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An Approach for Evaluation of Bio-gas Programme Development in Nepal

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BACKGROUND

After the oil embargo of 1973, Nepal realized its increasing dependency on imported fuels and depleting forest resources and started looking into the development of indigenous energy resources. The government formulated a plan to build 250 drum type family size bio-gas plants in the Agriculture year 1975/76, but only 199 were built. With the success of the progrramme, a specialized private organization named Bio-gas and Agricultural Tools Development P. Ltd. (hereinafter referred to as Bio-gas Company) was established in 1977 to construct and promote bio-gas plant. At present, there is another private organization named Energy and Agro Developers P. Ltd. at Bharatpur.[1-2]

Upto the fiscal year 1985/86, 2177 bio-gas plants were manufactured and installed in Nepal. The Bio-gas Company is manufacturing dome and drum type plants. In recent years more of dome type plants have been used because of lower cost and ease in handling.[2]

Increasing deforestation and unavailability of free fuelwood in the terai has led to the burning of dung as a cooking fuel. This deprives the soil of nutrients and reduces agricultural production. Rather than burning the dung, it is better to feed it into the bio-gas digester and use the slurry produced as manure. This will satisfy the need for cooking fuel as well as for manure.[3-5]

No fixed policy has been adopted for subsidy associated with bio-gas plant. Different subsidy mechanisms have been developed, provided and removed erratically.[6-8]

Previous studies assumed cent percent replacement of fuelwood for cooking and kerosene for lighting by bio-gas. In this analysis appropriate assumptions are made after studying the experience of different organizations involved with this technology.[8-12]

TECHNICAL CONSIDERATIONS

Technology

Bio-gas is produced by anaerobic digestion of organic wastes and water for which an air tight digester is a prerequisite. The digestion process ferments the organic materials in the presence of a natural mixed bacteria culture and produces gaseious products and a liquid affluent. The gas consists of a mixture of methane (50-60%), carbondioxide (30-40%), and other gases which include hydrogen, nitrogen, and hydrogen sulphide.

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Hydrogen sulphide gives bio-gas a slightly pungent smell. Gobar gas is colourless and non-toxic. The yield rate of bio-gas is temperature-dependent; the optimum temperature being 33°C. It is mainly used for cooking and lighting and sometimes as a fuel for internal combustion (IC) engines. The mixing ratio of diesel to bio-gas is 20:80 theoretically, while 40:60 ratio is frequently reported by the users. The affluent is used as a wet or sun dried fertilizer and is superior to green manure in nutrient content. The digestion process reduces the level of pathogens within the dung and therefore may generate public health benefits.[13-15] The two main types of bio-gas plants are floating steel drum (Indian design) and the fixed-dome model (Chinese design). See References 12 to 19 for figures.

The drum type consists of underground two-compartment chamber digester pits with a floating steel drum gas holder. Slurry is fed into the base of one chamber from the cemented inlet pipe. The gas rises and is collected inside the drum while the affluent overflows into the second chamber and then slurry is expelled through the outlet pipe, which is at a lower level than the inlet pipe. The few modifications to bio-gas plant designed by Khadi and Village Industries Commission (KVIC) to suit Nepalese conditions are as follows: the pit is designed to taper down into the ground; gas is removed through a central guide pipe; and two-compartment chamber design. The floating drum holds 60 percent of the daily rated gas output. The gas pressure which is supplied by the weight of the drum is 10 cm of water head. The gas drum has to be prefabricated in workshop and should be carried to the plant site.[12,16-19]

As the steel drums are expensive and difficult to transport, the fixed roof gas plant, called dome type, eliminates this component. As the gas forms, instead of pushing the drum up, it pushes the slurry down forcing it into the input and outflow chamber. When the gas is used the pressure diminishes, and the slurry flows back into the main pit. The plants have been modified slightly for use in Nepal. The major modification is a fixed stirrer which breaks the crest on the surface of the slurry in the plant and thereby maximizes gas production. It can be constructed at the site with locally available materials except cement and GI pipes, so this design is becoming popular.[16-19]

