BIOGAS TECHNOLOGY : THE INDIAN SCENARIO

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ABSTRACT

Energy in many forms is vital for national, economic and social development . The importance of energy was brought into sharp focus since the 1970's oil shortage which escalated the prices of conventional energy. Since then attention has shifted to alternative sources of energy. For a country like India, where resources are scarce and development essential, it is imperative that a strong infrastructural base be achieved for it's growth. One of the critical components is the generation and supply of cheap energy.

As an alternative source of energy ,biogas technology is being promoted in India in a mass scale in order to meet India's one of the most important energy needs ie. cooking energy (constituting more than 70% of the total energy needs in rural India).Biogas technology has received special attention because of the easy applicability , ,the vastness of the country and infrastructural deficiences which exists regarding the supply of power to all corners of India.

Alongwith providing an economic and practical alternative for energy generation , biogas technology also provides various advantages to the user. Biogas provides cheaper fuel and energy for lighting and domestic purposes, prevents or decreases deforestation , provides the farmers with cheaper and enriched manure for their fields, and lastly but not the least, improves the environment by keeping the kitchen clean and hygenic and decreases the drudgery for women.

1.0 INTRODUCTION

Out of all renewable technologies presently being promoted and considered biogas technology is the largest in terms of scale of development. operations and coverage. Among all other technologies.this is a technology selected as the National Project in the Country's overall economic plan. This implies that this technology is not only most relevant and important in meeting people's crucial component of energy/environmeant needs, but also that it has developed into a fairly stabilized and standardized design and their demonstration in actual field conditions has been successful. In fact, biogas technology would rate itself very high in relation to any other renewable technology when considered along the selection criteria as shown in Table 1.

Following the evaluation of biogas technology, it is clear that biogas technology meets three major requirements for a technology judged to be ready for mass scale diffusion or commercial utilization :

a) marketability of the technology meaning substantial demand, potential market share and supply situation;

b) technical feasibility of the technology meaning that it can be readily mass produced to satisfy cheaply a wide range of demands;

c) technology can be manufactured or used at a high rate of profitability both in terms of financial (i.e. individual user or business venture) and economic (i.e. added productivity and social benefits generated for the society or the country).

Table 1 : Rating of Selection Criteria for Renewable Technologies

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1. Meeting most important energy needs (cooking/heating) in rural India.

2. Technology utilizing only locally available feedstock/fuel (e.g. agro-waste, fuelwood, animal dung and nightsoil etc.)

3. Technology with farily long history of development in India both in terms of R&D and pilot demonstration.

4. Technology with fairly high degree of development in the sense of standardization.

5. Technology ready for mass promotion and diffusion.

6. System that can be construced, repaired and maintained by locally available skilled persons with some minimum training inputs.

7. Technology being actually used by a large number of potential users in rural India.

8. Large scale national level planned programme of diffusion almost in commercial scale.

9. Degree of national commitment in terms of financial outlays, organizational and other infrastructural support.

10. Level of local peoples' participation and NGO involvement.

11. Levels of economic and social benefits (direct and indirect) both at individual micro as well as at national macro-level (e.g. saving of forest & fuelwood, efficient use of feedstock, providing sanitation and healthy environment etc.)

2.0 BIOMETHANATION TECHNOLOGY: BIOGAS SYSTEM[1]

This is essentially a multiple stage process technology, which takes place under exclusion of air (anaerobic conditions) and mainly consists of two parts :

The first a very complex part called 'acid phase' in which the organic matter of high molecular combinations is rendered by micro-organisms into low molecular fatty acids The second part of the fermention or digestion process is the 'alkalic phase' in which the methane bactaria turn the fatty acids and alcohol mainly into methane and carbon dioxide, which is commonly known as 'biogas'. Methane is the medium heat value combustible component of biogas. Thus, to put it simply, the biogas technology involves the anerobic fermentation of organic waste materials, such as. animal dung, night soil, agricultural waste, etc. in a fermentation tank or digester in the presence of micro- organisms to produce a gas, called biogas, which contains about 60% methane and 40% carbon-dioxide along with traces of other gases like nitrogen and hydrogen sulphide.

The individual transformation processes as outlined above have to be adapted to one another. This is achieved in practice by

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1. For technical description of biogas technology, see, "T.K. Moulik, Biogas Manual, The Ministry of Agriculture, Government of India, Delhi, 1979; Tata Energy Research Institute, Fixed Dome Biogas Plants : A Design, Construction and Operation Manual, TERI, Delhi 1987; Action for Food Production, Construction Methodology of Fixed Dome (Janata) Biogas Plant, AFPRO, Delhi (undated); and BORDA, Biogas : Manual for the Realization of Biogas Programmes, BORDA, Bremen, Germany (undated).

leaving the first filling of feedstock several days in the digester, before feeding the plant anew. Thus the natural process can develop without disturbances.

In India, there are basically two types or designs of biogas plants that are being promoted :

- the floating gasholder or Khadi and Village Industries Commission (KVIC) design.
- the Chinese type fixed dome design or Janata Plants.

In KVIC type digesters, a floating gasholder is used and gas accumulates at the top of the digester, the gasholder rises, providing a variable volume for gas storage. However, the pressure of gas produced remains more or less constant. On the other hand, in the fixed dome Janata type plants, the gas collector, the domes and the digester form one unit and the whole unit is completely let into the ground. In this design, the gas generated pushes down the slurry into the inlat and outlat tanks. In the process, the gas gets compressed and the pressure of the gas rises. Thus, the gas pressure changes according to the gas volume. The outlet chamber has to be sized as to hold the gas volume to be stored (approximately 10% of the digester volume). Due to the geometrical shape of the dome, gas pressure with the displacement system varies considerably between 0 and 150 cm water column-always according to the type of construction. In Table 2 , the main technological parameters of the two designs are compared.

2.1 Besides the technological parameters, there are some important factors that determine the efficiency of the entire process of biogas production as enumerated :

i) Temperature

Various strains of bacteria thrive at different temperatures. For the biogas designs under discussion, the ideal temperature for the methane producing bacteria is in the mesophilic range i.e. 20°c-35°c. Thus, the plant should be fed during afternoon hours when outside temperature is highest. Under favourable conditions, i.e. constant high temperature the time for digestion (retention period) may even be shortened. The rate of biogas production is doubled for every 10°c rise in temperature ranging from 15°c to 55°c.

ii) PH-Value

The Ph-value indicates the concentration of acid or alkalic state of the liquid. A PH-value of 7.0 is designated as neutral. The ideal PH-value for methane formation lies between 6.5-7.5. Animal dung and night soil have normally this ideal range of PH-value. On the other hand, fresh green vegetable waste if used as feedstock ensures the danger of acid formation and delays the process of methane formation.

iii) Carbon-Nitrogen (C:N) Ratio :

Feeding the plant with feedstocks of different nature necessitates the ideal ratio of mixture, on which depends the composition of biogas and thus its calorific value as well as the quantity of gas produced. Carbon and Nitrogen are the chief nutrients for micro-organisms. The methane bacteria consumes carbon 25 to 30 times faster than nitrogen. Therefore biogas production will reach optimum when C:N ratio is between 25:30:1. Animal dung has a favourable C:N ratio.

