

AT MICROFICHE
REFERENCE
LIBRARY

A project of Volunteers in Asia

Renewable Sources of Energy, Volume II: Biogas

by: Economic and Social Commission for Asia and
the Pacific

Published by:

United Nations Economic and Social
Commission for Asia and the Pacific
The United Nations Building
Rajadamnern Avenue
Bangkok 2
Thailand

Available from:

United Nations Economic and Social
Commission for Asia and the Pacific
The United Nations Building
Rajadamnern Avenue
Bangkok 2
Thailand

Reproduced by permission of the United Nations
Economic and Social Commission for Asia and the
Pacific.

Reproduction of this microfiche document in any
form is subject to the same restrictions as those
of the original document.

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC



UNITED NATIONS

ECDC - TCDC

**ECONOMIC AND TECHNICAL CO-OPERATION
AMONG DEVELOPING COUNTRIES**

RENEWABLE SOURCES OF ENERGY

VOLUME II

BIOGAS

1981

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC



UNITED NATIONS

ECDC - TCDC

**ECONOMIC AND TECHNICAL CO-OPERATION
AMONG DEVELOPING COUNTRIES**

RENEWABLE SOURCES OF ENERGY

VOLUME II

BIOGAS

1981

ST/ESCAP/160

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of any firm or licensed process does not imply endorsement by the United Nations.

CONTENTS

	<i>Page</i>
Preface	(i)
Introduction	1
I. Biogas plants installed in the ESCAP region	1
II. Use of the products of biogas plant	11
III. Methods of improving plant productivity	14
IV. Activities in the ESCAP region	15
V. Economic, social and environmental aspects	18
VI. Scope for ECDC and TCDC	22
Cost-benefit analysis of Indian biogas system: a case study	25
I. Cost-benefit analysis and some empirical results	25
II. Some methodological problems	48
III. Some approaches to methodological problems	53
IV. Conclusion	58
Abbreviations	63
Key to numbers in entries under experts and institutions	65
Alphabetical list of experts and institutions	69
Subject index – by projects	231
Bibliography	245

PREFACE

The current volume is the second in a series of sectoral directories on renewable sources of energy to be issued under the ESCAP publications programme on co-operation among developing countries. With this volume the title of the series has been changed from TCDC to ECDC-TCDC to reflect the expanding scope and contents of the volumes intended to promote and support economic as well as technical co-operation among developing countries.

The present volume, like the preceding one on solar energy and the others to follow, carries not only inventories of experts and institutions and the projects undertaken by them but also technological as well as economic details of the designs, prototypes and hardware developed in ESCAP member countries in Asia and the Pacific. While it is hoped that more details will be made available, the information contained in these volumes may be found adequate for initiating programmes of co-operation among developing countries.

In preparing the roster of experts and institutions, the ESCAP secretariat has relied on the information provided by the experts and institutions concerned and expresses its appreciation of the co-operation extended by them. While every endeavour has been made to include as many experts and institutions as possible the coverage may not be exhaustive. The secretariat will greatly welcome suggestions for improving the coverage of this volume as well as material for publications in the series now under preparation on wind energy and mini-hydro plants and the others envisaged. It is hoped that all the volumes in the series will be found particularly useful in connexion with the forthcoming United Nations Conference on New and Renewable Sources of Energy.

Like the earlier publications issued in the TCDC series, funds for the present volume have been made available by the Netherlands Government as extrabudgetary assistance to ESCAP. This exemplifies "triangular co-operation" under which developed countries contribute to a joint undertaking to promote co-operation among developing countries.

INTRODUCTION

The decay of organic matter, particularly human, animal and plant wastes, in the absence of air produces an inflammable gas which consists mainly of methane (CH_4) and carbon dioxide (CO_2). The gas is known as biogas and the process as anaerobic digestion or fermentation. This process can be used to the great benefit of the rural community for a number of reasons. First, it produces a smoke-free fuel. Secondly, it produces an excellent fertilizer. Thirdly, it destroys most of the disease-carrying pathogens and parasites. Fourthly, the raw materials needed in the construction of the digestion and in its operations are available in rural areas. Finally, the biogas technology is appropriate to rural conditions as comparatively sophisticated devices and highly qualified expertise are not involved.