Operational Aspects

After the installation of bio-gas plant, the owner has to feed the digester with the required quantity of dung and water. The dung, collected from the livestock stall is poured into a dung mixing pit and an equal amount of water is added. It is mixed by hand or foot until no lumps are left, as the pressure of lump may reduce bio-gas production. All the plants manufactured in Nepal are continuous feed type, so the digester must be fed daily with the required amount of dung and water for a particular capacity. The operating cost is virtually nil since dung is obtained free from animals owned by the family, and labour for feeding the dung is provided by members of the family in most of the cases.[8-10]

Technical Problems

The problems with bio-gas plant is leakage of gas through the main gas valve and the connecting pipes. In a dome type plant, dung sometimes comes out of the gas pipe and blocks the flow of gas. The lamps are frequently found to be broken. The main problem with the lamp is the mantle, which has to be changed frequently. Sometimes the mantles may have to be changed a couple of times within a week. The glass cover is also frequently broken. Except for these few minor problems the plant itself is almost trouble free.[8-12]

EXISTING PROGRAMMES AND EFFORTS

Production System

The major manufacturer of bio-gas plant is Bio-gas Company established in 1977. It constructs, fabricates, and installs bio-gas plants. It is also involved in training, promotion dissemination, and research of this technology. The company has a head office in Kathmandu. It has two regional offices in eastern and western terai. A central workshop is in western terai regional office. Five sub-branch offices and 6 depot offices are established in each of the terai districts. These offices are responsible for demand collection, providing help services, and repair and maintenance facilities to the plants already installed which the office guarantees for 7 yrs. period (per. comm.).

Recently, an enterprenuer set up Energy and Agro Developers P. Ltd. in Bharatpur to manufacture dome type bio-gas plants. Till now they have manufactured 10 dome type plants. The cost of their plants for the same quantity of gas production is lower by 20-25 percent than those of Bio-gas Company. According to Bio-gas Company this is because all the expenses incurred for promotional and research activities, borne by the Company, are reflected in the total cost of the plant (per. comm.).

Implementation Arrangement

The implementation arrangement of bio-gas plant is done jointly by the Agriculture Development Bank, Nepal (ADBN) and Bio-gas Company. The Company is responsible for site selection, size determination, fabrication, construction of the plants and extending maintenance guarantee for 7 yrs. The ADBN extends loans to individual borrowers with economically feasible schemes, through its countrywide network of branch offices. It also extends loan to the Bio-gas Company to expand fabrication, facilities, and to procure raw materials.[8-9] Other credit funding agencies like National Commercial Bank (NCB) also extend loan for the construction of the bio-gas plants. The bank places orders with the Bio-gas Company's field offices on behalf of the client for the construction of the plant to the full satisfaction of the owner (per. comm.).

Planned Activities

The Bio-gas Company has planned to construct 1300 plants within a period of three years. This programme will be implemented to cover 48 out of 75 districts. More emphasis will be given to the terai areas where the climate is suitable for optimum operation of the bio-gas plant.[1]

According to the 7th Five Year Plan (1985-1990) document a total of 4000 bio-gas plants will be constructed throughout the Kingdom. Mention has also been made about the provision of 25 percent subsidy on bio-gas plant capital cost.[7] Unfortunately, nothing has been done by His Majesty's Government of Nepal (HMG/N) in this connection.

PROGRAMME DEVELOPMENT POTENTIALS

Nepal is predominated by the agricultural sector which occupies 90 percent of its population.[20] This sector depends heavily on animal power. So, livestock holding is quite high in the country. Due to its favourable temperature, teraï zone is more suitable for the installation of bio-gas plants with the technology available today. Out of 2120 farms in the terai area 70 percent households (HH) possess 5 big animals and 25 percent HH possess 13 and more big animals.[21] Theoretically, 4-6 big animals are required for the production of bio-gas with 10 m^3 size plant for cooking and lighting for a family size of 6-9. Unavailability of dung in the stall, lower dung producing capacity of Nepalese livestock and use of dung for other household activities may necessitate dung input of as many as 12 big animals to feed into 10 m^3 size plants.[1] It has also been observed that a household with a higher income and more agriculture land own more livestock and most of the bio-gas plant owners fall into this category.[8-9] It is estimated that there are 900,000 households (HH) in the rurals of terai zone.[22] Considering 25 percent HH as potential users, 225,000 family size plants can be installed in the terai. The lower the forest accessibility factor and/or availability of cheaper fuelwood, the higher will be the rate of construction of bio-gas plant.

