Biogas Technology

A Study of Community Biogas Plant

D R Veena

BIO-GAS TECHNOLOGY: A STUDY OF COMMUNITY BIO-GAS PLANT

Sponsored by UNICEF

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DR. VEENA

Content

List of Tables

1

Objectives and Framework of the Study

1. Introduction

Bio-gas as an alternative source of energy has been widely recognised in a number of countries. It is a low cost solution to energy problems particularly in third world countries. This appropriate technological solution got its prominence during the energy crisis. It provides better fuel for heating and cooking. It meets lighting needs in rural communities and provides power for irrigation. It produces highly enriched fertilizer and increases agricultural productivity. It destroys harmful parasites in human and animal waste. It stems the depletion of non-commercial energy sources such as firewood, dung, rice straw, etc. As a result, it eliminates environmental pollution and improves health and sanitation conditions. It provides an opportunity to improve economic conditions through using leisure time for work.

Recognising the vital role of bio-gas meeting the energy needs in rural areas, the Government of India has framed programme for installation of around four lakh individual bio-gas plants during the Sixth Five Year Plan (1981-85). However the extent of success seems to be limited. It is mainly due to the fact that rural people particularly small and marginal farmers, rural artisans and agricultural labourers do not have (*a*) enough number of cattle, (*b*) capital resources, (*c*) awareness about tangible and intangible benefits, and (*d*) suitable place to instal plants. Considering these constraints involved in the scheme for installation of family size bio-gas plants, the Government of India has decided to set up community plants in the country.

The scheme of setting up the community bio-gas plant has many advantages : (*a*) generating gas at a low cost due to distribution of overhead cost among beneficiaries, (*b*) economical operation as compared to individual plant, (*c*) to villagers not having suitable and sufficient site to instal small plant, (*d*) to villagers not having sufficient capital, (*e*) to villagers not having sufficient number of animals or required quantity of dung. (*f*) to dispose of slurry more conveniently as compared to individual plants, and (*g*) to villagers, who do not have individual plants; can enjoy all tangible benefits of community plants. In view of these advantages, a decision of setting up a community bio-gas plant at Khoraj village in Gandhinagar district was taken. It is one of the biggest plants in the country. As usual, this plant has also its own technical and non-technical problems, limitations and constraints in the smooth running. In this context, this study is aimed at obtaining some organised freedback on impact and performance of the plant which ultimately may help to improve and modify the technical design, organisational arrangement, and economic viability of similar bio-gas plants in other parts of the country.

2. Objectives

Objectives of this study are:

1. to monitor technical performance of the plant;
2. to examine performance of the organisational arrangements made to run and maintain the plant;
3. to analyse socio-economic effects of the plant on consumer families;

4. to examine the impact on the village environment and economy;
5. to study economic viability of the plant and cost benefits to the consumer households;
6. to make policy oriented suggestions for improving performance of the bio-gas plant in particular and similar other bio-gas plants in the country in general.

These objectives are examined through using a specific case study of the Community Bio-gas Plant at Khoraj Village, which is one of the biggest plants in the country.

3. Methodology Adopted by ASAG

The nature of this study is such that it is heavily based on quantitative and qualitative information available from the primary and secondary sources. Methods followed in the study are : Desk work, interview and discussion with experts and local people, Primary Survey of Bio-gas users and dung suppliers. Regular visit to the plant and experiments or test in laboratory.

In desk work method, qualitative and quantitative information were collected from the Gujarat Dairy Development Corporation (GDDC), Gujarat Agro-Industries Corporation (GAIC), Directorate of Population Census, Bureau of Economics and Statistics, Gujarat Mineral Development Corporation and Village Panchayat. Statistics and other information deal with socio-economic profiles of Khoraj village, technical and non-technical aspects of the plant, energy consumption pattern and potential sources of energy in Gujarat, development of bio-gas technology in India and Gujarat, etc.

Through using interview methods, Plant Incharge, Plant Operator, Technical Experts, Sarpanch of Khoraj village were contacted to collect information on various technical and non-technical aspects of the plant, problems and constraints involved in low performance of the plant, and overall prospects of the plant in future.

Discussion method was also followed for collecting critical opinion on energy consumption pattern and potential prospects of energy sources in Gujarat, development in various aspects of bio-gas technology, etc. For that experts from Government and Non-government agencies like GDDC, GAIC, GEDA, Khadi Gram Prayog Samiti (KGPS), ONGC, KVIC, Agricultural Tool Research Centre (ATRC), etc. were contacted.

An Advisory Committee on the project of the Community Bio-gas Plant at Khoraj village was formed. Experts on various aspects of the bio-gas technology were drawn from various organisations, namely GDDC, KGPS, GAIC, UNICEF, ASAG and ATRC. A series of meetings were held with the experts/members of the Committee to discuss several aspects of the plant and problems involved in each aspect.

A meeting has also held with beneficiaries and other local people to know their views on several aspects of the plant such as gas production, gas utilisation, wastage and leakage, distribution of slurry, supply of dung and local participation. Shri Harshadbhai Shah (GAIC), Shri Arvind Pandya (KGPS), Shri Kirtee Shah (ASAG) and Shri Haribhai Patel (Sarpanch of the village) actively participated in the meeting.

The field surveys of all bio-gas user-families and dung suppliers families were conducted to collect information about their socio-economic profiles, supply of dung, consumption pattern of energy including bio-gas, opinion about advantages/disadvantages of bio-gas, utilization of slurry, uses of toilets connected with the plant and their involvement and participation in problems and prospects of the plant. The surveys were conducted in August-September 1984.

Method of regular visit to the plant was also followed for knowing day to day position and performance of the plant and problems involved in it. An employee of ASAG looks after various activities of the plant regularly. Daily Information Record Card systems for plant operator, user-families and dung suppliers have been adopted to examine the pattern of gas production, consumption, supply hours, availability of dung to the plant and other related aspects. A number of visits of experts from various organisations have been arranged to look into technical and non-technical components of the plant. Some consultants from other parts of the country have also been requested for opinion to improve the performance of the plant.

4. Scope/Coverage of Topics

1. Survey of village on socio-economic profiles of people and ecological conditions of village.

2. Socio-economic survey of all 38 gas user-families and 30 dung supplier families,

3. Presentation of main technical and non-technical aspects of the plant.

4. Position of plant in gas production, distribution, utilization and wastage and leakages and slurry management.

5. Community participation and local organisation for maintenance of plant and other related aspects.

6. Opinions of plant operator, plant incharge and plant evaluator on various aspects of the plant.

7. Identification of technical and non-technical issues, problems, limitations and constraints involved in a low level of performance of the plant.

8. Actions taken and suggested by the experts and members of Advisory Committee on the study of the plant.

9. Energy consumption pattern and potential sources of energy in Gujarat.

10. Review of literature on the development of bio-gas technology and other related aspects.

5. Chapter Scheme

Following Chapter 1 on objectives and framework of the study, Chapter 2 deals with pattern of commercial and non-commercial energy consumption in Gujarat and potential sources of energy and constraints, problems and issues involved in supply prospects. Chapter 3 describes development of bio-gas technology in the developed and underdeveloped countries in general and Gujarat State in particular. Chapter 4 deals with some technical and non-technical aspects of the community bio-gas plant at Khoraj village. It also highlights technical and non-technical problems involved in smooth running of the plant. Finally, Chapter 5 presents the actions considered for improving the performance of the plant and some policy oriented suggestive measures.

2

Consumption Pattern and Potential Sources of Energy in Gujarat

1. Energy : A Critical Commodity

Energy is a critical commodity. It functions as a factor of production, as a process-feed stock and as a consumer good. The availability of energy determines, and the demand for energy is determined by, the shape of the life style of individuals and that of the total economy.

The evidence world over has shown a positive association between per capita income and per capita consumption. In fact, the per capita consumption of energy is now regarded as one of the important indices of economic development. Economic development is also seen to have been accompanied by substitution of one form of energy by another. As an economy develops, its demand for energy tends to increase and its consumption pattern in terms of energy-forms and energy sources also tends to change. But the stock of known viable sources of energy-supply particularly of commercial fuels are limited and to a large extent non-renewable. Further, the commercial exploitation of energy sources involves large investment and long gestation period. These and other considerations emphasise the need for taking a long-run view on demand and supply aspects of energy. Can Gujàrat count on enough energy sources from within the region to meet the requirement of increasing population and to support the increasing per capita income? In other words, will energy pose as the major constraint on Gujarat's development? What are policy options for advance planning? These are some of the critical questions. These questions pose a series of methodological problems arising from the unpredictability of factors like changes in the technology and product-mix of different sectors, relative prices of different fuel and substitution possibilities.

2. Energy : Consumption Pattern

The present pattern of energy consumption in Gujarat reveals that, from the demand view-point, energy sources can be considered in two groups, *viz.* commercial and non-commercial (traditional) fuel sources.

The non-commercial fuels are obtained from vegetable waste products, animal waste (dung) firewoods, etc. Although non-commercial sources of energy are inconvenient to use as fuel they are available at almost zero cost. Non-commercial fuels are in the nature of "inferior goods" and tend to be substituted by commercial fuels as income level increases (based on the information available from the 23rd Round of NSS).

One of the important characteristics of energy consumption in India is that a substantial part of the total energy consumption is accounted by non-commercial sources (50%). Gujarat also moves more or less close to the national average (See : NCAER, Demand for Energy in India, New Delhi). Fact is that since non-commercial fuels are available at almost zero cost, it might be constituting an important source of energy for poorer section of the population, especially in the rural areas.

Commercial energy can be distinguished in its two forms, *viz.* primary and secondary. The primary forms of energy are those which are used in the form in which they are available in the fossil base like coal, oil and natural gas. The secondary, forms of energy on the other hand are used by the transformation of the primary forms like electricity. Among commercial energy consumption petroleum (Like LPG, Kerosene, ATE, HSDO, LDO, motor gas, bitumen, etc.), electricity and coal constitute major commercial fuels items accounting for 50%, 30% and 20% (Table 2.1).

In the case of use of oil in different sectors of transport constitutes around 50%, domestic consumption sector constitutes 30%, industry and agriculture sectors constitute around 20%.

In the case of use of electricity, around 70% share goes to industries located in cities and towns, 15% for other categories of urban consumption and remaining 15% for rural use.

The commercial energy is used by only 20% of the affluent part of the population; while for 80% of the population mainly in rural areas energy crisis is not a problem of immediate relevance, except in so far as it has affected price rise in a few mass consumption items. However nature and extent of energy crisis in rural areas will be apparent if we look at existing rural energy needs and consumption pattern. As it is mentioned that shares of commercial and non-commercial energy are fifty-fifty. Since a large majority (more than 80%) of the rural population do not have enough purchasing power, they survive on non-commercial energy sources like firewood, dung cakes and agricultural wastes which compose by 65%, 15% and 20% respectively. Thus, in rural areas, wood is the basic cooking and heating fuel, where it is scarce, dung and agricultural wastes are used. Their non-commercial sources are supplemented marginally by commercial energy sources (like kerosene). Other commercial energy sources are almost exclusively used by a tiny affluent section of the population.

Population who survive mostly on non-commercial energy

Table 2.1

Consumption Pattern of Commercial and Non-commercial Energy in Gujarat State : 1980-81

Sl. No.	Categories	Consumption in Coal Equivalent (Value in '000 tonnes) Qty.	%
A.	**Commercial Energy**		
	1. Electricity	3,957	29.8
	2. Petroleum and Natural Gas	6,586	49.6
	3. Coal	2,736	20.6
	Total (A)	13,279	100.0
B.	**Non-commercial Energy**		
	1. Firewood	8,541	65.3
	2. Dung cake	1,988	15.2
	3. Others (Agri. Waste)	2,551	19.5
	Total (B)	13,080	100.0
	Grand Total (A+B)	26,359	

1. Share of Commercial Energy to total 50.38%
2. Share of Non-commercial energy to total 49.62%

Source: Based on information collected from various Government Departments; Gujarat Electricity Board, National Sample Survey, National Coal Board, Organisation of Natural Gas Commission, Annual Survey of Industries.

consume about 5,600 Kel per day per capita, as against 11,200 Kel per day per capita for the energy affluent urban elite. If we consider a reasonable need of energy for a satisfactory life pattern which is estimated to 28,000 Kel per capita per day then it implies that only 20% of the energy needs of the rural population are met. To bridge this enormous gap in rural energy needs, energy production would have to be thrice the production. Thus, the question is to what extent can bio-gas bridge the gap in rural energy needs and how efficient it is. In other words, it is a question of technology, choice and transfer of technology undergiven a techno-economic feasibility. Before analysing this let look at potential supply or energy and constraints involved in it.

