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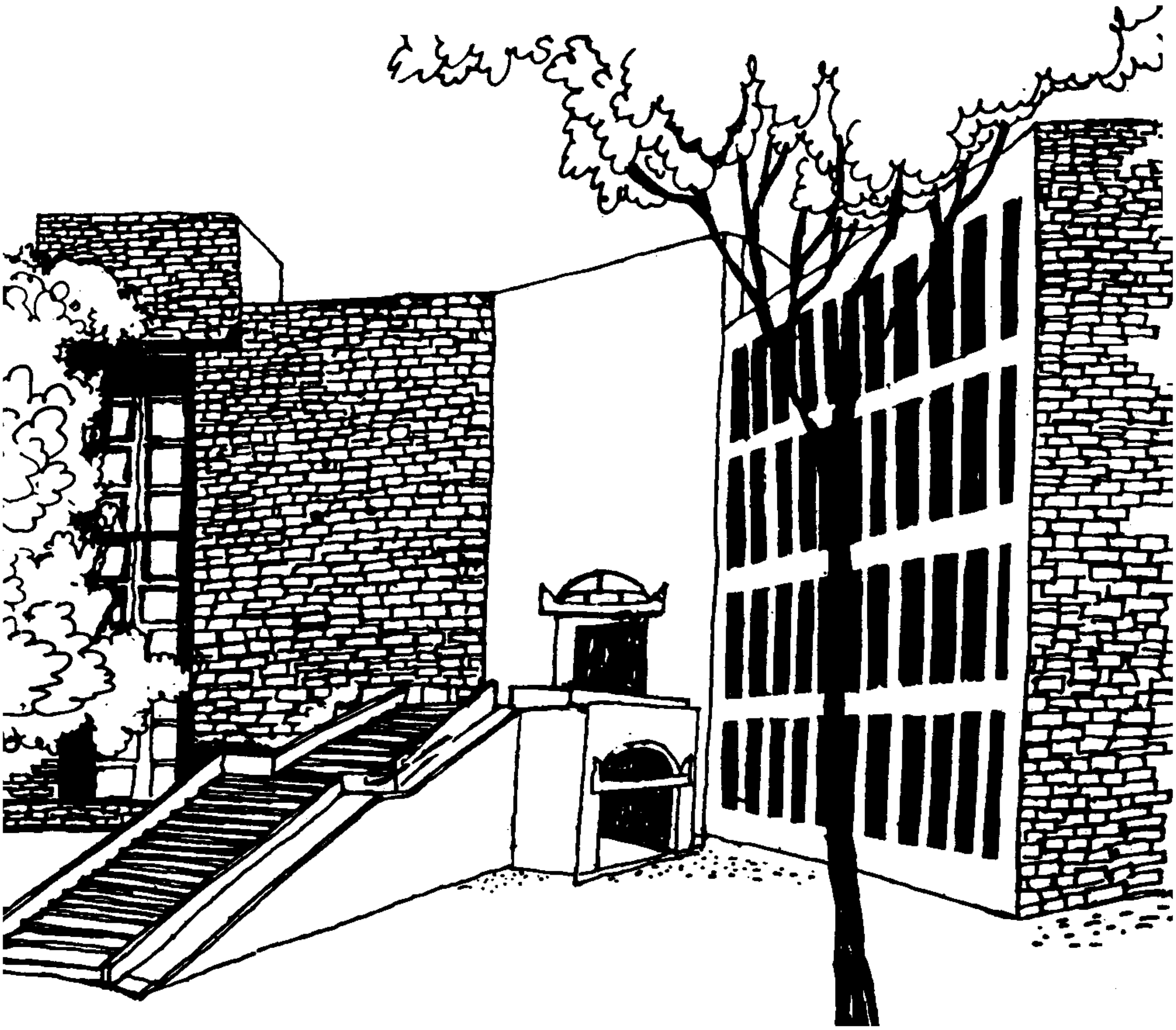

BIO-GAS PLANTS--
A CHALLENGE TO RURAL ENTREPRENEURES

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BIO-GAS PLANTS -- A CHALLENGE TO RURAL ENTREPRENEURES

Introduction

Much has been written on bio-gas plants as a solution to energy Crisis and for overall benefits to the rural community. The strategy adopted by the Government of India to encourage setting up small-sized individual farm-based units or large-sized community plants through subsidy has been examined. The social-cost benefit analysis of individual as well as community plants has been worked out. Many technical, operational and management difficulties are pointed out. However, there has been hardly any study investigating whether large sized bio-gas plants could be run on a commercial basis and whether rual entrepreneures could be attracted towards this enterprise. This paper attempts to study the strategy of setting up of bio-gas plants on a commercial basis by rural entrepreneures.

Review of Literature

In 1974, as a member of the committee to review the strategy of bio-gas plants, set up by the Indian Council of Agricultural Research (ICAR), I had worked out economics of bio-gas (gobar gas) plants on the basis of data provided in the literature by Khadi and Village Industries Corporation (KVIC)[1]. In 1975, Moulik and Srivastava studied the working of bio-gas plants at the village level and brought to light several technological and socio-economic problems which required to be solved before bio-gas plants became viable practical propositions.[2]

In 1976, Kirit Parikh studied the implications of large scale adoption of bio-gas plants to meet the energy requirements of rural households[3]. In the same year Bhavani wrote on social cost-benefit analysis of bio-gas for fuel and fertilizers in rural India.[4] In 1978 Tyner considered the potentiality of establishing biogas units in rural areas of India to increase availability of fuel and fertilizer while discussing alternative energy sources.[5] In 1980, Jyoti Parikh talked about the potential of Bio-gas plants while discussing

1. D.K. Desai, Economics of a Gobar Gas Plant, IIM, Ahmedabad, Technical Report No. 41, July, 1974.

2. T.K. Moulik and U K Srivastava, Bio-gas Plants at the village level. Problems and Prospects in Gujarat, CMA Monograph No. 59, Indian Institute of Management, Ahmedabad, 1975.

3. Kirit S. Parikh, Second India Studies Energy. The Macmillan Company of India Ltd., Delhi, 1976 , pp. 96-108

4. S. Bhavani, Biogas for fuel and fertilizer in Rural India - A Social Benefit-Cost analysis, Indian Journal of Agricultural Economics, Vol. XXXI, No.3, Conference number July-September 1976 pp. 219-231.

5. W.E. Tyner, Energy Resources and Economic Development in India, Allied Publishers Private Ltd. Delhi, 1978, pp. 111-124.

energy supply options for the developing regions[6]. In 1982 Moulik brought out a working paper on a community bio-gas plant in a Gujarat village and discussed about the technological and organizational aspects[7], and also a publication on bio-gas energy[8]. Recently an interesting article appeared on an experiment of a community bio-gas plant by the Centre for the Application of Science and Technology to Rural Areas (ASTRA) of the Indian Institute of Science, Bangalore[9].

