] \]

Where \( C_b \) and \( C_w \) are the annualized labour cost of cooking with gobar-gas and fuel wood respectively.

\( f_b \) and \( f_w \) are respectively total quantum of gobar gas consumed per annum in m\(^3\) and total quantity of fuel wood consumed in kg per annum.

\( C_u \) and \( P_w \) are the price of gobar gas per m\(^3\) and price of fuel wood per kg.

The cost per unit of emission reduction (Cea) obtained by the formula,

\[ C_{ea} = \frac{[C_b + (f_b \cdot C_u)] - [C_w + (f_w \cdot P_u)]}{[(f_w \cdot e_w) - (f_b \cdot e_b)]} \]

Where \( e_u \) and \( e_w \) are the total emission factors of biogas per m\(^3\) and total emission factor of fuel wood per kg.

5.5.5.9 BENEFIT-COST RATIO

In appraising capital projects from economic point of view, the most appropriate and popular method is the cost-benefit analysis. This implies weighting of benefits
against cost involved. This task is accomplished by the calculation of benefit-cost ratio.

The benefit-cost ratio (B/C) is calculated by the formula,

\[
\frac{B - C_m}{\lambda} / (C_K + C_s)
\]

Where \( B_g \) = total annual benefits of the gobar-gas plant.

\( C_m \) = total operational and maintenance cost of gobar-gas plant per annum.

\( C_K \) and \( C_s \) are the capital cost of the plant and capital cost of the stove respectively at the reference period.

\[5.5.5.10 \text{NET PRESENT VALUE}\]

Assuming the annual benefits and annual operating and maintenance cost are uniform over the useful life of the plant, the net present value of the gobar-gas plant (NPV) can be calculated from the mathematical expression,

\[
\text{NPV} = \frac{\left( B_k - C_m \right)}{\lambda} - C_K (1 + \epsilon)
\]

Where \( \epsilon = (C_s + C_L)/C_K \); \( C_L \) is the cost of the lighter. Others are as defined earlier.

\[5.5.5.11 \text{INTERNAL RATE OF RETURN}\]

The internal rate of return is the rate of discount which equalizes the present worth to the total investment. It represents the average rate of earning on the money invested in the gobar gas plant. If the Internal Rate of Return is higher than the rate of interest charged on the capital, it represents the economic worthiness of the gobar gas plant. It is calculated by the formula,

\[
\text{IRR} = \frac{\left( B_k - C_m \right)}{\left( C_k + C_s \right)}
\]
5.5.5.12 PAY-BACK PERIOD

Pay-back period which in this case is the length of the time from the onset of production of gas until the cumulative present value of the benefits reaches the total amount of capital invested in the plant. The pay-back period is calculated by substituting the values of \( t \) (useful life of the plant) and \( r \) (discount rate) in the mathematical expression for NPV and equating it to zero. The equation for pay-back period (PBP) is

\[
PBP = \frac{\ln(B_g - C_m) - \ln(B_e - C_m) - r \cdot C \cdot (1 + e)}{\ln(1 + r)}
\]

5.5.13 BREAK-EVEN ANALYSIS

The break even point (BEP) is the equilibrium point at which total income and total cost exactly match each other. It has been calculated by using the formula

\[
\text{BEP in plant size} = \frac{\text{FC}}{B_{UV} - V_{UV}}
\]

Where FC is the fixed cost of the plant

\( B_{UV} \) is the total benefits of the gobar gas plant per m\(^3\) size of the plant.

\( V_{UV} \) the total variable cost of the gobar gas plant per m\(^3\) size of the plant

Similarly, BEP in terms of quantum of gas produced per annum has been calculated

\[
\text{BEP in m}^3\text{ of gas produced per annum} = \frac{\text{FC}}{B_{m^3} - V_{m^3}}
\]

Where \( B_{m^3}, V_{m^3} \) are the annual benefits and variable costs of gobar-gas plant per m\(^3\) of gas produced.
5.6 LIMITATIONS OF THE STUDY

As the data and information of the energy use and installation of gobar gas were collected through survey method by personal face to face interview, the data might have been subject to recall bias. But it was minimized by cross checks. Besides, many benefits flowing out of gobar gas cannot be estimated in terms of monetary value on account of the problem of quantification. The benefits of hygiene, safe cooking etc., are very difficult to estimate as they involve subjective considerations. Similarly, improvement in environmental quality on account of forest wealth saved cannot be accurately estimated on account of inconclusive and inadequate technical information with regard to its environmental impact. Inconvenience of mixing cow dung with water and feeding slurry is also subjective and hence it is difficult to measure. Hence the study has limited its scope of measurement of social benefits to forest wealth saved in kilograms of wood, pollution reduction benefit, employment generated and social costs to cost of unused potential of gobar gas plant, cost of unutilized capacity of gobar gas plant or cost of gas wasted. As there are no end uses such as lighting and operation of CI engine in the study area, the scope of the study is limited to the end use of gobar gas to cooking.

5.7 SCHEME OF THE THESIS

The study has been presented in ten chapters. The first chapter is an introductory chapter which stresses the importance of the present study.

In the second chapter, the history and development of gobar gas plants in India and abroad during past decades has been presented.
Review of previous studies on gobar gas plant has been made in the third chapter. It gives a brief resume of the results brought out by different studies, reviews the objectives and methodology adopted by them.

In the fourth chapter, profile of the area under study has been presented. Here a brief description of the socio, economic and environmental condition of the area and the present status of the installation of gobar gas plant has been made.

Fifth chapter deals with the methodology adopted in the study. It specifies the objectives of the study, defines concepts and scope of the study and advances the relevant hypotheses. It explains different estimation methods adopted in the present study and gives the limitations of the study.

The sixth chapter analyses the capital cost structure of the gobar gas plants by making appropriate classification of gobar gas households by their different socio-economic characteristics.

The seventh chapter deals with the estimation of unit cost of gobar gas by cost pricing method by fitting cost functions. It also explains the estimation of unit pollution abatement benefit of gobar gas.

Chapter eight deals with the evaluation of social costs and social benefits along with economic costs and economic benefits flowing out of gobar gas and assess the economic viability of gobar gas plants using cost benefit analysis. It discusses the
economic viability of gobar gas plants under different social cost and benefit conditions to gauge the underlying factors in the economic viability of gobar gas plants.

The evaluation of the economic feasibility of gobar gas plant has been made in the ninth chapter using net present value, internal rate of return, pay-back period and break-even point analyses.

The last chapter is a concluding chapter, which summarises the findings of the study, brings out important conclusions on the analysis and gives policy suggestions.