REVIEW
OF
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In view of its importance and utility of bio-gas it has gained tremendous popularity. It also has attracted attention of the researchers. Number of studies appeared to have been conducted in various corners of the country covering various aspects of bio-gas. During the course of search, author could come across with some relevant references and the same have been presented here.

This chapter for the sake of convenience in its presentation, has been divided into following sections.

3. Personal, social, economical and situational characteristics of the farmers adopting various technologies in general and bio-gas technology in particular.
4. Types and sizes of bio-gas in use.
5. Time, money and energy spent and saved by using bio-gas.
6. Utilisation pattern of saved time.
7. Utility of bio-gas as perceived by the respondents.
8. Constraints faced in the utilisation of bio-gas and

1. **History, Genesis and Development of Bio-gas**

Bio-gas results from the anaerobic decomposition of organic material. According to Tietjen (1975) bio-gas was discovered by Shirely in 1667. It was however known much earlier as early as 1630 as stated by Partington (1960). Volta in 1776 recognized a close relationship between
the appearance of combustible gas and the decaying vegetation in the sediment of lakes and streams. Volta gave the first audiometric analysis of methane, the constitution of which was first developed by Delton in 1804. It was in 1808 that Humphrey Davy collected methane in his experiments with strawy cattle manure kept in a retort in a vacuum. This might be considered as the beginning of manure gas research. However, the first comprehensive study on various aspects of anaerobic fermentation was conducted, compiled and published in early 30's, by Buswell. These studies included testing of various agricultural wastes in the laboratory as well as in the field, with duration up to 800 days. In fact, this was the real breakthrough in the study of anaerobic fermentation of agricultural wastes for the production of fuel and fertilizer and till today it remained as one of the pioneering contributions as stated by Chawala (1984).

Development in India

According to Patel (1992), India was second to use bio-gas starting from 1887. The Ackworth Lepar Home of Matunga-Bombay started using bio-gas from its septic tank in 1887 for lighting. From 1907 they operated an engine generator and used for cooking as well. Joshi and Fowler of the Indian Institute of Science, Bangalore, worked on anaerobic digestion of waste materials like waste paper, banana rinds, leaves etc. to produce biogas.

According to Mignotee (1952) the first attempt to build a plant to produce methane gas from manure by biological decomposition appears to have been made in Bombay in 1900. Desai of the IARI, New Delhi, after visiting the sewage purification plant at Dadar, Bombay, which was commissioned in 1937, started investigation with Biswas and in 1939 achieved a breakthrough. He studied various environmental factors such as temperature, pH, substrate concentration, etc. affecting gas production.
from cattle dung and vegetable litter and thus made available basic data for further work. He devised a simple plant and his work was followed at Poona by Joshi. He designed a bio-gas plant in 1946 and patented the design.

Patel evolved a simple model of the cow dung gas plant called Gramlaxmi in the year 1951. Swami Vishwakarmanand of the Belur Math, Calcutta, Satish Chandra Das Gupta at Khadi Pratishthan, Sodepur, West Bengal, also started work on “Gobar gas” late in 1952. They evolved some cheaper models of these plants without using masonry material suitable for village homes in India.

Acharya at IARI, New Delhi, developed a model called the IARI design, after studying the requirement of gas for an average village home of 5-6 family members. Later, Idnani and his co-workers carried out laboratory and field studies in improving the operational efficiency of the innovation under different climatic conditions and developed effective methods for the efficient disposal and utilisation of the residual slurry.

However, Patel continued his efforts to simplify his earlier patented model which resulted in the development of his two-chamber model “Gramlaxmi-III”. This is the design which was adopted by the Khadi and Village Industries Commission, Bombay.

The Planning, Research and Action Division of the Government of Uttar Pradesh, Lucknow, established a permanent research station called the “Gobar gas Research station” at Ajitmal in 1960. Ram Bux Singh, made significant contribution. They have introduced the “Chinese design” under the name “Janata bio-gas plant” which is dome shaped and is drumless.

In August 1958, the Directorate General, Ordnance factories, Calcutta brought out a publication "Gas from Animal Dung", giving details
of construction and the material required for the construction. Venkata Rao did commendable work in bio-gas and evolved many designs and accessories and introduced latrine connected plants.

In 1962, the Hungarian Bio-gas expert in collaboration with the Government of India installed two demonstration models of bio-gas plants, one at National Sugar Institute, Kanpur and the other at Aarey Milk Colony, Bombay. The project aimed at converting agricultural wastes into methane-rich combustible gas of high calorific value (bio-gas) which could be utilised wherever the waste was being used as fuel and a fertilizer.

At the Indian Institute of Science, Bangalore, Reddy and co-workers have made significant contribution in this field. They have selected a village where a community type bio-gas plant is being installed and the concerned workers actually stayed in the village to study the operational and other associated aspects of this innovation. The structural Engineering Research Centre, Roorkee has manufactured ferrocement gas holders and digester components which will result in reduction in cost and facilitate the installation of the unit.

Most popular among the bio-gas digester design is the "Deenbandhu model". It was designed by an Indian non-governmental organization named "Action For Food Production (AFPRO)". It is considered the cheapest available model and was approved by the Ministry of Non-conventional Energy sources for large scale dissemination in 1986. Because of the relative small capacity combined with low price, this model mainly suits marginal farmers, lower costs and family groups as stated by Pandey and Chaturvedi (1993).

Neelkanthan at the National Dairy Research Institute, Karnal has provided useful data on microbiological aspects, relating to anaerobic
fermentation of the innovation. Rawat and Sharma at Aarey Milk Colony, Bombay, studied the quality and quantity of bio-gas produced from the excreta of poultry, piggery horse etc. and provided useful data.

The Indian Council of Agricultural Research, New Delhi, has been financing an All India Co-ordinated Programme of Research of Bio-gas Technology since 1977.

**Governmental Initiatives**

In 1981, the Ministry of Non-Conventional Energy Sources started the National Project on Bio-gas Development to popularize both family and community type bio-gas plants. In the first decade, more than 1.5 million bio-gas plants were set up in the country. In the period April 1992-March-1993 the target has been built 1,35,000 plants at a budget of US $18.5 million as observed by pandey and Chaturvedi (1993).

