PROSPECTS FOR COMMUNITY BIOGAS PLANTS

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INTRODUCTION

Biogas technology was initially propogated in India half-heartedly. With the onset of the oil crisis in the 1970s and the ensuing shortage of chemical fertilizers, the need for alternative sources of energy was made apparent. Biogas technology soon became the predominant source of renewable energy, particularly for the rural areas where the main feedstock--dung--is available in abundance. Although biogas plants were initially used only to produce cooking gas, technological improvements have made the fuel available for other end uses.

Despite great expectations of the national planners regarding biogas technology, only five percent of the families in India possess enough cattle to operate even the smallest biogas plant (Vidyarthi 1978). A number of studies have concluded that the technology is beyond the reach of poor families because of their lack of resources. It was observed that a small plant is not a viable unit for the operation of machines and engines. Technology also needs to be harnessed to provide the villages with energy for electricity, drinking water, flour milling, and village industries.

Why a Community Plant?

The community biogas plant (CBGP) emerged as a possible solution to these growing needs. A large-scale biogas plant, fueled by dung contributed by the cattle-owning families of the village, could provide cooking gas to the entire village as well as energy for the operation of a tube well, flour mill, or electric generator. These community plants would be owned and managed by the community itself, with technical and financial support from the government.

The community approach has been attempted in India for irrigation, agriculture, and small-scale industries, but the results are not encouraging. Neverthelesss, the idea of a community biogas plant was applied in the absence of a better alternative.

Early Attempts

The first experiment was conducted by the Planning Research and Action Division (PRAD) of the State Planning Institute of U.P. in 1978, at Fateh Singh Ka Purwa village in Etawah District (U.P.). The project installed two biogas plants, with capacities of 30 and 40 m^3, to provide street lighting and energy for a tubewell used for irrigation and drinking water, as well as to supply cooking gas and electricity to all 24 families of the village. The project, though it received considerable publicity as the first of its type, could not sustain itself due to misprojections of dung availability, reluctance of the villagers to provide dung, village factionalism, and poor management (Bahadur and Agrawal 1979).

About the same time, a similar attempt was made in the village of Kedumunja in Karimnagar District (A.P.) by the Sircilla Electric Cooperative Society. A plant with a capacity of 128 m^3 was installed to provide cooking gas to 60 families, and operate the pumpsets. The plant required dung from 300 cattle. This project also had inadequate supplies of dung, which then had to be purchased. The community failed to show interest in the project as cooking was not a priority need (Moulik 1982).

Another widely publicized experiment was conducted by the Application of Science and Technology to Rural Areas (ASTRA) unit of the Indian Institute of Sciences in the village of Pura. The project intended to meet the entire energy demand of the village with various renewable sources of energy, of which a large-scale biogas plant was one. The project is reported to be successful (Reddy and Subramaniam 1979), but the role of the community biogas plant is never mentioned.

In the early stage of the community biogas program, a large- scale biogas plant was installed in the staff colony of the Kurukshetra Sugar Mill. The gas was used for cooking purposes by 18 families of the colony. The plant ended operation within six months, due to an insufficient supply of dung and disputes over the timing of the gas supply.

The village of Masudpur near Delhi was selected for the demonstration of various new energy technologies. A large-scale biogas plant was commissioned and is still in operation. The project has been successful for several reasons: the dung is purchased; spent slurry is sold to the Horticulture Department; the beneficiaries are not directly involved in the management of the project; and the villagers, close to the capital city, are used to LPG supply.

An experimental 140 cubic meter-capacity plant was built in 1981 by the Vimla Gram Seva Samaj Trust in the village of Kubadthal in Ahmedabad District. It was designed to meet the cooking fuel requirements of 123 families. This project also faced a number of organizational, sociopolitical, and economic problems (Moulik 1984).

Present Status

The Department of Science and Technology (DST), formerly the apex body of the central government, fully aware of the results of these experiments, decided to conduct a few more trials under different agroclimatic and sociocultural settings. The Department assigned new projects to PRAD and the Khadi and Village Industries Commission (KVIC), using different drumless (PRAD) and drum (KVIC) designs.

The Department expected the future strategy of CBGP construction would be decided after examining the outcome of these trials, but neither institution completed the construction work within the stipulated time. The Department of Non-Conventional Energy Sources (DNES), newly established solely for these activities, commenced its policy of providing a 100 percent subsidy for community and institutional biogas plants.

The community biogas plants constructed by PRAD and KVIC met with the same fate as the initial experiments. The plants installed by PRAD were beset by technical problems (Agrawal 1983) because a new design was being tested. The plants installed by KVIC had many socioeconomic and administrative problems (Murthy 1983).

Under the Community and Institutional Biogas Plants Demonstration Scheme initiated by DST in 1981-82 and later managed by DNES, 34 community and institutional biogas plants were sanctioned to various states, with a maximum number of 12 given to Uttar Pradesh. The experiments cited above were conducted before 1981-82, with sufficient experience gathered to formulate sound policy. In recognition of the problems faced in involving the community in the operation and management of the plants, the construction of institutional plants was encouraged. These plants are mainly located in agricultural universities, dairy and animal husbandry farms, and other institutions where feeding materials and management facilities are available. In the institutional plants, technical problems can be isolated from the problems faced by the community biogas system, such as distribution, management, and contribution of dung.

By the end of 1984-85, DNES had sanctioned 240 community and institutional biogas plants, of which 60 were reported to be commissioned (DNES 1984). Among the 18 states where projects have been sanctioned, Assam and Himachal Pradesh are the only two hill states, although Uttar Pradesh has considerable hill area. In Assam, one community biogas plant was sanctioned in 1981-82 and is now operating in Silchar. In Himachal Pradesh, one plant was sanctioned and is operating in Sundernagar. In Uttar Pradesh, out of 15 completed plants, five are located in the hill districts of Nainital and Dehradun. However, the plants are installed in the foothills and thus cannot provide substantial information regarding the problems that may be encountered at high altitudes.