Table 2 : Comparision of Technological Parameters of Janata and KVIC Designs

	Parameters	Janata Design	KVIC Design
1.	Systems	Regular filling feedstock and irregular discharge	Regular filling feedstock and regular discharge via. overflow.
2.	Construction Materials	Concrete blocks/bricks/ quarry stones, sand, lime, cement.	Concrete blocks/bricks/ quarry stones, sand, lime, cement, steel.
3.	Main cost factors	Cement, bricks	Steel, cement, bricks.
4.	Construction	Can be built by self. High demands for masonary skill skill.	Construction by self possible. Gas holder has to be produced in workshop.
5.	Heat Insulation	Underground construction, thereby heat insulation & constant temperature; effect of heat insulation can be even increased by building the plant underneath the stables.	Loss of heat through steel gas holder; insulation of the gas holder problematic.
6.	Gas Tightness	The gas storage dome has to be given special treatment for gas-tightness and protection by paints.	Not problematic.
7.	Feedstock	Agricultural waste, even fibrous material, animal and human excrements.	Animal and human excrements chopped and pretreated agricultural wastes in addition only.
8.	Productivity	Time of digestion 50-60 days, gas yield 0.15-0.35 cm per cm digester volume. The plant being absolutely gas tight, the productivity goes upto 0.4-0.6 cm daily.	30-60 days digestion time, gas yield 0.3-0.6 cm daily per cm. digester volume.
9.	Maintenance	If fibrous materials added, the plant needs to be wholly cleared once or twice annually.	Gas-holder (steel) has to be painted annually and to be replaced after 10 years.
10.	Costs	Comparatively low (almost half of the other model).	Relatively expensive due to steel requirement (constitutes about 40% of total cost of plant)

iv) Solid Content of Feedstock

A high content of solid matter (20-25%) leads to increase in gas production per digester volume. On the other hand, the macro-organisms require adequate water. The optimum level of solid content in the feedstock should normally be between 7-9 per cent of the total weight. Dilution of dung or other feed materials is necessary because in natural state the solid content of these materials ranges between 10 to 25%. Generally a dilution of 1:1 to 1:2 is recommended as being ideal. To put it in practical terms, the normal recommended dilution for cow dung is 4 parts of dung to be mixed with 5 parts of water.However, due to cost considerations, Janata model plants are promoted in large numbers. Also, in spite of the fact that various organic matters as feedstock can be used for biogas plants, largely the main feedstock used is cattle or pig dung. Very few biogas plants are latrine-connected for nightsoil inputs.

It should be noted that dung from ruminants (cattle, human etc.) is most appropriate for biogas plants due to its homogeneity and its inoculation with methane bacteria in the intestines. Gas yield from dung as compared with other meterials (e.g. agricu. wastes) is, however, lower due to the fact that decomposition of the feedstock has already taken place during digestion in the intestines.

A well balanced and undisturbed process is basic condition for maximum gas production. It is therefore of importance also that no chemicals, detergents, other toxic substances etc. be led into the plant.

v) Utilization of Biogas

Biogas is a valuable energy carrier, consisting of 50-70% methane and 30-50% of CO_2 as well as low quantities of various gases (e.g. h2s). It is almost 20% lighter than air and has an ignition temperature of 650°C-750°C.

Biogas can be used for different purposes. However, the most important uses in India are for domestic cooking/heating and occasionally lighting. A family of five in India would consume about 4.25 m3 of gas per day for cooking and lighting purpose - an amount that is easily generated from the cattle dung of 3-5 cattle. Several specially designed biogas burners and lamps are commercially available in India.

Another important use of biogas is a fuel for both petrol and diesel operated internal combustion engines for water pumping. Practically only the carburettor has to be adjusted to the operation with biogas. Biogas operated engines have longer life. Indigenously manufactured dual-fuel (80% biogas: 20% diesel/petrol) engines are commercially available and are in use in India.

Similarly, biogas operated generator for producing electricity is also indigenously manufactured and commercially available. However, since large amount of gas is required for the efficient running of generator, only a big-size community-type plants could afford to use the generator.

vi) Utilization of Manure

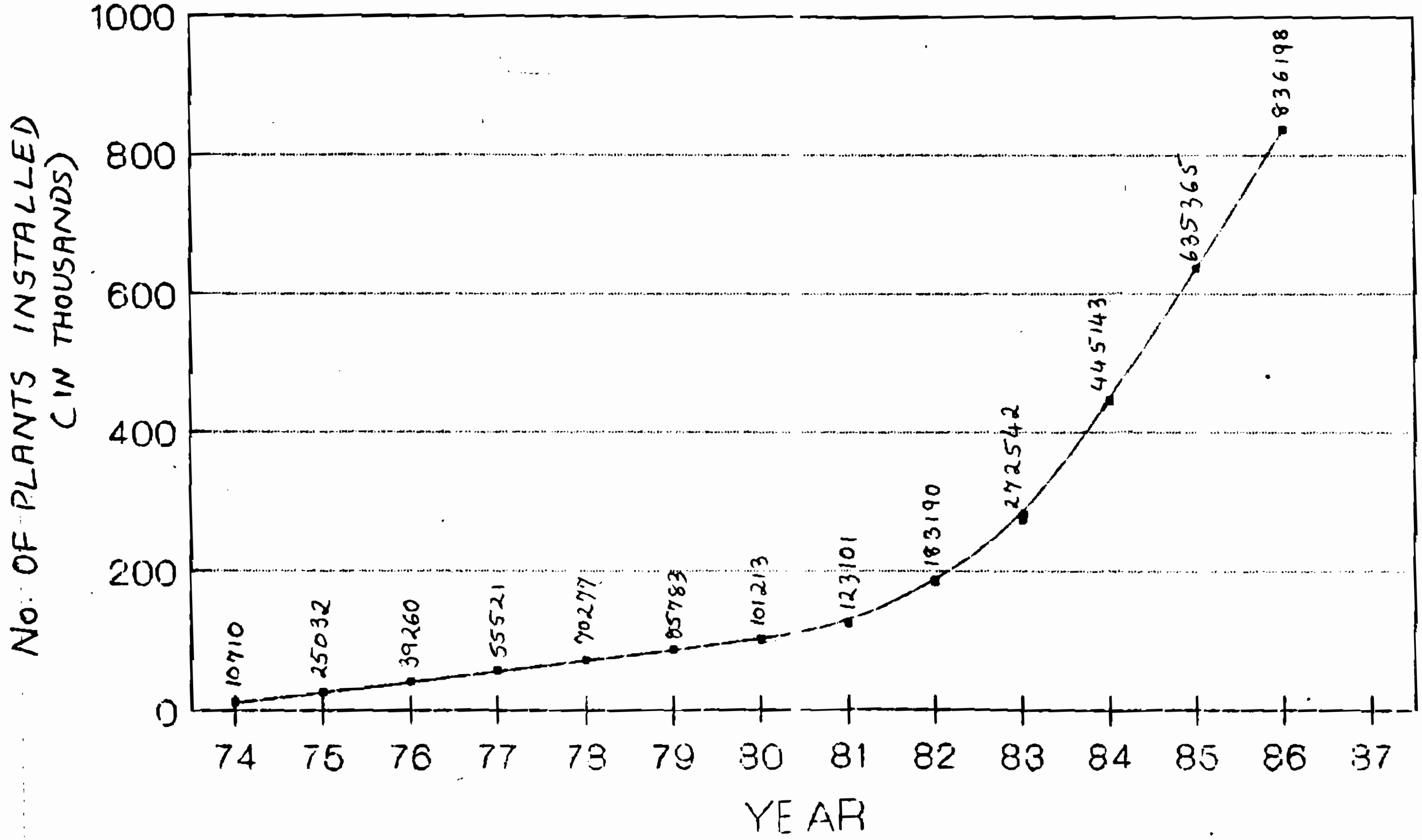
The discharge or outflow or biogas plant known as slurry has a relatively high fertilizer value to the farmers. Also, the part of the dung, which was otherwise burnt as cooking fuel in the form of dung cake is saved and available for rich organic manure. The slurry has a higher fertilizer effect that usual decomposed dung since it contains more nitrogen and is readily soluble in water. About 30-50% of nitrogen escapes into the air in case the dung is air-dried, while nitrogen escaping from digested slurry after more than 10 days of storage amounts to about 10-15% only. It is, therefore, a fact that the value of slurry as a fertilizer, if used directly in the field as it comes out of the plant is higher than when used after being stored and dried. In India, for example, mostly slurry is stored and dried before use in the field.

3.0 DIFFUSION APPROACH IN BIOGAS TECHNOLOGY

3.1 In 1974-75, total number of family size (2m3-6m3) individual biogas plants were 10,710 in India. By 1986-87, it reached to 836.198 a quantum jump of more than 80 times in a period of 12 years. Given the specific requirements of feedstock supply (mainly cowdung), for family size biogas plant (at least 3-5 cattle), the potential market size or user group in India is about 25 million rural households. The National Project for Biogas Development (NPBD) is essentially aimed at this market segment for deployment of the technology through an organized delivery system. Presently, the planned target for diffusion of biogas technology is at the rate of 0.2 million per annum.