3. Energy : Sources and Constraints

The availability position of the major commercial energy sources in Gujarat reveals that the primary sources of conventional commercial fuels in the State mainly rest on the oil and natural gas. Gujarat does not have proven resources (mining resource) except some deposits in Surendranagar, Kutch and Bharuch.

The sources of electric power are generally of three types—thermal, nuclear and hydro. At present the electricity power supply is generated from thermal power stations based on primary source of coal. As far nuclear power generation, Gujarat does not possess any proved uranium ore sources. A series of cost control issues are also involved in it. Hydro-resources for electricity generation depends on the State's receiver system, particularly consist of Narmada, Tapati and Mahi rivers.

In additions, unpredictability of factors like changes in technology and product mix of different sectors, relative prices of different sectors, relative prices of different fuels and substitution possibilities also have to be considered.

Considering a series of constraints involved in generation of commercial energy and increasing demand for energy particularly commercial energy in different sectors of the economy, alternative measures have to be considered.

The domestic energy consumption of the bulk of rural Gujarat is derived from the primary sources of firewood, dung cake and other non-commercial energy sources. Out of a total forest area of 1800 million hectares in the State (which constitutes 9.18% to total geographical area) the exploitable area (forest area in use) in Gujarat is already 1,613 million hectares. The potentially exploitable area thus seems almost insignificant.

The other major non-commercial energy sources of the State is dung cake, the availability of which depends on the cattle population. According to 1977 Cattle Census, Gujarat has had 144 lakhs cattle population. No definite estimate of dung availability for fuel supplies is available. As a rule of thumb, around 50% of the dry dump production is available for consumption.

The availability of estimates of non-commercial energy sources like firewood and animal waste in their traditional use does not provide a promising picture. What are then policy options? One that easily suggests itself is to increase the efficiency in dung use in fuel. In its ready use form (dried cake) the combustion efficiency is reportedly not more than 11%. The practice of burning extraction of its latent energy has evoked much interest. The KVIC has been pioneering the setting up of bio-gas (gobargas) plants, which are simple closed wells to subject the biological wastes to controlled fermentation and partial gastification. The joint product sludge is also a better fertilizer compost. The gas known as gobar gas or bio-gas contains 55% methane and can be used for cooking, heating and lighting in the domestic sector. It can also be used for motive power in energetise water pumps and other lighter industrial uses.

It has estimated that the smallest size plant with a capacity of 60 cft. gas per day have a capital cost of Rs. 5,000 and requires an input of 45 kg. of wet dung (9 dry dung) per day. The dung availability from an animal varies with size, age feed content and other factors. On an average a household with 5 animals can be expected to maintain the input supply of the smallest size bio-gas plant. The private profitability of bio-gas plant has been established—a gross return 14% to 18%—and from a social benefit-cost view point the plants are even more attractive, particularly as both fertilizer and kerosene, the alternative source of energy have (See: Kirit S. Parikh, Second India Studies : Energy, The Macmillan, Delhi, 1976).

The more relevant question relating to the viability of gobar gas option to the total energy picture in Gujarat still remains. The large scale generation of energy from bio-gas plants has tremendous organisational problems concerning dung collection, mass production, developmental feasibility and gas distribution system, etc. As a matter of fact, decentralised energy generation potential is the unique feature of bio-gas plants. From this view-point, a basic question emerges, how many households in rural Gujarat have the technical viability of generating energy for their domestic use from bio-gas plants?

The relevance of this question emerges due to the technical constraint that a dung-input of 45 kg. (dung waste of at least 5 animals) is required to operate the smallest sized plant. The NSS (26th round) data on land holding pattern and number of cattles for various regions of Gujarat were analysed to arrive at a frequency distribution of number of households in relation to land holding and boring ownership. It is observed that 2.2 million *i.e.* 45% of estimated rural households in Gujarat has more than 1 hectare of operated land holding and more than 5 cattle. If one venture to generalise, nearly one-half of the rural households in Gujarat can thus instals bio-gas plants and generate their own domestic requirements of energy and thus reduce the demand pressure on the commercial fuels like kerosene oil and electricity.

3

A Review of Literature on Development in Bio-gas Technology

Bio-gas technology offers a low cost alternative for energy requirements in rural areas. It is based on recycling a variety of organic wastes. It has been considered as a priority activity in rural development programmes. Different types of family size digester models have been developed in view to reduce the cost of this technology and bring it within the reach of households. However, benefits of the family size models have remained restricted to households possessing 3 to 4 cattle. A large majority of poor households who have no cattle of their own are consequently excluded from the benefits of this potential source of energy in rural areas. In this context, the installation of community bio-gas plants assumes a high priority as it is an effective alternative source for extending the benefits of bio-gas generation to all households in rural community.

1. Reasoning of Bio-gas Development

Bio-gas development has been experiencing in a number of countries. Motivation observed from the country view-point is overall reduction in firewood consumption and, therefore, on the ecological problem of deforestation. Extensive use of bio-gas may substitute commercial energy like kerosene and thus serves on foreign exchange and maintain public health through uses of organic wastes. In short, reasons advanced for bio-gas plant application in view of its economic viability and feasibility are as follows :

(*a*) bio-gas as a supplier of fuel for cooking, lighting, engine, etc.

(*b*) bio-gas as a substitution of non-commercial and commercial energy such as firewood, dung cakes, kerosene, electricity, LPG, etc.

(*c*) bio-gas plants as a supplier of organic fertilizer, sanitation, waste treatment, pollution control, etc.

(*d*) bio-gas plants as a mean for income and employment generation.

2. Bio-gas Development in the World

Presence of natural gas and its burning has been observed in a number of countries. The ancient China, Egypt and Rome recorded burning of natural gas in the beginning of 17th century. First person observed the burning gas with decaying vegetation matter was Alessandro Volta of Northern Italy. It was in 1776. During 1806, William Henry had shown that Volta's observation on gas was apparently identical with the main constituent of synthetic illuminating gas which was later called methane. The presence of methane in farm yard manure was noted by Humphrey Darey in the early 1800s. During 1875 a scientist named Popaff published the process of gas production. Around eight years later, first experimental digester produced bio-gas. The first plant for obtaining methane from wastes was set up in 1900 at Matunga in Bombay (India).

After First World War, production of methane was received in Great Britain. In 1940, French scientists in North Africa devised a systematic process of production of methane. Around one thousand methane gas plants were set up by 1951. Later on the process of methane production evoked in Austria, Italy, Russia, Kenya, Uganda and South Africa.

Bio-gas development experienced a boom in a number of bio-gas plants constructed during the early 1970s, particularly in India and the Peoples Republic of China. In the light of China's amazing results in small scale bio-gas production, the First International Bio-gas Training Seminar was organised in mid-1979 sponsored by the United National Environment Programme. The main purpose of the seminar was to enable scientists from developing countries to get knowledge about the Chinese method of waste digester construction and factors responsible for China's success in this technology. The seminar concluded "Third World Countries are . . . depending on the developed nations for their own development and destruction of cultural values, loss of self-confidence and exploitation . . . Development of appropriate technology such as bio-gas demonstrates that Third World Countries could achieve their own development by implementing a science and technology capable of solving our problems which taking into consideration—the people's needs, beliefs and resources."

Then after a number of countries like Thailand, Singapore, Hong Kong and Indonesia have followed this initiative. The motivation for development of this technology has varied for the different countries based upon their location, specific needs and problems.

3. Bio-gas Development in India

The process of generating combustible methane gas through anaerobic fermentation of organic materials containing cellulose was first released in India in 1900. A plant utilising this process was set up at Matunga in Bombay. However, there was no further development in this technology till 1940s. After 1940s, a number of scientists carried out experiments in this technology. First pioneering experiment on the anaerobic digestion was carried out by Dr. S.V. Desai of Indian Agricultural Research Institute (IARI). He designed and built the first cattle dung digester and studied the nature of the cattle dung digestion process. The first small plant was made available to the public in 1946 by Prof. N.V. Joshi. It is proved that farmer could obtain fuel for his domestic requirements and manure for his field from cattle dung without having to burn it. Further, research was continued by Dr. C.N. Acharya, Dr. M.N. Idnani, Dr. O.P. Chawla, Prof. S.C. Das and Swami Vishkarmanand.

The credit for developing the first model suitable for widescale adoption in rural areas, however, goes to Shri Jasbhai Patel. He designed a couple of bio-gas plants at Khadi and Village Industries Commission (KVIC) in the early fiftees. He patented his plant as "Gramlaxmi" in 1951. which was the first big break through in the manufacture of a practical plant. It renewed the interest in bio-gas technology. The "Gramlaxmi" Gas Plant underwent to substantial modifications in design. A modified version was adopted by KVIC in 1959. The KVIC since then has been popularising use of bio-gas plant through a nationwide programme.

The pioneering work of KVIC received the Central Government support through the Ministry of Agriculture in 1974, following the worldwide energy crisis. The Department of Science and Technology undertook an "All India Coordinated Project on Bio-gas Technology and its Utilization." Target of establishment of around one lakh bio-gas plants was fixed during the Fifth Five Year Plan (1975-80). A subsidy of 25% in construction cost and 50% grant were offered to each beneficiary. It was conditioned by the fact that a beneficiary must have 5 to 6 cattle and two hectare productive land. Such requirements could only be met by a very small privileged group. Disappointing results were observed due to small amount of grants, slow spread of technical knowledge some restructive conditions on number of cattle and availability of land, and administrative problems involved in getting financial help in time.

By the end of 1980, in all 94 thousand plants were working. At an aggregate level, gas production was estimated to 131.22 mlllion cu. mtr. per annum which was equivalent to 210 million litres of kerosene valued at Rs. 24 crores. So far concerned with performance of the plants, some primary surveyed were conducted. P.V.R. Subrahmanyan (1978) disclosed that 89% of 56 plants were working whereas, according to T.K. Moulik and U.K. Srivastava (1975) only 68% plants were in working order.

For a systematic effort, the Government of India established a Commission for Additional Sources of Energy (CASE) in 1981. It had task to formulate policy, programme and strategy for new and renewable source of energy. At the end of 1981 the Department of Agriculture launched a National Project on Bio-gas Development, predominantly to cater the individual family sized bio-gas plants as the part of the Sixth Five Year Plan (1981-85). An another programme for development of community type bio-gas plants started under the responsibility of the Department of Science and Technology and CASE. The importance was underlined when the Central Government included the promotion of bio-gas plants in the Twenty Point Programme in January, 1982. In September 1982, the Department of Non-Conventional Energy Sources was established within the Ministry of Energy to coordinate research and development of bio-gas technology as well as for the CASE activities.

In the Sixth Five Year Plan (1981-85), the Government of India has allocated an amount of Rs. 50 crores with break-up of Rs. 41.05 crores, Rs. 5.35 crores for organisational support, Rs. 2.35 crores for setting up a national board and Rs. 1.2 crores for training persons in construction and marketing skills. In addition, Rs. 125 crores have been made available from banks and other financial institutions to actively involved agencies like KVIC and Agro-Industries Corporations to meet the target of around 4 lakh plants in 112 districts of the country. It is decided in view of the fact that India has 210 million cattles which produce 421.5 million tonnes of dung per annum. Hence, there is a potentiality to establish 8.75 million family size plants and 5.6 lakh community plants of capacity of 57 million cu. mt. and 142 million cu. mt. per day respectively. So the target of 4 lakh plants is a friction of the potential capacity. If the target is achieved 360 million cu. mt. of gas equivalent to 1.28 million tonnes of firewood valued at Rs. 3.84 crores would be produced. It would also produce 7.6 million tonnes of manure and create employment opportunities of 3.3 lakh man months.