2. **Meaning, Definition, Principles and Types of Bio-gas**

Energy plays a crucial role in the economic and social development of the country and the standard of living of people is judged to great extent on the per capita availability and consumption of energy. The decade since the spurt in oil prices in 1973 has witnessed the much needed concern for the development of renewable sources of energy.

Roy (1989) defined renewable energy as “the energy obtained by tapping into the continuous and repetitive currents of energy occurring in the natural environment. Growing attention has been paid to the development of technologies using new and renewable sources of energy such as solar energy, wind energy, tidal energy, bio-mass and hydropower as pointed out by Kharbanda and Qureshi (1986).

Photosynthesis, the process by which green plants use solar energy to fix carbon-dioxide for elaboration into organic material has provided man
a source of food, fibre and fuel throughout his development. This solar energy stored in these organics offers a vast reservoir and scope for the production of significant quantities of renewable clean fuel in the form of natural gas (methane) under anaerobic fermentation. The benefits of this process include not only energy production, but pollution control, labour reduction, potential volume reduction, aesthetic value, general ease of operation, residue recovery for refeeding and as a source of plant nutrients and other uses, as stated by Chawala (1986).

According to Khandelwal and Maithani (1989) bio-gas is a clean and cheap fuel in the form of gas. It contains 55 to 70 percent methane which is inflammable. Bio-gas is produced from cattle dung in a "Bio-gas plant" commonly known as "Gobar gas plant" through a process called "digestion". The manurial value of the dung is not diminished in this process rather, it is improved.

George (1989) in her paper "Renewable energy systems for cooking application status and prospects" said that, the concept of "Bio-gas" enhances the scope for the organic wastes to be utilised in farms. Bio-gas consists mostly of methane gas and is a clean smokeless fuel. This is produced through an anaerobic digestion of organic material like cattle dung, agrowaste and water plants. The digested slurry is an excellent manure. Therefore, bio-gas technology helps in generating economic benefits in terms of saving firewood as well as chemical fertilizers besides social benefits like clean cooking environment, general sanitation due to smokeless cooking, cooking conditions with less health hazards, reduction in drudgery of all especially women and children involved in cooking cycle right from collection of fuel to cleaning up of cooking pots, Mathur (1989) supported the benefits of bio-gas such as low cost, reduction of pollution,
environmental stability, high employment potential, and above all self reliance and energy self sufficiency.

Bio-gas, or methane is produced when organic matter is decomposed by bacteria in an anaerobic environment. The bacteria survive and multiply only in an airless condition. In a bio-gas plant complex molecules are broken down step by step into methane and carbon dioxide through the simultaneous actions of different kinds of bacteria. The decomposition process can be divided into 2 broad categories - acid formation and methane formation. During the acid formation stage, short chain fatty acids such as acetic acid and formic acid are generated, in the second stage these acids are converted into methane and carbon dioxide.

The bacterial process in the reactor are mainly influenced by the pH and temperature. A temperature around 35°C is considered to be the optimum, below 10°C bacteria cease to function. Other factors which influence the methane production are carbon to nitrogen (C/N) ratio, retention time, loading rate, total solid concentration and mixing as stated by Pandey and Chaturvedi (1993).

Khandelwal and Maithani (1989) described the various types of bio-gas plant. The Centrally approved designs of bio-gas plants are

A) 1. Floating gas holder, commonly called KVIC type (1 to 10 cu m capacities)

2. Fixed dome, commonly called Janata type (1 to 10 cu m capacities)

3. Pragati model (1 to 10 cu m capacities)

4. Modified fixed dome called Deenbandhu model (1 to 6 cu m capacities)
5. KVIC type plant having digester made of angle iron and polythene sheet called Ganesh model (2 to 10 cu m capacities).

6. KVIC type plant having digester made of pre-fabricated ferrocement segment (2 to 6 cu m capacities).

7. KVIC type plant having fiber glass reinforced plastic (2 to 10 cu m capacities).

B) Sanitary latrine linked bio-gas plants.

3) Personal, Social, Economic and Situational Characteristics of the Respondents.

Rogers and Shoemaker (1971) has very significantly pointed out that various socio-economic characteristics influence adoption of technologies so also various other studies confirmed the same and therefore, it was thought appropriate to quote relevant references.

Age:

Paralikar et al (1988) in their study undertaken in Baroda district of Gujrat observed that, majority of the respondents (36 percent) fell in the age group of 25-35 years. That is most of the women were young who installed the bio-gas plant.

Aggarwal and Arora (1990) reported that 58.67 percent adopters of bio-gas were in middle age group i.e. between 40 - 60 years.

Djebharathy and Jayshree (1992) pointed out that, the majority of the adopters of bio-gas plants were between 30-40 years of age. It reveals that perhaps, younger people are more receptive to change than old.

Dimarkar and Wangikar (1993) found that majority of respondents (58.33) percent who installed the bio-gas plants were hailing in the young age group and remaining were of old age group.
Findings of the earlier researchers presented above have clearly brought out that adopters of bio-gas were prominently from the comparatively younger age. The trend, thus, is in conformity with the anticipation held in this behalf.

Education:

Nag et al (1986) reported that 87 families out of 114 adopted the bio-gas technology who did not have any formal education. The educated families (12 out of 114) have involved themselves in selection of site, plant size, material and construction activities. Their plants were maintained well, slurry disposal was managed well and gas was utilised maximum.

Subramaniam (1987) observed that only 16 percent of the beneficiaries attained the higher educational level i.e. up to post graduation. About 45 percent of the respondents attained the education upto S.S.C. or below.

Kalantri and Kubde (1987) reported in their study that 8.58 percent bio-gas plant adopters had the highest educational level up to post graduation and about 51.42 percent of the respondents received the education up to S.S.C.

Aggarwal and Arora (1990) found that about 57.33 percent adopters were illiterate. Only 13.33 percent bio-gas adopters had education above graduation.

Djeabarathy and Jayashree (1992) revealed that there was nobody illiterate in their sample, and so education is probably a facilitating factor in the adoption of new technology.