The strategy of diffusion of biogas technology in India can be clearly understood in identifying the critical landmarks in the history of the programme (see Table 3) . It is to be noted that while the period till 1960 's could be termed as a critical

FAMILY BASED BIOGAS PLANTS*
CUMULATIVE PROGRESS



* ANNUAL REPORT 1987-88, DEPARTMENT OF NON-CONVENTIONAL ENERGY SOURCES, MINISTRY OF ENERGY. Pg. 12.

period for indigenous development of biogas design and limited demonstration projects, 1970's should be termed as the growth period in terms of planned R&D efforts and mass deployment programme. The Fuel Policy Committee of the Government of India, in the wake of fuel crisis of 1970's, strongly recommended the popularization of biogas plants as alternative sources of energy. The success in developing a vastly cheaper Janata Model (fixed dome, Chinese-type) during this time, made it easier to plan for enhanced target for plants to be promoted with concomitant resource commitment by the government, both in terms of financial, physical and manpower resources. However, along with mass-level diffusion programme since 1975, simultaneous efforts on R&D in relevant areas as well as critical demonstration and training programme continues.

Apart from providing an alternative energy supply based on local available resources, the biogas programme in India is also aimed to bring other benefits e.g. enriched manure, alternative gainful use of available biomass, checking deforestation and soil erosion, improvement of health and sanitation.

3.2 Till 1970's, the biogas programme in India has been relatively centralized and operated through normal government bureaucracy, apart from KVIC. The initiative and administration of biogas programme in this period has been largely a top-down process in which the concerned government departments (either KVIC till 1970's, Agriculture Ministry and DST during 1970s-1980s and DNES from 1980s) took the lead and responsibility for implementation. In other words, emphasis in India in this period has been a mass transfer of technology to the target group

Table 3 : Critical Steps in Historical Evolution of Biogas Programme in India.

Time Period	Steps with Basic Thrust
- Early 19th Century (1900-1920)	Historically referred early attempts to devlop biogas technology.
- 1938, at the Indian Agricultural Research Institute, Delhi.	Serious attempt for development of indigenous technology.
- 1940-1950s, at various research institutes.	Spurt of indigenous development research
1951, by JJ Patel	First standardized floating dome KVIC-model developed.
1954, by JJ Patel	Floating dome design improved.
1955, when 500 KVIC-model plants installed with Govt. support, but failed subsequently due to design defects.	First government supported demonstration programmes.
1960, first govt. sponsored programme	KVIC taking the biogas programme as a part of its regular ongoing development programmes.
- 1960s, at various national research institutions, with setting up of Biogas Research Station at Ajitmal, UP.	Renewed interest in biogas research.
- 1970, fossil fuel energy crisis	Importance of Biogas as an alternative energy source recommended by Fuel Policy Committee.
- 1975-80, national mass promotion programme with emphasis on relatively cheaper Janata model, officially supported and involving both govt. and NGOs including KVIC.	Biogas as a major programme for diffusion under Agriculture Ministry, promoting multi-agency and multi-design projects.

Time Period	Steps with Basic Thrust
- 1975-80, by the Dept. of Science and Technology, Govt. of India.	All-India Coordinated Biogas Research and Experiments through a network of national organisations and institutions.
- 1981, a planned target of 0.4 million plants in the remaining 4 years of 6th Plan and inclusion of biogas in the Prime-Minister's 20-point programme.	National Project for Biogas Development (NPBD) launched with enhanced target.
- 1981-creation of the Commission of Additional Sources of Energy.	Organisational interface for overall policy review and coordination of renewable energy programme.
- 1982, setting up of Department of Non-Conventional Energy Sources under the Ministry of Energy.	Exclusive implementing and administrative government organisation for promotion and R&D of renewable technologies.
- 1984-85, Crash programme with a target of 0.15 million plants and the proposed 1.5 million plants during the VIIth plan period.	Planned enhanced target.
1985-86, creation of State-level specific and exclusive nodal agencies for implementation of renewable energy programme.	Network of official organisations and NGOs at the State level were involved in deploying biogas technologies.

from an external system (e.g. research institutions, experimental stations, government departments) through a network of official and non-official agencies.

In an official administrative system, as it operates in India, it would require a network of institutional and administrative units at different levels of operation right from the national to the States/district/blocks/villages. As mentioned earlier, till 1973-74, it has been the single model-single agency approach with KVIC as the only focal institution. KVIC has its network of recognized or affiliated network of institutions throughout the country which has been utilized in deploying the biogas technology.

By late 1970s, when biogas became a part of the national planned programme, the institutional arrangements have of necessity gradually become relatively more structured on the one hand and broad-based on the other. The monopoly of KVIC has been replaced by a multi-model-cum-multi-agency approach in which a large number of official and non-official agencies have been involved in implementing the programme under a common fiscal arrangement in terms of subsidies and cash incentives.

3.3 Just as the subsidies have been gradually raised to attract more customers in consonance with the urge for achieving expanded targets, a programme for cash incentives to private motivators at the local village/block level for attracting customers, fees for turn-key construction by private masons or entrepreneurs and easy bank loan facilities have also been initiated in India from 1970 onwards. In the early 1980s when NPBD was launched and Janata Model was introduced in large-scale, it became necessary to initiate a systematic training programme for the masons, which perhaps was the first organised attempt for creating technical manpower at the local village level and thereby directly involving the potential users.

There have been a number of organisational strategies for effective diffusion of biogas technology initiated in recent years in India. Firstly, in order to achieve the demonstration effect to the maximum and multi-benefit impact of biogas programme and also to reduce the administrative costs, there has been deliberate plan to intensify deployment in a cluster of villages (cluster approach) as against spreading it thin over a large number of dispersed villages. Secondly, in order to expand the size of the potential market segment, there has been a planned programme to popularize medium-size community or group biogas plants. Thirdly, the importance of manure production in biogas plant as equally important objective has received critical attention in the popularization programme in India. Fourthly, there has been a planned intensive publicity campaign on biogas technology using all kings od media and methods during the last few years which has made the Indian public relatively more aware about the biogas technology and the national programme. Lastly, it has been increasingly felt necessary to integrate biogas programme in India with other ongoing rural development activities which necessarily brought about close collaboration with and assistance from various developmental departments of the government and NGOs.

4.0 STAGES IN THE ADOPTION PROCESS

4.1 The adoption process is characterized by five well-known stages of acceptance : awareness, interest, evaluation, trial and adoption.

Mass-media, such as, television, radio, newspapers etc. play an important role in making the prospective user aware of the biogas technology and about the national biogas programme. But it should be noted that the awareness created due to exposure to these media do not necessarily lead to active interest. In a study, for example, it was observed that hardly 1 per cent of the biogas adopters exposed to these media actively searched for more information (interest stage) about the technology. Thus, the awaremess created by exposure to mass media can be termed as a 'general awareness' about the technology as merely a 'stored-information-yet-to-be-activated'. However, in recent years, with intensive mass-media-campaign in India, the chances of multiple exposures have become high to the extent that it may arouse sufficient interest to more potential adopters.

- Almost all the biogas adopters were found to become really interested in the technology only through credible personal contacts. The credible personal contact could be close relatives/friends, village leader, social worker, local NGOs, govt. official etc. In other words, the awarness created through this person-to-person contact, if appropriately and convincingly communicated, are most likely to arouse active interest. It was observed that about 70% of those who became aware through this process were actively interested.

- Once the active interest was aroused, most of the adopters were found to actively seek detailed information from various credible sources : concerned government agencies/officials or NGOs at the local level, visiting the actually operating biogas plants in the village or a nearby village or the plant owner indicated by the credible personal contact at the first instance. It is at this stage, the demonstration projects became an important facet in the adoption stages.

- Having obtained all the relevant information, the potential adopter usually passes through a stage of evaluation and trial, in which all the input information observed or obtained are critically examined and discriminated upon in relation to adopters' own situation. In this stage, actual operating plant owner in his own village or nearby was found to be best credible sources of information supported by detailed relevant information from official or NGOs. Also, the training camp for the local masons usually become a live field-demonstration, during which the trainee masons are required to construct a few plants in the village. it was observed that of the 70% people who became aware and got interested, about 40% of them passed through these stages of evaluation and trial.