GOBAR GAS PROGRAMME EVALUATIONS

General

Evaluation of the bio-gas plant from economic and financial perspective is based on the benefit-cost ratio. The analysis from economic perspective proceeds on the basis of the economic benefits to be delivered in terms of fuelwood and imported kerosene fuel saved, with the installation of a bio-gas plant, by the nation as a whole. The financial evaluation of a bio-gas plant will proceed from an assessment of the cost and benefits which may be attributed to the users of a plant.

The rural people do not relize the value of fuelwood. Members of the households especially the women and children collect it in their free time for which they do not assign opportunity cost. Villagers, in most cases, also augment their fuelwood collection with twigs and branches from their own farm. Conversely fuelwood is generally purchased among high income groups and in urban areas.[12,24]

No fixed policy has been adopted for subsidy associated with bio-gas plant. Sometimes there is a subsidy on interest rate. Occasionally different aid giving agencies provide 50 percent subsidy on capital cost of the plant under various programmes. This frequent change in subsidy mechanism has created a negative impact on demand. The Seventh Five Year Plan document has spelled to provide a 25 percent subsidy on capital cost for this technology. But nothing has been done in in this regard so far.[5-8]

Mathematically, the relationship between various parameters which affects benefit-cost ratios of the bio-gas programme from both economic and financial perspectives can be derived as follows:

Benefit-cost Ratio[23] = (BCR) = NPWB/NPWC .... (1)

Where,

$$NPWB = VK \times \sum_{T-1}^{L} HH \times KC_T \times (1 - UFK_T) \times SPWF_T$$

$$+ VK \times \sum_{T-1}^{L} HH \times FC_T \times (1 - UFF_T) \times SPWF_T \quad (Rs) \ \ldots\ldots \ (2)$$

$$NPWC = CC + \sum_{T-1}^{L} RMC_T \times SPWF_T \quad (Rs) \ \ldots\ldots \ (3)$$

Where,

- NPWB = Net present worth of benefit (Rs);
- NPWC = Net present worth of cost (Rs);
- $SPWF_T$ = Single payment present worth factor in a year T;
- HH = Household size (Nos);
- VK = Value of kerosene (Rs/lit);
- VF = Value of fuelwood (Rs/Kg);
- RMC_T = Repair and maintenance cost in a year T (Rs);
- KC_T = Kerosene consumption per capita in a year T (lit);
- FC_T = Fuelwood consumption per capita in a year T (Kg);
- UFK_T = Kerosene utilization factor in a year T;
- UFF_T = Fuelwood utilization factor in a year T;
- L = Life of the bio-gas plant.

Equation No. 1 could be written as follows;

$$BCR = (C_1 \times VK + C_2 \times VF) / (CC + C_3) \quad \ldots\ldots \quad (4)$$

Where,

$$C_1 = \sum_{T-1}^{L} HH \times KC_T \times (1 - UFK_T) \times SPWF_T \ (lit) \ \ldots\ldots \quad (5)$$

$$C_2 = \sum_{T-1}^{L} HH \times FC_T \times (1 - UFF_T) \times SPWF_T \ (Kg) \ \ldots\ldots \quad (6)$$

$$C_3 = \sum_{T-1}^{L} RMC_T \times SPWF_T \qquad (Rs) \ldots\ldots (7)$$

Rearranging equation No. 4 results into following form;

$$VF = (C_3/C_2) \times BCR + (CC/C_2) \times BCR - (C_1/C_2) \times VK \quad (Rs/KG) \ldots (8)$$

Assumptions

A certain amount of fuelwood will continue being used even after the installation of bio-gas plant and this is defined as fuelwood utilization factor. The main purposes for which fuelwood will keep on being used are to prepare animal food, home made alcohol Jand or Raksi, servant's meals, washing clothes, and so on. Kerosene too will continue to be used and this is defined as kerosene utilization factor. This is because kerosene lamps are portable while gas mantles are prone to breakage.[8-10]