Digraskar and Wangikar (1993) observed that as good as 26.66 percent respondents had attended the high school education, whereas
20.83 percent respondents had primary education while 14.16 percent were able to read and write. This information gave indication that the literate person though had bio-gas plant was not having higher education. In other words, literacy status of bio-gas owners was low.

Thus high level of education does not seem to be an influencing factor for the adoption of bio-gas technology.

Family size:

The size of the bio-gas plant depends on family size, so that plant can meet the fuel requirements fully.

Mulmule (1986) found that bio-gas were installed by the families comprising 2-5 members.

Nag et al (1986) reported that out of 114 bio-gas plant owners, 67 bio-gas plant owners had 6-10 family members, 31 families had 5 and below family members, very few families had above 15 family members. Study further revealed that beneficiaries give first priority to family size so that the plant can meet the fuel requirement fully.

Kalantri and kubde (1987) observed that out of 105 families, 60 families had 6-9 members in their family and 31 families comprised of up to 5 members. Very few i.e. 14 families had above 10 members.

Aggarwal and Arora (1990) revealed that majority of the adopters had 6 or less members in their family.

Djeabarathy and Jayashree (1992) pointed out that joint family system with more than 5 members in each household was noted in 72 percent of adopters.

Susheela (1992) found that majority of the households who adopted gobar gas plants were joint families i.e. 70.83 percent. It was also evident
that 33.33 percent of each small, medium and large size families had adopted the gobar gas plant.

Digraskar and Wangikar (1993) reported that majority of the respondents (46.34 percent) were having medium size family while 38.33 percent had small size family. Only 13.13 percent owners were found to have big family.

**Land holding**:

Mingalani and Singh (1977) indicated that gobar gas plants were popular among the relatively big and richer farmers. The average size of holdings of the owners of 150-250 cu ft. gas plants varied from 20 to 23 acres. Medium and small farmers with not more than nine acres owned only 12 percent of the plants which were of a small size too.

Mulmule (1986) found that 31 gobar gas plants were provided to the cultivators having land holdings of 11-20 acres, followed by 29 gobar gas plants with land holdings of 1-10 acres and the lowest, 2 gobar gas plants were financed to landless villagers.

Nag et al (1986) reported that "National Project on Bio-gas Development" did not confine to economically well to do farmers, but it was received uniformly by backward families too, though the 107 plant owners out of 114 did not have any land in their name. In few cases the head of the family had some land holdings. To get maximum benefit of subsidy, the plants were constructed in wife's or son's name who were landless or small farmers. In fact most of the farmers had land between 6-20 acres.

Subramaniam (1987) observed that most of the beneficiaries of bio-gas plants were economically better of in terms of land holding and socially forward groups in the rural areas.
Kalantri and Kubde (1987) indicated that the small and marginal land holders sought the maximum advantages of the concession offered to them to install the bio-gas plant. Out of 105 families, 41 adopters had land holdings upto 5 acres. Landless respondents who were below poverty line were noticed to the extent of 10.

Krishna Mohan and Gupta (1989) stated that bio-gas plant has been adopted by the relatively well to do farmers who have the where withal to install and feed the plants. Out of the total number of plants put up, as many as 21.1 percent bio-gas plants were owned by farmers owning more than 20 acres of land, about 17.8 percent farmers having between 15 to 20 acres and only 8.3 percent were landless labourers.

Susheela (1992) revealed that more than half (64.58 percent) of the adopters of gobar gas plants belonged to the large land holding and medium land holding households (12.5 percent). An equal percentage i.e. 33 percent of small and landless households also adopted gobar gas plants and the same was found to be the least in case of marginal land holding households (6.25 percent).

Digraskar and Wangikar (1993) stated in their study that 47.50 percent of owners had big land holdings, while similar percentage of respondents were found to be marginal and small land holders.

4. Types and Sizes of Bio-Gas in Use:

Subramaniam (1987) found that over all 71.00 percent of the plants installed are of the KVIC type and 29.00 percent belonged to fixed dome type (Janata type) bio-gas plant.

Kalantri and Kubde (1987) observed in their study that the Janata type model was preferred by the 74.28 percent of respondents over the KVIC model (25.72 percent) may be due to the advice and suggestion by
the Panchayat Samiti officers and due to its low cost out of 105 gas owners only 29 bio-gas owners have connected the latrines with the bio-gas, others opined that it won’t suit to their culture.

Paralikar et al (1988) stated that 75.70 percent of the population in selected villages had KVIC gobar gas plants. Only 24.30 percent of the villagers had fixed dome gobar gas plants. The reason for selecting KVIC model were that the KVIC model requires less space and as plant is open, so in case of damage, they don’t have to open the plant.

Khalache (1988) found that as many as 103 respondents out of 110 preferred bio-gas plant with iron tank (KVIC), 6 preferred dome shaped tank (Janata) while only one preferred a bio-gas plant with plastic tank.

Djeabarathy and Jayashree (1992) observed in their study conducted in Mannadipet commune of Pondicherry that Janata model plants were installed by 32 families and KVIC model plants by 18 families. Their low construction and maintenance cost and smooth functioning were the reasons for their acceptability.

Dutt (1985) pointed out that 45.00 percent farmers constructed 105 cu ft. capacity gobar gas plants while 25.00 percent and 20.00 percent farmers installed 70 cu ft. and 140 cu ft. capacity gobar gas plant respectively. A small number of 10 percent of farmers installed 210 cu ft. capacity plants.

Nag et al (1986) reported that majority of the respondents (110 out of 114) liked to have 3-6 cum plant. Very few preferred a plant of higher capacity.

Khalache (1988) observed that about 9.00 percent, 51.00 percent and 41.00 percent of the respondents possessed bio-gas plant up to 1.40 cu m in between 1.40-20 cu m and above 2.10 cum respectively.
Susheela (1992) revealed that the adoption of a particular size depends on the advice of the officials, financial status, family size and herd size possessed by the households. Majority of the household i.e. 43.75 percent had adopted the bio-gas with capacity of 8 cu ft., 37.50 percent had adopted 6 cu ft. and only 18.75 percent had adopted 10 cu ft. capacity plant.