The interesting aspect of my study was that in 1974, when the government was advocating setting up small-sized individual bio-gas plants at farmers' houses and had approved a proposal of KVIC to set up 20,000 bio-gas plants in the country to be located in 2,000 blocks at the rate of 10 per block with the total investment of Rs.7.81 lakhs, I had advocated setting up large-sized plants at the village level after working out the economics of bio-gas plants.

Kirit Parikh advocated community-based large-sized biogas plants because he felt that the community plant made it possible to process dung from all animals, and not just the animals owned by 20 per cent of the animal-owning-households. Moreover, he had estimated that community-sized biogas plants could meet 71 per cent of rural energy needs in India by the year 2000 A.D.[10]

6. Jyoti K. Parikh, Energy Systems and Development, Oxford University, Press, Delhi, 1980, pp. 122-130.

7. T K Moulik, Introduction of Community Bio-gas Plant in a Gujarat Village, A Case Study of Technological and Organizational Interventions. Working Paper No.420, Indian Institute of Management, Ahmedabad, 1982.

8. T.K. Moulik, Biogas Energy in India, Academic Book Centre, Ahmedabad, 1982

9. Praful Bidwai, Science for Villages, Times of India, Ahmedabad Edition, October 9, 1982.

10. Kirit S. Parikh, Ibid, pp. 104-107.

Moulik and Srivastava had also calculated the economics of bio-gas plants based on the data of actual operations in the field conditions vis-a-vis the benefits claimed by the KVIC experts[11]. They found using the actual data of the sample plants that the internal rate of return (IRR) varied from 13.53 to 58.87 per cent as the size of the plant varied from 60 cft to 1250 cft in capacity. When they used KVIC data, the IRR varied from 19.99 to 63.94 per cent for the corresponding capacities[12]. This corroborated with my finding that large plants were more economical.

Bhawani had carried out the cost-benefit analysis of a 2 cmt. or 70 cft. biogas plant. According to him, the net present values of the plant were Rs.1,366 and Rs.703 at the discount rate of 10 per cent when the alternative uses of cow-dung were assumed as fuel and manure respectively. The economic life of the plant was assumed to be 30 years. These findings were at somewhat variance with my findings of the net present values of a 60 cft. bio-gas plant with an economic life of 10 years at 10 per cent discount rate, which were Rs.385 and Rs.767 when the alternative uses of cow dung were assumed as fuel and manure respectively. Thus in my view a bio-gas plant was more economical as a producer of manure than that of fuel while comparing the alternative uses of cow dung as manure and fuel respectively.

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11. Moulik and Srivastava, Ibid, p. 60.

12. Moulik and Srivastava, Ibid. P. 60

Another observation I had made was that the large sized plant at the village level should be operated under proper management, be it community, cooperative or private. Moulik and Srivastava also felt that the setting up of large-sized community plant was desirable. But their survey showed that the majority of households did not favour the ideas of community plants because of their apprehension about the management problems of these plants. The survey of 25 community plants showed that all but four were relatively small-sized plants and had capacity below 300 cubic feet. The four large-sized plants were having the following capacities :

Institution	District	No. of Plant	Size of the Plant cft.	Age of the Plant (yrs.)	Operating condition
Sarvodaya Ashram	Mehsana	1	1250	6	Operating
Dudhotpadak Sahkari Mandal	"	1	1250	13	non-operating
Jadeshwar Mahadeo	Rajkot	1	1000	2	non-operating
Dham-Khijada Mandir	Jamnagar	1	500	2	operating

Of the four large-sized plants only two were operating whereas from among the remaining 21 small-sized community plants only 4 were operating. The authors had gone into the details of the practicabilities of the community plants. The results indicated that the problems associated with the management of the community plants seemed to be so overwhelming that a large majority of the respondents in the sample tended to shy away from the idea.[13]

13. Moulik and Srivastava, Ibid. p. 51.

The third observation of my study was that we would need 166 plants of 250 cft. capacity and a cattle population of 3,320 for supplying mannure from bio-gas plants to an area of 10,000 acres. It was also stated that if it was possible to have large size-plants say 3,000 cft. capacity, the number of plants would reduce considerably but the management of operating these plants would be somewhat difficult. To supply manure to all farmers in the village on an equitable basis, it would be more desirable to have large-sized plants under proper management than to have small plants under individual ownership.[14]

Moulik and Srivastava indicated that the strategy of bio-gas plants to supply manure and fuel to the community had faced technical socio-economic and organizational problems in the real world. They felt that the planned strengthening of R & D efforts would take care of some of the technical problems at the laboratory level.[15]

ASTRA installed two units of community bio-gas plants with a capacity of 750 cft. per day each in a village called Pura, about 115 kms. away from Bangalore. The R & D work of ASTRA was rigorous. The plan. of the community plants was very attractive and technically

14. D.K. Desai, Ibid, p. 13.

15. Moulik and Srivastava, Ibid, p. 125

viable. However, it did not work. These plants were not run on a commercial basis. The gas was piped free of cost to all households in Pura at a fixed time of the day. The dung was collected by an ASTRA employee and charged into the digester of the plant. The following day an equivalent quantity of sludge, the nitrogen rich output from the plant, was returned to the households which contributed dung. The operation was more of a social activity than a commercial enterprises.

The difficulty faced by ASTRA in this non-commercial operation was that the demand for the free gas was much higher than the supply which was not enough even for cooking needs. What was supplied was good enough to cook at the most one meal a day of rice, dal and balls of ragi. The short supply of gas was due to 1) increase in population of the village Pura, 2) higher requirement of gas in the prevalent cooking practices and 3) lower yield of cow dung than anticipated in the plan.[16]

The experiment of ASTRA indicated that even if a technically sound bio-gas plant was installed as a community plant, and if it was not operated on a commercial basis, the large-sized technically viable biogas plant would also not be a practicable proposition.

The Commission for Additional Sources of Energy (CASE) operated a scheme of establishing and managing community type bio-gas plants.

16. Praful Bidwai, Ibid.,

By 1982, CASE had commissioned 19 such plants and 30 other plants were under installation. Five of these plants were established at military farms and defence institutions. CASE director thought that military farms were ideal sites for such plants because of the availability of a large number of cattle on the farms and the military could be entrusted to run the plants hygenically and efficiently. However, their demonstration value to communities was limited.

CASE has constructed several of these plants in villages in Andhra Pradesh, UP and Maharashtra and all of them are being run by it or by institutions entrusted by it.

According to Mr. Maheshwar Dayal, Secretary to CASE, the management of the plant was a major constraint. They had not found any answer to the management of a community plant. He hoped that answers would come once they had a large number of plants running.

Bhavani concluded that although bio-gas plants were viable propositions, there was no felt need from the farmers because the bio-gas did not seem to be more economical than the alternatives of kerosene and coal the going prices and the low prices of fertilizers in the past might be one reason for the slow growth of the bio-gas plants.[18]

17. "Community gas plants going to Military Farms", in Indian Express, October 16, 1982.