- It was observed that about 30 to 40% of the people who passed through the evaluation and trial stage, ultimately adopted the technology. It should be noted that for various reasons (e.g. design defects, lack of required facilities etc.) about 10% of the adopters in India were found to discontinue the use of *biogas* technology after a lapse.of time. Thus, about 80 to 90% of those adopted the technology were found to be continuing the use of it with varying degrees of regularities and efficiencies.

- The time gap between awareness and decision for adoption was found to vary between 1 to 5 years in 1970s - an average of 2 years. However, with the recent development of infrastructure, organised delivery system and the conspicuous demonstration effects of large number of operating biogas plants in easily accessible vicinity, the time gap has been reduced drastically to about an average of 6 months.

4.2 Factors Influencing the Diffusion Process

There are generally three main factors influencing the diffusion process. These are as follows :

4.2.1 Individual Indifferences

People differ markedly in their penchant for trying new technologies. In other words, there are inherent differences among individuals in their response to innovations i.e. innovativeness or innovation-proneness, irrespective of their socio-economic characteristics. Thus there are those who are apt to be early adopters: others adopt the new product much later.This is clearly evident when we examine the time gap between awareness and decision to adopt biogas as discussed above.

On the basis of the time gap between awareness and decision to adopt, the biogas adopters in India can be broadly classified into the following categories as shown in Table 4.

4.2.2 Role of Personal Influence

Personal influence or person-to-person communication between a potential beneficiary and a communicator of biogas technology plays a very important role in the adoption of the technology.

Table 4 : Biogas Adopted Categories

Categories	% of adopters'	Time taken to decide to adopt after being aware
Innovators	1	Within 6 months
Early adopters	9	6-12 months
Early Majority	30	1-2 years
Late Majority	40	3-4 years
Laggard	20	4-5 years and above

This is more so when the communicator is a credible, respectable, knowledgeable and dependable person. In fact all through the adoption stages, personal influence is a big contributing factor in the process of final decision making to adopt.

In all the evaluation studies, it was consistently observed that friends/relatives, the local developmental officials, the field supervisors, the trained workers/masons and the local NGOs were the most influential personal sources during awareness and interest stages. However, during evaluation, trial and adoption stages, contacts with the local biogas implementing agencies (NGO or official department), the owner of an operating biogas plant, the mason and fabricators of biogas equipment, the banks were most useful sources.

4.2.3 Influnces of Technology Characteristics on the Rate of Adoption

Every technology has its own inherent characteristics, which affect the rate of adoption. Five characteristics seem to have an especially important influence in the adoption rate, as discussed below :

a) <u>Relative Advantage</u>

Compared to traditional cooking system, the following advantages of biogas system clearly appear superior :

- Clean energy (mathane) without any smoke
- No sooting on utensils and wall, requiring less labour to clean.
- Provides enriched manure and saves dung from wasteful use as fuel (dung cake) for use an important organic manure for agriculture.
- Cleanliness of digestion process (hardly any flies or bad odour) of the slurry output, i.e. improvement in living condtions.
- Multiple use of biogas-cooking/heating, lighting and as fuel for pumping water or other agricultural operations,electricity generation etc.
- No labour requirement for fuelwood collection and dung cake making, thus saving forests and agricultural wastes for other useful purposes.
- Relieves drudgery of women in their work in cooking, collecting firewood etc.
- Status symbol for a rural family.

b) <u>Compatability</u>

Technologies differ in their degrees of compatability in terms of existing values and experiences in the social system. In terms of compatabillity of biogas system the following observations could be made :

- Cooking is the primary energy need in rural areas and biogas is compatible because it addresses itself to solve this primary need in more efficient and cleaner way as compared to the traditional technology.

- Raw materials as feedstock used for biogas systems are otherwise used either as fuel (dungcake) and manure. So handling cowdung as feedstock, - usually considered as "pure" is consistent with existing traditions and practices.
- Only when nightsoil is used for biogas it creates resistance due to "impurity" attached to it.

c) Complexity

Compared to traditional technologies in practice, biogas system is certainly more complex, particularly in relation to technological processes and design parameters. However, for daily operations, routine maintenance and use, it is simple enough to be understood by even illiterate rural people. It should be noted that in case of major operational disorder or design defects, it requires trained technical help and therefore to that effect, it is more complex than the traditional technologies.

d) Divisibility

Except in relation to size of the plant, feedstock, plant model and end-uses. biogas technology as such is indivisible. One must have the basic digestion-process as an unit. Other equipments related to specific end uses are optional for the plant owner.

e) Communicability

Some of the results or advantages of biogas system are almost instantaneously and conspicuously observable. The clean blue flame of methane gas without any sooting effect, reduction of cooking time, saving of dung for manure, smokelessness, reduction in drudgery of working women are extremely communicable results. What is not easily and instantaneously communicable is economic benefits since there is no direct cash flow of income and other indirect benefits, such as, value of enriched manure, saving of fuelwoood, general hygiene/sanitation. However, all these indirect benefits can be rationally and persuasively described to others.

4.3 Diffusion Approaches

There are basically three diffusion strategies :

i) The 'top-down' strategy in which centralized agencies are entrusted with task;

ii) The 'bottom-up' strategy where individual and voluntary initiative is harnessed for the effort; and

iii) The 'franchising' strategy where the advantages of centralized agencies are coupled to the strengths of entrepreneurship.

The biogas programme predominatly uses the first and third strategies and to a lesser extent the second strategy (although increasingly more in recent years). Thus it is a mix of three strategies. Diffusion strategies viewed as an approach to technology adoption can be categorized in five education approaches. As would be shown below, India's biogas diffusion strategies use a mix of these five education approaches with varying degrees of emphasis.

4.3.1 Motivation Approach

In recent years, this approach has been increasingly used in India. A number of video and TV strips uisng typical cinematic social stories with main focus on introduction of new technologies in rural India are produced and screened all over India. In fact, the mobile van with miniature technologies along with these video or regular 16 mm screen projections are in use. There is hardly any exhibition,or big fairs in India, where these technologies often along with the mobile van and above cinema shown are not in the show. There are even comic books, puzzle games and simple rhymes developed for education. There are also attempts to include these technologies in the curricular of primary and secondary education. At several places permanent energy parks' are established where all the technologies are there to be seen and fiddled with by the visitors. Lastly, the importance of motivation approach in biogas programme could be seen in designating the village level local stimulator as motivator who is given cash incentive on the basis of his/her performance.Similarly, national level annual competitions between States and within State competitions and well-publicized prizes for both qualitative and quantitative performances are other means for stimulating extra motivation among the promoters of the biogas programme.

4.3.2 Creative Approach

Apart from training camps, workshops, and seminars, where free sharing of ideas and experiences occur, there is hardly any planned effort to use this approach. In fact, out of the five approaches, it is probably the lowest in rank in terms of planned emphasis. However, a note should be made that a large number of NGOs involved in biogas diffusion programme do often use this approach in small discussion groups of the beneficiaries in identifying 'felt needs' within the framework of existing socio-economic conditions and development efforts.

4.3.3 Analytical Approach

The mason-training camps regularly organised all over the country is perhaps the best example of this approach being utillized while the masons are trained and actual biogas plant construction is in operation. The gathering villagers in the camp for 2-3 weeks find an opportunity to understand the technological aspects more rationally and analytically.

4.3.4 Planning Approach

Perhaps, this is the second most important educational approach used in biogas diffusion strategies. "To see is to believe" is the dictum highly emphasized and the predominant place of the 'demonstration projects or plants take' in the strategy is obvious. The potential beneficiaries are encouraged to visit the successful 'demonstration plants' or a show case in actual field conditions. Field-days are organised by the implementing agencies apart from training camps.