For the implementation of such an ambitious programme, an extensive network of organisations and institutions has been involved. Out of 134 organizations, 36 are under the Central Government, 59 under the State Governments, 30 are private enterprises, 7 are financial institutions and 2 are international organisations. Agencies like KVIC and Agro Industries Corporations are asked to undertake task on the guidelines mentioned in the scheme.

Along with the family size plant scheme, an another scheme launched by the Government is the community bio-gas plant. The task is carried out by the Department of Science and Technology (CASE). The scheme is launched in view of economise the scale to be operated through reduction in construction, equipments and operational costs; channelising large extent economic benefits in rural communities; creating intensive energy system in rural areas and saving in space for installation and convincing involved in community bio-gas plants.

A series of experiments on the community bio-gas plants have been carried out by KVIC, GAIC and Planning Research and Action Division (PRAD) of State Planning Institute, Uttar Pradesh. The size of the community plant varies from 30 M^3 to 145 M^3 gas production per day and can supply to 30 to 140 families. A target of 100 community plants was fixed and for that a financial provision of Rs. 5 crores was made in the Sixth Five Year Plan.

First pilot community bio-gas plant in Fateh Singh Ka Purwa was developed by PRAD with the assistance of UNICEF. Later on a number of community plants were set up. Worth mentioning plants are located in Masudpur, Karuthin-goundanpatti, Kubadthal Khoraj villages. However, a series of technical, operational and managerial problems have been observed in smooth running of community plants.

Table 3.1

District-wise Position of Bio-gas Plants in Gujarat, 1982

Sl. No.	District	Total installed up to March '82	Latrines connected to plants so far Total	Col. 2 as percentage Col.3
1.	Surat	4,409	1,443	32.73
2.	Bulsar	2,735	568	20.77
3.	Broach	1,244	238	19.13
4.	Baroda	1,085	416	38.34
5.	Panchmahals	154	77	50.00
6.	Kaira	706	238	33.71
7.8	Ahmedabad and Gandhinagar	401	163	40.65
9.	Sabarkantha	1,784	391	21.92
10.	Mehsana	163	158	96.93
11.	Banaskantha	80	56	70.00
12.	Kutch	228	38	16.67
13.	Surendranagar	71	17	23.94
14.	Jamnagar	32	12	37.50
15.	Rajkot	69	52	75.36
16.	Junagadh	72	18	25.00
17.	Bhavnagar	255	245	96.08
18.	Amreli	105	86	81.90
19.	Dangs	10	—	—
	Total/Gujarat	13.603*	4,216**	30.99

* 13,000 biogas plants have been established in nearly 3,000 villages.

** Nearly 100 plants are fed only on human excreta.

Source: Gujarat Agro-Industries Corporation, Ahmedabad.

4. Bio-gas Development in Gujarat

Out of 35 million population about 27 million live in rural areas of Gujarat. The 27 million population maintain 15 million cattle. The State has been the pioneer in the country in setting up 100 gobar gas plants as early as in 1955-56. By 1983 Gujarat had shared around 15% to total set up plants in the country (Table 3.1).

The Sixth Plan (1981-85) envisages setting up 35,000 family size bio-gas plants in the State. The 35,000 bio-gas plants to be set up are expected to generate 32,000 KW of energy in the decentralised sector at a capital cost of Rs. 25 crores. If the same amount of energy is to be generated by setting up small power plants of 10 KW capacity each, the capital cost would be around Rs. 96 crores. Besides the saving capital investment, the bio-gas plants would provide about 4 lakh metric tonnes of enriched fertilizer per annum. The energy produced by the bio-gas plants would be equal to 300 lakh litres of kerosene valued at about Rs. 4 crores per annum which will conserve foreign exchange to that extent. Viewed in a different perspective the energy generated would save about 2 lakh M.T. of firewood.

The operational task of setting up family size and community bio-gas plants have been carrying out by the two predominant organisations namely KVIC and GAIC.

4

Community Bio-gas Plant at Khoraj Village

Following socio-economic profiles of Khoraj village, this Chapter deals with the background of community bio-gas plant including project partners, investment, salient features, extent of performance and benefits of the plant. Then after process involved in gas production considering each input component has been discussed in details. Major issues, constraints and problems involved in different aspects of the plant have also been highlighted. Finally, suggestive measures have been explored.

1. Profile of Khoraj Village

Khoraj village is situated on the State highway between Ahmedabad and Gandhinagar. At present it constitutes 4,300 persons with break-up of 2,335 male and 2,065 female. A sex ratio is 924. Literacy rate of population is 38%.

Total number of households is 667. By communities, 44.2% are Patels followed by Thakores (23.7%), Muslims (13.5%), Rabaries (12.0%) and other communities (6.6%).

Total number of workers in population is observed to 28%. Out of total workers, 51.3% are engaged in trade, commerce and services followed by 42.7% as large, small and marginal farmers and 6.0% as agricultural lendless labourers.

Out of total farmers, 22.8% farmers have their own and more than 5 acres, 43.8% farmers between 2.5 to 5 acres and 33.4% farmers below 2.5 acres.

Out of total land, fourth-fifth is cropped land. Irrigated land constitutes more than three-fourth share.

The number of fully grown animals in the village is 1,212 with break-up of 860 buffalos (70.9%), 300 cows (24.8%) and 52 bullocks (4.3%). A ratio of animals to households is estimated to 1.82.

The village is highly developed. It has basic infrastructural and community facilities like primary school, dispensary, drinking water and water pipe-line, approach road, electricity, public toilets, post office, train and bus routes.

More than two-third of the village population (3 thousand) live above the poverty line. The households are well to do in their living standard. A majority of the households live in *pucca* and semi-*pucca* house.

Khoraj village is one of the three top villages in the State. A well coordinated, co-operative and community feeling is observed among people. As a result, the present Sarpanch/head of the village has been elected unanimously in the last elections.

Some statistics on demographic and socio-economic profiles of the village are presented in Table 4.1.

Table 4.1

Profiles of Khoraj Village

1. Population		
	Total	4,300
	Male	2,235
	Female	2,065

2. Households

667

3. Sex Ratio

924

4. Literacy Rate

38%

5. Economic Status of Working Population

1. Share of workers in population : 28%
2. Workers by activities

—Large farmers	117(9.7%)
—Small/marginal farmers	397(33.0%)
—Trade, commerce and service	613(51.3%)
—Agricultural landless labourers	72(6.0%)
Total	1,204(100.0%)

6. Land Holding

—Above 5 acres	117(22.76%)
—2.5—5 acres	225(43.77%)
—Less than 2.5 acres	172(33.46%)
Total	514(100.0%)

7. Status of Land

—Cropped land to total	: 4/5th share
—Irrigated land to cropped land	: 3/4th share
—Unirrigated land to cropped land	: 1/4th share

8. Animal Stock (Fully Grown)

—Buffaloes	860(70.96%)
—Cows	300(24.75%)
—Bullocks	52(4.29%)
Total	112(100.0%)

9. Social Status of Households

1. Share of persons above poverty line	69%
2. Communities	
—Patel	295(44.2%)
—Thakore	158(23.7%)
—Muslim	99(13.5%)
—Rabari	80(12.0%)
—Others	44(6.6%)
Total	676(100.0%)

10. Community Facilities in the Village

—Primary school
—Dispensaries
—Drinking water tank and water pipe line
—Electricity
—Approach road
—Public latrines
—Post office
—Sewa Sahakari Mandli
—Linked with State highway
—Linked with railway line/station

2. Community Bio-gas Plant : Salient Features and Performance

(*a*) *The Genesis*

The Ministry of Agriculture, Government of India sent a techno-economic feasibility report for installation of a Community Bio-gas Plant at Khoraj to UNICEF during October 1980. This report was prepared by Gujarat Agro-Industries Corporation (GAIC) which was then also actively involved in establishing family size bio-gas plants in the State. The Ministry had recommended that the project be aided by

UNICEF and implemented by Gujarat Dairy Development Corporation (GDDC). UNICEF approved this report on 28th October, 1980 appointing GDDC as the implementing agency and GAIC as turn-key consultants and to carry out the project in consultation with the State Government.

(*b*) *The Project : Investment*

UNICEF had originally accepted to aid this project at a cost of Rs. 1.94 lakhs. The work started immediately. During July 1981, the progress was reviewed and UNICEF agreed to aid the project to a limit of 2.59 lakhs owing to cost escalations and certain additional requirements. But disaster struck the project in form of heavy rains during July 1981 itself when the digester was flooded and the inner wall of the well collapsed. GDDC reported this to UNICEF immediately but did not stop the work. The reconstruction was carried out by GDDC's own funds in anticipation of reimbursement from either UNICEF or Ministry of Energy. The cost of the completed project escalated to Rs, 4.43 lakhs approximately, *i.e.* an additional cost of Rs. 1.84 lakhs approx. An application was made to the Ministry of Energy through Government of Gujarat during April 1983. The Ministry had been very considerate in sanctioning Rs. 1.11 lakhs approximately during March 1984. Satisfactory clarifications for the rest of the items have been provided by GDDC to get the remaining amount of Rs. 0.73 lakhs from the Ministry.

(*c*) *Status : Salient Features*

The Plant has a capacity of 140 cm./per day and can supply gas to 112 families. GDDC had also installed 10 community latrines and the night soil is being used for production of gas. This is particular importance as the village had no such facility for defection previously. Main objective of the plant is to supply bio-gas for cooking. Till today GDDC has supplied gas connections to 38 households. Gobar is purchased from the villagers—beneficiaries and non-beneficiaries—at a cost of 4 paise/kg. and gas is sold at the rate of Rs. 9.00 per adult member for 7 hours of gas supply per day. No charges are made for child members of the households.

In all 6 lines were laid down for distribution of gas among user-families. Gas distribution among user-families started from 11 April, 1983. For getting gas connection per user-family expenditure was estimated between Rs. 800 to Rs. 1000 with break-up of Rs. 410 for above, Rs. 200 as deposit and remaining for pipeline and labour charges at the rate of Rs. 2 per ft. respectively. Key aspects/salient features of the plant are presented in Table 4.2. (As per Feasibility Report prepared by GAIC) :

Table 4.2

Salient Features of the Community Bio-gas Plant, Khoraj Village

1. Capacity of gas production		140 cm./day
2. Coverage of families		112
3. Cost of the plant (Rs. lakhs)		4.43
4. No. of connected latrines		10
5. Availability of main inputs		
—Dung from villages		10,450 kg./day
—Dung from beneficiaries		3,831.6 kg./day
6 Requirement of inputs for the plant		
—Dung		3,496 kg./day
—Human excreta (from 400 persons)		200 kg./day
7. Unit level gas generation capacity		
—From Human excreta		0.567 cm./kg.
—From dung		
Rainy season	0.0396 to 0.0425 cm/kg.	
Winter season	0.0368 to 0.0396 cm/kg.	
Summer season	0.0425 to 0.0510 cm/kg.	

8. Total estimated production of gas

—From 200 kg. human excreta	11.34 cmt./day
—From 3831.6 kg. dung	140.00 cmt./day
	152.34 cmt./day

9. Stock of animals

	No.	Dung
—No. of cows	200	1,000 kg./day
—No. of buffaloes	450	9,000 kg./day
—No. of bullocks	50	450 kg./day
Total	700	10,450 kg./day

10. Consumption of gas

Between 0.2265 to 0.283 cm./day/person depending on different size of family

11. Criteria for selection of location of the plant
   1. Suitable soil (medium lommy soil)
   2. Adequate land available for plant, pits, etc.
   3. Nearness to the point of user (user-families)
   4. Distance from drinking water well (200 ft.)
   5. Availability of water (from the village tank)

12. Village

—Land cultivation	: 200 acres
—Agricultural waste	· 600 kg/acre or 120 tonnes/per year

13. Fixation of gas price

Rs. 9 per adult person (equivalent to kerosene cost) per month

14. Cost-benefit ratio (as per feasibility report)

—Total cost (fixed+variable)	Rs. 40,400 p.a.
—Total revenue (gas+manure)	Rs. 71,800 p.a.
—Gross annual surplus	: Rs. 78,800—40,400=31,400
Or Cost Revenue Ratio	: 1 : 1.78

15. Management of the plant at present

By GDDC through appointing
—Plant Incharge (local man/beneficiary)
—Plant Operator

16. Design : Dimension of holder

—Diameter	: 8 meter
—Height	: 1.82 meter
—Volume	: 90 cu. meter

(*d*) *The Position and Performance*

1. Charging dung feeding was started during December 1982. After felling the digester, connections were provided to 17 households during April 1983. It increased to 38 in July. Then after number of user-families remained the same, *i.e.* 38. (Table 4.3).