18. Bhawani, Ibid, P. 229.

The conclusions from these studies can be drawn as follows :

1. Large sized plants are more economical than small sized plants.

2. Community plants can be operated only if the technical and management problems can be solved. The experience so far goes against the practicabilities of community plants.

3. If a large sized bio-gas plant has to be operated on a commercial basis as a supplier of gas and manure, the following parameters should be taken into account.

    1. Number of cattle population
       a) per sq.kilo meter and b) per village

    2. Transport cost of cow dung per ton per kilometer to and fro the plant and farmers' households.

    3. Density of user population and location of their households.

    4. Total investment cost

    5. Price of cow dung

    6. Price of manure

    7. Price of gas

    8. Intrinsic value of dung fuel in terms of equivalent fuel

    9. Intrinsic value of farm yard manure in terms of equivalent nutrients.

    10. Operational cost of a plant.

    11. Economic life of a plant

    12. Interest rate at which the entrepreneur would like to invest in the bio-gas plant.

Inspite of so many adverse reports on the practicabilities of either small-sized individual-ownership-basis-operated or large-sized community-basis-operated biogas plants, the number of bio-gas plants which were only 6,000 by 1972-73 and had taken nearly 11 years to reach this level from a small number of 315 had reached a figure of 90,000 plants by the year 1981-82 and the total investment was of the order of Rs.54 crores (Exhibit 1). The government has fixed a target of four lakh bio-gas plants during the Sixth Five Year Plan[19]. In our anxiety to find out a substitute source of energy in place of fossilized fuel, a heavily subsidized programmeof bio-gas plants is undertaken.

The experience narrated by Moulik and Srivastava on operational problems of bio-gas plants in Gujarat and of other case studies calls for a rigorous evaluation of the strategy of setting up a large number of small-sized individual-ownership-operated or large-sized community-operated bio-gas plants through subsidies.

Economies of bio-gas plants:

In light of the above discussion, the model which I had used to work out the economics of bio-gas plants in 1974 (Exhibit 2) was modified: 1) to take into account various parameters and to see whether within these parameters, a bio-gas plant of a particular size was a commercially viable proposition for a rural entrepreneur in the private sector (Exhibit 3). Variables used in this model are explained in Exhibit 4.

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19. Times of India, Ahmedabad Edition, November 12, 1982.

The objective of modifying the model was to find out the viability of a bio-gas plant if it was run by a private entrepreneur instead of running it as a community plant which had faced many socio-political and technical difficulties and management problems. But this assumes that the plant of the economically viable size was perfected technologically at the research laboratory level and also at the pilot trial stage and ready for application in the field condition. Without this it would be much riskier for the private entrepreneur to undertake this type of enterprise.

In order to obtain realistic results from this model, data from a case study of Kubadthal village community bio-gas plant (Exhibit 5) and other plants were used.

Data :

In the discussion of economics of bio-gas plants, the most important variable is the number of animals required to supply dung to a plant of a particular capacity. The number depends on the size of the plant (Ki) and the average quantity of cow dung produced per adult animal. We have considered 10 different types of plant-capacities but the average dung produced per animal (Xj) was fixed at 4 kg. per day on the basis of the experience of Pura bio-gas plant experiment.

The capacity of a bio-gas plant is constrained by the number of animals available in the area. We have taken a large-size-plant (141.55 cmt or 5000 cft) and tried to find out how many of such plants could be established within a radius of 9.3 kms* of the plant depending upon the cattle density per square kilometer or how many villages having average number of animals in a district would have to be covered by the plant. (Table 1). The number of animals (cattle), area in square kilometres and number of villages in a district were obtained for the Gujarat State. It is observed that the number of large-sized-plants (141.55 cmt.) that can be established within a radius of 9.3 kms in the rural areas will vary from 2 in Kutch to 29 in Panchama-hals in Gujarat State depending on the cattle density per square kilometer. As cattle population is concentrated in the village site, a better measure would be the number of villages that can be covered by the large-sized plant. This varies from 3 in Amreli, Junagadh and Jamnagar to 8 in Dang and Vadodara in the Gujarat State. It is assumed that these villages will be covered within the radius of 9.3 kilometers.

The data on investment (I_i) were collected from the sample survey conducted by Moulik and Srivastava.[20] They were updated by using the index number of prices of iron and steel for the years 1975 and 1982. The data on investments for the largest size (141-55 cmt). were available from Kubadthal case study. But it exceeded much more than 4 times the value of a 35.39 cmt. plant and hence it was scaled down to Rs.1,40,000 on the assumption that research and development work conducted at various places would be able to bring down the investment cost to this level.

* This radius was fixed on the basis of the following formula

$$r = \frac{P_3}{T_e}$$

where P_3 is the intrinsic value of manure produced from a bio-gas plant and T_c is the transport cost of cow dung per kg/km.

20. Moulik and Srivastava Ibid. pp. 130-139.

The data on annual expenditure (D_{ik}) which included fixed cost and variable cost were assumed as follows :

1. Rs.1000/year plus updated cost of paint and variable cost of purchase of dung for gas plants upto the size of 8.49 cmt. or 300 cft.

2. Rs.2000/year plus updated cost of paint and variable cost of purchase of dung for gas plants varying from 9.91 (350 cft.) cmt. to 35.39 cmt. (1250 cft.)

3. Rs.14500/year for the 141.55 cmt. (5000 cft.) bio-gas plant plus the purchase of cow dung.

Price of gas (P_1) was varied from Rs.0.70/M^3 to Rs.1.10/M^3. The highest price was kept at 20 per cent below the price of the equivalent value of butane gas which was available in urban in gas cylinders.*

Price of dung fuel (P_2). This was worked out on the basis of the equivalent value of kerosene as the price of dung fuel was not easily available from the rural areas.

Price of bio-gas manure (P_3): On the basis of average nutrient contents (Exhibit 4), and the prevalent prices of N, P and K the price of one kilogram of manure was worked out as Rs.0.17. It was realised that farmers would not be ready to pay this price (Kubadthal case) and hence it was varied between Rs.0.06 and Rs.0.17 per kilogram of manure.

Price of farm yard manure (P_4): The intrinsic value of FYM in terms of nutrients was worked out as Rs.0.06 per kilogram.

* Gas cylinders were not easily available and there was a premium price in the black market.

Price of Cow dung (P_5): The maximum value of cow dung that can be offered should not exceed its intrinsic value of manure and the minimum value should not be less than its intrinsic value as fuel. Thus the price of cow dung was varied between Rs.0.02 and Rs.0.08 per kilogram. It was assumed that at these prices farmers would deliver cow dung at the plant. If cow dung was required to be collected by the plant personnel, the price paid would have to be reduced by the cost of collection of cow dung.

Economic life of a plant (t): This was assumed as 10 years mainly because of the obsolescence that would take place because of R&D work.