4.3.5 Didactic Approach

This is undoubtedly the most pronounced approach in use in India's biogas diffusion strategies. Having considered that biogas technology is developed and available in fairly acceptable and standardized form along with sufficient successful demonstration effects. this widely known 'shot gun approach' is used. Essentially, this approach considers that the 'technology is given and means of inducing users acceptance should be devised.' The delivery system in terms of implementing organisations, financial, physical and manpower infrastructure supports are clear indicators of the predominance of this approach. Also, taking a view that potential target group is ready for technical information, construction manual and users manual for biogas have been made available.

5.0 SOCIO-ECONOMIC CONSTRAINTS

A close examination of biogas programme clearly reveals that it is subject to a host of socio-economic constraints operating both at micro and macro levles.

5.1 Micro-Aspects

The micro-aspects of socio-economic constraints concern itself with biogas technology and access to it. It is concerned with biogas technology's availability and its utility to a specific person or group of persons. These constraints may come broadly in terms of user constraints, economic constraints and technical constraints.

5.1.1 User Constraints

These constraints refer to hindrances for biogas diffusion and adoption to reasons within the user or person itself as mainfested in the following issues :

a) Lack of Motivation

The biogas technology has certain deterministic characteristics that keep a large number of rural houses away for active consideration for adoption. As mentioned earlier, an average family-size biogas plant requires 3 to 5 cattle to provide necessary input of dung. The rural households which fulfil this cattle-ownership requirements cannot account for more than 15 per cent of the total population i.e. not more than 25 million households. Since cattle dung is the major feedstock in India, to a large majority of rural households having no access to required amount of dung, the biogas technology is preceived to be too irrelevant to be motivated.

Closely related to this basic constraint are the two important constraints of space and water. A 3 m3 floating- dome KVIC-type plant requires about 27 m2 of land area for the plant and the compost pit. It is also advisable to build the plant within six-meter radius of the kitchen in order to provide efficient supply of gas for cooking. But in villages in India dwellings are often clustered so closely together in a network of narrow lanes and alleys that a villager is constrained in his motivation to own a plant due to non-availability of required land area near homestead even when having access to required amount of dung. However, the problem of space is largely overcome by introducing fixed-dome Janata plant, which being underground does not exclusively occupy large space.

Scarcity of water is an equally serious resource constraint in many villages. To enable a biogas plant to operate smoothly, dung and water are mixed in the ratio of 4:5 by volume. For many households water has to be carried from a far-off well or other sources. Fetching the necessary number of buckets of water for biogas plant adds additional burden dampening the motivation.

Lastly, and perhaps one of the most demotivating factors is the fact that biogas plant does not produce any direct cash- flow of income. All the benefits appear to be notional only. Since cash income is the crucial motivating force for a large section of rural population, its absence removes any immediate incentive to adopt biogas plant.'

b) Lack of Information

In spite of vastly improved information campaign on biogas programme , and in spite of enlarged organisational network, there are many villages and villagers who remain still unaware of the relevant details about the biogas programme, e.g. whom to contact; how much is the subsidy and where to get it; who will construct: and who will repair in case of breakdown etc. Partly this is due to vastness of the country and widely dispersed relevant market segment to cover. With the concentrated cluster-approach and with large increase in the number of biogas plants installed, the information gap over the period has become considerably narrower as compared to 1970's.

c) Lack of Staff or Skilled Manpower

As mentioned earlier, except for construction and repair for a major breakdown, biogas operation does not require any particular skill, but simply manual labour. Since construction and major repairs are taken care of by the implementing organization, lack of such a skilled manpower within the adopter family should not pose any constraint.

d) Inadequate Incentive

On an average, a family-size biogas plant, depending on sizes (2m3 to 4 m3), costs Rs. 5000 to Rs. 8000. The rate of subsidy inclusive both Central Government and State Government on an average varies between 33% to 60% (The rate varies between landholding categories and for scheduled castes/tribes and in hilly regions). Thus, we may assume that a biogas adopter in India has to invest around Rs. 2000 to Rs.. 4000 on his own. Against the investment of such amount, it works as a disincentive if one considers only the direct cash flow of income which is nil. For many poor rural households, with meagre or almost nil purchasing power. the situation is indeed the way it is described above. However, many rural households to consider positively the contribution of other benefits, even if notional, and to them investment in biogas is economic in the sense that the investment can be repaid within a period of 2-4 years, considering the savings in terms of manure, firewood, agricultural wastes, kerosene etc. Thus to the group whose priority need is immediate flow of cash income, biogas does not appear to be providing sufficient incentive for investment considerations.

e) Social and Cultural Unacceptability

There are no particular social and cultural factors which could inhibit the acceptance of biogas system except in two situations. Firstly, because there are strong inhibitions about the use of nightsoil and even about cooking food over gas generated from slurry containing nightsoil, connecting latrines with biogas, in spite of considerable propaganda, is generally resisted.

Secondly, and perhaps the most serious cultural constraint is the role and status of women in decision making in a predominantly patriarchal male-dominated society. The most conspicuous and immediate beneficiaries of biogas technology are the village women. But these benefits are not usually given high priority by the decision-maker, the male head of the household. Because of this attitude of the male decision maker, investment choices often goes against biogas as a non-priority. Also for the same reason, when plants break-down, often they are allowed to remain out of order for a long period without repair or attention, and eventually many of them are irreparably damaged and never replaced by a new one.

One more serious constraint in the biogas programme is related to commonly practiced open grazing cattle rather than stall-feeding. As a result 40% to 50% of the available dung (varying between regions) are not directly available for biogas. So long as biogas programme remains almost totally dependent on cattle dung/pig drops, as it obtains today, this becomes a limiting factor both in terms of expansion of market segment as well as efficient running of plants. Given the economic situation and age-old social practice, stall-feeding of cattle cannot be perceived to be practised widely in the near future and therefore it would remain a constraint to that extent. In fact, a number of evaluation reports revealed that about 20% of the non-operating plants were due to inadequate and irregular feeding, including inadequate initial charging because of unavailability of sufficient quantity of dung.

f) <u>Reluctance to Innovation/Change</u>

Given the attitude of male decision makers towards women, given the fact that biogas technology does not yield direct flow of cash income, and also the fact that cooking fuel is available in rural India almost always at zero private cost, there is initial reluctance to change into biogas system. This tendency may be termed as 'risk-aversion' or lack of innovativeness - the behavioural trait which gets strengthened with the factors mentioned above.

g) Lack of Funds to Acquire the System

A large majority of rural households have a very limited purchasing power. As mentioned earlier, in spite of higher subsidy rate many of these households would lack the necessary small funds to acquire biogas plant. Even when bank credit is made available this group of people is too low to be able to obtain this credit facility. The problem is compounded by the fact that investment in biogas does not yield any flow of cash income required to repay the loan.

h) Education Level

Because of the inherent characteristics of the biogas technology, it has been adopted largely by a relatively higher socio-economic strata in the rural households. Although, spread of biogas technology in recent years has been increasingly reaching to small and marginal farmers, the level of education seems to influence considerably the decision to adopt. In all evaluation surveys it has been shown that the percentage of educated (different levels of schooling) among the adopters are quite high-only 5% were illiterates during 1970s as against 28% in 1985-86. It appears that education makes it easier for the person to conceptualize and be convinced about various direct and indirect benefits of biogas technology as well as to understand the basic technological parameters. Prevailing high illiteracy level (about 70% to 80%) in rural areas may, therefore, act as a constraint for biogas technology.

i) Labour Scarcity

Rural areas are normally characterized by surplus labour situation except during particular busy agricultural operations. Labour scarcity therefore hardly ever pose a constraint in the biogas programme. However, in some States and regions trained and skilled masons are not locally available, which necessitates importing skilled masons from other areas causing delays. It is for this reason a wide-scale mason-training programme has been undertaken in India to meet the local requirements. It seems that it would take at least another 5-10 years to fill up the gap given the drop-out rate of trained masons from biogas construction activities.

5.1.2. Alternative Competing Factors

Two important outputs of biogas technology are biogas as fuel (used mainly for cooking/heating in India) and enriched manure. In Indian villages, the competing fuels like agricultural wastes/firewood and dung-cakes are available through collections/gathering almost at a zero private cost. The conventional cooking technology like traditional stoves, although highly energy inefficient, are generally home-made with local materials without any cost. Biogas technology, therefore, is positioned unfavourably in competition with existing practices and technologies as far as individual villager is concerned.