The assumptions made for economic and financial perspective of a dome type family size bio-gas plant are valid for terai region, where bio-gas production is favourable. They are as follows: 10 m^3 dome type plant with 3 m^3 retention capacity requires 60 kg. (wet basis) of daily dung input to meet the energy requirement for lighting and cooking of a household with a family size of 6-9; fuelwood consumption per capita for cooking is 640 kg. in a year; kerosene consumption per capita for lighting is 19 lits. in a year; the market and economic price of kerosene is NRs. 5.75 and NRs. 4.42 per lit., respectively; the life of a bio-gas plant is 15 yrs. after which its salvage value is zero; the fuelwood utilization factor is 0.3; the kerosene utilization factor is 0.5; the discount rate is 10 percent.[8-10,24]

Further, incurred benefits due to slurry is not considered because improved agricultural performance is dependent on its applications which may not be consistent. Wealthy farmers who install bio-gas plant will not have burnt dung previously so that no savings pertaining to dung availability for fertilizer is considered. Users would not assign opportunity cost for the labour provided by themselves as the dung is obtained free from their own animals and labour for feeding the dung is provided by themselves.[8-10] Hence, the value of the dung and the opportunity cost are not considered in this evaluation.

Cost Streams

The capital cost of a 10 m^3 dome type family size bio-gas plant is NRs. 15, 535. Upto the 7th year, major repair and maintenance cost is borne by the manufacturer with the fixed initial guarantee charge. It is assumed that about NRs. 100 per year is required for minor repair and maintenance upto the 7th year, after which NRs. 365 per year will be required (per. comm.). These cost figures are considered in this analysis.

Benefit Streams

Intangible benefits such as increased value of the manure, good lighting, non-staining of utensils, reduction in the use of dung as cooking fuel, etc. is not considered in this analysis. The major tangible benefits considered are savings in fuelwood and kerosene each year. Fuelwood saving is the function of household size, per capita fuelwood consumption, and fuelwood utilization factor. Kerosene saving is the function of household size, per capita kerosene consumption, and kerosene utilization factor. For monetary benefits, the value of fuelwood and kerosene have to be considered.

Economic Perspective

The cost associated in economic perspective are capital and repair-maintenance cost excluding shadow price for local labour. The foreign currency conversion factor is assumed to be unity. The benefits arising out of the installation of a family size bio-gas plant are the saving of forest resources due to the replacement of fuelwood and of foreign currency due to less import of kerosene. The economic price of fuelwood and kerosene are considered. The relationship between the value of fuelwood and benefit-cost ratio is examined. The economic value of fuelwood attributed from bio-gas plant will determine where benefit-cost ratio equals unity and this value will be compared with the economic value of fuelwood in order to judge the viability to the nation.

In order to arrive at a relationship between the economic value of fuelwood attributed from bio-gas plant and benefit-cost ratio, the economic value of kerosene and capital cost of a bio-gas plant are assumed a fixed value.

With the above consideration, equation No. 8 takes the following form:

$$VF_E = A_1 + A_2 \text{ X } BCR_E \qquad \text{(Rs/Kg)} \ldots\ldots \text{ (9)}$$

Where,

VF_E = Economic value of fuelwood attributed from Bio-gas plant;

BCR_E= Benefit cost ratio (economic perspective);

$$A_1 = -(VF_E \text{ X } C_1)/C_2 \qquad \text{(Rs/Kg)} \ldots\ldots \text{ (10)}$$

$$A_2 = (C_3 + CC)/C_2 \qquad \text{(Rs/Kg)} \ldots\ldots \text{ (11)}$$

A_1 and A_2 are coefficients.

With the assumptions made earlier, equation No. 9 results into the following equation and is also shown in Figure 1.

$$VF_E = -\ 0.094 + 0.832\ BCR_E \qquad \text{(Rs/Kg)} \ldots\ldots \text{ (12)}$$

Financial Perspective

The cost associated in financial perspective are capital and repair and maintenance cost. The benefits considered are cash savings due to the replacement of fuelwood and kerosene to a bio-gas plant owner. The market price of kerosene and fuelwood are considered. The relationship between the price of fuelwood and the rate of subsidy (financially viable capital cost) is examined where benefit-cost ratio equals unity.

In order to arrive at a relationship between the market price (financial) of fuelwood and the rate of subsidy (financially viable capital cost to the user) for financial benefit-cost ratio to be unity, the market price of kerosene (VK_F) is assumed a fixed value.