2. *All user-families are Patels* by caste. Out of them 13 are large farmers (34.2%) and remaining 25 are small and marginal farmers (65.8%).

3. Out of 38 user-families, one family has *alternative facility* of LPG. All 38 families also use kerosene stove and firewood. Two user-families have recently constructed family size bio-gas plants to maintain their convenience and regularity in supply of gas.

4. User-families are expected to get gas about 7 hours in a day. Accordingly on an *average 210/217 hours per month have been fixed for supply of gas* to user-families. However, on an average supply level was observed to 76.8%. In the first three months (April to June 1983), achievement in gas supply was observed to 100%. Then after supply hours reduced to 40.3%, specially in monsoon season. It varied from month to month.

5. In early months, supply of gas to user-families was fixed to three times in a day—morning, noon and evening.

Table 4.3

Community Bio-gas Plant at Khoraj Village, Gandhinagar

Sl. No.	Month	No. of Gas user-families[3]	No. of dung supplier families[5]			Per family dung collection(kg.)	Total dung collected (kg.)[6]	Rise of gas holder (ft.)[7]	Revenue from supply/ sale of gas to users (Rs.)
			Users	Non-users	Total				
1	2	3	4	5	6	7	8	9	10
1.	December '82[1]	—	10	13	23	201.8	4,641	—	—
2.	January '83	—	14	22	36	378.8	13,636	—	—
3.	February '83	—	21	40	61	427.8	26,098	—	—
4.	March '83	—	16	21	37	769.7	28,480	—	—
5.	April '83[2]	17	24	24	48	744.2	35,723	—	783
6.	May '83	24	26	23	49	963.8	47,226	—	1,048
7.	June '83	29	31	27	58	876.7	50,850	—	1,305
8.	July '83	38	29	25	54	857.1	46,283	1 to 1.4	1,594
9.	August '83	38	31	27	58	791.9	45,929	1 to 1.4	1,584
10.	September '83	38	33	23	56	511.2	28,627	1 to 2	1,394
11.	October '83	38	28	22	50	798.8	39,940	1 to 1.7	

12. November '83	38	28	32	60	633.3	38,000	1 to 1.4	646
13. December '83	38	21	43	64	1,217.1	77,892	1 to 2.4	940
14. January '84	38	13	43	56	1,130.3	63,296	1 to 2.6	1,121
15. February '84	38	8	35	43	1,592.6	68,481	1 to 1.11	848
16. March '84	37	6	54	60	1,004.5	60,268	1 to 2.4	867
17. April '84	37	6	32	38	1,178.5	44,786	1 to 2.5	—
18. May '84	37+1[4]	—	—	—	—	—	—	—

1. Dung feeding started from 17th December, 1982.
2. Gas distribution among user families started from 11th April, 1983.
3. All 38 families are Patels, Out of them 13 are large farmers and 25 are marginal/small farmers. One family uses LPG and all 30 families use kerosene stove and firewood for cooking, etc. At present 2 user-families have their own gobar gas plants.
4. Panchayat office for demonstration.
5. All user-families who supply gas are Patels and non-users-families who supply the dung are Rabaries.
6. Collected at the rate of Rs. 0.03 per kg from 17th December, 1982 to March, 1983 and Rs. 0.04 per kg. from April 1983.
7. Around 4 ft. rise must be there to meet the demand for gas to families (*i.e.* 7 hours supply). At present gas production is observed at 50%. There is a possibility of wastage and leakages between 15—20% at production process, distribution level (full cock opening) supply line/joints burning level (full or excess was of gas. no meter or restriction).

Table 3 (*Contd.*)

Sl. No.	Month	Per family collection Rev./ income (Rs.)	No. of hours of supply of gas to user families: Targets[8]	No. of hours of supply of gas to user families: Actual	Per day supply of dung (kg.)	Timings of gas supply in a day[9]	Wages and salaries paid to plant operator/ plant incharge (Rs)[10]	Sale of slurry (In No. of Tractors[11])	Meeting held with user-families to discuss problems
11	12	13	14	15	16	17	18	19	20
1.	December '82[1]	—	—	—	332	—	1,068	—	—
4.	January '83	—	—	—	440	—	947	—	—
3.	February '83	—	—	—	732	—	756	—	—
4.	March '83	—	—	—	949	—	822	—	—
5.	April '83[2]	46.1	140	140.00	1,855	—	546	—	—
6.	May '83	43.7	217	217.00	1,523	—	522	—	—
7.	June '83	45.0	210	217.00	1,695	—	686	—	—
8.	July '83	41.9	217	187.80	1,493	MNE	637	—	—
9.	August '83	41.7	217	146.25	1,482	MNE	643	5	—

10. September '83	18.3	210	102.10	951	MNE	643	—	Yes
11. October '83		217	128.30	1,288	MC	753	—	—
12. November '83	17.0	—	87.40	1,226	ME	666	13	Yes
13. December '83	24.7	217	136.00	2,513	ME	666	—	—
14. January '84	29.5	217	157.30	3,042	ME	666	—	—
15. February '84	22.3	203	111.15	2,446	ME	666	—	—
16. March '84	23.4	217	123.25	2,009	ME	666	—	—
17. April '84	—	217	—	1,493	—	—	—	—
18. May '84	—	—	—	—	—	—	23	—

8 Fixed on the basis of need of gas supply to users (*i.e.* 7 hrs. per day : 3 hours morning, 2 hours noon, 2 hours evening)

9 Due to less production of gas the supply of gas in noon time was stopped from December '83.

10 Maintenance cost is borne by GDDC.

11 One tractor is equal to 2000 kg. wed dung. It is sold at the rate of Rs. 80 per trailor. Dung sold to user families/large farmers.

From September 1983 the timings/frequency of supply has reduced to morning and evening. Main reason for reduction in timings is low level of gas production.

6. Nominal *price for sale of gas* was fixed to Rs. 9 per person per family per month. Children below the age of 12 years are not included. This rate was fixed in April 1983 and the same rate is prevailing at present. It is further conditioned by 7 hours supply of gas in a day.

7. *Revenue collected from* user-families during one year (April 1983 to March '84) is reported to Rs. 12.16 thousand. Revenue collected from the sale of slurry is reported to Rs. 2.48 thousand. The slurry was sold to user-families/large farmers.

8. In spite of low level of gas supply to user-families, they have been *paying their charges regularly*. Not a single case of default is observed. Mode of payment is monthly. GDDC prepares bill for payment in the first week of month and collect the money, through the Plant Incharge appointed by GDDC, by the second week of month.

9. In the context of dung supply, on an *average number of supplier* is reported to 50. The highest number of suppliers was reported to 61 in February 1982 and the lowest number 23 in December 1982. Dung suppliers are Patels and Rabaries. Out of total number of dung supplier, the proportion of user-families was the highest in September 1983 (33 to 58.9%) and the lowest in April 1984 (6 or 15.8%).

10. On an *average supply of dung* is estimated to 1,794 kg./day with break-up of the highest in January 1983 (3,042 kg./day) and the lowest in early months and in monsoon seasons (332 kg./day to 954 kg./day). The supply of dung per family varies from day to day and month to month.

11. *Rate fixed for purchasing dung* was 3 paise/kg. in the first four months (December 1983 to March 1984). Then after it was

revised to 4 paise/kg. in April 1984. Same rate is prevailing at present.

12. By now 31 tractors *slurry* has been sold. It was sold in the months of August and November 1983 and April/May 1984. It was sold to large farmers and/or user-families at the rate of Rs. 80 per trailor. As a result a revenue of Rs. 2.48 thousand was collected.

13. *For maintenance of the plant*, GDDC has appointed two persons as Plant Operator and Plant Incharge. The plant operator is getting Rs. 516 per month. Plant Incharge has been getting Rs. 150 p.m. since December 1982. Total cost of wages and salary is reported to Rs. 666 p.m. Rest of expenditure is borne by GDDC. At present the plant is running under loss between Rs. 1,200 to Rs. 1,500.

14. About the production of bio-gas, information is not available. There is no measurement tool or meter for *measuring production of gas*. However, from July 1983, GDDC has started to keep the record of gas production by noting the extent of rise of gas holder. Extent of rise of gas holder has been reported between 1 ft to 2.6 ft. It was quite low in monsoon as 1 ft to 1.4 ft in July, August and September 1983. According to an estimate the gas holder must rise to around 4 ft. for meeting need of users. In view of that present level of gas production to meet the present requirement is about 62.5% which was 35% in the last monsoon.

15. Requirement of gas per family per day is estimated to 1.25 cmt. (140 cmt capacity/112 families). At present the *capacity of gas plant is highly underutilized* in terms of number of families (as it covers only 38 or 33.9% of total families) and production of gas (1.25 cmt. per family × 38 families=47.5 cmt. or 47.5 cmt./140 cmt—33.93% extent of supply of gas to user-families). However, it is quite crude procedure to measure a level of gas production.

16. It is felt that there is a *possibility of leakages and wastage* of gas at various levels: at production process level,

distribution level, supply lines and joints, gas burning level (carelessly use/over use of gas). In the absence of reliable measurements and parameters it is difficult to work out the extent of wastage and leakage. However, visits of the Jyoti Consultants and Plant Incharge's observations reveal that wastage and leakages of gas at various stages are there and that may be between 15—20%.

17. *Some experiments* at the plant were carried by GDDC. To carry gas to agricultural field to run water pumps the GDDC used balloon developed by Kirloskar, but due to low level of capacity of big size balloon failed to achieve desired results. For using night soil and toilets some steps were taken by GDDC but could not succeed.

(*e*) *Benefits of the Plant*

Some distinct benefits of the project may be enumerated as follows :

1. Establishing the utility of dung and night soil as alternative source of energy.

2. Supplying cooking gas to villagers at a reasonable rate of Rs. 9.00 per member.

3. Providing a market for dung. Purchases are being done at 4 paise per kg.

4. Promoting hygiene of the village through community latrines.

5. Establishing slurry as a better compost. The slurry is presently being sold by auction. The average rate realised is Rs. 80 per trolly (approximately two ton) as against Rs. 50 to 60 for traditional compost.

6. Innovations in the form of using bio-gas for street lighting and running due-fuel engine for motive power.

(f) Drawbacks

Originally it was proposed to handover the plant to a Bio-gas Committee of the village is itself to run it on co-operative basis but it could not be done till date because the plant is incurring some losses every month (between Rs. 1200—1500). The main bottlenecks are: low gas production and less number of connections. In fact these two points are inter-related. Due to low gas production, GDDC is not in position to provide more connections.

By providing connections to around 80 households the plant will reach to break-even point. After making the plant economically viable, it is proposed to handover the management and control to a co-operative society of villagers itself.

To understand the problems and their nature and cause, a detailed examination of technical and non-technical aspects of the plant is required.

3. An Analysis of Production Process Aspect of the Plant

One of the critical raw materials for production of bio-gas is dung. Out of the total dung production, 69% is used for fertilizer, 29% for meeting need of domestic fuel and remaining 2% for other requirements.

People use dung for three purposes: First, to make dung cakes from the dung for meeting requirement of domestic fuel. Second, to produce fertilizer from collected dung at a particular place or pit. Third, to produce bio-gas and fertilizer from the dung. In the first process of dung, people loose benefits of fertilizer and health care. In the second process, people loose facility for domestic fuel and health care. In the third process, the people loose nothing. They get all three benefits of fuel for domestic needs, fertilizer for agricultural development and health care.