Critical perusal of the responses cited above tend us to believe that different factors determine the size of the bio-gas for adoption. The capacity of the plants installed varied according to the number of family members, availability of space and amount of cow dung.

5. i) Time Spent and Saved by Using Bio-Gas:

Paralikar et al (1988) reported that bio-gas reduced cooking time and time taken for cleaning the utensils by 50.00 to 78.00 percent of the respondents. Almost all (100.00 percent) respondents said that they save time and energy by installation of bio-gas plant.

Aggarwal and Arora (1990) observed that before the installation of gobar gas plant only 21.33 percent adopters were spending on an average one hour and 10 minutes daily in preparing the cow dung cakes. The job of making dung cakes by adopters house wives vanished with the introduction of gobar gas plant. On traditional Chulha, the average time spent on cooking of meals by the households was 3 hours 44 minutes with some variations according to their socio-economic status and size of household. With gobar-gas plants, the house wives were found to spend an average of 2 hrs, 58 minutes thus saving 46 minutes daily on cooking.

The respondents used to take on an average one hour daily for cleaning of utensils as against 40 minutes after the installation of gobar
gas plant. This reduction in time by 20 minutes was due to the fact that on gobar gas utensils were not blackened too much.

Average time spent on cleaning the house before the installation of gobar gas plant was 1 hour 10 minutes and after that it was 57 minutes daily, thus there was net saving of 13 minutes in this activity. The average time spent on washing of clothes was 1 hour. After the installation of gobar gas plant it was reduced to 46 minutes which means a saving of 14 minutes daily. On an average the housewives saved 93 minutes daily on various household activities.

Bhati and Laharia (1990) observed that bio-gas owning women spent less time in food preparation activities as compared to non bio-gas owning women. They saved about one and quarter hour per day. Considerable time was saved by bio-gas owning women in arrangement of fuel, cooking and cleaning utensils and kitchen. Non bio-gas owning women spent more time in chapati making and cooking of vegetables/cereals because of poor burning efficiency of dung cake and wood as compared to bio-gas. The smoke produced by dung cake and wood sticks make the utensils black, that is why, non bio-gas owning women spent 7 to 19 minutes extra per day in cleaning of utensils and kitchen.

Nagpal and Yadav (1991) studied the impact assessment of bio-gas technology on rural women. They found that the estimated impact had been to the extent of 58.04 percent. It implies that moderately high impact is observed on rural women by bio-gas which might be due to less consumption of time and labour.

The study conducted by Soundarapandian (1992) showed the average time spent for food preparation activities such as arrangement of
fuel (0.58 hrs.), preparation for cooking (1.14 hrs), cooking of food (4.82 hrs.), serving of food (0.87 hrs.) and cleaning of utensils and kitchen (1.38 hrs) before the installation of bio-gas plant. As compared to this, after installation of bio-gas the average time spent was observed as (0.34 hrs) for arrangement of fuel, (1.09 hrs) for preparation of cooking, 3.92 hours for cooking of food, 0.78 hrs for serving of food and 1.09 hrs for cleaning of utensils and kitchen. It was found that the total time spent for food preparation for a family by a housewife was 8.79 hrs per day before installation of bio-gas and time has been reduced to 7.22 hours per day, after using the plants. The time of 1.57 hours as an average was saved per day by the bio-gas plant.

It can therefore be inferred from the above that the time spent on utilization of bio-gas and time saved due to its utilization had a range of 3 hrs and ten minutes to 8 hrs and 43 minutes to 1 hour and 57 minutes respectively.

5. (ii) Money Saved by Using Bio-gas:

Indravati and Raji (1969) observed that the income realised from the plants treated with cow dung slurry was greater (Rs. 16.79) than the control, farmyard manure and vegetable compost (Rs. 3.53, Rs. 12.08 and Rs. 5.33 respectively).

Dutt (1985) observed that when the respondents were asked about the direct benefits they received from the plants, 58 percent farmers reported to have saved up to Rs. 800/- per year. The saving of 29.00 percent and 13.00 percent farmers ranged between Rs. 800 to Rs. 1,000/- to Rs. 1200/- per year respectively.

Mulmule (1986) found that the income from agriculture increased by 19.7 percent due to the utilization of increased manure produced by the
gobar gas plant. The savings on fuel amounted to Rs. 1029/- per family. Income and expenditure from the plant worked out to Rs. 1,828/- and Rs. 755/- respectively, leaving a net surplus of Rs. 1,073/- per annum.

Nag et al (1986) reported that 58 plant owners out of 114 are using slurry in their field, out of which 24 are of the view that it has increased crop production.

Kalantri and Kubde (1987) revealed that the respondents who adopted the bio gas to save the expenditure on fuel were 100 percent.

Krishna Mohan and Gupta (1989) found that the monthly requirements of fuel for a family of about 5-6 members comes to around Rs. 60-70/-. Bio-gas plant provides free cooking with almost the same running cost as that of LPG.

Paranipe et al (1989) revealed that on an average 17.6 hundred thousand K-calories of energy is saved from traditional sources per year per gas plant. This is equivalent to saving of 2160 kg of firewood. It was observed that average consumption per family per month was 264 kg dung cakes and 176 kg fire wood (collected), before the installation of bio-gas plant. It was clear that use of cow dung and fire wood was reduced to the extent of an average per family per month 45 kg and 38 kg respectively, after the installation of bio-gas plant.

Manjappa (1990) assessed the monetary benefit for the family from bio-gas in terms of differences between expenses incurred on fuel in pre-investment and post-investment periods and the value of dung/manure in terms of nitrogen contents in pre and post investment periods. It is observed that average expenses incurred on fuel by a family is Rs. 1,668/- per annum in pre investment period. In post investment period it is observed that expenses on fuel is reduced considerably. The average
expenses incurred for such purpose worked out to Rs. 654/- per annum.
The net savings on fuel for a family by installing bio-gas is Rs. 800/- per annum.

Kalra (1991) reported that over 74,000 bio-gas plants were installed from April to December 1989 in the rural areas. This saved fire wood worth Rs. 175.6 crore a year and also provided enriched manure valued Rs. 174.5 crore annually.