Thus, at present, only two CBGPs are available for gaining practical experience in hill areas. However, these are both institutional plants and the village communities are not directly involved in project operation. The two projects could provide important information regarding the applicability of biogas technology in hill areas, but no document on these projects is yet available.

In the absence of any data on CBGPs in hill regions, the author focused on the family biogas plant experiences in hill areas. There are 6 family biogas plants in Nagaland, 2172 in Himachal Pradesh, and 106 in Jammu and Kashmir. Most of these plants have been installed in foothills and valleys. Although separate figures for the hill districts of U.P. are not available, many biogas plants have been installed in the foothills, and a few are operating at altitudes of up to 5000 feet. Valuable information has been collected from these plants and was used as the basis for this paper.

FEASIBILITY OF THE SYSTEM

Technological Factors

Design. The KVIC design for large-scale plants is considered to be the most successful. The drumless design developed by PRAD is also successful but its large-size design has not yet been released. The Ganesh model, a polythene sheet-lined digester made from an angle iron frame, is also accepted by DNES but its large-scale design is not available. Similarly, the prefabricated *ferro* cement digester has only been tested for capacities of two to six m^3. Thus, the KVIC design is used in most of the plants.

The major difficulty in operation of the KVIC model in the hill region is heat loss through its metal gas holder. The holder remains exposed and thus is susceptible to temperature variations, resulting in reduced gas production during winter (Prasad and Sathyanarayan 1979). A second limitation of the design is that an underground digester requires substantial digging which is often impossible. Transportation of the steel gas holder is another problem associated with the KVIC design.

Accordingly, the Janata design is more suitable for the hill regions because the heat losses are smaller and construction materials can be obtained locally. This design has been incorporated in the large-scale biogas plants in the hills of Nepal, China, and Korea, and in family biogas plants in the hill states of India.

Soil. Soil conditions are important for the construction of the biogas plants. Sandy soil is not recommended for the KVIC model (KVIC 1975), and rocky soil may restrict construction of an underground digester. Since the hill regions mainly consist of sandy and rocky soil, additional engineering inputs will substantially increase costs.

Water table and water requirements. To facilitate the construction of an underground digester, a site should be chosen where the water table is low. The water table in the hills may not pose any problem since it is quite low at high altitudes. However, an almost equal amount of water is required to be mixed with the dung before it can be used as biogas fuel. For a 30 cubic meter-capacity plant, about 675 liters of water would be required on a daily basis. In the hill regions, where even the collection of enough water for drinking purposes is difficult, the availability of water in such large quantities is highly doubtful. Even if a water source is available near the site, transporting the water to the plant will be a highly labor-intensive job (UNESCO 1984). Thus, water may be a limiting factor in the hill regions (Santerre and Smith 1981) since reducing the water to dung ratio can decrease gas production considerably.

Feedstock. Cattle dung is the most common feedstock used in India for the generation of biogas. A 30 cubic meter-capacity plant would require 9.1 quintals of dung daily (NAS 1977), which could be produced by 90 adult cattle at a rate of 10 kg per day (NRDI 1977). This figure is based on the data from the plains of northern India, where cattle have higher body weight than in the hill regions. The smaller breed of cattle available in the hill region means that at least double the current number

Table 1: Per Family and Per Person Cattle Ratio in U.P. Hills

District	Population	Families	Cattle	Man/ Cattle ratio	Family/ Cattle ratio	Sheep/ goat	Man/ sheep ratio	Family/ sheep ratio
Dehradun	688000	137600	45553	1:0.06	1:0.34	133044	1:0.19	1:0.96
P. Garhwal	599000	119800	64513	1:0.10	1:0.53	232001	1:0.38	1:1.93
T. Garhwal	428000	85600	101982	1:0.23	1:1.42	134565	1:0.31	1:1.57
Uttar Kashi	165000	33000	32587	1:0.19	1:0.98	173600	1:1.05	1.5.26
Chamoli	318000	63600	57202	1:0.18	1:0.90	202806	1:0.63	1:3.18
Pithoragarh	463000	92600	95810	1:0.20	1:1.03	216785	1:0.46	1:2.34
Almora	711000	142200	151568	1:0.21	1:1.06	204346	1:0.28	1:1.43
Nainital	952000	190400	149443	1:0.15	1:0.78	56643	1:0.06	1:0.30
Region	4324000	864800	698658	1:0.16	1:0.80	1353790	1:0.31	1:1.56
U.P.	98200000	19640000	13964751	1:0.14	1:0.20	10521127	1:0.10	1:0.59

Source: Livestock data : Livestock Census, Govt. of U. P., 1978.
Population data : Projections in Statistical Dairy, Govt. of U. P., 1978.

of cattle will be needed to run a biogas plant in this area. The author's studies revealed that the total amount of dung produced in a village is never available for the plant because the villagers are reluctant to contribute dung, as it is difficult to collect during the grazing period, and families retain a portion of the dung for plastering the floor and walls (Agrawal 1980). Thus, the number of cattle needed (estimated on the basis of per day dung production) will be misleading and insufficient.

An alternate method of estimating the number of cattle required in a community for the operation of a CBGP is to consider the man-cattle ratio, which should ideally be 1:0.5 (PRAD 1983). During a search for a suitable village in the valley area of Dehradun District and the Terai area of Nainital District, the author could not identify a single village in which the ideal man-cattle ratio was maintained. The village finally selected in the valley area had a 1:0.6 ratio; the Terai village selected had a 1:0.8 ratio (Agrawal 1980). The situation in the village at high altitudes can thus be inferred.(Table 1)

The number of family biogas plants in the hill regions will be limited by the small cattle population and the low dung supplies. Nonetheless, a number of families which have sufficient cattle for the operation of a four cubic meter-capacity plant can be identified.