Interest rate (i) : The interest rate was assumed to be 15 per cent; the on-going rate of interest on deposits in the private sector.

Efficiency of the plant operation (e): As the operation depends on the ambiviant temperature and also management efficiency, the plant efficiency was assumed to vary from 0.50 to 0.75. This would take care of many practical problems.

The relevant data are presented in Exhibit 6 :

Results and Discussions

As the main emphasis of the analysis was to see whether the bio-gas plant was economical from the commercial point of view of a private rural entrepreneur, the results of private cost-benefit analysis are discussed.

Bio-gas Plants as a Commercial Proposition

Various cenarios under which a bio-gas plant would be operated by a private rural entrepreneur are constructed as follows :

Scenarios :

1. Gas Price fixed at Rs.1.10 per M^3; the bio-gas manure price fixed according to its intrinsic value (Rs.0.17 per kg), the rate of interest fixed at 15 per cent, the economic life of the plant fixed at 10 years; the efficiency of the plant was fixed at 0.75 only, prices of cow dung and capacities of the bio-gas plants were varied.

2. The bio-gas manure price fixed at its intrinsic value (Rs.0.17/kg); the purchase price of dung fixed at Rs.0.08 per kg; and the bio-gas prices were varied, other variables same as in Scenario 1.

3. Only the large-size plants with 35.39 cmt (1250 cft) and 141.55 cmt (5000 cft) capacities were considered, the prices of gas, the prices of manure and the prices of cow dung were varied, other variables/the same as in Scenario 1./were

Scenario 1: At the favourable prices of gas and manure, all sizes of bio-gas plants (except 1.7, 2.83 and 4.247 cmts) were economically viable even after paying the price of Rs.0.08 per kilogram of dung (Table 2). The internal rate of returns in all cases except those mentioned above ranged from 28.67 to more than 50 per cent. Even the smallest bio-gas plant (1.7cmt) was economical (IRR 29.48 per cent) if the purchase price of dung was only Rs.0.02 per kilogram (Table 3).

This is the most encouraging scenario for the rural entrepreneur. If he is very optimistic, he can take the risk and start the business of setting up a bio-gas plant with perhaps the small-size-capacity of 5.66 cmt, and pay the price upto Rs.0.08 per kilogram of cow dung at the plant site.

Scenario 2:

Although enough quantity of cow dung would be available at the price of Rs.0.08 per kilogram, one was not sure whether the demand for gas which was generated existed at the price of Rs.1.10 per cubic meters. As no data were available on price elasticity of gas it was assumed that there would be sufficient demand for gas as the price of gas was decreased. At this stage it was assumed that farmers were ready to pay the price of bio-gas manure reflecting its intrinsic value. It was observed that all small-sized plants became uneconomical as the price of gas was reduced from Rs.1.10 to Rs.0.70.The only two large-size plants (35.39 and 141.55 cmt) were found to be economical. It is clear that if the rural entrepreneur faced the difficult situations of very low gas price and high cow dung price, the only solution was the establishment of large-sized plants. But in this scenario there is an assumption that farmers would pay the intrinsic value of manure.

Scenario 3 :

If the rural entrepreneur decided to run the large-sized plants, he would be faced with a situation in which farmers after asking for a high price of Rs.0.08 per kilogram of cow dung would not purchase bio-gas manure at its intrinsic value and offer lower prices. Manure being a bulky commodity, it is difficult to sell outside the village or the area from which farmers would be ready to lift manure from the plant site. Moreover, farmers would think that the plant was making profit from selling gas hence the price of manure which was a bye-product should be much less. Under these circumstances, we considered three prices of bio-gas manure, Rs.0.06, 0.12 and 0.17 per kilogram. It becomes very clear from Table 5 (Figure 1) that if the manure price was reduced and the cow dung price was kept at a high level of Rs.0.08 per kg, both the large-sized plants would run in loss. It was observed that all other smaller-sized plants were also running in losses. It will also be noticed from Table 5 that increasing the price of gas from Rs. 0.70 to 1.10 per cubic meter did not wipe out, the losses incurred by reducing the price of manure from Rs.0.17 to Rs.0.12 per kilogram. The only solution to make the large-sized plants profitable, when the manure price was reduced to Rs.0.06 per kg.,was to reduce the dung price to Rs.0.02 per kg. At this price of dung, the plants become profitable even if the gas price was reduced from Rs.1.10 to Rs.0.70 per cubic meter (Table 6).

It becomes very clear therefore that the crucial variables in bio-gas plants are the prices of manure and dung. Hence, instead of calling a bio-gas plant, it should be called a <u>bio-manure plant</u>.

Table 7 gives the relationships between the price of manure and price of cow dung when the gas price was fixed at Rs.0.90 per cubic meter. At the price of manure of Rs.0.6 per kg. the large-sized plants became profitable only when the cow dung price was reduced to Rs.0.02. If farmers wanted to keep the price of cow dung at Rs.0.08 per kg., they would be ready to pay the price of manure at Rs.0.17 per kg., which was the intrinsic value of manure.

The rural entrepreneur will have the scope of adjusting the prices of manure and cow dung depending on the supply and demand situations.

Conclusion:

All the three scenarios lead us to conclude that there is a good scope for the private entrepreneur to set up large-sized bio-gas (bio-manure) plants and run them as commercial propositions. What the government should do is to encourage private entrepreneurs on the same basis as small-scale-industrialists. If bio-gas plants, perfected at the technical level and tried at the pilot stage, are given to the rural entrepreneurs on a turn-key basis with funds provided from the commercial banks with interest rate upto 15 per cent, it should be possible forthem to operate them on commercial basis.

If this strategy is adopted, the present strategy of subsidy-based individual-farm-operated small-sized plants or large-sized community-plants may have to be re-examined. This would save the exchequer a large sum which is going waste because of non-operating bio-gas plants and making a viable proposition non-viable by making non-entrepreneurs dependent on subsidies.

The strategy of setting up a large number of small-sized biogas plants adopted in India is a good example to show how a large scale operation gets into trouble when proper home work is not done at the research level. The setting up of large-sized community plants has faced the problem of non-availability of management talents to run the community plants. The community plants may be beneficial from the point of view of social-cost benefit analysis but if this strategy is not operationalized because of lack of management personnel, it would be a wiser strategy to encourage private entrepreneur to set-up large sized bio-gas plants and run them so that not only they would earn profits but they would also render services to the rural people through invisible benefits of cleanliness, prevention of diseases and complimenting energy sources and make social benefits realized.

The Chinese had set up 9 million digesters-many of small size by the end of 1980. According to Moulik, during 1977-78, the number of biogas units in China increased from 0.5 to 7 million. The unit size was reduced; small, flat, circular models were popularized. In 1979, there was a rethinking and the thrust was shifted from the individual plants to community plants.[21]

The Chinese could afford to have national level experiments of "the great leap forward" and "four modernization" in their system. But in the system adopted in India it is better to perfect the technology at the "research and development" stage and operate economically viable plants at the pragmatic level. If we can get community plants managed and operated efficiently, we should encourage setting up such plants. But if there are to remain non-operational after being set up, it is much better to encourage private entrepreneurs to run large-sized plants on a commercial basis.