Pathania and Sharma (1991) evaluated the labour input in bio-gas plant in monetary terms, while studying labour utilization pattern in bio-gas plants in Haryana. They observed that, the utilization of family labour resulted in a saving of Rs. 343/- per annum for 2 cu m bio-gas plant owners, Rs. 420/- for 3 cu m Rs. 392/- for 4 cum and Rs. 379/- in case of 6 cu m bio-gas plant owners. The installation of bio-gas plants thus provided gainful part time employment to the family labour taking the opportunity cost of labour into consideration.

Devdas (1992) indicated that for cooking a days menu, 1190 litres of bio-gas were needed for a family of 5 members. A quantum of 1935 kg of fire wood could be saved per annum per family by installing bio-gas plants.

Soundarapandian (1992) stated that the direct income received from the gas plant as manure ranged from Rs.238/- (8 percent) to Rs. 546/- (12 percent) on an average per year. The indirect income such as gas value and electricity value from the plant varied from Rs. 2,581/- (88.7 percent) to Rs. 4,323/- (92 percent) due to the size of the plant. The annual net income was Rs. 1203/- from 3 m³ size, Rs. 1779/- from 4 m³ size, and Rs. 2479/- from 6 m³ size. The income from the gas value and
manure value was higher for 6 m³ size than 3 m³ and 4 m³ size. The electricity value was higher for the small size plant.

5 (iii) Energy Saving by Using Bio-gas:

Inspite of exhaustive search of the author to locate specific references indicating the net energy saving due to bio-gas installation as was attempted in the present study could not be located and therefore, references which reported saving of energy indirectly due to the saving of man power were considered appropriate for presentation.

Mukherjee (1975) showed that the use of gobar gas had taken away labour from the women folk for making the dung cakes.

Ramarao (1985) reported that 18 percent man power is lost mostly by women folk for collection of fuel. Bio-gas plant installation would substantially save this labour which could be diverted for other productive purposes.

Bhati and Laharia (1990) reported that the farm ladies were supported by other family members in the food preparation activities. The share of supporting labour on an average was to the extent of 12 percent for bio-gas owning and 15 percent for non owning families respectively. This attributes to the fact that non bio-gas owning families have to put more labour as compared to bio-gas owning families in food preparation activities and thus main farm ladies among these families seek comparatively more supporting labour than bio-gas owning women. It is also observed that during one year a bio-gas owning family on an average spends about 220 women days in food preparation activities whereas a non-owning family spends about 286 women days implying thereby that bio-gas owning families save about 60 women days labour per year.
Verma (1991) stated that cooking accounted for 2.48 human hours per day and a woman contributed 2.28 hours on an average per day per household. Thus, the rural women is more affected by the energy crisis.

Women and children are saved from hardships and drudgery of collecting and head loading of heavy bundles of firewood. Large scale promotion of bio-gas plants helps to generate employment for entrepreneurs, masons and unskilled workers in rural areas as stated by Ministry of Non-conventional Energy Source, Govt. of India, (1995).

6. Utilization of Saved Time:

Kalantri and Kubde (1987) revealed that time saved in cooking by using bio-gas was judiciously used towards farm activity by 50.00 percent of the respondents.

Paralikar et al (1988) observed that 100.00 percent of the respondents used their time in relaxing as they have to do lot of physical labour and so they relaxed before starting the evening household work. 100 percent of the respondents used their time in entertaining, gossiping, cleaning, washing clothes etc. About 57.00 percent of the respondents mentioned that they could spend more time for child care and their studies, looking after cattles and dairy etc.

Aggarwal and Arora (1990) found that 67.00 percent of the total average time saved was spent on attending the children including their look after and education and on economic activities like knitting, embroidery, sewing, spinning, curry making and ironing. The percentage of adopters doing economic activities before and after the installation of gobar gas plant was 13.33 and 22.67 percent respectively and the time spent increased during the later period by one hour i.e. from 30 minutes to one hour and thirty minutes. The time saved 33.00 percent from
household activities was utilised for the leisure activities like resting, enjoying radio and TV, visiting friends, seeing films and reading magazines and religious books.

Bhati and Laharia (1990) observed that bio-gas owning women spent about 27 minutes, 14 minutes and 11 minutes per day more than non owning women in livestock care, personal care and cloth care respectively. They saved about an hour in food preparation during peak agricultural season and this time was generally spent in cattle care and personal care.

Soundarapandian (1992) found that a total of 23.88 days (573.05 hrs) were saved on an average by bio-gas owning family in year. The saved time was mainly used in their personal care, child care and looking after cattle.

7. Utility of Bio-Gas as Perceived by the Respondents:

Bhadoria (1984) contended that the village-folk were freed from the drudgery of collection of fuel.

Dutt (1985) observed that almost all respondents got a high quality manure from their bio-gas plants in addition to the monetary gains.

Mulmule (1986) found that improvement in sanitary conditions due to the absence of smoke, soot, flies and mosquitoes in homes, saving in time of cooking, availability of more spare time for the women folk for some other productive purposes, relief from the botheration of collecting firewood and dung-cakes for cooking etc. are found to be some of the social benefits derived by the beneficiaries, households from the gobar gas plants.
Kalantri and Kubde (1987) revealed that almost all (100.00 percent) respondents agreed that they could get the weedless manure for its application in their land.

Khalache (1988) reported that 100.00 percent of the respondents found the slurry received from bio-gas plants helps in improving the structure of soil and it serves as media of organic manures and electric source. Almost all the respondents (100.00 percent) agreed that, bio-gas serves as a substitute to overcome the shortage of fuel, helps in increasing the water holding capacity of soil, about 92.72 percent of the respondents were of the opinion that, bio-gas promote to maintain forestry plantation upto desired date of harvest and slurry gives additional nitrogen.

Paralikar et al (1988) observed the advantages referred by almost all the users of bio-gas as, the 92.80 percent of respondents did not face any problem of fuel and that was available round the year, 100.00 percent respondents expressed as it is smokeless fuel and due to that they do not have any adverse effect on their health. They also opined that bio-gas was found to be easy and convenient and it helped in maintaining cleanliness.