In the process of direct use of the dung for domestic fuel and other requirements, the extent of capacity utilization of dung is estimated to 11%. It is quite low as compared to direct use of electricity (70%), natural gas (60%), kerosene (48%) and coal (20%). Through processing dung in form of production of bio-gas, its capacity utilization can be increased by four-folds. It meets not only domestic fuel requirement but also generates benefits of fertilizer and favourable health and environment conditions.

Proportion of gases in bio-gas and replacement and equivalent values of bio-gas by different fuel are presented in Tables 4.4 and 4.5.

Table 4.4

Proportion of Gases in Bio-gas

Sl. No.	Name of Gas	Formula	Proportion in percentage
1.	Methane	CH_4	50 to 68
2.	Carbon-dioxide	CO_2	25 to 35
3.	Hydrogen	H_2	1 to 5
4.	Nitrogen	N_2	2 to 7
5.	Oxygen	O_2	0 to 0.1
6.	Hydrogen Sulphide	H_2S	Rare

Source: *A Workshop on Bio-gas Technology and Utilization*, 28 July—2nd August 1975, New Delhi.

(*a*) *Production Process of Bio-gas*

Bacterias produce bio-gas from the process of dung, human waste and other waste in a plant. Functions of bacterias depend on several factors and forces. These factors and forces are classified into two categories—technical and non-technical, such as dung, human waste, use of culture, re-cycling of slurry, design of the plant. These factors must be adjusted at a certain proportion to get maximum production of ages and to maintain

Table 4.5

Replacement and Equivalent Values of Bio-gas by Different Fuels

Sl. No.	Name of Fuel	Unit	Replacement value	Equivalent value
1.	Gobar gas	M^3*	1.000	1.000
2.	Kerosene	Litre	1.613	0.620
3.	Firewood	Kg.	0.288	3.474
4.	Dung cakes	Kg.	0.081	12.296
5.	Charcoal	Kg.	0.686	1.458
6.	Soft cake	Kg.	0.623	1.605
7.	Butane	Kg.	0.309	0.433
8.	Furnace oil	Litre	2.398	0.417
9.	Coal gas	M^3	0.849	1.177
10.	Electricity	Kwh	0.213	4.698

*M^3 (Cubic Meter)=35.315 Cubic Feet.
Source: *Gobar Gas Why and How*, by Khadi and Village Industries Commission, Bombay.

optimum productivity of the plant. Let us see the all aspects of the plant before the intervention of ASAG.

(*i*) *Proportion of Water with Dung*

Around 20% rajkans (inorganic particles) are available in dung. Its share declines with increasing quantity of water in the dung. Bacterias work effectively and satisfactorily if rajkans are available at least at 10%. This proportion can be maintained its quantity of dung and water to be mixed equally (1: 1 ratio). Through maintaining this ratio gas production and productivity of the plant can be optimised.

In the case of the Plant at Khoraj it is observed that the proportion of water with dung has not been maintained. The proportion of water might have remained excess which, in turn, reduced the proportion of rajkans (below 10%). As a result, bacterias might have not been performed effectively. And, the production and productivity levels of the plant might have remained quite low.

(ii) Dung Feeding Rate

The dung feeding rate to run a gas plant and produced bio-gas at optimum level is varied across size of digester.

In the summer season, twenty days are required for production of gas at 80%; thirty days are required for production of gas at 90%; and forty days are required for maximum production of gas out of feeded dung. In the winter season, temperature goes down and intensity of cold increases. It, therefore, takes more time in production of gas from feeded dung. As a result, levels of gas production and productivity of the plant remain quite low.

In case of the community plant, the optimum dung feeding rate is estimated to 3,500 kg. per day. While the dung feeding rate has remained quite low (between 40% and 70%). Moreover it has varied from day to day, month to month and season to season. An a result fermentation cycle has been taking double time (50 to 60 days) in production of gas and maintaining the productivity level of the plant. This longer duration of fermentation cycle has adversely affected the levels of production of gas and productivity of the plant.

(iii) Recycling of Fresh Slurry and Night Soil

Apart from the dung, many other inputs are also useful in generating bacteria for production of gas. Combinations of the inputs in dung process are as follows :

(*a*) Re-cycling of 2% share of fresh slurry.
(*b*) Utilization of night soil which must be equal to 3% share of fresh slurry.
(*c*) Use of waste materials available from kitchen.

(*d*) Use of calcium ammonium nitrite which must be equal to 1% of fresh slurry.

Through an optimum combination of these inputs, gas production and productivity of the plant can be increased substantially.

Table 4.6

Relationship Between Inputs and Bio-gas Production

Sl. No.	Item	Gas production per kg. (in litres)
1.	Only Dung	38.6
2.	Dung + Re-cycling of fresh slurry	49.0
3.	Dung + Recycling of fresh slurry and molasis	49.6
4.	Dung + Recycling of fresh slurry + calcium ammonium nitrite	59.0

The observations, based on the several visits to the plant and discussions with the plant incharge and plant operator, reveal that not a single effort has been made to re-cycle the fresh slurry and use night soil, kitchen waste materials and other waste which produce calcium ammonium nitrite. The production of gas and productivity of the plant completely depend on supply of the dung. The capacity of gas generation from dung is 38.6 litres per kg. and that can be increased to 59 litre per kg. (8.53 times more) if other inputs as mentioned above are to be mixed/taken into consideration. Hence, there is a need for recycling of fresh slurry, use of night soil, and other waste materials in the community plant.

(*iv*) *Use of Human Waste*

Human waste is a critical input in gas production. It contains more nitrogen to generate bacterias which are responsible to maintain a fresh rate of fermentation/gas production. An estimate reveals that gas production from dung is 38.6 litre per kg. which can [be increased by 36.8 per cent if dung is to be mixed with human waste.

In case of the community plant, it is observed that though 10 toilets have been constructed and connected with the plant to collect at least 200 kg. human waste per day, but these toilets have not been utilized by villagers—beneficiaries and non-beneficiaries. As a result levels of production and productivity of the plant have remained quite low. Thus, there is a strong need to utilize these connected toilets. Newly constructed 5 toilets must also be connected with the plant for collecting human waste.

(*v*) *Use of Culture*

A latest analysis shows that in all 14 kinds of bacterias are found in a bio-gas plant. Out of them, some are more active. These bacterias can be separated in a laboratory. If this kind of culture is mixed with input process in the digester then production of gas and productivity of the plant can be increased substantially.

The culture of the community plant has not been examined. Culture available in the open market has also not been utilized. If it is to be utilized then production of the gas can be increased between 10 to 15%.

(*vi*) *Velocity of Digester/Gas Holder*

Light weighted processed materials of dung, human waste and other waste use to come up in the digester slowly. Gradually materials become harder and suppress the pressure of gas to rise up. Similarly, increasing pressure of slurry in the digester also suppress the pressure of gas to rise up. As a result, pressure of gas for distribution among beneficiaries remains at a low level. To overcome such obstacles, the velocity of digester/gas holder must be maintained. By this way the pressure of gas can be kept up (or at the gas zone level) and gas production can be increased by 10 to 15%.

(vii) Design of the Plant

Broadly the design of the plant is classified into three types:

(*a*) Design of plant with a greater diameter of digester which explores scope for bacterias to produce more gas.
(*b*) Design of plant with a greater depth of digester which reduce scope for bacterias to produce gas.
(*c*) Design of plant with a greater diameter and less depth of digester which generates scope for bacterias to produce more gas.

First and third types of the plant produce more gas than the second type of plant.

The design of the community gas plant falls in the third category. Parameters of the design of the plant are given in Table 4.7.

Table 4.7

Parameters of the Design of Community Plant, Khoraj

Sl. No.	Dimension	Holder
1	Diameter	8 meters
2	Height	1.82 meters
3	Volume	90 cu. mts.

By and large, the design of the plant is reasonable to maintain the input-output relationships in view to optimize the production of gas and productivity of the plant.

(viii) Temperature

Gas production is conditioned by a certain degree of temperature. Functions of bacterias are affected by the temperature. Temperature between 35°C and 38°C creates a favourable condition for bacteria to produce maximum gas. Falling temperature reduces the gas production capacity of bacterias. At 15°C temperature, bacteria become inactive in process of gas production. Moreover, low level of temperature also takes more time in production of gas (Table 4.8).

Table 4.8

Relationship Between Temperature and Gas Production

Temperature	Gas production from one M. ton waste (In cu. mt) per day	Duration require for production of gas from dung (months)
15°C	0.150	12
20°C	0.300	6
25°C	0.600	3
30°C	1.000	2
35°C—38°C	2.000	1

To maintain the level of temperature several measures have been suggested by experts. These are as follows: (*a*) to use solar panels, (*b*) to carry out experiment of hot water on gas holder, and (*c*) to process the dung in water in noon time.

In case of the community plant, temperature in digester is measured between 82°E and 85°E (in the month of May 1984) which is quite low. It is mainly due to the fact that above-mentioned measures have not been considered since the installation of the plant.

(*ix*) *pH: Value of Slurry*

pH is a measure of acidity and alkalinity. pH value of 7 is neutral, anything lower is acidic, anything greater is alkaline.

pH balance breaks the acids down into methane and Carbon-dioxide. Generally, pH value of slurry must be maintained around 7. Acid producing bacterias can work up to 5.5 ph value as they are quite hard. Whereas gas producing bacterias being quite soft, can work actively if the pH value is 7. Old slurry generates more acidic elements whereas new slurry generates more alkaline elements. For faster procession, the pH value must be ascertained from time to time and to be kept around 7 point.

The pH value of the community plant has not been ascertained since its installation. It has to be ascertained from time to time to maintain the optimum production of gas and productivity of the plant.

3. A Need for Intensive Study

Main issues emerged from the facts on some aspects of the plant are as follows:

1. Increase production of gas and productivity of the plant.
2. Increase the number of connections which is constant since July 1983.
3. Measurement of production of gas, fluctuation in production from day to day, month to month and season to season.
4. Measurement of leakages and wastage of gas at various stages.
5. Maintenance of regular supply of dung from villagers—beneficiaries and non-beneficiaries.
6. Involvement of community or beneficiaries' participation in supply of dung, use of gas, minimise the wastage, use of public latrines regularly and to meet day to day problem.

7. Organisation of community/beneficiaries and nature of organization for collection of dung stopping of wastage of gas, etc.

After analysing the above issues and through sorting out the technical and non-technical problems of the plant, its performance can be improved.

4. A Need for Action

An advisory committee (represented by GDDC, GAIC, UNICEF, KGPS and ASAG) on the Project on Impact Performance Study of Community Gobar Gas Plant at Khoraj examined the plant, its attachments and the distribution arrangements, measured temperature, observed gobar collection practices and examined burners. The committee members also discussed with user families, plant-incharge, plant operator, Sarpanch, dung suppliers (families) and other experts. They reached to the conclusion that there is nothing fundamentally wrong with the plant, its design and even working. However, two warning signals are: (*i*) low level of gas production and (*ii*) less number of connections (38 since July 1983). In fact, these two observations/problems are inter-related. Due to low gas production, the GDDC is not in a position to provide more connection.

To improve the gas production (to serve around 80 families and/or to reach to the break-even point of the plant) the following steps are suggested by the Advisory Committee to the GDDC, along with a financial implication of Rs. 34,000.

(*i*) Raising temperature of the plant (from existing level of 85°F) through considering measures like heat exchanger through circulation of hot water, installation of solar collector, preventing heat looses through using glass cage on the drum, lifting the peripheral wall above the maximum height of the gas holder, fixing a steel frame about it and panelling it with transparent glasses.

(*ii*) Stopping viable gas leakages from main and sub-pipelines and joint junctions through adopting appropriate measures.

(*iii*) Though checking of burner efficiency at KVIC laboratory, KGPS and/or GAIC.

(*iv*) Analysis of gas composition at an appropriate laboratory.

(*v*) Ascertain of pH value of the slurry.

(*vi*) Installation of meters for accurate measuring of gas supply and gas utilization at family level.

(*vii*) Analysis of bio-gas culture in the digester and slurry through contacting a micro-biologist.