There are a number of alternative feedstocks, such as *ipomea*, *salvinia*, water hyacinths, banana stems, industrial effluents and waste; canteen, kitchen, and agricultural wastes; and night soil, sludge, and city garbage. Experimental plants based on a few of these, such as sludge, night soil, and water hyacinths, have been built but of these only night soil is available in the hill region. Human excreta can be used as an additional feedstock, but the latrine system is not common in the hill regions and the gas produced from it is not socially acceptable.

In the following table, the average gas production from various feedstocks is presented, indicating that both poultry and sheep dung produce gas in amounts comparable to cow dung. Forage leaves available in the hills can also be used as an alternative feedstock. In light of the scarcity of cow dung in the hill region, the use of alternative feedstocks may increase the promise of biogas technology in the hills. However, a change in the design of the plant or pretreatment of the slurry may be required.

Table 2: Yield of Biogas From Various Waste Materials

Raw materials	Biogas production per unit weight of Dry Solids	
	ft^3/lb	m^3/kg
1. Cow dung	5.3	0.33
2. Cattle manure	3.6 - 8.0	0.23 - 0.50
3. Poultry manure	8.9	0.56
4. Sheep manure	5.9 - 9.7	0.37 - 0.61
5. Forage leaves	8.0	0.50
6. Night soil	6.0	0.38
7. Elephant grass	4.8	0.30
8. Paddy straw	2.1	0.13
9. Farm waste	3.9	0.24

Temperature. Temperature plays a crucial role in the anaerobic decomposition of biomass because methane-producing bacteria are particularly sensitive to temperature. Below the 10° to 15°C range, the digestion process is very slow, although it can function down to 5°C (Meynell 1976). The optimal range is from 30° to 35°C for the mesophilic bacteria to flourish. It is possible to achieve a faster digestion in the 40° to 55°C range, in which the thermophilic bacteria operate. The temperature should be maintained as constant as is possible and not vary by more than one or two degrees centigrade within a 24-hour period. In the hill regions, the low temperatures during most of the year and fluctuations of daily temperature are bound to present major problems for the functioning of the biogas plant.

In the Khadi Commission Biogas Research Centre, 2.4 m^3 of gas was produced from 5.4 m^3 of cattle dung every day at a digestion temperature of 25°C. When the temperature was raised to 28.3°C, the gas production increased to 6.3 m^3/day.

At the Indian Agricultural Research Institute, it was observed that gas production was reduced by almost 50 percent during the winter months when the mean monthly temperature dropped to 2.7°C in January.

Experiments in China proved that within the 15° to 35°C temperature range, total gas yields per ton of raw material were almost equal. When the temperature is lower, the digestion is slow, necessitating an increase in the detention time and plant size, and increasing the cost of the plant. Research findings, however, do not match the observations of visiting scientists. An FAO team reported that a decrease in gas production during winter was observed in all regions (FAO 1987). Another report (DGTZ 1981) reports that in Shanyang, in the Idaoning Province, the average temperature ranges from 0° to 13°C, which is unsuitable for biogas production.

It is reported that the gas production per kg of input material at 20°C is about 90 percent of that achieved at 30°C. At 20°C the yield is about 66 percent, at 15°C it is about 50 percent, and at 10°C the yield is down to about 40 percent of what would have been produced at 30°C (PRAD 1980). Sharma and Panwar (1985) found that higher average daily temperatures result in higher peak relative gas production. When the temperature decreases from 35.58°C to 24.55°C, gas production decreases by 44.8 percent; when the temperature further drops by 12.11°C, the total reduction in gas production is 77.39 percent.

Though individual biogas plants are operating at altitudes up to 5000 feet, personal communication with the plant owners revealed that gas production dropped by 50 percent during winter, despite precautions taken such as using hot water, cattle urine, and urea fertilizer, and covering the plant with paddy straw.

Systematic investigations of digester/slurry heating have been carried out in China, Korea, India, and Japan. On the basis of these studies, it is recommended that the plants be insulated and the slurry be heated. A feedback principle was applied in India, in which part of the gas produced is used for heating the slurry. In China, wasted heat from gas-operated engines is used to maintain the slurry temperature. Experiments using solar heat have also been successful in India (DNES 1984).

At the Indian Institute of Science, Bangalore, heat loss from the top of the gas holder has been minimized by adding a transparent cover. In Korea, a heating and mixing device known as a bubble gun has been developed which generates intermittent gas bubbles inside a mildsteel tube.

The temperature variation in the hill region is shown in Maps 1 and 2. It is evident that unless the precautions mentioned above are applied, the successful operation of a biogas plant will be a remote possibility.