Chole (1990) reported that about 88.00 percent respondents perceived very high utility of bio-gas while 11.67 percent opined that its utility was high. None of the respondent perceived its low or no utility. He observed that major use of bio-gas was done for cooking of food, about 98.00 percent respondents used bio-gas for cooking of food, 10.00 percent for lighting in house and 15.00 percent for water heating.

Manjappa (1990) pointed out that the farmers stood to gain additional monetary benefit of Rs. 1000/- by way of manure which contains more nitrogen and more manure available in post investment period.
Djeabarathy and Jayashree (1992) stated that all the 50.00 adopters used bio-gas as fuel for cooking. The users were fully satisfied with the easy operation, smokelessness and time and energy saving aspects of bio-gas. The slurry was utilised as a manure in the field.

Digraskar et al (1992) found that more than half (66.67 percent) of the respondents had perceived high level of utility, one fifth (20.50 percent) of the respondents had perceived medium level of utility, while only 13.13 percent respondents had perceived low level of utility of bio-gas plants. They further observed that majority of the bio-gas owners (95.00 percent) opined that bio-gas helps in eliminating environmental pollution, 94.16 percent respondents said that because of the gas plant they could get good quality manure. As good as 93.33 percent respondents were of the opinion that bio-gas reduces deforestation, 92.50 percent owners viewed that by adding bio-gas manure to the soil their agricultural production was increased, whereas bio-gas gives blue flame and doesn’t spoil the cooking and cooking utensils was the opinion of 83.33 percent respondents.

The respondents also reported that heat efficiency of gas is more than cow dung cake (64.16 percent), keeps kitchen clean (63.33 percent) builds the fertility of soil (60.83 percent), increases social prestige (53.83 percent), useful for light (47.50 percent) reduces import bills of crude and chemical fertilizer (46.66 percent), minimise the fertilise problem (45.00 percent), saves time (41.66 percent), keeps house free from smoke (31.66 percent), helps sanitation (24.16 percent) and it is also useful to improve the health of rural life (15.83 percent).
8. Constraints Faced in the Utilisation of Bio-gas:

Patel (1983) stated the causes for slow pace of gobar gas programme such as lack of proper publicity and motivation by the promotional agencies, lack of proper technical advice for the construction of plant and post construction maintenance and unwillingness of small farmers to take up. These investments owing to high cost, absence of the required number of animals, enough site and absence of incremental income etc.

Rao and Ramana (1984) observed that the failure to achieve the target was attributed to the factor such as lack of motivation on the part of the promotional agencies, unsatisfactory recovery of the loans from beneficiaries, non linking of gobar gas scheme with other items of agricultural activity such as dairy and unwillingness of small farmers to take up the installation of gobar gas plant on account of high initial cost, lack of required number of cattle and land and lack of incremental income from the gobar gas plant besides unsatisfactory post installation service.

Lavasa (1985) stated that ruralities would be normally receptive to bio-gas technology, yet the impediments are far too many, some of these are the idea of storing “this much” in the house itself, the availability of sufficient space in the home stead, unavailability of enough cattle shed, the problem of finance from the banks and the villages, “Lethargy of custom” and his/ in difference of outside technology.

Tomar and Singh (1986) indicated that all the plants owned by schedule caste/schedule tribe people and marginal farmers are non functional, structural defects are observed in 70.00 percent plants, operational defects such as non feeding of dung, components damage in stove, water accumulation in gas supply system and reduced production
are reported by 18.00 percent of the respondents. Other defects such as non-supply of stove, defective delivery pipeline and poor structure of construction were faced by 12.00 percent respondents.

Mulmule (1986) pointed out that out of 95 plants, 74 plants were in working condition and 21 were not in working condition due to scarcity of water and cracks developing in digester leaving it beyond repairs.

Kharbanda and Qureshi (1986) observed that, high proportion of bio-gas plants are lying idle due to various technical, economic and social constraints. In India, 70.00 percent of the farmers have below two hectares of land which cannot feed five to six cattle heads. Thus, the bio-gas plants are mostly owned by farmers in higher and middle income groups. The poor families do not have the capital assets to mortgage against the loans by the banks. It has been noticed that in some cases the credit and subsidies received for the installation of plants have been mis-utilised. The houses do not have sufficient space in the courtyard for the installation of plants. For economic functioning of the bio-gas plant it is necessary that the kitchen, cattle-shed, compost pit and the plant itself are located near to each other. The kitchen and the plant are at quite a distance with each other requiring a very long pipe to connect the plant with the kitchen and the pressure of the gas reduces at the user end. In general, the main reasons for the failure of the plants are masonry construction defects, non-painting of the gas holder, improper feeding and lethargy of the plant owners. They further added that cultural constraint is the low rate of literacy in the villages which restricted the access of information to the villages. A considerable number of plants are lying idle primarily due to the lack of the availability of information to the owners of the plants on their functioning and the precautions to be taken in their maintenance.
Yeshwanth (1987) found that installation of gobar gas plant is being undertaken by affluent ruralities and not by weaker sections due to the fact that this activity is not generating incremental income, but it is a wrong notion.

Kalantri and Kubde (1987) reported that 33 families out of 105 families adopted the bio-gas plant of 3 cu m size, they are not able to cope up their requirements. This implies that the concerned officers did not care to recommend a suitable size of bio-gas plant to 46 families out of the total lot. It was astonishing to note that even cattleless households who were five in number (out of 105) were also provided with bio-gas.

Malik (1987) observed that one of the major problems in adoption of this technology in the rural area was the disposal of bio-gas slurry. It takes a long period for drying before it is transported to the fields. Also a large area is required for storage of slurry which is not available with most of the ruralities.

Subramaniam (1987) revealed that the most frequently encountered problem was low gas pressure from the bio-gas plant. This accounts for more than 65.00 percent of the respondents. Collapsed wall, blocked inlet and outlet of the plants were also reported.

Vyas et al (1987) observed that inadequate supply of gas is a result of the plants being underfed in terms of dung. The dung supply to plants ranges from 18 to 61 percent of their capacity. Ten plants have been connected to latrines to cut the demand of animal dung but the latrines were not being used because of the people prejudices. The gas production at these plants has been poor during the winter season.