Similarly, composting dung has been the traditionally practised method among the Indian farmers for organic manure production. This is also an operation at almost no cost. The only motivating factor for biogas, therefore, is the saving of dung from wasteful use as dung cake and enriched manure.

Thus, it is clear that unless a villager is convinced and persuaded by a host of other benefits, (short-run and long-run as well as monetized), biogas technology faces an unfavourable competition with the traditional practices and technologies. Fortunately, as the labour time required for collection of firewood/agricultural wastes have been increasing due to deforestation, increase in rural labour wage and often pressure from women for cleaner fuel and relief from drudgery, there has been increasing positive evaluation of benefits of biogas system as compared to alternative traditional practices. The possible alternative use of biogas for lighting and water- pumping engines has the added comparative advantage for biogas technology.

- <u>Inappropriate Entry Options</u>

Identifying potential target group in a village with adequate cattle and water resources and creating a conscious 'felt need' on a priority basis among them for biogas are the essence of working mode for the promoters. It also requires, in the existing socio-economic structure, a legitimization and acceptance of biogas technology introduction from the village leadership. Given the caste/class conflicts in the villages, this is often a long arduous educational/extension task. On the other hand, without creating preparedness as outlined above which entails a certain degree of popular local participation, the entry of promoters - most often external - is not only inappropriate but also may create backlash effect. In this regard, local NGOs working in the area for sufficient period on various development projects as compared to government bureaucracies are in definite advantageous situation. Often, in order to achieve the target in terms of number of plants installed, many promoters overlook this aspect and cause ultimate failures of the programme.

- Credibility of Technology Promoters

Perhaps the most important and crucial aspect of the channel factor is the credibility of the promoter in the eyes of the potential target group. The promoter's credibility is generally judged by the past performance not only in relation to biogas technology but also in relation to other activities that the promoters are involved in the past. The performance of the promoters is not simply evaluated in terms of technological knowledge/competence, but on factors like his ability to deliver in time, his social relations, his interactions with villagers and various other personality factors.

- Technical Familiarity of the System

As pointed out above, it is not enough that the promoter has adequate familiarity with the technology and social system. It is equally important that the potential users of biogas develop enough familiarity with the technology, so that it is not treated as a mere 'black box'. The basic parameters of the biogas technology should be made known to the users for its efficient management, which means a purposive user - education programme. Observing an operating biogas plant and interactions with the plant owners can provide useful insights to the potential users, apart from relevant literature. Similiarly, observing the details of the construction of biogas plant during mason-training programme can be important input. The mainfold increase in number of installed plants spread all over the rural areas and the intensive promotional programme through a 'cluster approach' provide easy access to the potential customers to gain information about the operation of the plants. Only when such pre-installation user-education programme is neglected by the promoter in 'top-down' approach of biogas programme, there is likely to be failure in the ultimate adoption-process.

- <u>Inadequate Promotional Strategy and Lack of Timing</u>

It is clear from the above discussions that an appropriate promotional strategy is largely dependent upon existing socio-economic conditions and the level and kind of exposures to biogas technology. Usually, an appropriate promotional strategy should have a relevant mix of approaches keeping the target group in mind. The basic aim of the promoter or the channel is to ensure sufficient degree of mental preparedness and motivation for the acceptance of biogas technology.

Often the promoters are bound to hurry through the biogas programme and installation of plants in order to achieve the targetted number of installed plants, without sufficiently preparing the ground through user-education and legitimization process. This inevitably leads to wrong timing of the entry into the villages with two possible consequences : first, outright rejection or stiff resistance to the introduction of technology; second, uninvolved and passive acceptance of the technology by some either due to bureaucratic force or fear of creating displeasure to the promoters or even simply to please the promoter in order to gain some other benefits through him/her. In this process, the biogas plant is usually not properly taken care of, inefficiently used or not used at all.

- <u>Lack of Post-installation Services and Lack of Follow-up Activities</u>

Adequate and regular post-installation services and follow up are the <u>sine-qua non</u> for successful biogas programme. This is all the more important for the decentralized and dispersed nature of the biogas installation spread over large number of villages in the country. There are various kinds of post-installations, small and complicated problems develop in the installed biogas plants ranging from construction faults to negligence of the plant owners, which need rectifications and re-education. There is, therefore, the necessity of follow up monitoring and easily accessible post-installation services. It was observed in evaluation studies that about 20 to 30 per cent of the installed plants remained non-functional or in sub-optimal level of functioning due to lack of proper maintenance often requiring minor repairs. Keeping this in view, financial provision has been made in India's biogas programme for repair and retrieval of the non-functioning or sub-optimally functioning plants. There is also a recent proposal to start mobile repair/maintenance van to provide post - installation services. Some promoters, mainly NGOs, consciously plan for follow-up and post-installation services as well as guaranteeing trouble-free operation of plants charging nominal fees from the plant-owners. Also a ready to fill complaint cards are often distributed by many promoters, on receipt of which post-installation services are organized. However, such services are not streamlined and organized on regular basis by many promoters , due to various reasons, such as, manpower shortage, administrative costs and often sheer negligence of responsibilities. It is to correct this situation a regular follow-up surveys are organized since last 5 years on a scheduled management information system (MIS) covering the length and breadth of the country. These annual evaluation- surveys are entrusted to recognized research institution/organizations outside the government system in order to ensure unbiasness of the information. Apart from these evaluation studies, there is also a MIS-operated in each of the States by the nodal implementing agencies.

5.2 Macro Aspects

Macro-level constraints are 'relatively extraneous' to the biogas technology referred to policy matters, information deficiency and institutional problems.

5.2.1 Information

There are tow interconnected aspects of information; first, suitability of the research for the intended purpose and second, knowledge of the availability of the technology including its technical and economic utility.

Let us take the second aspect first for discussion. In this connection, we may refer to the history of development of biogas programme in India as shown in Table 3. It is striking to note that the experimentation with biogas digestor dates back to 1930s and initial motivation for biogasification has been the cheap source of energy and better quality manure. Serious interest in indigenous development of biogas technology started at the

Indian Agricultural Research Institute (IARI), Delhi around 1938. The motivating factor for IARI scientists was the realization in early 30's that there was a loss of 40-60 per cent nitrogen in the standard anerobic composing. With the experience of initial successes with the German "Edelimist" anaerobic process at the Indian Institute of Science, Bangalore, IRAI scientists started a large scale study for preparing synthetic manure from town refuses and other waste materials. It was interesting to note that the initial interest in biogasification in India was primarily with manure and not with energy or gas, neither was cattle dung the feedstock for biogasification research.

The focus of IARI research turned to cowdung and gas when the scientists visited the Sewage Purification Station at Dadar, Bombay in 1938. The Sewage plant had an anaerobic sludge digester, out of which gas was used for running truck for disposing of garbage and the digested slurry was sold to the farmers near Bombay. The beginning of the present biogas design was made. The intensity of research and diffusion of biogas technology with emphasis on energy started with fuel crisis in 1970s.

By 1960s various research institutions became seriously involved in biogas research and experimentation. An exclusive Biogas Research Station was established in Ajitmal in UP in 1960s, which concentrated its research work on Chinese-type fixed dome model, ultimately coming out with the cheaper Janata Model in 1970s.

By 1975, the Department of Science and Technology (DST) Government of India, took up biogas technology as one of the important areas for technology research. Instead of haphazard spread of research, DST sponsored an All India Coordinated research and experimentation programme involving large number of research institutes and organizations in the country. The focus of this coordinated research programme was both on hardware (technological parameters) and software (social, economic and management problems).

By 1970s, with the enhancement and enlargement of biogas technology and the incoming inputs from the coordinated research programme, researcheable issues are being continuously identified in order to feedback the input into the research system for developing suitable technology for intended purpose. In general, there are few thrust areas for research identified in the process as shown below:

- Cost reduction either through new designs, use of cheap construction materials or use of new more efficient microbial processes.
- Diversification of feedstock, apart from cattle dung, agricultural wastes, water hyacinth, nightsoil, oil-cakes etc. are identified for R&D.
- Use of gas for other than cooking/heating e.g. internal combustion engines, electricity generation etc.
- Efficient biogas equipments e.g. stove, mantle for lighting, generator, carburettor etc.
- Economics of biogas for various and uses
- Evaluation and Management of Biogas Programme
- Problems of large-size community plant.