(*viii*) Installation of thermometers in the digester to maintain temperature records at different depths.

(*ix*) Use of human waste for improving production/productivity of the plant.

5

ASAG'S Intervention : Suggestive Measures and Actions for Improving Performance of the Community Plant

Considering identified issues, problems and constraints involved in the smooth running of the community bio-gas plant in earlier Chapter, here an attempt is made to specify the actions and suggestive measures considered by ASAG for solving them and, as a result, for improving the performance of the community plant. These measures have been considered through intensive investigation of the working of the plant, discussions and meetings with experts on bio-gas technology and local peoples and extensive socio-economic surveys of the beneficiaries—gas user-families and dung suppliers.

1. Socio-economic Profiles of Beneficiaries

Two field surveys of bio-gas user-families and dung suppliers were conducted to examine the consumption pattern of commercial and non-commercial energy including bio-gas, requirement of bio-gas, day to day supply of bio-gas, wastage of bio-gas, extent of dung supply of plant, and relative economics of alternative uses of dung. The surveys were also conducted in view to examining effects of bio-gas on shift in consumption pattern of traditional energy sources, cooking habits, kitchen environment, convenience, sanitation and village environment. The surveys were also commenced to know the extent of benefits of bio-gas in terms of improvement in agricultural productivity, saving in energy budget of household, earnings of dung supplier families and improvements in health, sanitation and environmental conditions.

All 38 gas user-families and dung suppliers were surveyed in middle of the year 1984. A brief summary on socio-economic profiles of gas user-families and findings on bio-gas technology and community plant is presented in Table 5.1.

Table 5.1

Socio-Economic Profiles and Aspects Related to Bio-gas Plant

1. Number of Connections/Beneficiaries		38 families 213 persons
2. Size of Family: Average		5.6 persons
Size	No.	Percentages
(*i*) 1-2 members	1	2.3
(*ii*) 3-4 "	13	34.2
(*iii*) 5-6 "	13	34.2
(*iv*) 7-10 "	10	26.3
(*v*) 10 and above	1	2.6
Total	38	100.0

3. Economic Activities

Activities	Families by Activities: Primary	Families by Activities: Secondary
(*i*) Agriculture	20	21
(*ii*) Service	13	3
(*iii*) Trade and Commerce	5	4
Total	38	28

4. Land Holding

—Average land holding: 8.5 bighas: *i.e.* 4.8 acres

Land holdings (Bighas)	No. of families	Percentage
(*i*) No land	1	2.6
(*ii*) 1-2	5	13.2
(*iii*) 3—5	8	21.0
(*iv*) 6—10	13	34.3
(*v*) More than 10	11	28.9
Total	38	100.0

5. Animal Stock and Dung Potentiality

—Average animals per family: 3.02

Animals	No. of animal	Per animal dung kg./day	Dung available (kgs.)
(*i*) Buffaloes	83	15	1,245
(*ii*) Cow and sub. adult (buffaloes)	27	8	216
(*iii*) Bullocks	5	10	50
Total	115		1,511

6. Income of Gas User-families

—Average household Rs. 15,210 p.a.

—Average household Rs. 1,268 p.m.

—Average per capita income Rs. 2,716 p.a.

—Average per capita income Rs. 226 p.m.

7. Use of Bio-gas

—for cooking

—for heating bathing water

—for (occasional) cattle feeding

8. Hours of Gas Supply

	Available	Needed
(*i*) Morning	2.5 hrs.	3.0 hrs.
(*ii*) Noon	—	1.0 hr.
(*iii*) Evening	1.5 hrs.	1.5 hrs.
Total	4.0 hrs.	5.5 hrs.

9. Estimated Wastage of Bio-gas

—As per beneficiaries	5 to 10%
—As per plant incharge	10 to 15%

10. Shift in Consumption Pattern of Energy

Fuel	Before plant (per month)	After plant (per month)	Percentage of reduction
(*i*) Kerosene	518 litres	286.5 litres	45%
(*ii*) Coal	1,175 kgs.	469.5 kgs.	60%
(*iii*) Wood	4,350 kgs.	1,060.0 kgs.	76%
(*iv*) Dung cakes	4,230 Nos.	350 Nos.	91%

11. Advantage of the Bio-gas Plant

—Saving in time	84.21%
—Convenience	98.00%
—Economical	63.50%
—Better domestic environment	94.73%
—Status symbol	60.52%
—Better hygiene	50.00%

12. Disadvantages of the Plant

—Inadequate supply	89.47%
—Irregular supply	60.52%
—Connection being expensive	21.05%

13. Dung Supply to Plant	
—Share of user families supplying dung to plant	7.9%
—Reasons for not supplying dung to the plant	
—Alternative use of dung	57%
—Inconvenience; dissatisfied with plant and low price	43%
14. User Families having Own Toilet	37%
15. Persons Using Toilets Connected with the Plant	Around 70 per day
16. Potential Buyers from Gas User-families at the Rate of Rs. 80 per Trailor	27

Findings of the survey clearly reveals the fact that:

1. the community plant covers only 5.70% families of the village;
2. all gas user-families are Patel by caste. They are well to do in their living standard or above the poverty line;
3. in all, user-families have 115 animals and can supply around 1,500 kgs. dung per day. But at present only three user-families supply the dung on an average of 120 kg. per day (or 8% to total availability). It is quite low due to availability of alternative uses of the dung in more profitable manner;
4. there is definite shift in consumption pattern of energy before and after the plant. It varies from 45% to 91%, depending upon the type of energy sources;
5. a number of advantages of the community plant have been listed out, *viz.* saving in time, ecological, better hygiene and domestic environment; and
6. at present 90% of dung suppliers are Rabari by caste. They do not have gas connection.

II. Key Areas of Concern

1. Insufficient Dung Feeding Load

A major problem that plant has been facing is insufficient feeding of dung since its establishment. It has been observed between 60% and 76%. The consequency of underfeeding is that it increases the retention time which, in turn, affects rate of gas production. A low level of dung supply is attributed to many factors such as lack of awareness about implications of under feeding, better remuneration available in alternative uses of dung for dung cakes, fertilizer for agriculture and ill-equipped feeding system.

Steps are required to encourage bio-gas user-families, plant operator and local people to encourage supply to dung to the plant regularly. At least all user-families having animals must be asked to supply dung regularly. For restructurting alternative uses of dung in more remunerative activities, the rate of dung supply must be reviewed from time to time. It is also essential in view to maintain the quality of dung.

2. Fluctuation in Supply Hours of Gas

The plant's inability to produce sufficient gas regularly creates a problem of fluctuation in supply hours of bio-gas. The user-families often face the inconveniency arises due to fluctuation in supply hours. As per the terms fixed by the GDDC; the user-families are expected to get bio-gas about 7 hours in a day. Accordingly an average supply of gas is fixed to 210 or 217 hours per month. However, an extent of supply has remained to 76.8% in the last year. In the first three months (April to June 1983), an extent of achievement in gas supply hours was 100%. It was mainly due to the fact that number of connections was limited (around 50%). Then after supply hours (and intensity of gas) reduced to 40.3%, specially in monsoon season. Moreover, it varied from month to month and season to season.

Moreover, in early period of the plant, supply of gas to user-families was fixed to three times in a day—morning, noon and evening. From September 1983, the timings and frequency of supply have been reduced to morning and evening. Main reason for reduction in timings is low level of gas production. No doubt, several measures and actions have been taken for increasing production of gas but, success in this context is still limited. Currently the gas user-families are getting gas three times in a day. However, pressure and intensity of the gas supply is quite low. Efforts are required to increase dung supply load to the plant and optimum combination among inputs in the digester.

3. Lack of Economic Viability

Monthly income and expenditure on the maintenance of the plant as given below reveal that this plant is running at a loss of Rs. 1,465 per month. The loss at present is being met by GDDC.

Expenditure (*Rs.*)		*Income* (*Rs.*)	
1. On Dung	Rs. 2170.33	1. Gas	Rs. 984.69
2. Salaries	693.82	2. Slurry	514.28
3. Other maintenance expenditure	100.00		
Total	2,964.15		1,498.97

Loss: 2,964.15—1,498.97=Rs. 1,465.18

Considering the overall economy of the project, the loss can be minimized through realising better prices for slurry. Better prices can be obtained by drying the slurry and selling it to urban markets in powdered and packaged form. In the wake of the awareness for indoor and outdoor gardening and preference for organic fertilizers, a potential market lies in the urban plant, shops, private and public gardens and nurseries. These possibilities must be explored in nearby places such as Ahmedabad city and Gandhinagar.

4. Managerial Problems in Effluent Slurry

When dung/water mixture is fed to the plant an equal volume of slurry flows out. It means the community plant must produce around 4 to 4.5 thousand litres of liquid slurry per day. If the water content is reduced to 30% of the original weight then dried slurry can be collected to around one thousand kg. per day. This would give 30 tonnes of dry slurry every month. At prevailing rate of Rs. 80 to Rs. 90 per trailor, this would generate Rs. 1,200 to Rs. 1,350 only. This amount is very, low as compared even to the open pit compost prices (45%). If the slurry is decomposed and to be sold in outside market around 5 to 6 times more income can be generated. This way of getting substantial income may help to improve the economic viability of the plant. Unfortunately, there is no extra personnel involved to help the plant operator to deal with nearly four tonnes of semi-liquid slurry that comes out every day. It is just allowed to flow and find its own way. This results into improper storage of slurry. Thus, there is no need for an effective management of the effluent slurry particularly in proper storage and subsequent sale at a reasonable price.

5. Lack of Community Involvement

Considering facts on development of the community plant at Khoraj village, the term "community" seems a misnomer. It seems a "bio-gas company" rather than a "community plant". As the community does not participate in decision-makings and in the running of the plant. The community was even not consulted at the time of installation of the plant. All gas user-families are only Patels and a few of them supply dung to the plant. The Rabari community seems a major supplier of dung. The communities from other social status are completely left out for deriving the benefits of the gas connection.

Lack of community participation affects the running and maintenance of the plant adversely. The community remains completely indifferent whenever any problem emerge in the plant. Instead of suggesting any solution to the problems, the community members stand at a distance and expect from "outsiders" to solve them. Due to lack of people's participation, toilets connected with the plant remained unutilized for more than an year. This problem was solved through creating awareness among the local people and forming a local committee consisting of villagers from all communities and sexes.

This local committee is expected to look into day to day problems and issues arise in smooth running and maintenance of the plant such as stopping wastage of gas, supply of dung to the plant, use of toilets, maintenance of gas stove, etc. However, there is a strong need for constant inter-actions with members and for that local leadership has to be developed. In this context, information record systems developed for the plant operator, user-families and dung suppliers (families) to record day to day gas production, gas consumption, dung supply to the plant and other related information are welcome steps for motivating local people. Display of "Bio-gas News" at the site of the plant is also make a way for an effective people's participation.

6. Recording of Technical Performance Parameters

To study the technical performance of the plant, there is a need for day to day information about production and distribution of gas. Hence three sets of "Record Cards" were designed. First set of Record Card for plant operator deals with daily record of feed load, number of dung suppliers, quantity of water added, temperature within the digester, rise of gas holder and daily supply hours. It is framed in view to examine the day to day, month to month and season to season relationships betwen feeding load and gas production.

The second set of Record Card for the gas user-families undertakes information about hours of gas consumption, details on fuels other than bio-gas and expenditure pattern of different fuel consumption.

The third set of Record Card for the dung supplier deals with records of daily dung supply to the plant, its money value, alternative uses of dung, etc.

Detail analysis of accounted and recorded information is being carried out. However some recorded information for last few months shows that supply of gas to user-families has remained thrice in a day and between 5.5 to 6.5 hours per day. An average fuel expenditure is computed to Rs. 17.75 per month where share of bio-gas is worked out to 42.44% with the fact that price change for bio-gas is quite low as compared to other fuels like kerosene.

So far concerns with two parameters *viz.* temperature in the digester and the water being added with the dung in equal proportion are not recorded because a long stern thermometer and a water meter are still to be installed. Temperature record helps to understand the climate effect on the plant and the relationship between temperature and gas production.