The main handicap in biogas application is the relatively high capital cost which small-scale farmers cannot afford on an individual basis. Besides, as with any new technology, it needs well-planned programmes for promotion and extension.

The present introduction is meant to give a brief account of the stage of development of and of the economic, social and environmental issues in biogas technology in developing countries in the ESCAP region. Several more comprehensive technical reviews of the subject have been published.^{1 2 3 4 5}

I. BIOGAS PLANTS INSTALLED IN THE ESCAP REGION

There are two main types of biogas plant that have been developed in this region; the fixed-dome digester, which is commonly called the "Chinese digester" (see figure 1) and the floating gas holder digester known as the Indian (KVIC) digester (see figure 2). The digesters used in the other developing countries in the ESCAP region, with the exception of the bag digester, are slightly modified forms of one or the other of these two main types.

¹ *A Chinese Biogas Manual*, translated from the Chinese by Michael Crook and edited by Ariane van Buren from the original by the Office of the Leading Group for the Propagation of Marshgas, Sichuan Province, China (London, Intermediate Technology Publications, 1979)

² "Guidebook on biogas development", *Energy Resources Development Series*, No. 21 (United Nations publication. Sales No. E.80.II.F.10).

³ Sichuan Provincial Office of Biogas Development, "Biogas technology and utilization" (Chengdu Seminar, China, 1979).

⁴ Sichuan Provincial Institute of Industrial Buildings Design, "Construction of marsh-gas-producing tanks (digesters) in simple ways".

⁵ *Simplified Biogas Digester Drawings*. Compiled by the South-west Engineering Institute, Beijing, China, 1979 (in Chinese).

A. THE BIOGAS DIGESTER

1. Fixed dome digester (China)

This digester which was developed and is widely used in China runs on a continuous-batch basis (see figure 1). Accordingly, it could digest plant waste as well as human and animal wastes. It is usually built below ground level; hence it is easier to insulate in a cold climate. The digester can be built from several materials, e.g. bricks, concrete, lime concrete and lime clay. This facilitates the introduction and use of local materials and manpower. The variable pressure inside the digester was found to cause no problems in China in the use of the gas.

2. Floating gas holder digester (India)

This type was developed in India and is usually made of masonry (see figure 2). It runs on a continuous basis and uses mainly cattle dung as input material. The gas holder is usually made of steel, although new materials such as ferrocement and bamboo-cement have already been introduced. The original version of this floating gas holder digester was a vertical cylinder provided with partition wall except for the small sizes of 2 and 3 m³ of gas per day. The main characteristic of this type is the need for steel sheets and welding skill.

3. Flexible bag digester

This digester is made usually of Hypalen-Neoprene (see figure 3). It is portable, could be easily erected and has low capital cost. It has, however, a short lifespan in view of its low resistivity to ultraviolet rays and rodents.

4. Other types of digesters

(a) *Taper digester with floating gas holder (Nepal)*

This digester (see figure 4) is more suitable than the vertical type digester in sites with a high water-table.

(b) *Floating gas holder with water seal (Pakistan)*

This type (see figure 5) eliminates the smell and decreases gas leakage and corrosion of the gas holder. It is, however, considered more expensive than the original model.

(c) *Two-chamber digester (Philippines)*

Clogging problems hindered the widespread use of this digester (see figure 6), requiring more appropriate designs of the inlet and outlet.

(d) *Oil drum digester (Indonesia)*

This digester has been used for research purposes (see figure 7). The oil drum tends to rust out within a few years.