21 Tushar Moulik, Radio Talk, June 3, 1982.

Table 1 : No. of Large-sized Bio-gas Plants (141.55 cmt) within a radius of 9.3 kms or No. of Villages required to be covered by one biogas plant with 141.55 cmt. capacity

District	No. of Revenue Villages	CD/per sq.kmt.	No. of animals within the radius of 9.3 kmts	No. of plants required	Per village No. of animals	No. of Villages/ per plant
1	2	3	4	5	6	7
Kutch	906	6	2896	2	288	5
Surendranagar	659	21	10451	7	334	4
Jamnagar	679	21	10451	7	435	3
Broach	1102	25	12441	8	205	7
Ahmedabad	699	29	14432	10	363	4
Bhavnagar	905	29	14432	10	363	4
Gandhinagar	75	31	15427	10	270	6
Mehsana	1109	32	15925	11	263	6
Kheda	986	32	15925	11	232	6
Dang	311	35	17418	12	189	8
Rajkot	865	35	17418	12	449	3
Banaskantha	1372	38	17418	12	328	5
Vadodara	1689	41	20404	14	188	8
Amreli	609	42	20902	14	463	3
Junagadh	956	46	22892	15	513	3
Surat	1231	46	22892	15	291	5
Sabarkantha	1365	52	25878	17	284	5
Bulsar	842	71	35334	24	444	3
Panchamahals	1898	87	43250	29	408	4
Gujarat	18258	31	15427	10	329	5

CD = Cattle Density

Table 2 : Net Present Value of Bio-gas Plants at Varying Purchase prices of cow dung.

(Price and Value in Rupees)

Capacity in cmt.	Price	P_2=0.02	0.04	0.06	0.08
1.700		289.7	-1402.8	-3095.3	-4787.7
2.830		5169.6	2352.2	465.3	-3282.8
4.247		11270.0	7041.9	2813.7	-1414.5
5.660		17747.4	12112.4	6477.5	842.6
7.080		23054.1	16005.5	8956.9	1908.2
8.490		29894.4	21442.0	12989.6	4537.2
9.910		30276.2	20410.1	10544.0	677.8
14.160		48118.3	34021.0	19923.7	5826.4
35.390		140579.8	105346.5	70113.2	34880.0
141.550		514016.6	373093.5	232170.3	91247.3

C = 0.75 P1 = Rs.1.10 P3 = Rs.0.17 i = 15%

Table 3 : Internal Rates of Returns for Various Capacities of Bio-gas Plants

(Percentage)

Capacity in Cmt.	Price	P5-Rs. .02	.04	.06	.08
1.7		29.48	< 5	<5	< 5
2.83		48.20	40.64	12.57	< 5
4.247		50	48.83	40.01	11.21
5.66		> 50	>50	46.94	31.15
7.08		> 50	>50	47.30	33.98
8.49		> 50	>50	> 50	40.37
9.91		> 50	>50	46.58	28.67
14.16		> 50	>50	49.51	37.94
35.39		> 50	>50	> 50	47.48
141.55		> 50	>50	> 50	41.63

C = 0.75 P_1 = Rs.1.10, P_3 = Rs.0.17

Table 4: Net Present Value of bio-gas plants of varying capacities at 15% rate of interest

Value in Rupees & Price per cubic meter in Rs.

Capcity cmt.	Biogas price for cmt. (Rs.) 1.10	1.00	0.90	0.80	0.70
1.700	-4788	-5021	-5255	-5488	-5722
2.830	-3283	-3672	-4060	-4449	-4838
4.247	-1414	-1998	-2582	-3165	-3749
5.660	843	65	-713	-1490	-2268
7.080	1908	935	-37	-1010	-1283
8.490	4537	3371	2204	1038	-128
9.910	678	-684	-2045	-3407	-4768
14.160	5826	3881	1936	-10	-1955
35.390	34880	30018	25156	20293	15431
141.550	91247	71800	52353	32905	13458

$P3$ = Rs. 0.17, $P5$ = Rs. 0.08, C = 0.75, i = 15%

Table 5: Net present Value of Large-size bio-gas plants at varying prices of gas and manure

(Value in Rupees)

Price of gas Rs.	Price of manure/kg. Rs.	Plant capacity 35.39 cmt. 0.06	0.12	0.17	Plant capacity 141.55 cmt. 0.06	0.12	0.17
0.70		-90743	-32830	15431	-411207	-179572	13458
0.80		-85880	-27967	20293	-391760	-160124	32905
0.90		-81018	-23105	15156	-372312	-140677	52353
1.00		-76156	-18243	30018	-352865	-121230	71800
1.10		-71294	-13381	34880	-333417	-101782	91247

C = .75 P3 = Rs. 0.06, P5 = Rs. 0.02 i = 15 per cent.

Table 6: Net present Value of Large sized bio-gas plants at varying prices of gas at the low price of manure at Rs. 0.06 per kg. and low price of cow dung at Rs. 0.02 per kg.

(Value in Rupees)

Gas Prices Rs/M^3	Plant Capacity (35.39 cmt)	Plant Capacity (141.44 cmt)
0.70	14957	11562
0.80	19819	31009
0.90	24682	50457
1.00	29544	69904
1.10	34406	89352

C - .75 P3 = Rs.0.06, P5 = Rs.0.02, i = 15 per cent.

Table 7: Net present value of large sized plants at varying prices of manure and cow dung when the price of gas is fix at Rs. 0.90 per cubic meter.

Value in Rupees

Price of dung per kg	Price of manure per kg	Plant Capacity (35.39 cmts)			Plant capacity (141.55 cmts)		
		0.06	0.12	0.17	0.06	0.12	0.17
Rs.	Rs.						
0.02		24682	82595	130855	50457	282092	475122
0.04		-10552	47361	95622	-90466	141169	334199
0.06		-45785	12128	60389	-231389	246	193276
0.08		-81018	-23105	25156	-372312	-140677	52353

Rs.

C = 0.75 P1 = 0.90, i = 15 per cent

Exhibit: 1   Number of Gas Plants and Amount Disbursed per Plant.