With the above consideration, equation No. 8, takes into the following form:

$$VF_F = A_3 + A_4 \text{ X } CC \qquad \text{(Rs/Kg)} \ldots\ldots (13)$$

Where,

VF_F = Financial (market) price of fuelwood;

$$A_3 = -(VK_F \text{ X } C_1 + C_3)/C_2 \qquad \text{(Rs/Kg)} \ldots\ldots (14)$$

$$A_4 = 1/C_2 \qquad (\text{Kg}^{-1}) \ldots\ldots (15)$$

A_3 and A_4 are coefficients.

With the assumption made earlier, equation No. 13 results into equation No. 16 and is also shown in Figure 2.

$$VF_F = -0.049245 + 0.000049 \text{ X } CC \qquad \text{(Rs/Kg)} \ldots\ldots (16)$$

RESULTS AND DISCUSSIONS

Figure 1 shows the conditions under which a 10 m^3 dome type family size bio-gas plant would be viable from an economic perspective. A curve in Figure 1 shows the relation between the value of fuelwood and the benefit-cost ratio. The family type bio-gas plant will be economically viable if the value of fuelwood exceeds NRs. 0.74 per Kg (see Fig. 1). In other words, the economic value of fuelwood attributed from bio-gas plant is NRs. 0.74 per Kg. If the economic value of fuelwood perceived by the nation is higher than NRs. 0.74 per Kg then the family size bio-gas plant is economically viable even with cent percent subsidy. The economical value of fuelwood perceived by the nation is NRs 1.4 per Kg. in which case benefit-cost ratio results into 1.8 as shown in Fig. 1. The Promotion of bio-gas technology should receive a higher priority as it is viable economically to the nation.