Anonymous (1987) in a report of Agriculture Department of Goa stated that 70.00 percent of the beneficiaries interviewed had setup
plants larger than required. About 56.40 percent of the households did not have the required number of animals. About 26.50 percent of the beneficiaries reported that they were not satisfied with the technical guidance rendered to them either because it was not proper or because nobody visited the plant site during the construction stage.

Sing (1988) observed that availability of labour to work with dung is a major problem in Punjab, as it is considered to be below status. Secondly the technology needs to be sufficiently improved to generate gas in winter.

Paralikar et al (1988) found that only issue was concerning consistency of flame with which 50.00 percent of the respondents were not satisfied, as they have to make use of supplementary fuel like kerosene and wood due to discontinuance of gas supply. About 80.00 percent of the respondents said that chapatis are not cooked properly on bio-gas. About 71.00 percent of the respondents faced the problem of mosquito due to open bio-gas plant. About 21.00 percent of the respondents opined that the flame is extinguished and gas pressure was found to be low in winter. Some general problems reported were, corrosion of the gas holder and unavailability of cow dung.

Khalache (1988) observed that, the respondents were facing the problems of shortage of dung to feed the tank (10.01 percent); problems of working of gas pipes (27.00 percent). About 22.73 percent were suffering from getting lower pressure of gas due to more distance in between plant and gas burners. About 98 respondents out of 110 expressed that masons need to be brought from outside as skilled masons for this work are not locally available. The loan sanctioning procedure of financial source is rather time consuming and required number of documents to be produced.
Pandya and Trivedi (1988) indicated that 50.00 percent adopters of bio-gas plants had socio-economic constraints, 10.00 percent had technological constraints and 16.00 percent had organizational constraints.

Krishna Mohan and Gupta (1989) observed the following reasons contributed to the non-working of 420 bio-gas plants out of 1276 plants installed. There was leakage in gas holder (105), partition wall collapsed (19), defects of outlet and inlet pipes (9), gas holders completely damaged (28), gas valves broken (7), shortage of cow dung (7), damage due to flood (17), negligence of farmers (13) and farmers were not interested to use (215).

Various procedural problems in finance, maintenance and inputs required for the bio-gas plants are pointed out by Kumar Bhaskar and Ravishankar (1989).

Supe et al (1990) stated that many of the constraints expressed by plant owners have originated due to improper technical guidance (36.94 percent), use of low quality material and inappropriate construction of the plants (6.50 percent). Many times water garbage accumulate in pipe line thereby blocking passage of the gas (36.94 percent) The leakages and foul odour (8.69 percent) are mainly due to faulty construction and cracks developed in digester.

Dhawan et al (1990) revealed that about 87 plants (3.24 percent) were not in use due to technical defects in construction. About 28.74 percent of plants were not working due to shortage of dung. Improper handling of plants led to the closer of 14.00 percent plants. It was also observed that 0.74 percent and 1.22 percent plants were not working due to excess and less water feeding respectively. About 51.00 percent plants
were not in use due to a variety of reasons like lethargy, lack of knowledge regarding the importance of bio-gas technology.

Swamy and Jalihal (1991) observed that whenever there was close supervision while constructing plant, they were found functioning (51.67 percent) successfully. The results have revealed that the majority (48.33 percent) of cases of non-functioning plants, there was no evidence of such close supervision by extension functionaries.

Soundarapandian (1992) expressed various problems in his study faced by the gas owning families, such as non-availability of technical knowledge in the initial stage, higher initial cost, non-availability of space, difficulty in collecting the dung during the period of cattle grazing, difficulty in generation of gas in winter, non-availability of proper maintenance and repairs facilities and delay in disbursement of subsidy by the Government to the beneficiaries.

Singh et al (1992) pointed out operational problems concerning to bio-gas plants. Improper feeding can be one of the main reason for failure of the gas plants. Defective construction by untrained mason, lack of strict supervision in training, delayed supply of raw material and plant components and lack of coordination among various agencies were the organizational problems related to bio-gas plant. Technological problems to be faced by the bio-gas owners were as seasonal variation in gas production due to lack of temperature control, accumulation of water in pipeline and need to remove it at periodic interval, inefficient designing of gas appliances and unsuitability of a design in a given climate and/or topography.

Digraskar et al (1992) observed that high expenditure in maintenance of animals and initial cost of plant is high, was the major
economic problem reported by 26.66 percent and 20.83 percent of the respondents respectively.

Under the social problems 3.33 percent owners stated that they found environmental pollution and 1.66 percent of owners opined that prestige is lowered down in society.

Under the personal problems, lack of transportation of dung from farm to bio-gas plant (15.82 percent), dearth of place (13.30 percent), inadequate number of animals (10.83 percent), and unhealthy atmosphere in the house (3.30 percent) were the major constraints put forth by the respondents.

Delay in getting loan/subsidy (19.16 percent), untimely guidance given by the officers (3.33 percent) officers are not expert in technical knowledge (3.33 percent) about bio-gas and non co-operation by concerned officer (1.66 percent) were administrative problems faced by the respondents. Considerable number of the bio-gas users expressed major constraints like less gas production in winter and choking of gas pipe.

Djeabarathy and Jayashree (1992) observed that 17 adopters out of 50 had financial problems as the sanctioned loan amount was not sufficient. Technical problems such as defective construction and leakage were noted by 13 users. Seven plants needed maintenance like painting, cleaning and charging which again was a strain on the limited resources of the users.


Tomar and Singh (1986) pointed out that initially, plant should be financed by the beneficiary through loan/self financing or subsidy amount should be released after ascertaining satisfactory performance for two
years or regular payment of loan installment to the bank. In view of structural defects, it is necessary to introduce strict quality control at various stages of construction. It is essential to train the beneficiaries about the constructional and operational aspects of bio-gas plant. It is also desirable to assess the potential based on the availability of water throughout the year, scarcity of water even for one or two months makes the plant inactive and it remains idle.

Mulmule (1986) expressed that the cement of better quality should be provided on top priority basis and masons be trained in construction of the digester. The beneficiaries need to be educated to cure the digester with water and the representatives of KVIC and State Agriculture Department should do extension work to motivate the rural masses for installing gobar gas plants. Technical officers of KVIC should identify the site for plants on the basis of norms of distance from the kitchen.