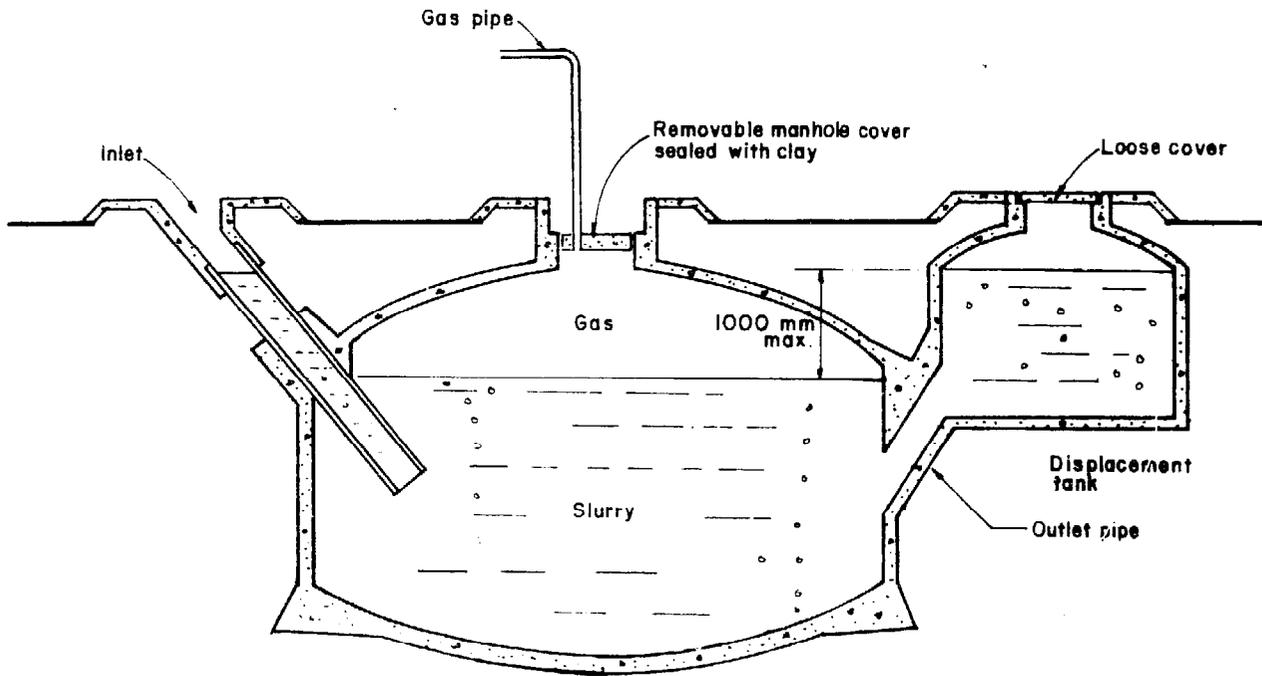


Figure 1. Common circular fixed dome digester (China)

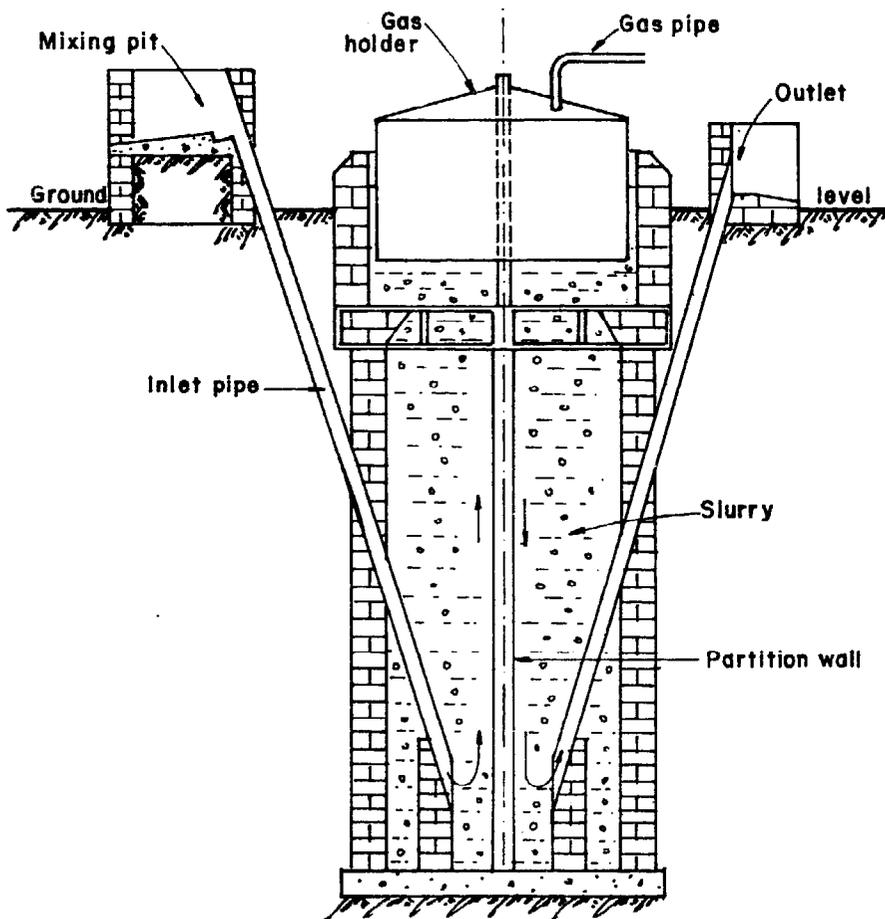


Figure 2. Common circular digester with floating gas holder and no water seal (India)