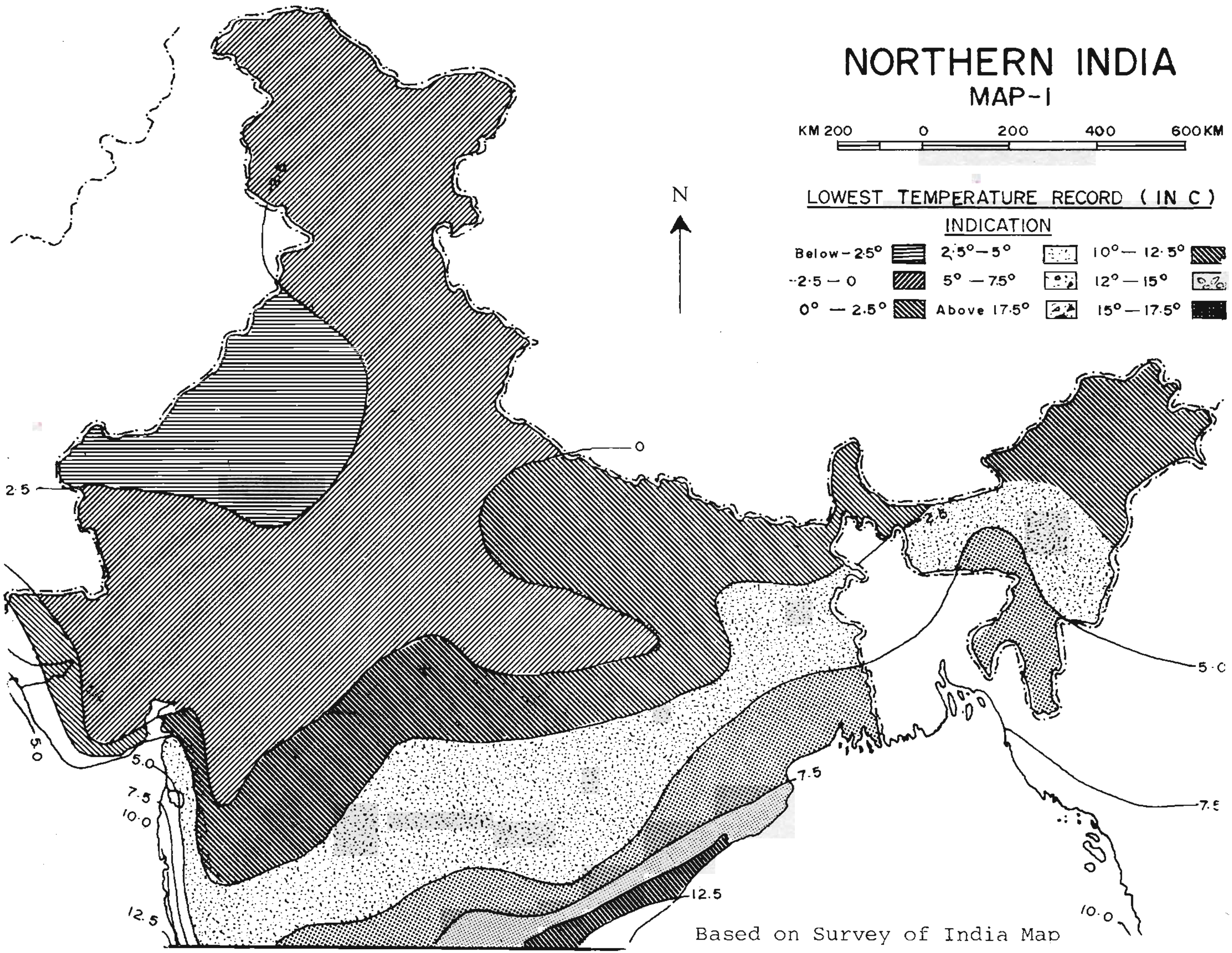
Due to low and varying temperatures, and insufficient supplies of dung, biogas plants in the hill region may fail to meet energy demands of the community during a large portion of the year. If a plant cannot function during winter when fuel demand is highest, the villagers will lose enthusiasm for the plant and will not supply dung, ultimately terminating the project (Bahadur and Agrawal 1979).

Spatial pattern. Sufficient space is required for the construction of a large-scale biogas plant, the digging of pits for the accumulation of spent slurry, and the installation of the required machinery. A minimum of 150 m^2 of land is acquired in Uttar Pradesh for each plant. Agricultural land cannot be used for the construction of the plant. Common land is rapidly shrinking in the hill area, and whatever common land is available is used as pasture land. The prevalence of fodder shortages will make the villagers unlikely to forsake their pasture land to build a biogas plant. This problem was faced by the author during an intensive search for a suitable site for a community biogas plant in Himachal Pradesh. Out of 16 villages suggested by the state, common land of sufficient size was available only in one village (Agrawal 1980). However, land may not be a limiting factor in the valleys and foothills.

Even if sufficient land is available, the laying of a gas distribution system in a hill village would be an arduous task. A minimum gas pressure is required at every burner point, which is maintained by providing a constant slope in the pipeline, starting from the plant and ending at the last house of the village. In the hill villages, where houses are dispersed and constructed at different ground levels, the gas supply could not be managed easily even by providing boosters or gas accumulators.