From the foregoing, it is clear that at macro level there has been continuous attempt to direct research on biogas technology suitable for the intended purpose. Many useful results of this research programme are put to widescale use and application in India. However, there are still gaps in many of the areas mentioned above and hence the continuing efforts on research. In this connection, the mention must be made about the establishment of Regional Biogas Training Centres which are intended to cater to the needs specific to particular regions. Three such centres (Coimbatore. Tamil Nadu ; Udaipur, Rajasthan; and Puse, Bihar) were set up during the Sixth Plan period. Four more such centres in MP (Indore), III Kharagpur (West Bengal), Palanpur (Himachal Pradesh) and Ghazipur (UP) were set up subsequently during 1986-88. These centres provide technical and training support to the State Government and Programme Implementing agencies for effective and accelerated implementation of the biogas programme.

5.2.2 Institutional Support

There has been a conscious and deliberate attempt in India for indigenous development of biogas technology. The broad objectives of the R&D projects in biogas have been to reduce the cost of installation of biogas plants by way of using new types of construction materials and optimization of designs with reference to biological and engineering parameters, exploration of new feed materials other than cattle dung, development of process and design packages for alternate feed stocks including low and high strength wastes to bring about system improvements on volumetric efficiency and substrate decomposition rates.

The central nodal agency, DNES has sponsored and supported about 60 R&D projects coveing various aspects of biogas technology at national laboratories, Indian Institute of Technologies and Universities including Agricultural Universities. There have been considerable achievements made under the ongoing research projects as outlined in the DNES Annual Report, 1987-88. However. most of the research results are presently at the field pilot - testing stage rather than for mass diffusion programme, e.g. biogas using water hyacinth and biogas using distillery waste. Many of these research institutes are involved in popularising the technologies devloped in the surrounding demonstration areas.

It is only since 1980s, when the biogas programme was greatly expanded that a number of well known commercial manufacturing sectors in India have shown interest considering the large market segment. Many of them, on their own have developed linkages with DNES and other R&D organizations. The interface, thus developed between R&D organisations/DNES on the one hand and the commercial sector is likely to be strengthened further as the programme continuous and expands.

5.2.3 Policy Directives

The National Project on Biogas Development (NPBD) is the plan commitment of the government with required financial and infrastructural outlays. The biogas programme has been envisaged with the policy objective of not only to provide energy at local levels using agricultural wastes and dung but also to have a direct and indirect relevance to save forests, improvement in the environment, employment generation, upgrading of health and hygiene, social and womens' welfare, bio-fertilizer production, agriculture and drinking water etc. In fact, the production process of the biogas system with multiproduct outputs meeting multi-end- uses, in which primary production process output (agriculture residues and cattle dung) as by-product become an input to process energy and fertilizer (slury manure). It is this integrated aspect of biogas technology which finds its strength in policy and programme commitment of the government support.

While the policy directives in relation to the relevance of biogas technology in meeting cooking needs (for which electricity and fossil fuel derivatives are not the alternatives in near future) in the rural areas and in providing enriched manure are clearly in consonance with the objectives, the subsidies and prices of oil/kerosene/diesel/ electricity too seem to be competitive and often unfavourable to biogas system. This is particularly so when biogas is intended to be used for pumping irrigation/drinking water or lighting or electricity generation. Since the total potential market segment for biogas system cover only a part of rural households and since the cooking energy need is overemphasized as the most urgent application of biogas technology, the problem of competition with other fossil fuel energy sources are compounded to the extent that the economics of biogas technology are unfavourably compared.

In response to such unfavourable comparisons, the sympathetic policy makers refer to private individual investments in the case of biogas technology as compard to no direct private contributions to the fossil fuel based centralized technologies. Irrespective of arguments and counter-arguments regarding biogas technology, there are hardly any disputes and conflicts among the government policy makers about the relevance of expanded biogas programme.

5.3 Economic Constraints

Here in this section an attempt is made to to analyse the economic constraints at the macro level on the following aspects :

5.3.1 Unaffordable Investment/Acquisition Cost and Lack of Funds :

Since 1981, the annual budgetory allocations from Central Government for NPBD in India varied between Rs. 300 to 400 million. This budgetory allocation cover subsidy, turn-key job fee (Rs. 300 per plant), promotional incentive (Rs. 50 to Rs. 100 per plant for the motivators), Regional Biogas Training Centre, training, organisational and manpower support, post-installation service costs (Rs. 500 to Rs. 1000 per plant repair), publicity and research. In 1987-88 for example, the approved budgetory allocations for NPBD from the Central Government was about Rs. 440 million. Apart from central subsidies, some state governments also give additional subsidies and cash incentives for NPBD.

The annual achievement of biogas plant installations have been about 0.2 million plants. About 70% of the total investment on NPBD from Central Budget is accounted by subsidy. it thus appears that NPBD in India is highly subsidized programme. For a developing country like India with competing claims of other development sectors and almost crippling revenue shortage, the cost of the biogas programme as revealed in the budgetory allocations do seem high. On the other hand, it is the lack of available fund, particularly the subsidy which compels State Implementing Organisations to reduce the annual target of plant installations.

5.3.2 High Operational and Maintenance Cost

About 20% to 30% of the total annual budget for NPBD is the D&M cost, which is also on the high side. As mentioned earlier, this is largely due to dispersed and decentralized nature of the programme covering the length and breadth of a large country like India. Also to be noted is the fact that a substantial part of this D&M Cost is to create required infrastructure in terms of trained manpower and physical facilities, which inevitably is high due to lumping effect in the initial years and therefore is likely to taper-off as the programme progresses over time.

5.3.3 Unpredictable Cost of Feedstock

The NPBD or India's household biogas programme is almost solely dependent on cattle dung as feedstock. Since the biogas plant is privately owned by the household and its size is normally based on its access to cattle dung from its cattle holding the cost of feedstocks is not a macro level economic constraint, neither is it unpredictable. However, if the feedstock is diversified into agricultural wastes and widely used, which otherwise could have alternative and more profitable use, there could be situations when the cost of feedstock would become high and unpredictable. But even in this eventuality, although very unlikely for NPBD in near future, for an individual household depending on his agricultural production, the cost considerations would be less important.

5.3.4 Lack of Competitiveness Relative to Traditional Competing Technology

The traditional cooking stove is obtained at a zero private cost. The same is true for the traditional fuel e.g. cattle dung-cake, firewood and agricultural wastes. So, to an individual household investment in biogas technology, which do not produce any direct cash-flow or income, apparently seems to be unworthy for investment, unless all the benefits - tangible and intangible - are monetized and seriously considered. On the other hand, at the mecro level, biogas technology is highly competitive in relation to traditional cooking technology because of saving in dung manure, firewood and agricultural wastes in addition to other social benefits like sanitation, health and relief in drudgery for women.

The biogas technology appears to be equally and favourably competitive when compared to other end-uses such as, electric or diesel pumping for irrigation and drinking water.

5.3.5 Inadequate Financing and Incentives

The major element in the budgetory allocations is the central subsidy. For the last few years, depending on the installation costs of plant, the central subsidy is given according to size of the plants at a flat rate instead of a percentage share of the cost as done before. Also, the rate of subsidies differ according to the socio-economic status of the target groups, as shown in Table 4.