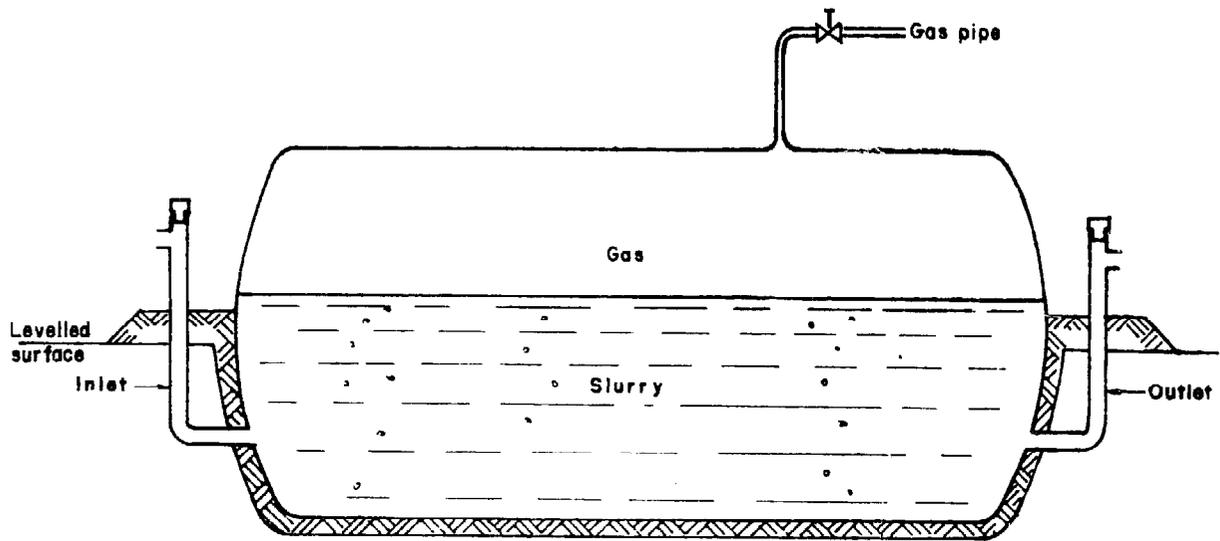


Figure 3. Flexible bag type combined digester/gas holder

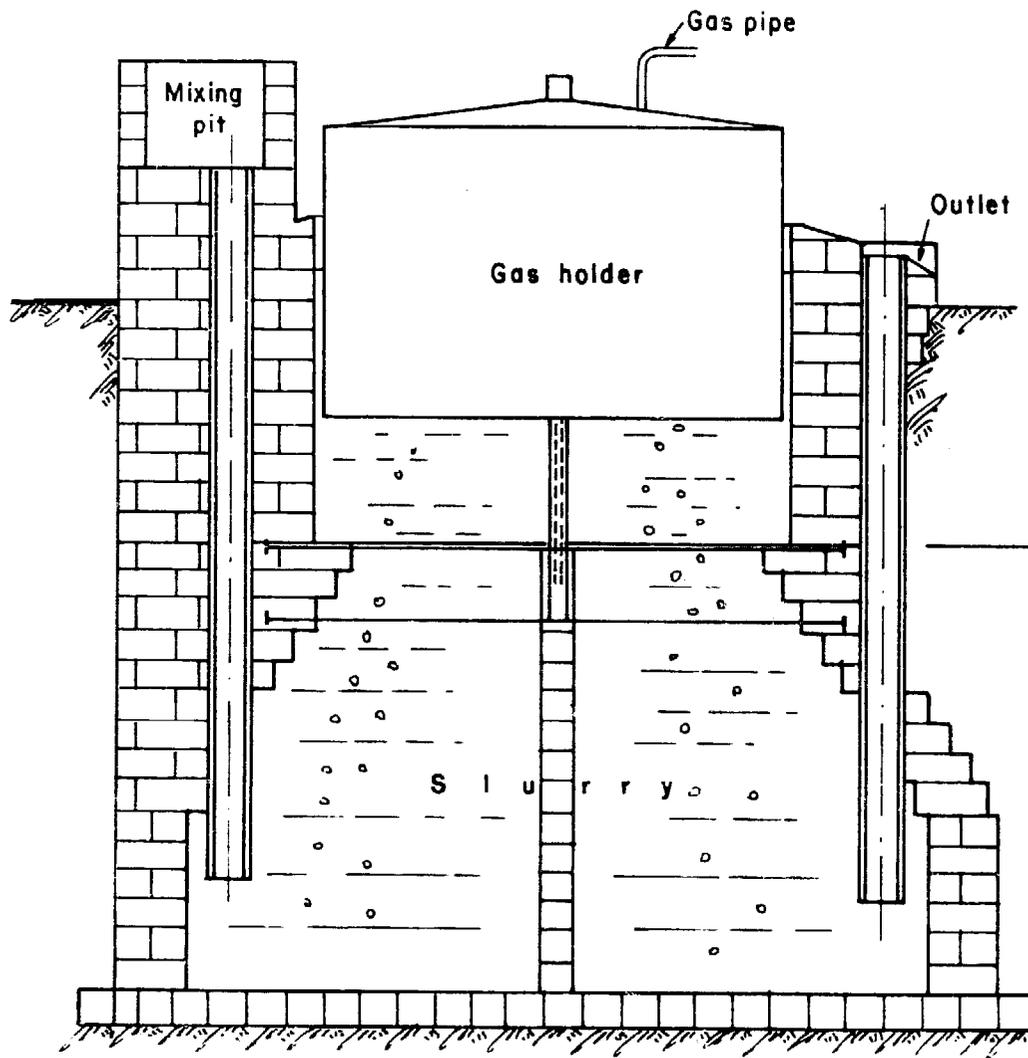