Social Factors

In the adoption of any technology, several socioeconomic and cultural factors play a significant role. Evaluation studies conducted by research teams have pointed out the association of economic status, population, education, and landholding (Moulik and Shrivastava 1976; Agrawal 1979; UNESCO 1984), family size (Moulik and Shrivastava 1976; UNESCO 1984), and age (UNESCO 1984) with the adoption of biogas technology. The study carried out by Smith et al (1980) in Nepal indicated that a higher percentage of those who adopted the technology had bigger families, more land, more livestock, and greater leadership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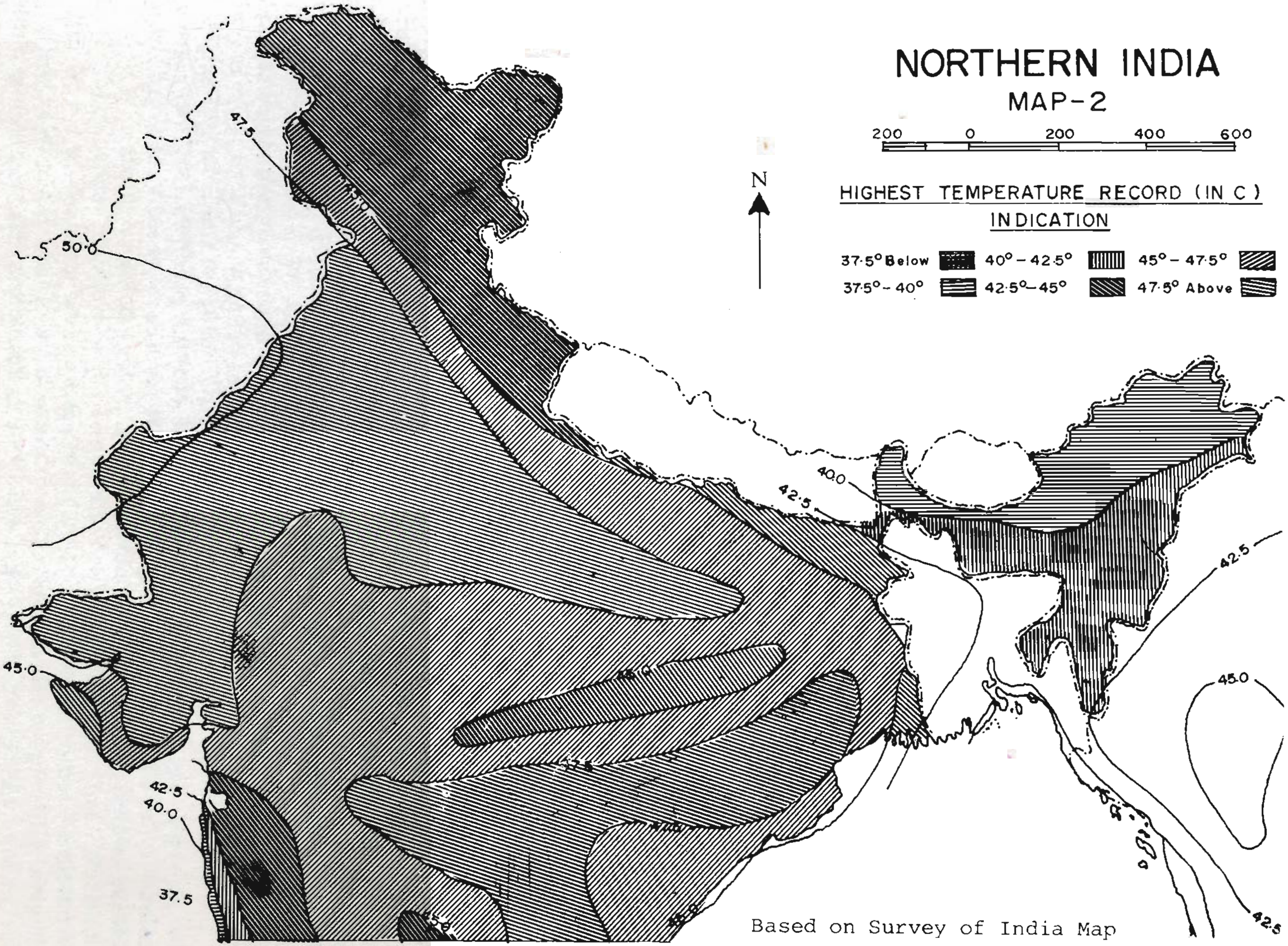
Based on Survey of India Map


NORTHERN INDIA
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HIGHEST TEMPERATURE RECORD (IN C)
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37.5° Below
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40.0
37.5
Based on Survey of India Map

responsibilities. Limiting factors include: high initial cost (Briscoe 1977; Agrawal 1979; Moulik 1982; Chun 1984; Skulbhram 1984), problems in handling waste and spent slurry (Chun 1984), symbolic factors (Agrawal 1979; Chun 1984; Skulbhram 1984), lack of space (Agrawal 1979), and breakdowns (Agrawal 1979; Moulik 1982; Chun 1984) Additional socioeconomic issues are discussed below.

End-use patterns. The basic objective of the CBGP is to meet the cooking and lighting needs of the villagers. Other objectives, such as providing facilities for drinking water, street lighting, irrigation, and flour milling, are decided on the basis of local needs. The gas budget and size of the plant are estimated, taking into account the energy priorities and requirements of the community. However, the shortage of dung to fuel the plant makes it unable to provide sufficient gas for all these activities. As such, in most cases only the cooking requirement is being met (NEDA 1985). In projects where gas for other activities is being provided, this is done only occasionally. Nonetheless, prior to installation, the villagers are assured of the availability of gas for these facilities. As a consequence of false assurances, the villagers' confidence in the system is shaken, expressed by their non-cooperation (Bahadur and Agrawal 1979).

The energy priorities of the hill community are mainly cooking fuel, drinking water, lighting for domestic purposes, and irrigation for the agricultural sector (Agrawal 1980). Villagers will forgo electric lighting for a drinking water facility (Agrawal 1980). In studies of several rural villages in Almora, Nainital (U.P.) and Kangra (H.P.) Districts, it was estimated that the per person annual requirement of cooking fuel is 7.2 x 10^5 kcal.

In a study conducted by NCAER (1981), per family annual energy requirements for cooking and lighting in the hills was about 88 x 10^5 kcal., or 993 m^3. biogas. For a village of 30 families, under ideal gas production conditions, a 82 cubic meter-capacity CBGP would be sufficient. For the operation of the plant, 10.3 quintals of dung would be needed daily, requiring at least 205 cattle, or a person-cattle ratio of 1:1.5--a remote possibility as seen in Table 1.

Thus, even if optimal gas production is assumed, a community biogas plant may not even be able to meet the cooking needs of the community.

Food habits. The rate of cooking fuel consumption is higher in the hill regions than in the plains (NCAER 9181). Free access to fuelwood, use of traditional stoves, present food habits and cooking practices all cause higher fuel consumption. With the exception of rice, most cooking by the hill population consumes a lot of fuel and requires heat of low thermal value. Use of the pressure cooker is not common in the rural hills. Continuation of these practices under the limited gas supply of a biogas plant would lead to its rejection (UNICEF 1984). Changes in food habits and cooking practices to conserve energy will increase the chances of biogas technology being adopted.

Community cohesion. A primary component of the community project is the cohesiveness and community feeling among the villagers. **Indian society is** divided both horizontally and vertically on the basis of caste, class, and kinship. Despite these divisions, a joint venture can be successful if the members have a strong sense of belonging to their village. Community unity surfaces only when the community considers issues to be important.

Whether a community will attach the necessary importance to a CBGP is doubtful, as shown by the following statement:

"Sahib, when two brothers cannot live jointly, cannot share a property, how can a community share a plant?" Dharam Singh (Dharmuchak, Dehradun)

Similar reactions were common in both the hills and the plains. The villagers were convinced of the advantages of biogas technology but most were reluctant to have a community plant.