Table 4. Central Subsidy for Biogas Plants (1988-89)

Capacity of Plant (m/day)	For North Eastern Region States (except Assam & Sikkim)	Assan, HP, J&K and other Hill areas where the cost of construction is very high	For scheduled castes/tribes as well as beneficiaries in notified desert districts.	For all others (General Categories)
1	-	-	1250	1000
2	4410	2940	2350	1560
3	5490	3660	2860	1900
4	6580	4390	2860	2140
6	8020	5350	2860	2610
8	8020	5350	2860	2610
10	8020	5350	2860	2610

It is noted in Table 4 that the rate of subsidies is kept constant beyond 4 m3 size of the plant. This is to discourage the tendency of beneficiaries to install more than required size of the plant. Recently, there are serious considerations among the policy makers to reduce drastically the subsidy rates beyond 2 m3 size plant and increase the subsidy rate for 2 m3 size plant with a view that for most rural housholds 2 m3 size plant is sufficient for their energy needs for cooking and heating. This may also save substantial among in central revenue.

The cost of construction of biogas plants, over and above the subsidy, is met by the beneficiaries either through bank loan or through their own personal savings. Like subsidies, lower than commercial interest rates on bank loans are made available to economically and socially backward classes and regions. Subsidies are given in kind in the form of construction materials e.g. cement, bricks, steel etc. In certain regions and for a certain group of beneficiaries subsidy amount is sufficient to cover almost the entire cash component of biogas installation costs, particularly, for cheaper Janata type plant and when labour cost is met through family labour of the beneficiares. For those where the subsidy amount is not sufficient to cover the cash component, there is always a demand for increase in subsidy rate. However, the present rate of subsidies as shown in Table 4 is generally found to be adequate and acceptable to a large section of the beneficiaries.

There are three cash incentive schemes for NPBD: first, a turn-key fee (Rs. 300 per plant), cash incentive for motivators (Rs. per plant) and repair of non-functioning plants (Rs. 500 to Rs. 1000 per plants). While the turn-key fee is generally considered to be adequate, the cash incentive for motivators or promoters is perceived to be too low to be effective. it is recently suggested that the motivators be given extra responsibility of facilitating commissioning of plants beyond identification of beneficiaries, processing of applications and site selection and to that extent the incentive may be raised to Rs. 100- Rs.200. Similarly, considering relatively small number of structurally defective non-functioning plants and the positive motivational impact, the repair cost is suggested to be increased to Rs. 2000 per plant. In fact, even in the present scheme, the repair cost is not strictly restricted to an upper limit of Rs. 500, but there is a provision to consider each case on merit.

5.3.6 Non-profitability of Biogas Technology

Economics of biogas production have been examined by several authors in India.[3] For an individual owner, although benefits are many, ther is no direct incremental income flow to the family arising out of the investment on biogas plant. For an individual family, it is only the notional saving money on traditional fuel and manure - both generally non-monetized benefits, usually collected traditionally at zero private cost.

In spite of the above mentioned limitations, the benefit/cost analysis of biogas plant in India, both for the national economy as well as for individual households are found to be positive and favourable, using the following assumptions :

- the volume of gas and fertilizer slurry produced by a volume of cow dung compared to the fertilizer value of thedung it used in scientific composting:
- the value of the biogas in terms of equivalent energy from kerosene, electricity, soft coke, agricl. wastes and dung cake.
- the value of the manure; and
- indirect costs and benefits.

However, it should be noted that the results of benefit/cost analysis of biogas plants vary widely depending on the uses and actual benefits of biogas production, public and private costs associated with the development and utilization of methane.

3.See for example, T.K.Moulik, "Cost-Benefit Analysis of Indian Biogas System : Case Study", ESCAP, Bankok 1981; T.K.Moulik, "A Critique on Cost-Benefit Analysis of Biogas Programme,: in M.M. El-Halwagi, Biogas Technology, Transfer and Diffusion, Elsevier Applied Science Publishers, 1984, pp. 106-110; Parikh Jyoti K and Kirit S. Parikh, "Mobilization and Impacts of Biogas Technologies," Energy, Vol 2, No 4, 1977. pp.441-455; and Tata Energy Research Institute, Biogas : A Viable Energy Option for Developing Countries, TERI, Delhi 1981.

Given the variations in the results of benefit/cost analysis and considering only the monetized benefits of manure and energy vis-a-vis alternatives, biogas plants are in general found to be profitable both for individual as well as for the nation. If, however, several non-tangible benefits are considered, the economics of biogas plant becomes extremely profitable. To a private household, the total investment on biogas plant is repayable within 3-4 years with internal rate of return of 13.53 to 58.97 varying with increasing sizes.

6.0 TECHNICAL CONSTRAINTS

Some of the technical parameters of the Biogas technology have already been discussed earlier. Biogas technology for rural households in India, as it is promoted presently has some technology-specific constraints, as described below :

6.1 Difficulty of Operating and Maintaining the Technology System

With ensured access to adequate quantity of feedstock i.e. cattle dung and water, there is hardly any complexity or difficulty in day-to-day operations and maintenance of the biogas plant. The daily slurry making in proper mix of dung and water (4:5) and feeding the slurry into the plant can be easily accomplished by even an unskilled labour. Two things need to be manually checked: first, it may require some stirring by a stick at the mouth of the outlet for regular slurry outflow due to thick deposition of slury and closure of the mouth; and draining of water in the gas-carrying pipe through one or two nozzles fit into the pipe and aligning the pipe in a downward slant. Except these daily operating activities and minor maintenance, biogas plant do not pose any difficulty.

However, if the construction of plant is structurally defective, if there is cracking of the wall, if there is any leakage and if the alignment of inlet and outlets are not proper, then it requires skilled labour to correct the situation.

6.2 Inadequate Raw Materials/Feedstocks

This is often found to be a serious constraint even to the extent of limiting the potential market segment in India. The problem becomes crucially important at the initial feeding or charging stage when the plant requires a substantial amount of dung. A 4 m3 plant, for example, requires 5 tonnes of dung for initial charging. Even if a household has adequate number of cattle for providing daily requirements of dung, a huge amount of dung at any one point of time is difficult to obtain, unless one starts accumulating dung for the purpose sufficiently ahead. As a result, many plants in India, even after completion of construcion, remain uncommissioned for a long time due to lack of required amount of dung for initial charging.

6.3 Poor or Inadequate After Sales Service

It has been pointed out earlier that there is sufficient scope for improvement in follow up and post-installation services, particularly in those places where the biogas programme is run directly by a bureaucratic government department. The record of NGOs in this regard is comparatively better. The recent government policy for organized follow-up and retrieval services is likely to improve the situation.

6.4 Lack of Technical Know-how

Often biogas plants are constructed by untrained or ill- trained masons without proper understanding of the technical know-how, which inevitably results in failure. The shortage of trained masons is felt bitterly, particularly, for Janata Plant, which requires specific skills. The mason training programme in India therfore is an important element for the succes of biogas diffusion.

At another level, there seems to be apparent neglect in user-education in terms of imparting basic minimum technical know-how to the beneficiaries. Wherever such attempts are made seriously, not only the plants are found to be operating efficiently, but the user participation in the programme is active and extremely helpful.

7.0 SUMMARY AND CONCLUSIONS

The biogas diffusion programme is characterized by multi- model-cum-multi-organisations approach. Also, there are several critical elements involved in the programme right from scientists and R&D organisations, State level nodal agencies, district/block/vilage level functionaries, large number of NGOs and a number of manufacturing commercial sector as well as provate entrepreneurs and masons. To do a comprehensive study of biogas technology in India, it necessarily requires information input from all these important factors. A mere structured questionnarie is not sufficient to elicit relevant information from all these sources. It also requires person - to - person discussions with all the relevant officials and non- officials. Also important is the familiarity of the researcher about the basic technological parameters of the technology as well as about programme administration and socio-economic conditions of rural India.

The study of household biogas technology reveals a number of socio-economic and technological constraints, such as, almost exclusive dependence on cattle-dung as feedstock, predominance of cooking as end-use of biogas technology, limit of potential market segment based on land and cattle holding, reduction of gas production in winter months i.e. low temperature, the crucial role played by the trained masons and their local availability, the important role played by personal influence and demonstration projects and scientific regular monitoring and post-installation services, the important role played by subsidies and the overall plan commitment of the Government in terms of financial and infrastructural support.

The study also indicates the importance of R&D efforts and R&D institutions. The socio-economic constraints revealed in the study points out major thrust areas for research e.g. cost reduction of biogas plant through better designs, use of alternative construction materials, efficient microbial processes etc.