7. Testing of Technical Parameters

Accurate measuring of bio-gas produced is a long-standing need. It is required to understand the relationship of gas production with dung feeding, climatic factors and operational changes.

Measurement of the volume of gas produced is a basic parameter to judge the performance and efficiency of the plant. At present estimation of gas produced is done by measuring the rise of gas holder twice in a day. But this method is neither scientific nor accurate. As it is incapable to explore the nature and magnitude of relationship between gas production and daily feeding, climatic factors and operational changes. That has to be measured through installing a gas meter at the supply end. A reliable source indicates that an efficient meter for such large volume of gas production is not available in the country. As an alternative, an effort was made to measure the gas consumption at the user's end. This was done through using small gas meters.

But the meters could not work efficiently even in few cases as the pressure of gas production/distribution was low.

Two analytical tests were carried out to examine the pH value, NPK content and total solid and total volatile solid contents. pH value of the effluent slurry of the plant was 7.5 which is within the normal range of 6.5 to 8.0. It implies a balancing position between acid forming bacteria and methane producing bacteria. A shift of pH value towards the acidic side (below 7) means a change in the balance of acid forming bacteria and methane producing bacteria. Results of chemical analysis of effluent slurry to determine its pH, N-P-K content, total solid and total volatile solid content are yet to be worked out in a laboratory.

8. Changing Operational Practices

Small changes in operational practices seem very trivial but have positive effect on the performance of the plant. Small changes made in day to day practices are as follows: (*a*) change in feeding time from morning to noon. The idea behind this change was to take the advantage of solar heat radiation to heat up the feeding slurry to some extent. (*b*) Rechanging of the feeding through using around 2% of total fresh liquid from the effluent slurry. It has been started in view to the fact that re-cycling of fresh slurry helps to maintain bacterial activity more effectively. (*c*) Maintenance of 1:1 ratio between dung and water in feeding process to maintain the micro-biology of the digestion process. However, all these measures are based on a rule of thumb rather than scientific methods as tools like water meter, etc. are not available. (*d*) Agitating of the gas holder regularly to liberate the gas collected in and below the scum layer and to ensure regularity in gas production. The scum layer (consists of pieces of hair, feathers, straw, undigested vegetable matter, etc.) occupies valuable digester space and thus retards, organic degradation. This is being broken regularly through agitating the gas holder by the plant operator and other villagers regularly. Scum formation is also retarded by mixing the sludge through using various methods such as spraying of waste on the sludge surface cycling of sludge by heat exchangers and recirculating of methane produced. Since the plant has an in-built system for recirculating methane, this practice is being utilised regularly. (*e*) Feeding the plant even on Sundays and other public holidays which was not a practice in the past. It was done in view to the fact that the loss of a day's production against no reduction in the day's consumption adversely affect the performance of the plant.

III. Suggestive Actions and Plans

A series of actions for improving performance of the community bio-gas plant in particular and developing a replicable action model in general, are required in different aspects of the plant *viz.* technical aspect, community participation, operational practice, organisational aspect, analytical studies of various components of the plant. Actions proposed in the next few months are discussed below:

(*a*) *Technical Aspect*

In the technical aspect, actions are required :

1. To maintain a daily record of ambient temperature and temperatures in the plant digester at the depths of 10′ and 20′.
2. To measure the bio-gas produced by installing a large meter at the supply end. This is in view to understand the performance of the plant under varying conditions of feeding and ambient temperatures.
3. To measure gas consumed at the user's end in order to understand consumption pattern of user families classified by demographic and socio-economic characteristics.
4. To raise and maintain the temperature of the digester by feeding solar heated water and insulating the gas-holder using urathane.
5. To use a compressor for breaking the scum occasionally.

6. To modify the feeding system in view to improve micro-biological efficiency by 10 to 20%.

7. To develop a system for instantaneously drying the effluent slurry and for sorting out managerial problems involved in marketing and packaging of the slurry.

8. Through checking of main and sub-gas supply lines and joints in view to prevent leakages and wastage of the bio-gas.

(*b*) *Community Participation*

Actions required in the community participation are :

1. To arrange regular meetings of the local committee to solve day to day of the problems review the functioning of the plant to make a plan for betterment of the plant.

2. To display news on black board on various aspects of the bio-gas plant regularly say on statistics on gas production, dung supply, hours of gas supply and any specific incident.

3. To show informative audio-visuals to the villagers in view to equip them to sort out day to day problems and improve the performance of the plant.

4. To encourage gas user-families and other villagers for supplying dung to the plant and maintain the trend of toilet utilization regularly in view to meet the dung feeding requirement of the plant.

5. To develop managerial system to sort out the problems of slurry distribution and marketing in view to get better rates or prices.

(*c*) *Operational Practices*

Actions are also required in areas of operational practices. More specifically, the practices are as follows :

1. To instal a signalling system which will announce the start of the gas supply hours. It is essential in view

to prevent wastage of gas as at present many gas user-families keep the gas knobs open to smell out the gas.

2. To strain the fresh effluent slurry and use the liquid for re-circulating of methane. This can provide very vital bacterial culture to the dung.

3. To maintain proportion of 1 : 1 between dung and water, regularity in agitating the gas holder, measuring temperature and feeding of dung in afternoon to take the advantage of solar radiation and, analysis of pH value of slurry.

(*d*) *Organisational Aspect*

Actions require in organisational aspect of the plant are :

1. To organise and involve people in the affairs of the plant through holding meetings of local committee.

2. To organise beneficiaries to undertake day to day problems like dung collection, dung feeding, collecting of payment, maintenance of plant, payment to dung suppliers, etc.

3. To organise marketing channel for sale of slurry or bio-fertilizer for gardens, nurseries, plant-shops, etc. in nearby places namely Ahmedabad city and Gandhi-nagar.

(*e*) *Academic Aspect*

After undertaking suggestive actions and their effects on performance of the plant, an academic exercise for analysing the effects on performance of the plant, will be done. It will be in the context of followings :

1. Analysis of relationships of gas production with dung feed-load, climatic conditions, bacterial culture and operational changes across month, season and year.

2. Analysis of technical and non-technical performance of the plant in view of detailed study of all inputs and output and trend between them.

3. To examine the extent of efficiency of the plant through analysis of proportion of gas production as against the input composition.

4. To study the impact of the gas plant on socio-economic profiles of beneficiaries and environmental conditions of village.

5. To examine economics of the plant and identify the areas for generating economic viability of the plant.

Hopefully, all these measures will be considered and analysed thoroughly in view to make bio-gas technology more effective.

APPENDIX

Information Recording Cards
and
Questionnaire for Gas User-Families and Dung Supplies

Community Gobar Gas Plant, Village Khoraj

(Monthly Record Card for Plant Operator)

(1) Plant Operator's Name____________________ Month __________

Date	day	Dung supply Supplier (No.)	Dung supply Qty. (kg.)	Water added	Temperature	Height of gas holder Morn.	Height of gas holder Even.	Supply hours Morn.	Supply hours Noon	Supply hours Even.	Slurry produced (kgs.)	Special* Remarks
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												
.												
.												
30.												
31.												

* Example :— 1. Entry of rain water into the plant
2. Tilting of the gas holder
3. Explosion
4. Leakage
5. Any special experiment conducted

Community Gobar Gas Plant, Village Khoraj

(Monthly Record Card for Gas User-family)

1. Head of the family (Name) ____________________
2. No. of family members :— Male_______Female _______
   Children ____________
3. Records of gas and other fuel consumption :

Date	Day	Time of gas consumption					
		Morning		Noon		Evening	
		Hours	Minutes	Hours	Minutes	Hours	Minutes
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
..							
..							
..							
..							
30.							
31.							

4. Details about fuels other than gobar gas :
   1. Kerosene_____ ltrs. ______ in days Rs. _______
   2. Coal__________ kgs. _______ in days Rs._______
   3. Dung cake_____ Nos. _______ in days Rs._______
   4. Wood__________ kgs. _______ in days Rs._______
   5. LPG_____ 15 kg. Cyl. _______ in days Rs._______
   6. Others__________ _______ in days Rs._______
5. Monthly fuel bill : (*a*) Gas plant Rs. _______
   (*b*) Others Rs._______
6. Any remarkable incident (if any) during the use of the gas.

Community Gobar Gas Plant, Village Khoraj

(Monthly Record Card for Dung Supplying Families)

1. Name____________________________________
2. Gas User☐ Non User☐
3. Total No. of Animals : Buffalo________________ Male Buffalo________ (S.A.)* Female Buffalo________ (S.A) Cow________ Male Cow__________ (S.A.) Female Cow_______ (S.A) Bullock________ Any other__________
4. Information on use of gobar gas :

Date Day	Use of dung		Value realised	
	To the plant (kgs.)	Other uses (kgs.)	From the gas plant	From other uses
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
. .				
. .				
31.				

5. Details about fluctuation in quantities of dung supplied to the Gas Plant :

***Note** : S.A. stands for Sub-Adult (Animal below 3 years of age)

Ahmedabad Study Action Group (ASAG)

Community Gobar Gas Plant, Village Khoraj

Survey of Gas Consumers and Dung Supplier Families

SECTION I

For Gas Consumers/Dung Supplier Families

1. Head of the family (Name) ____________
2. Caste ____________
3. Education—Head of the family ____________
4. No. of family members
   Male ____________
   Female ____________
   Children ____________

5. *Economic Activity*

   Primary (Place) ____________
   Secondary (Place) ____________

Timings

(*a*) Leaving the House ____________
(*b*) Returning from work ____________

6. *Family Income*

   (*i*) Primary
   Monthly ____________
   Annually ____________
   (*ii*) Secondary
   Monthly ____________
   Annually ____________

7. *Assets*
   Land (in Bighas) ____________
   House ownership Yes/No

8. *Caste*

(*i*) Details of the animals

Animal	Number: Adult	Number: Sub-adult	Daily Feed: Fodder (includes freshly cut grass)	Daily Feed: Cattle feed	Daily dung production	Details of grazing habits
1. Buffalo						
2. Cow						
3. Bullock						
4. Others						

(*ii*) Details of dung production and utility

Daily dung produced ______________________ kgs.

Daily use of the dung

— To the gas plant ____________ kgs.

— Household use ____________ kgs.

— On farm ____________ kgs.

— Any other ____________ kgs.

SECTION II

For Gas Consumers

9. *About the gas connection*

(*i*) When did you take the gas connection?

(*ii*) What motivated you to take the gas connection?

(*iii*) Who took the decision about the gas connection?

(*iv*) What amount did you pay for the connection?

Deposit	Rs.________________
Stove	Rs.________________
Pipeline	Rs.________________
Other expenses	Rs.________________
Total	________________

(*v*) How much do you pay every month for using the gas? Have you paid all the instalments regularly till date?

Yes/No

Are there any dues? Yes/No

(*vi*) How do you use the gobar gas?

—to cook food

—to boil tea/milk

—bathing water

—to boil cattlefeed, etc.

(*vii*) For how many hours you use the gas?

Morning________ Noon ________ Evening________

(*viii*) For how many hours the gas is available:

Morning Noon________ Evening________

(*ix*) For how many hours do you wish to have the gas?

Morning________ Noon________ Evening ________

10. (i) Details about uses of fuels other than the gobar gas

Fuel	Before connection Quantity in days	After connection Quantity in days
1. Kerosene (litres.)		
2. Wood (kgs.)		
3. Dung ca kes (Nos.)		
4. Coal (kgs.)		
5. LPG (Nos. Cyl.)		
5. Others		

(ii) Order of preference for different fuels

Fuel	*Rank*	*Reason*
1. Gas from Community Gas Plant		
2. LPG		
3. Kerosene		
4. Gas from self-owned gas plant		
5. Wood		
6. Coal		
7. Dung cakes		
8. Others		

11. (i) Advantages of the gas plant

—Saving of time
—Increase convenience in cooking
—Economy in expenditure on fuels
--Domestic hygiene
—Advantages to health
—Advantages of fertilizer
—Rise of social status

(*ii*) *Disadvantages of the gas plant*

—Commitment to supply dung
—Issue of social status in supplying dung
—Reduction in income from the dung
—Bio-gas connection being costly
—Bio-gas costlier than other fuels
—Insufficient gas supply
—Irregular gas supply
—No saving in time
—Cannot perceive any advantages to the health
—We have no access to the slurry fertilizer
—Danger of explosion
—Gas is smelly

12. *About the gas stove*

(*i*) Have you been trained to use a gas stove?