"If you ask me, I will go for an individual plant for my family, but sharing a plant with other people will deteriorate the village life." Mohan Singh (Jagaria, H.P.)

The respondent believed that any community project would not only fail but would create conflict and tension within the village. There is no empirical evidence to substantiate this claim, but most villagers expressed similar doubts.

Village factionalism is a strong barrier to the cooperative spirit required for a communal scheme to succeed. Inter-factional rivalries often arise during the later stages of the project if one faction achieves prominence through the project, even if the benefits are distributed equally and with mutual consent (Bahadur and Agrawal 1979).
The reasons for conflict and dispute as observed in the existing projects are mainly related to:

- The social status of the president of the village committee belonging to one faction, thus making other factions disgruntled

- Families who do not contribute dung or land, yet share equal benefits

- A lack of cooking gas supplies for large families, prompting them to continue their dependency on dung-cake, and reduce their contribution of dung. (Other families may follow their example even if their needs are being satisfied, starting a vicious cycle.)

Village leadership. The identification of formal and informal village leadership and their attitude toward the project is crucial for the project's success. The more traditional hill communities do not distinguish between formal and informal leadership. The informal leadership is comprised of different people for various spheres of life. The village leadership in the hill regions have not lost social and political values like their counterparts in the plains. This style of leadership facilitates the creation of a community system.

Level of cooperation. Social values, customs, and traditions--the major tools of social control--are not as disrupted in the hill communities as in the villages of the plains. Interactions between various sections of the community in the hill regions are stronger, and despite ritualistic barriers, caste and non-caste Hindus share many common values. The hardship of hill life has prompted a greater sense of cooperation. It is common to see people in the hill regions carrying boulders or slate on their heads to distant villages to help with house construction. Cooperation is also seen in several labor-intensive agricultural operations. This spirit could be harnessed for a community biogas plant, enabling the hill regions to avoid the factionalism seen in the plains.

Administrative systems. In the case of India's first CBGP, it was proposed that the system be managed by an elected village committee with technical support from PRAD. A similar approach has been adopted in the other CBGSs (NEDA 1985). The institutional plants are managed by the institution itself. There may be a better administrative system, but thus far no other method has been adopted in a community biogas plant.

This administrative system has not been very successful, as shown by the fact that seven years after its completion, the village committee of Fateh Singh Ka Purwa has failed to take responsibility for the project. A study of several CBGPs in U.P. revealed similar situations in which plants are being managed by government agencies (NEDA 1985).

In the context of the hill regions, this administrative system appears even more difficult. The various socioeconomic and technical problems posed by a CBGP can be solved only if, before the project is initiated, the village committee is aware of the problems and if the community is prepared to share the responsibilities (Morseat et al 1984).

Alternatively, voluntary organizations could be used for plant administration. In the CBGP at Kashipur, the services of the Gandhi Ashram were sought and results were very encouraging. In a project at Bulandshahar,a local voluntary organization was involved at the initial stage of implementation which helped to create a favorable atmosphere in the village.

A third alternative for the administrative system is to involve private entrepreneurs who can purchase the dung and provide it on a commercial basis. To safeguard the interests of the poor families, restrictions on the rate of various services provided by the entrepreneurs can be fixed by the government through project subsidies. Private firms have already emerged, specifically created for the construction of large-scale plants, which are then responsible for operation over a specified period of time. These contractors are prepared to run the project on a commercial basis if the project is subsidized (personal communication). The major difficulty of the private sector approach is once again the availability of dung. For many socioeconomic reasons, the villagers are reluctant to sell the dung (Agrawal 1981). This attitude is changing in villages located near urban areas, but attempts in remote villages to purchase dung have failed. This system is being experimented with in the NEDA-run projects. However, the author observed during field visits that sufficient dung was not available and the villagers would not purchase the slurry, which then accumulated.

Lastly, the CBGP could be run by a central agency at the state level. The agency or board in charge of promoting new energy systems could be responsible for the continuous management of the plants in a commercial manner similar to the electricity boards.

In the hill villages, of these four administrative options, a government agency would be able to manage a CBGP plant most successfully. Few volunteer organizations are active in the area who could share the responsibility.

Distribution systems. Expectations from a community project vary among different groups depending on their priorities. However, whereas an affluent family may value lighting over cooking gas because they can afford other fuel sources, a poor family will give more weight to cooking gas and will resist any project which threatens its availability. A compromise among the various groups is essential for the success of any community project. This task is made more difficult when the benefits are limited.

Maintaining the supply of cooking gas is essential because the plant requires dung previously used as fuel. Thus, the dung supply will cease if cooking gas is not available. However, this problem may not arise in the hill village where dung is not commonly used as fuel. This provides a possibility of utilizing gas for non-cooking activities.

The energy survey conducted by the author in the hill regions of U.P. revealed the following energy priorities, based on first, second, and third choices given by respondents:

Table 3: Energy Priorities in the U.P. Hills

Activities	weightage score
Drinking water	1170
Cooking	1045
Threshing	980
Heating	850
Lighting	850
Flour milling	530
Oil extraction	440

Irrigation, though a priority need, was not included in the survey because of the limited possibility that a biogas plant could provide sufficient energy for it. In the foothills and valleys, an irrigation facility can be run by a dual fuel (diesel gas) engine. The problems with this engine are almost the same as those encountered in the operation of a diesel engine.

Another distributional problem is timing the energy supply to the villagers, whose demands for energy vary with the occupation and mode of living of the family. Agricultural families require cooking gas on a different schedule than a family involved in services. The amount of energy demanded is directly related to family size. Economic status is also a determinant of energy demand. These variations are present in every community posing real problems for designing a distribution system. These can be overcome only by strengthening the cohesiveness and mutual understanding in the community.