Bhati and Laharia (1987) on the basis of study suggested that, a vigorous extension programme should be launched to educate the bio-gas owners about their proper operation, maintenance and utilisation. The bio-gas plants are still in limited number considering this limitation. "Distance leaning" approach of informing and educating bio-gas plant owners would be the most effective and economic one. In addition there should be regular broadcast on radio, group discussion and personal contact by the officials engaged in the promotion of this technology. The agricultural extension workers should also be given thorough training in this regard. The bio-gas plant owners who are educated as well as have more extension contact and exposure to mass media should be identified for intensive training so that the technology may further diffuse among others through them.
Kalantri and Kubde (1987) observed that 72.38 percent owners expressed need for trained local persons or Gram Sevak for making the minor repairs in the bio-gas plant. Many bio-gas plants were found to be lying unutilised and therefore, sufficient efforts should be made to put into use such bio-gas plants.

Singal (1987) recommended that the choice of an appropriate location for the methane digester is very important for a good integration of the bio-gas plant. The effective utilization of the bio-gas produced should be made for lighting, power generation or heating.

Pandya and Trivedi (1988) revealed that 16.00 percent adopters and 30.00 percent non-adopters laid emphasis on increased rate of subsidy followed by 34.00 percent adopters and 10.00 percent non-adopters suggesting immediate service and guidance for installing gobar gas plant. While 14.00 percent adopters suggested that effect of season or gas production should be controlled and 4.00 percent suggested for mechanized process of pouring the slurry into the plant.

Rama Rao (1988) suggested simple design and low cost bio-gas plants with locally available cheap and durable material to find out alternate feed material for bio-gas plants, to study methods for shortening the retention period in bio-gas plants to study constraints, lack of proper support services and public policy for the propagation of the bio-gas technology.

Advisory board on energy (1988) observed that some of the problems need to be taken by national laboratories such as to find out alternate feed material for bio-gas plants, to utilize solar energy for raising the temperature of bio-gas plants under colder climatic condition and to establish different packages of services, incentives and subsidies, such as
credit, or subsidy and regulations, extension service, training, education after sales services, peoples' participation to promote propagation of bio-gas technology.

Khalache (1988) suggested to create an awareness about the importance of holding bio-gas plant.

Kumar Bhaskar and Ravishankar (1989) opined in their study that, the promotion and implementation of renewable energy programmes should be done on the basis of the qualitative criteria but not mere quantitative targets. The unit once commissioned should be able to function without any interruptions owning to input shortages, mechanical breakdowns etc.

Tawade and Ranmare (1990) reported that 90.54 percent and 62.16 percent of the respondents were of the opinion that amount of subsidy and loan should be increased and sick plants should be immediately repaired respectively. Maintenance cost on animals should be subsidised and Government agency should conduct the training camps for farmers and house-wives, were some of the suggestions given by the respondents (28.37 percent) and (24.32 percent) respectively.

Supe et al (1990) stressed that, it is necessary to test the material and if possible mention the quality of material by affixing ISI standard, which is to be used in construction of plants. Other material like gas pipeline, burners and cocks should be supplied through approved agencies. The drudgery of mixing the dung and water, needs to be removed by developing some mechanism Some techniques need to be developed to dry the slurry coming out of the plants as early as possible. The excess gas in summer needs to be used for lighting, engines etc.
some mechanism to remove the water in the pipeline and to avoid scum
development in the digester need to be developed.

Dhawan et al (1990) pointed out that, selection of beneficiaries
should go strictly according to the feasibility as formulated by Department
of Non-Conventional Energy Sources rather than giving more emphasis on
completion of allocated targets. The construction of plants should be
carried out with the help of trained masons and families should be
motivated to attach latrines to the bio-gas plants. At the same time
systematic research work should be undertaken in order to explore and
exploit other source of biomass locally available in the rural area for
generation of bio-gas. For identifying and rectifying the minor technical
defects, creation of mobile maintenance unit at block level with trained
personnel will go a long way in ensuring smooth working of commissioned
bio-gas plants. It is also necessary to step up programme of promotion
and motivation with the help of Audio-visual aids in order to create fresh
awakening among the beneficiary families and potential user families.

Vashisht and Sharma (1990) stressed that in order to popularize
bio-gas technology among rural masses, continuation of subsidy is must.
The withdrawal of the subsidy would hamper the adoption and
development of bio-gas technology.

Soundarapandian (1992) offered some suggestions to overcome the
problems faced in installation and operating the plant, such as to
overcome the problem of non availability of space, the Government must
install community plants, impart technical knowledge before installation of
plant for solving the technical initial stage problems, making proper
maintenance and repair facilities available after installation service is
necessary, creating awareness of the technology, emphasize on i) Shortage of fuel, ii) better sanitation, iii) Smokeless cooking, iv) good
manure and v) time saving for women, getting the required amount of cattle dung, there must be proper sanitation to the number of animals and patterns of feeding and disbursing the subsidy promptly, government officials must take necessary action.

Keeping in view the various constraints, Chockalingam and Bhanugopan (1992) expressed some of the suggestions. They stated that the Government of India with other agencies should introduce the educational and public awareness programmes at national level, focussing on imparting the knowledge of bio-gas technology among the uneducated rural people. Since most of the people are illiterate, information regarding operation, maintenance, sources of finance, subsidy, pre and post installation service etc. should be inculcated to them in such a way that they could understand easily. In every village model bio-gas plant should be established for demonstration purpose.

Digraskar et al (1992) suggested that the extension personnel in the Department of Agriculture, specialists of Agricultural Universities and concerned agencies should intensively be involved themselves in rendering technical guidance to the farmers for acceleration and continued acceptance of bio-gas plants. It was suggested by the 1/4th out of the 120 bio-gas installer that efforts should be directed to lower down the expenditure on initial installation of bio-gas plant.

Djeabarathy and Jayashree (1992) expressed their views that people should be educated thoroughly about any innovation before it is put into practice. The loan procedure can be simplified and agriculturists with sufficient source of income need not be asked to produce surety.