Year	No. of Plants	Disbursement in Rs. (lakhs)		Total Lakhs	Average per plant
		Grant	Loan		
1962-63	315	0.87	1.27	2.14	679.3*
1963-64	203	1.21	1.79	3.00	1477.8
1964-65	230	0.75	1.10	1.85	804.5*
1965-66	204	2.03	2. 96	4.99	2189.5
1966-67	313	1.58	3.38	4.96	1584.6
1967-68	436	3.94	5.64	9.58	2197.2
1968-69	664	5.41	15.45	20.86	3326.2
1969-70	720	6.13	29.93	36.06	5008.3
1970-71	811	9.76	29.92	39.68	4892.7
1971-72	1041	7.27	32.32	39.59	3803.0
1972-73	1065	9.17	31.20	40.37	3790.6
	6002	48.12	154.96	203.08	3383.5
1981-82	90,000	N.A.	N.A.	5400.00	6.000

* The average investment is much less than the cost of the smallest sized gas plant.

Source: Directorate of Gobar Gas Scheme, Khadi and Village Industries Commission, Gobar Gas on the March.

+ Author's estimates.

Exhibit 2 : Model for Economics of Gobar Gas Plant

Notations for the model are as follows :

K_i = Capacity of a gobar gas plant where i varies from 1 to 5

5 specific capacities were considered as follows : 60 cft., 100 cft., 150 cft., 200 cft., 250 cft.

I_i = Investment for a gas plant where i varies from 1 to 5 denoting the above specified capacities.

L_{1i} = Methane gas in cft. produced per year per plant where i denotes the capacity of a gobar gas plant.

L_{2i} = Fuel in kgs. from the dung of equivalent quantity which is processed in the gobar gas plant, where i denotes the capacity of a gobar gas plant.

N_i = Number of animals required per plant where i denotes the capacity of a gobar gas plant.

X_j = Dung produced per day per animal where j varies from 1 to 6

1	=	4 kgs. per day per animal
2	=	6 kgs. per day per animal
3	=	8 kgs. per day per animal
4	=	10 kgs. per day per animal
5	=	12 kgs. per day per animal
6	=	14 kgs. per day per animal

C = Efficiency of gas production varying from 0 to 1.

h = The proportion of raw dung used as fuel in the existing system. This varies from 0 to 1.

1-h = The proportion of cow dung used as manure in the existing system

Mi = Manure obtained from dung per year where i denotes the capacity of a gobar gas plant.

Ei = Difference in the value of gas and the value of fuel obtained from dung where i denotes the capacity of a gobar gas plant.

Fi = Difference in the value of manure produced through a gobar gas plant and the existing system, where i denotes the capacity of a gobar gas plant.

Di = Recurring expenditure for maintenance of a gas plant where i denotes the capacity.

Ri = Contribution per year for the investment in a gas plant where i denotes the capacity

i = Rate of interest

t = Economic life of a gobar gas plant

P_1 = Price of gas per one cubic foot

P_2 = Price of dung fuel per one kilogram

P_3 = Price of nitrogen per one kilogram.

Assumptions

1) It is assumed that dung would be collected from the required number of animals and used in the gobar gas plant. No additional expenditure is involved compared to the existing system.

2) The average quantity of gas produced per 1 kg of wet dung is 1.3 cft.

3) The proportion of manure to wet dung is assumed to be 40:73.

4) The proportion of fuel to dung is assumed to be 25:73.

5) Manure obtained from the gobar gas plant will have 1.5 per cent nitrogen.

6) Manure in the existing system has .75 per cent nitrogen.

Equations :

1) $Ni = \frac{Ki}{1.3\ Xj}$ where Ni is the smallest integer

2) $L1i = Ki \times 1.3 \times 365$

3) $L2i = Ni \times Xj \times 365 \times \frac{40}{73}$

4) $Ei = P1 \times C \times L1i - P2 \times h \times L2i$

5) $Fi = P3 \times .015 \times Mi - P_3 \times .0075 \times (1-h) \times Mi$

6) $Ri = Ei + Fi - Di$

7) $NPV = \frac{Ri}{(1+i)} - Ii$

<u>Exhibit 3</u>: Modified Model for Economics of a Bio-gas Plant

<u>Notations for the models</u>: In the beginning the notations which are common to the two situations :

a) Private-cost benefit analysis and b) social-cost benefit analysis are given and Specific notations for individual situations are given after the common notations.

<u>Common Notations</u>

Ni = Number of animals required to supply cow dung daily to i^{th} capacity plant.
Where $Ni \leq 0.66\ N$ where N is cattle population in the village. It is assumed that cow dung will be collected from at 2/3rd of the cattle population.

Ki = Capacity of a bio-gas plant where i varies from 2 cmt to 140 cmt or 10 to 100 per cent of a specific capacity of a plant.

I_i = Investment for a bio-gas plant where i varies according to the capacity of the plant.

X_j = Dung produced per day per animal wherej varies from 4 to 14 kgs.

C = Efficiency of gas production varying from 0 to 1

P_1 = Price of gas per one cubic meter where it varies between max. em $P_m > P_1 >$ min. em P_m

em = Fuel equivalent where m varies from 1 to 10

P_m = Price of fuel material per unit where m varies from 1 to 10.

e_m	P_m
e_1 = 1 M^3 of biogas	P_1 = Price of 1 M^3 of bio-gas
e_2 = .620 litres of Kerosene	P_2 = 1 litre of Kerosene
e_3 = 3.474 kg. of firewood	P_3 = " kg. of firewood
e_4 = 9.31 kg. of cow dung cake	P_4 = " kg. of cow dung cakes
e_5 = 1.458 kg. of charcoal soft	P_5 = " kg. of char coal
e_6 = 1.650 kg. of soft cake	P_6 = " kg. of Soft cake
e_7 = 0.433 kg. of butane gas	P_7 = " kg. of butane gas
e_8 = 0.417 kg. of furnace oil	P_8 = " kg of furnace oil
e_9 = 1.177 cmt of coal gas	P_9 = " M^3 of coal gas
e_{10} = 4.698 of Kwh electricity	P_{10} = " Kwh electricity.

P_3 = Price per kg. of basic nutrients of N + P + K in a particular proportion in bio-gas manure where $P_3 \leq$ a weighted average price of $.0160\,P_n + .0145\,P_p + .01\,P_k$ where P_n = price of nitrogen (N) per kg; P_p price of Phosphorous (P_2O_5) per kg, and P_k = price of potash (K_2O) per kg.

D_i = Recurring annual expenditure comprising of fixed and variable costs for varying capacities of bio-gas plants.

R_i = Annual contributions from varying capacities of bio-gas plants.

i = Rate of interest

t = Economic life of a bio-gas plant

L_{1i} = Methane gas in cmt produced per year for varying capacities of plants or for varying utilizations of a specific capacity plant.

M_i = Manure produced from a biogas plant with capacity i.

Y_{1i} = Revenue from the sale of bio-gas.