Economic and Financial Factors

The economic viability of both family

and community biogas plants may be estimated using various techniques. The most popular among these is social cost-benefit analysis. In the initial stages, this analysis helps the decision-makers fix the subsidy rate and encourage banking institutions to finance the plants. Along with cost-benefit analysis, the internal rate of return, net present value, and pay back period are calculated (Bhatia 1976; Barnett 1976; ICAR 1976; Sanghi 1976b; Verma 1976). However, in evaluating the benefits of methane generation in a developing country, the possible sources of the gas should be identified and only those benefits should be included which are likely to directly accrue from the project (NAS 1977).

In recognition of the limitations of this approach, actual consumption of fuel by the people and services to be rendered by the plant was used rather than estimating benefits on the basis of coal and kerosene replacement values (Maulik 1982; Bahadur and Agrawal 1979; Bhatia 1977; Briscoe 1977; Prasad et al 1974). Even in this form of analysis, the economics is worked out by examining only a few dimensions of the problem. In addition to the technical and economic dimensions, consideration should be given to the social and environmental impacts (Barnett 1976). The Fuel Linked Energy Resources and Technologies. FLERT approach has been suggested for evaluating small-scale rural energy technologies (Smith and Santerre 1980).

The economic analyses carried out by Moulik (1982) for several different plant sizes reveal that all sizes of plants,

Table 4: Pattern of Central Subsidy for Biogas Plants (in Rupees)

Size of Plant (cum.)	For North-Eastern Region States, Sikkim and notified hilly areas and desert districts.	For other areas		
		For Scheduled Tribes/small marginal farmers and landless labour	For Scheduled Castes	For others
2	2940	2350	2350	1560
3	3660	2860	2860	1900
4	4390	3220	3220	2140
6	5350	3920	-	2610
8	6460	4640	-	3100
10	8080	5540	-	3700
15	11440	8150	-	5430
20	15260	10960	-	7300
25	17640	12280	-	8190

except 60 cubic feet are economically viable. For the community biogas plants, a large-scale plant is more economical than a family plant (Moulik 1982; Verma 1981; Bhatia 1980; Ghate 1979; Bahadur and Agrawal 1979; Reddy and Subramanian 1979). A number of authors have also established the economic viability of CBGPs in India, Korea, China, and Thailand. Reduction in per unit costs by increasing the plant size is presented in Figure 1.

However, controversy continues about the benefits of the system. Usually the manure value of the slurry, savings in terms of fuelwood, kerosene and dungcake, in addition to financial returns from commercial activities, are considered direct benefits. These estimations are meaningful only when supported by actual field data. From this point of view, the CBGP system will remain economically viable in the hill region.

The DNES has made provisions for subsidizing construction costs. The rates of subsidy for different sizes and categories of plants are shown below. The table reveals that higher subsidies are allowed in the northeastern states, Sikkim, notified hill areas, and desert districts. The subsidy rates are given for plants to a maximum capacity of 25 m^3 because an individual family is not expected to want anything larger.

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The total cost of the CBGP is borne by the government, including construction of the plant and distribution system, purchasing machinery and equipment, and contributing operational expenditures for three years. A CBGP project with a capacity of 85 m^3 costs from Rs. 217,000 and Rs. 286,000 (NEDA 1985). The community contributes its share by providing free land. Cooking gas is provided only to families which agree to pay for the service. In the hills, the project costs will be higher because of additional transportation needs and changes in the plant design. How long projects of such high initial cost can be fully subsidized is an important policy question.

A recent development is the escalation of construction costs of large-scale plants. The total cost of a 60 cubic meter-capacity plant, about Rs. 100,000 in 1977, is now at least Rs. 400,000 (NEDA 1985). The cost-benefit ratio is not computed by any non-official agency based on current construction costs. On the other hand, though an increase in the price of fuelwood and kerosene is observed, the increase is not at par. As a result of this trend, the gap between costs and benefits will certainly become narrower. In addition, the geographical limitations of the hill area will escalate construction costs, further shrinking the gap between cost and benefits.

When estimating average gas production, decreasing gas yields caused by temperature variations should also be