(*ii*) What, normally, is the colour of the flame?

(*iii*) Have you ever come across any inconvenience or accidents in the use of the stoves?

(*iv*) Do you know of any cheaper/better stove?

13. *Details about dung supply to the gas plant*

(*i*) Had you committed to supply dung when taking the gas connection? Yes/No

(*ii*) If yes, then what sort of commitment was there?

(*iii*) Do you supply dung to the plant at present? Yes/No
If yes, how much? ______kgs./day
______kgs./day

(*iv*) This quantity of dung is what percentages of the total dung produced?

(*v*) What income is generated by dung supply to the gas plant? _____Rs./day
_____Rs./month

(*vi*) Do you generate any cash income from the rest of the dung? Yes/No
If yes, how much? ____ Rs./day
_____Rs./month

(*vii*) If you are not supplying dung to the plant, Why so?
Reasons:

—Inconvenience to deliver dung to the plant
—Other uses of dung (fertilizer, cakes)
—Low price offered for dung supplied to the plant
—Do not like to deliver dung on my own
Other reasons

(*viii*) At what time do you deliver your dung?

Which, according to you, is the most suitable time to deliver dung?

14. *Do you think that a community gas services centre should exist to facilitate round-the-clock gas supply* Yes/No
Should this be near the gas plant? Yes/No

15. *About misuse of the gas*

(*i*) Do you think that the gas is misused? Yes/No
(*ii*) What percentage of the total gas is being misused?
(*iii*) How is it misused?
(*iv*) Why is it misused?
(*v*) How can we check this misuse?

SECTION III

For Dung Supplying Families

16. *Details about uses of fuels other than gobar gas*

Fuel	Before connection Quantity in days	After connection Quantity in days
1. Kerosene (litrs.)		
2. Wood (kgs.)		
3. Dung cake (Nos.)		
4. Coal (kgs.)		
5. LPG (No. of Cyl.)		
6. Others		

17. *Order of preference for different fuels*

Fuel	*Rank*	*Reason*
1. Gas from Community Gas Plant		
2. LPG		
3. Kerosene		
4. Gas from self-owned plant		
5. Wood		
6. Coal		
7. Dung cake		
8. Others		

18. *About dung supply to the gas plant*

(*i*) For how long have you been supplying dung to the gas plant? ____________months (*ii*) At present, how much dung do you supply to the gas plant? ________kgs./day

______kgs./month

(*iii*) This quantity of dung is what percentage of the total dung produced?

(*iv*) What income do you generate by supplying dung to the plant? ________Rs./day

______Rs./month

(*v*) Do you generate cash income from the rest of the dung? Yes/No

(*vi*) At what time do you deliver the dung?

(*vii*) Which, according to you, is the most suitable time to deliver dung?

19. *About the connection*

(*i*) Do you intend to take a gas connection? Yes/No

(*ii*) Have you applied for this? (with the plant-incharge) Yes/No

(*iii*) Why do you want to take a gas connection?

—Saving of time

—Increased convenience

—Economising on fuel expenditure

—Domestic hygiene

—Advantages to health

—Advantages of fertilizer

—Rise of social status

SECTION IV

For Gas Consumer and Dung Supplying Families

20. *About the toilets attached to the gas plant*

(*i*) Where do you go to defeacate now?

(*ii*) If out in the open, how far have you to go?

(*iii*) Do you use the toilets attached to the gas plant? Yes/No

If No, then give reasons

—too far from house

—toilets not built properly

—Other reasons

21. *About uses of fertilizers*

(*i*) Which fertilizers do you use? Give details

Name	Qty. per bag (kg.)	Cost (Rs.)	Remark
1. Urea			
2. Ammonium Sulphate			
3. D A P			
4. Potash			
5. S S P			
6. Farm Yard Manure			
7. Castromeal, etc.			
8. Others			

(*ii*) Do you use the gas plant slurry as fertilizer? Yes/No (*iii*) Advantages/disadvantages of the gas plant *vis-a-vis* chemical fertilizers

(Rank in order of preference)

Particulars	Chem.	FYM	Slurry	Others
1. Increase productivity				
2. Reasonable cost				
3. Convenient to use				
4. Soil improvement				
5. Weed control				
6. Easy availability				
7. Local availability				
8. Injury to health				
9. Others				

(*iv*) If the gas plant slurry is mixed with phosphates and sold as a fertilizer would you like to buy it?

Yes/No

What would be your estimated annual consumption?

Rs.__________

22. *Please briefly mention any remarkable incident about the gas plant?*

23. *In your opinion, what steps should be taken to make the plan economically feasible?*

Select Bibliography

Badrinath, S.D., V. Raman, S.K. Gadkari, D.G. Deshpande, "Design for Community Bio-gas Plant : Salient Features, *Journal of the IPHE India*, No. 4, 1981.

Bahadur, Shahzad, S.C. Agarwal, *Community Bio-gas Plant at Fateh Singh Ka Purwa : An Evaluation*, Planning Research and Action Division, State Planning Institute, Lucknow.

Barett, A., L. Pyle, S.K. Subrahmanian, *Bio-gas Technology in the Third World : A Multi-disciplinary Review*, International Development Research Centre, Canada, 1978.

Bhatia, R., "Economic Appraisal of Bio-gas Units in India : Framework for Social Benefit Cost Analysis", *Economic and Political Weekly*, Nos. 32-33, 1982.

Chowla, O.P. "Night Soil for Fuel and Fertilizer", *Indian Farming*, March 1980.

Dhussa, S.K., O.V. Rangnekar, "Some Thoughts on Development of Bio-gas Technology in Rural Areas", Paper presented at *Panel Meeting on Bio-gas Technology*, ATRO, Bardoli November '81.

Eggeling, G., B Stephan (ed.), *Bio-gas in the People's Republic of China*, GTZ, Germany, 1981.

ESCAP, *Renewable Sources of Energy*, Vol. II, Economic and Social Commission for Asia and the Pacific, Bangkok, 1981.

GAIC, *National Project on Bio-gas Development*, Ahmedabad, 1982.

Government of India, *Sixth Five Year Plan* 1980-85, New Delhi.

Ganguly, R.I., "Bio-gas Programme : Pioneering Work of KVIC", *Financing Agriculture*, Vol. XIV, Nos. 2 & 3, 1982.

Gupta, C.L, "Bio-gas Centred Domestic Waste Recycling System", *Urja*, April 1983.

Gupta, D.R. "Human Waste Management : A Field Experience", *Changing Villages*, New Delhi, Vol. 4, No. 6, 1982.

Gupta, Rajiv, "Community Bio-gas Plants : The Lessons Are Those for Learning", *Urja*, March 1983.

JETS, *PECU Bio-Fertilizer Plant*, Janta Educational and Training Society, Bombay.

Kaoup, K., Bio-gas Technology and Its Impact on Human Environment", Paper presented at 68th Session of *All India Science Congress*, Varanasi—January 1981.

Khandelwal, K.C., *Guide to Bio-gas Plants*, Ministry of Energy, New Delhi.

Kumar, Devendra, "Bio-gas Potential in India : An Interview", *Science for Villages*, Nos. 63-64, December 1982.

Kumar Devendra, "Ownership Pattern of Cow Dung in the Village, *Science for Villages*, Nos. 71-72, Sept. 1983.

Kumar, R.S. "Perspectives in Bio-gas Programme", Paper presented at *Seminar on Prospectives in Bio-gas Programme*", Jaipur, July '83.

KVIC, *Gobar Gas : Retrospect and Prospects*, Khadi and Village Industries Commission, Bombay, 1979.

KVIC, *Gobar Gas—Why and How*, Bombay, 1983.

KVIC, "Scheme of Payment of Advance Subsidy for Setting up of Gas Plants", *Bio-gas Newsletter*, No. 6, January 1983.

KVIC, *Community Bio-gas Project, Masudpur (Delhi)*, Bombay, 1982.

Lalli, B.S. "Planning, Implementation and Monitoring of Bio-gas Programme in a District", *Financing Agriculture*, Vol. XIV, Nos. 2 & 3, 1982.

Mahdi, S.S., "Bio-gas Programme in India", *Financing Agriculture*, Vol. XIV, Nos. 2-3, 1982.

Meynell, P.J., *Methane: Planning A Digester*, Prism Press, 1982.

Moulik, T.K., U.K Srivastava, *Bio-gas Plant at the Village Level : Problems and Prospects in Gujarat*, Indian Institute of Management, Ahmedabad, 1975.

Moulik, T.K., "Bio-gas System : Energy Alternative in Rural India," Paper presented at the *National Workshop on Renewable*, Energy Technologies, Hyderabad, February 1982.

Moulik, T.K., *Bio-gas Energy in India*, Academic Book Centre, Ahmedabad, 1982.

Moulik, T.K., *Bio-gas Manual*, Ministry of Agriculture, Government of India, New Delhi.

Moulik, T.K., Nirmala Murthy and Ashok Subrahmanian, *Interim Report on Community Bio-gas Plants*, Indian Institute of Management, Ahmedabad, 1982.

Myles, Raymond, *Socio-Economic and Feasibility Report of the Community Bio-gas Plant Systems of Village Dadu Haryana*, Action for Food Production, Delhi, 1982.

Mohan, Shailaja, "Gobar Gas Plants : Community Types to Portables", *Urja*, March 1983.

NAS, *Methane Generation from Human, Animals and Agricultural Waste*, National Academy of Science, Washington, 1981.

NCAER, Project Proposal for "*A Study to Evaluate the Social, Economic and Administrative Aspects of Community Bio-gas Plants*", National Council of Applied Economic Research, New Delhi, 1980.

Neelakanthan, S. (Ed.), *Janta Bio-gas Technology and Fodder Production*, National Dairy Research Institute, Karnal, India, 1981.

Parikh, M., M. Kakalia, *Garbage Gas Plant as Decentralized Alternative and Renewable Sources of Energy and Manure*, Agricultural Tools Research Centre, Bardoli, 1978.

Parikh, M., M. Kakalia, Ruhul Parikh, *Bio-gas Manure Plant and Garbage Gas Plant as Decentralized Alternative and Renewable Source of Energy and Manure*, Agricultural Tools Research Centre, Bardoli, 1983.

Patel, Biharil, "*Popularising Bio-gas Plants*, Kurukshetra, March, 1983.

Paul, T.M. "Recycling Organic Wastes for Pollution Control, Energy Production Sanitation and Health and Food Nutrition", *Energy Recovery and Utilization of Solid Wastes*, Nagoya 1982.

Peacock, D.C.M., "The Energy Crisis and the Poor Man," *Paper presented at Panel Meeting on Biogas Technology*, ATRC, Bardoli, 1981.

Pethiya, B.O. Harshad C. Shah, "*A Techno-Economic Feasibility Report on Cluster of Community Biogas Plants Based on*

Dung and Water Hyacinth at Village Kasor (Anand Block), GIAC, Ahmedabad, 1982.

Roy, R. "Family and Community Bio-gas Plants in Rural India", *Appropriate Technology*, Vol. 8, No. 1, 1981.

Stuckey, David C. *Technology Assessment Study of Bio-gas in Developing Countries*, International Conference Centre for Waste Disposal, Switzerland, 1983.

Taiganides, E.P., Bio-gas Energy Recovery from Animal Wastes—I & II, *World Animal Review*, Nos. 35-36, 1981.

Tam, D.M., N.C. Thanh, *Bio-gas Technology in Developing Countries : An Overview of Perspective*, Environmental Sanitation Information Centre, Bangkok, 1982.

Yadava, L.S., P.R. Hesse, *The Development and Use of Bio-gas Technology in Rural Areas of Asia*, Food and Agriculture Organisation, Rome, 1981.

Index

K

L

M

N

O

P

R

S

T

U

V