Specific situations

a) for private cost benefit analysis

b) for social cost benefit analysis

a) P_5 = Price per kg. of raw cow dung where

$P_5 \leq .5479 \; P_3$

a) Q_i = Quantity of raw cow dung purchased per day at the price P_5

$0.66 \; Q_i \leq Ni \quad Xj$

b) P_2 = Price per kg. of dung fuel

b) P_4 = Price per kg. of farm yard manure

$P_4 \leq .01 \; P_n + .006 \; P_p + .012 \; P_k$

b) h = Proportion of dung used as fuel by the community

b) $1-h$ = Proportion of dung used as manure by the community

b) Q_i = Quantity of cow dung supplied by the community at the rate of X_j for all dung producing animal $Q_i \leq N_i \times X_j$

b) E_i = Difference in the value of gas and the value of equivalent fuel obtained from dung where i denotes the capacity of bio-gas plant.

b) F_i = Difference in the value of manure produced through a bio-gas plant and farm yard manure where i denotes the capacity of a bio-gas plant.

b) Y_{2i} = Value of farm yard manure.

<u>Equations</u> :

	a	b
1)	$N_i = \frac{K_i}{.0368 \times X_j}$	$N_i = \frac{K_i}{.0368 \times X_j}$
2)	$Y_{1i} = L_{1i} \times P_i$	$Y_{1i} = L_{1i} \times P_i$
3)	$L_{1i} = C \times K_i \times 365$	$L_{1i} = C \times K_i \times 365$
4)		$L_{2i} = .3425\ Q_i \times 365$
5)	$M_i = .5479 \times Q_i \times 365$	$M_i = .5479 \times Q_i \times 365$
6)	$Y_{2i} = P_3 \times M_i$	
7)	$D_{ik} = D_i + P_5\ Q_i \times 365$	D_i = given annual running cost with capacity of a plant.
8)		$E_i = Y_{1i} - P_2 \times L_{2i} \times h$
9)		$F_i = P_3 \times M_i - P_4 \times (1-h)\ M_i$
10)	$R_{ik} = Y_{1i} + Y_{2i} - D_{ik}$	$R_i = E_i + F_i - D_i$
11)	I_i = given	I_i = given
12)	$NPV = \frac{R_{ik}}{(1+i)^t} - I_i$	$NPV = \frac{R_i}{(1+i)^t} - I_i$

Exhibit 4 : Explanations of the variables in the Model.

Variables of the Model

1) Number of Animals (N_i) : The bio-gas plant receives a daily input of raw dung and/or human night soil. It is estimated that one kilogram of raw cow dung produces about 1.3 cft. or .0368 cmt. of bio-gas. The number of animals required to supply a daily through out of cow dung depends on the capacity of the plant and the daily average production of dung per animal. The number of animals can be worked out by the following equation :

$$N_i = \frac{K_i}{.0368 \times X_j}$$

Other exogenous constraint on N_i is the number of animals in the village. It is assumed that it will be possible to collect dung from 2/3 number of animals in the village at price P_5 or the community would agree to supply cow dung at this minimum level. The transport cost of dung from farmer's place to the plant is adjusted through price P_5 and hence not explicitly considered in the private cost benefit analysis. In the community plant, it is assumed that farmers would supply cow dung to the plant free of cost.

2) Capacity of a Bio-gas Plant (K_i): The size of the Plant for which KVIC have given estimates varied from 60 cft. (1.7) to 1250 cft (35.39). We have information on a 5000 cft. (140 cmt). plant but we do not have informations for plant capacities varying between 1250 cft(35.39) to 5000 cft (140).

3) Investment (I_i) : Information on investment for different capacities plants. This includes costs of the gas holder, civil structure, the pipe line and appliances.

4) Cow-dung Production per day per adult unit of animal (X_j) : The quantitative information on this variable is not easily available either from the experimental farms or surveys. From the general knowledge of informed people, it is sait to vary between 4 kg. to 14 kgs. per day per animal. The average cow dung collected per animal per day in Pura experiment was 4 kilogram.

5) Efficiency of gas Production(s) : Looking to operational problems and technical difficulties the efficiency of the plant is supposed to vary between 0.25 to 1. This depends on the daily temperature and also operational efficiency.

6) Price of bio-gas : (P_1) The price of bio-gas per cubic metre should be more than the value of cow dung required to produce one cubic meter of gas in terms of equivalent value of priced fuels used in the village but less than 80 per cent of the price of bottled butane gas. This value would depend on the prices of equivalent fuel materials and equivalence co-efficients which are given in Exhibit 3.

7) Price of dung fuel : (P_2) This is the price which the suppliers of cow-dung would realize if cow dung is dried and dung fuel is sold. It is assumed that this would be lower than the value of dung fuel in terms of equivalent priced fuel material, particularly kerosene.

8) Price of basic nutrients: (NPK) in one kg. of bio-gas plant manure (P_3)		This should be less than or equal to ($.160\ P_n + .145\ P_p + .100\ P_k$) where P_n = Price per kg. of Nitrogen P_p = Price per kg. of P_2O_5 P_k = Price per kg. of K_2O This is the price at the plant.
9) Recurring annual Expenditure (D_i)	:	This will include the establishment cost and other fixed costs plus variable cost for varying capacities of a bio-gas plant.
10) Annual Contribution from varying capacities of bio-gas plants (R_i)	:	This comes from the sale of bio-gas plus the sale of manure less the annual cost (D_i) plus the purchase value of raw cow dung ($P_5 \times Q_i$) in case of private cost-benefit analysis, and the sale of gas plus difference in the value of manure produced by a bio-gas plant and the value of farm-yard-manure produced from the equivalent quantity of raw dung processed less the annual cost of operation of the plant.
11) Rate of Interest (i)	:	This is the rate of interest at which the net present value of R_i is worked out or it would be the internal rate of return at which the contribution and cost are equalised for a given period of time.
12) Time Period (t)	:	Economic life of a bio-gas plant.
13) Methane gas (L_{1i})	:	Methane gas in cmt produced per year for varying capacities of plants or for varying utilization of a specific plant.

14) Fuel equivalent of one cmt. of bio-gas (e_m)	:	KVIC has given fuel equivalence of about nine other materials. This means that the thermal energy generated by one cmt. of bio-gas would be equivalent to the thermal energy generated by say 3.474 kg. of fire wood or 9.31 kg. of cow dung cakes (Exhibit 3).
15) Price of fuel equivalent material (P_m)	:	This is the price per unit of fuel equivalent material (Exhibit 3).
16) Manure produced from a bio-gas plant (M_i) or as farm yard manure	:	The composition of this manure in nutrient forms is as follows :

Bio-gas form	Farm Yard manure
N = 1.6%	1.0%
P = 1.45 %	0.6%
K = 1.00 %	1.2%

One kilogram of wet cow dung is assumed to produce 0.5479 kg. of manure.

17) Cow dung cakes from raw dung (L_{2i})	:	It is assumed that one kilogram of raw dung produces .3425 kg. of dry cow dung cakes on an average.
18) Price of Farm Yard Manure (P_4)	:	This should be less than or equal to $0.01\ P_n + 0.006\ P_p + .012\ P_k$. Transport cost to be the field is ignored.
19) Price of raw cow dung (P_5)	:	The price of raw cow dung should be less than or equal to the intrinsic value if it is used as manure produced from a biogas plant but more than the intrinsic value of farm yard manure produced at the farmers' house or the intrinsic value if it is used as dung fuel, whichever is the lowest.