FIG. I BIO - GAS PLANT : ECONOMIC PERSPECTIVE

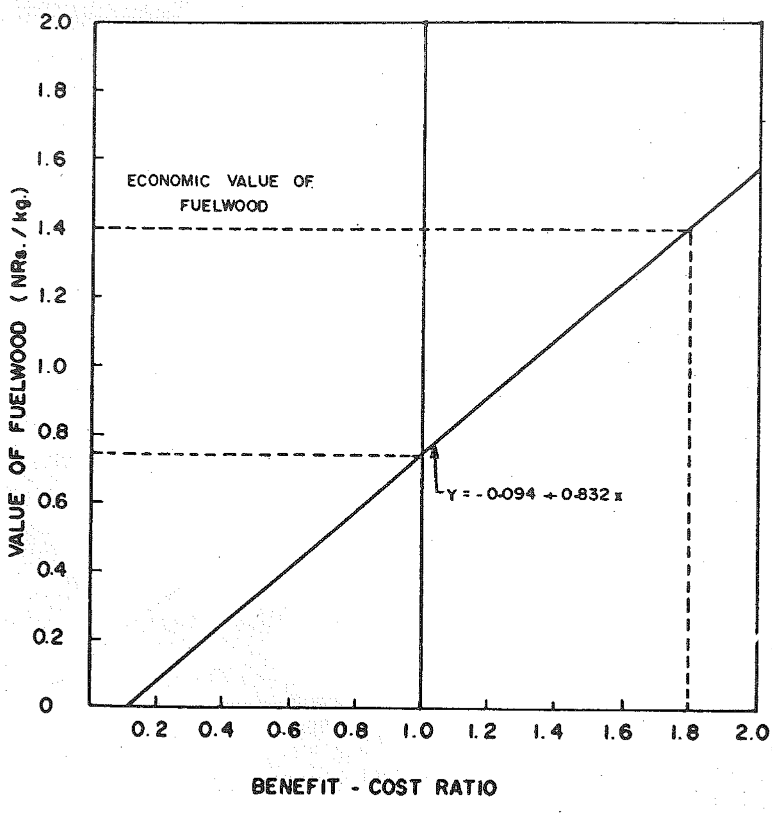

FIG. 2 BIO - GAS PLANT : FINANCIAL PERSPECTIVE

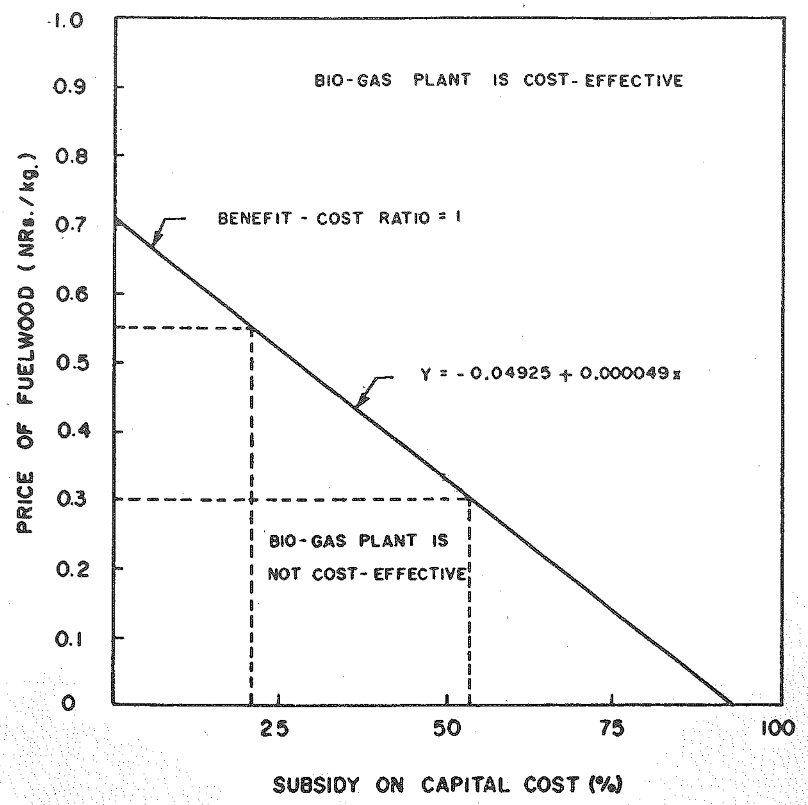

Figure 2 shows the conditions under which a family size bio-gas plant would be financially viable. A curve in Figure 2 shows the relationship between the market price of fuelwood and the rate of subsidy on capital cost when benefit-cost ratio is unity. In areas where the market price of fuelwood exceeds NRs 0.71 per Kg. then no subsidy on capital cost is required for a family size bio-gas plant to be financially viable. In areas where the price of fuelwood is NRs 0.55 per Kg. (highest price of Fuelwood Corporation) then for a family size bio-gas plant to be financially viable about 21 percent subsidy on capital cost is required. Further, in areas where the price of fuelwood is NRs 0.3 per Kg. (lowest price of Fuelwood Corporation) then 54 percent subsidy is required. In areas where the price of fuelwood is not perceived at all the need is for over 90 percent subsidy on capital cost.

ISSUES AND POLICY RECOMMENDATIONS

The plant is costly because the cost incurred for extension, promotion, training, and research are also being met by Bio-gas Company. The Bio-gas Company is a private enterprize and therefore all those costs (30-35 percent of the plant cost) are being passed on to the farmers. Under these circumstances, the bio-gas plant installation becomes a financially viable proposition for those paying NRs 0.71 per Kg. of fuelwood. The price of fuelwood in urban areas is higher than in the rurals. If the economic value perceived by the nation is higher than NRs 0.74 per Kg. then the family size bio-gas plant is economically viable in terms of fuelwood resource and imported kerosene saved even bearing the full cost of the family size bio-gas plant. Hence, to increase the dissemination of this technology Government subsidy should be considered. A subsidy of 21 percent and 54 percent on capital cost of a family size bio-gas plant would be required to bring the opportunity cost of fuelwood per Kg. down to a level of NRs 0.55 and NRs 0.30, respectively. The amount of subsidy could be lowered if other user benefits are considered including the increased value of the manure, good lighting, reduction in the dung as a cooking fuel, and so on.

In the past, erratic programmes and policies regarding the development of bio-gas technology have been made. This has been harmful for the promotion and dissemination of this technology. Several times the plans and policies have been developed but not implemented.

The target of HMG/N in Seventh Five Year Plan will not be met without increased private sector involvement and/or increasing the market potential of technology.

Research and development for bio-gas technology has not received a higher priority. Hence more R & D financing is required.

Based on the foresaid issues a number of policy recommendations can be drawn as follows:

- His Majesty's Government of Nepal (HMG/N) fulfill the programme adopted in the Seventh Five Year Plan by providing subsidy in order of at least 20 percent to 50 percent in urban to rural areas, respectively.