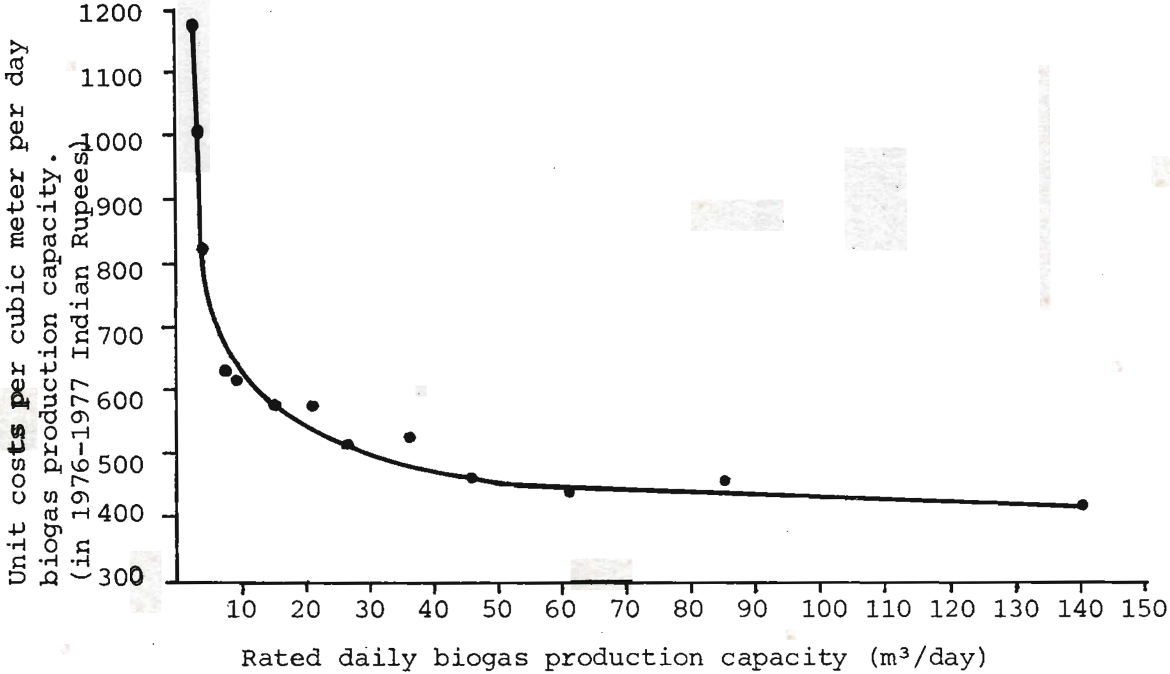

Figure: 1 Economics of Scale in anaerobic digesters. Comparative initial costs of floating dome anaerobic digesters, per cubic meter of installed daily biogas production capacity. (Adapted from Ghate 1979) taken into account, as should the increased costs of gas distribution caused by the dispersed spatial pattern of the village.

The financial aspects of the project depend mainly on cash returns from the project. As mentioned earlier, with the limited supply of dung and decreased gas production during the winter, a CBGP located in the hill regions will not be able to fully meet the cooking gas requirement. Based on past experiences, it can be safely said that in most areas, people will be reluctant to pay any amount for the services provided by a CPBG. The shortage of financial returns will place a continuous burden on the managing agency. It is thus essential to analyze potential alternative end uses of gas.

For a self-sustained CBGP system, provision of cooking gas is not an advisable activity; the best financial returns can be expected when the gas is converted into electricity which can be utilized for domestic and street lighting, and operating village-level industries (Agrawal 1984).

Environmental Factors

Fuelwood constitutes a major share of the cooking fuel consumption in the hill regions (NCAER 1981). With the current rate of population growth, fuelwood demand is increasing and, as a result, deforestation has reached an alarming stage. The ecosystem is badly affected, the upland areas are subjected to destructive erosion, and the resulting sediment causes rapid filling of the reservoirs and flooding downstream. Use of fuelwood is also a major source of air pollution which adversely affects human health.

The environmental deterioration can be checked to a certain extent by introducing biogas technology. Annual per household consumption of fuelwood in the hill region is estimated to be 1103 kg compared to 466 kg in the plains (NCAER 1981). As shown in Table 1, in 1978 the hill districts of Uttar Pradesh possessed 698,000 cattle and 1,354,000 goats and sheep. Using an average dung production of 5 kg for cattle and 1.5 kg for goats and sheep, 791×10^6 m^3 of gas could be produced annually from the dung, replacing 800×10^6 kg of fuelwood. Since the thermal efficiency of biogas is 60 percent, compared to 17.3 percent for firewood, effective heat from biogas will be much higher. If the other biomass materials listed in Table 2 are used, available gas can easily replace the use of fuelwood.

However, in light of socioeconomic and technological constraints, even if fuelwood consumption could not be completely replaced by biogas, individual family plants would be useful in the hills as additional energy sources.

CONCLUSIONS

Serious environmental degradation and scarcity of fuelwood make the search for alternative sources of renewable energy an important priority. Biogas has emerged as a viable alternative source of energy. However, its applicability in the hill regions depends on various technological, socioeconomic, and institutional factors.

The hill regions have extremely diverse

topographical conditions which make any generalization misleading. The technological constraints discussed earlier may not pose such serious problems in the foothills and valleys as in the hills. It is apparent that current biogas technology, especially community biogas systems, has a limited chance for success in the hills.

The most serious limitation of the technology is low gas production during winters. Among the existing designs, the drumless biogas plant has an edge over the KVIC design, although its performance is still limited by temperature fluctuations. The use of fiberglass in place of steel has successfully solved this problem in Korea (UNESCO 1984). India has attempted to solve this problem by insulating the plant and using a solar heater (DNES 1984). These and other possible technical solutions may control the fermentation of the slurry at low temperatures.

Inadequate water supply is another constraint requiring immediate attention. In Thailand, one-fourth to one-fifth of the biogas non-users had water supply problems because they lived in high-lands far away from a water source, and faced acute water shortages during part of the year (UNESCO 1984). The plants must be redesigned to use less dung, and hence less water, in order to be applicable in the hill regions. In addition, the high water table in the valleys and foothills may necessitate additional engineering inputs.

Inadequate dung supply may be compensated by linking the system to latrines. This will require additional effort to induce people to use the latrines. It will also require a change in social values before using gas produced from human excreta is widely accepted. This problem was overcome in Korea and Thailand by an educational program (UNESCO 1984). The goat and sheep dung available in the hills can compensate for the shortage of cattle dung. The hill region has an abundant supply of pine needles and other biomass sources, which could also be used for the generation of gas.

The spatial pattern of the hill villages may not pose any problem for the family biogas plants, but it will be a limiting factor for the larger community biogas plants. Gas distribution will also be difficult in the hill regions.

The main socioeconomic factors restricting the adoption of biogas technology are high initial cost, problems in handling waste and spent slurry, high fuel consumption, insufficient technical knowledge, and the lack of proper institutional facilities. In addition, a CBGP requires mutually agreed upon gas budget decisions and changes in traditional cooking practices. The sociocultural environment in the hills is more conducive to CBGP, although individuals may be reluctant to accept a joint venture.

The system will be more socially and economically acceptable if the CBGP becomes a nucleus of the industrialization of the village. A major part of gas production should be used for the operation of cottage and small-scale industries. Any project that generates employment opportunities will be welcomed by the people, especially in the hill region where job opportunities are scarce.

Other social constraints can be minimized by pre-project educational programs. A favorable atmosphere can be created in a village by discussing the project with the villagers and convincing them of the project's merits. It may be a time-consuming process but it is essential for success.

In conclusion, individual biogas plants may have limited potential in the hill regions, but it would be fatal to impose CBGP systems in the hills at the present premature stage.

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