20) Quantity of cow dung purchased (Q_i) : This is the actual purchase of raw dung in case of private cost-benefit analysis and it would be annual quantity of dung supplied by the community on the basis of an average daily output per dung producing animal. $Q_i \leq 0.66 N_i X_j$

21) Difference in the values of gas and the value of equivalent fuel obtained from cow dung cake (E_i) : This is the difference between the value of gas sold and the value of cow dung cakes in terms of fuel equivalent.

22) Difference in the value of manure produced through bio-gas plant and farm yard manure produced in traditional manner (F_1). : This is the difference between the values of manure valued at P_3 and P_4.

Exhibit 5 : Kubadthal Village Community bio-gas plant - A Case Study

Kubadthal village gas plant was built with a capacity of 140 cmt. (4943.4 or about 5000 cft.) with cow dung requirement of 3458 kg. per day. Because of the collapse of the wall twice during the initial phase, the plant was made of complete RCC construction. The design of the bio-gas plant was different from the conventional KVIC design. It had no central wall dividing the digester into two chambers. There was a perforated pipe inside the digester to push hot water and to stir the slurry for bubbling. The plant was constructed as a single large size digester. This created problems for maintenance as the plant operation was required to be totally stopped to carry out a maintenance job.

No such plant was tested at a "laboratory level" and was established by Mr. Mehta, an industrialist and a Gandhian Political worker in the village Kubadthal, situated 35 kms. away from Ahmedabad city through a voluntary agency called the Vimla Gram Seva Samaj Trust (VGSS) in 1980.

There were 2330 animal heads of which 1800 were dung producing cattle. The total population of the village was 2376 comprising 534 familities.

VGSS objectives in establishing the large size plant were :

i) to provide better fuel

ii) to provide richer manure

iii) to eliminate environmental pollution

iv) to prevent deforestation

v) to improve the health of the rural families, and

vi) to improve economic conditions of the rural households by providing more leisure for part-time employment[1].

The site for locating the bio-gas plant was selected in such a way that 1) there was no fear of getting the plant flooded; 2) there was sufficient area to have sufficient number ofpits for drying the liquid slurry into manure; 3) it was near houses which would help efficient distribution of gas and reduction in pipe lines; 4) there was no drinking water well in its surrounding so that the question of percolation of slurry into drinking water would not arise; and 4) there was a good supply of water near the site.[2]

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1. Moulik, Ibid, p. 3

2. C J Shukla, V.D. Kulkarni and Vinita Rimani, "A Technoeconomic study Report on Community Bio-gas Plant on Village Kubadthal, Taluk Dascroi, Dist. Ahmedabad", a report submitted to IIMA in Management of Rural Development Programme, 1981.

The plant was constructed by Gujarat Agro-Industries Corporation Limited, Sarkhej.

The total availability of dung from the whole village was estimated as 14341 kgs,/day of which 4629 kgs. would be available from the cattle belonging to the families who showed willingness to take gas connections. There were such 123 families.

Original Assumptions

The expressed objective of setting up the bio-gas plant by VGSS was welfare of the villagers. Hence the price of dung was kept at Rs.0.02 per kg. which was agreed upon by the villagers. The village panchayat had assured availability of sufficient water to the plant. Manure produced from the plant would be sold at Rs.60 per tonne or Rs.0.06 per kilogram.

The price of gas was fixed at Rs.0.90 per cmt. The original cost of the plant was to be met as follows :

	Rs.
a) Subsidy from the state government	22,275
b) Long term loan @ 11% from financial institution	1,87,741
	2,10,016

It was worked out that the project would generate a net surplus of Rs. 32,062/- every year apart from bringing numerous tangible and intangible benefits to villages particularly the weaker section of the society. The loan would be repaid in 10 years.[3]

Changed Situation

But these assumptions did not come true. The cost of construction went up from Rs. 210,016 to Rs. 392,620. This induced VGSS to increase the price of gas from Rs.0.90/cmt. to Rs.1.10/cmt. and the price of digested manure from Rs.0.06 to Rs.0.15 per kilogram.[4]

It was also decided that the consumers of gas should bear the cost of a sub-pipeline which was to be borne by the trust. The philanthrophic attitude of VGSS was shown by their willingness to charge only Rs.0.55/cmt. of gas to the poorer landless labourers.

Reaction to Price Changes

The reaction of the villagers to the price changes by VGSS was that they would not pay the higher rate of Rs.1.10 cmt. of gas and would pay for manure only at the rate of Rs.0.06 per kilogram and they would supply dung at higher prices than Rs.0.02 per kilogram. They also refused to pay deposit for a gas connection. Those who had paid such deposits withdrew them immediately. As a result the plant remained closed for six months.

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3. C.J. Shukla, et al., Ibid, P.7

4. Moulik, Ibid, p. 7.

After a lapse of six months, an agreementwas reached between VGSS and the consumers. The following conditions were stipulated:

1. Price of cow dung would be Rs.0.02 per kilogram
2. Price of manure would be 0.06 per kilogram for those who would sell dung to the plant and buy back manure.
3. Those who did not buy manure from plant and only sold would be paid at the rate of 0.05 per kilogram.
4. The gas charges would be Rs.0.90 per cubic meter.
5. The expenditure of sub-pipeline and gas connections would be borne by the customers.
6. The meter rent of Rs.5/- would be charged every month.

<u>Exhibit 6</u> : <u>Data for Different Variables used in the Model</u>

Sr. No.	K_i Capacity per day in cmt.	N_i No. of animals required to supply cow dung	Q_i Quantity of raw cow dung required per day in kgs.	I_i Given Invest ment Rs.	D_i Recurring annual Expendi- ture Rs.
1	2	3	4	5	6
1	1.7	12	47	3094	1071
2	2.83	20	77	4016	1075
3	4.247	29	116	5136	1091
4	5.66	39	154	5728	1133
5	7.08	49	193	7637	1153
6	8.49	58	231	7956	1174
7	9.91	68	270	9706	2207
8	14.16	97	385	13525	2254
9	35.39	241	962	29276	2487
10	141.55	962	3847	140000	15000

P_1 = Rs.0.70, Rs.0.80, Rs.0.90, Rs.1.00, Rs. 1.10 per kg.

P_2 = Rs.0.10 per kg (kerosene equivalent)

P_3 = Rs.0.06, Rs.0.12 and Rs.0.17 per kg. (Intrinsic value)

P_4 = Rs.0.06 per kg. (Intrinsic value)

P_5 = Rs.0.02, Rs.0.04, Rs.0.06, and Rs.0.08 per kg.

C = .50 and .75 Efficiency of a Plant

i = 15 per cent

t = 10 years (life economic of the plant

h = 0, .5 and 1.00