- A set of guidelines should be developed by Water and Energy Commission Secretariat (WECS) for HMG/N to adopt a consistent long term strategy for the development of bio-gas technology. This will mean cooperation and coordination with the Ministry of Finance and implementing agencies such as Bio-gas Company and Credit funding organizations.

- Private entreprenuers capable of constructing bio-gas plants should be encouraged in order to make the price of bio-gas plant competitive. The encouragement may be in the form of soft credit loans.

- HMG/N should finance the research and development of the bio-gas technology to lower the cost and to improve its performance in cold climates.

FOOTNOTES

1. Water and Energy Commission Secretariat, Five Energy Workshops, Report No. 6/3-230486/1/1, Seq. No. 235, Kathmandu, 1986.

2. Water and Energy Commission Secretariat, Nepal: Directory of Energy Organizations, Report No. 5/4/200187/1/1,Seq.No. 251, Kathmandu, 1986.

3. S.N. Sharma and K. Rijal, "Energy Sector - Synopsis Report (Updated and Revised-1983/84)", Water and Energy Commission Secretariat, Kathmandu, 1985.

4. C. Smith and K. Rijal, "Bio-gas Resources of Nepal", Water and Energy Commission Secretariat, Kathmandu, 1985.

5. A.B. Karki and B.A. Coburn, "The Prospect of Bio-gas as one of the Source of Energy in Nepal", Tenth World Conference, Necatibey Caddessi, 1977, Turkey.

6. Water and Energy Commission Secretariat, The Role of Bio-gas in Rural Community, Kathmandu, 1983.

7. National Planning Commission, Basic Principles of Seventh Five Year Plan, Kathmandu, 1985.

8. Agriculture Development Bank, Impact Study of Bio-gas Installation in Nepal, Kathmandu, 1986.

9. New ERA, Bio-gas Plants in Nepal: An Evaluative Study, UNICEF, Kathmandu, 1985.

10. B.P. Devkota, "A Viable Alternative Energy for Rural Nepalese Villages: A Case Study of Gobar Gas, Forestry Research Paper Series No. 2", Winrock International Institute for Agricultural Development, Kathmandu, 1986.

11. A.B. Karki, K.N. Pyakuryal and N.W. Axxinn, "Techno-Socio-Economic Study on Bio-gas Plants in the Chitwan District, Nepal", Paper presented at Indicative Research Plan on Energy and Rural Development, Chiang Mai, 1980, Thailand.

12. K. Rijal, "Resource Potential and Economic Evaluation of Bio-gas Utilization in Nepal", Energy - The International Journal, Vol. 11, No. 6, pp. 545-550, Pergamon Press Ltd., Great Britain, 1986.

13. A.V. Buren, A Chinese Bio-gas Manual, Intermediate Technology Publication Ltd., London, 1979.

14. National Research Counci, Food, Fuel and Fertilizer from Organic Wastes, National Academy Press, Washington D.C., 1981.

15. B. Saubolle and A. Bachmann, Fuel Gas from Cowdung, Sahayogi Press, Kathmandu, 1980.

16. D.J. Fulford, "Bio-gas in Nepal - The State of Art, Development and Consulting Services", United Mission to Nepal, Butwal, Nepal, 1978.

17. D.J. Fulford , "Report on Chinese Style Gobar Gas Plan", Bio-gas Newsletter, No. 5, A Shakti Publication, Sahayogi Press, Kathmandu, 1979.

18. C.H. Hogger, "The Gas Drum", Bio-gas Newsletter, No. 8, A Shakti Publication, Sahayogi Press, Kathmandu, 1980.

19. J-M. Chapallaz, "Technical Report on the Bio-gas Component-Draft", Asian Development Bank, Manila, 1984, Phillipins.

20. Ministry of Finance, Economic Survey, Fiscal Year 1985/86, Kathmandu, 1986.

21. Land Resource Mapping Project, Economics Report - Draft, Kathmandu, 1985.

22. National Bureau of Statistics, Statistical Pocket Book - 1984, Kathmandu, 1984.

23. N. Barish and S. Kaplan, Economic Analysis for Engineering and Managerial Decision Making, Second Edition (Mc-Graw Hill Company, 1978).

24. Integrated Development Services Pvt. Ltd., Household Energy Survey of Terai Region - Draft, Kathmandu, 1986.