Figure 4. Taper digester with floating gasholder (Nepal)

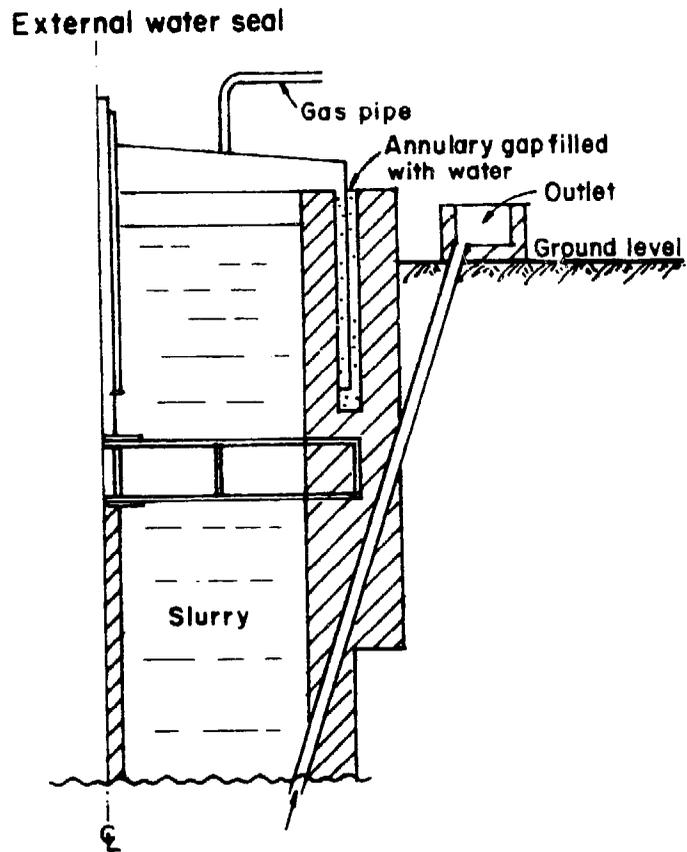


Figure 5. Digester with floating gas holder and water seal (Pakistan)

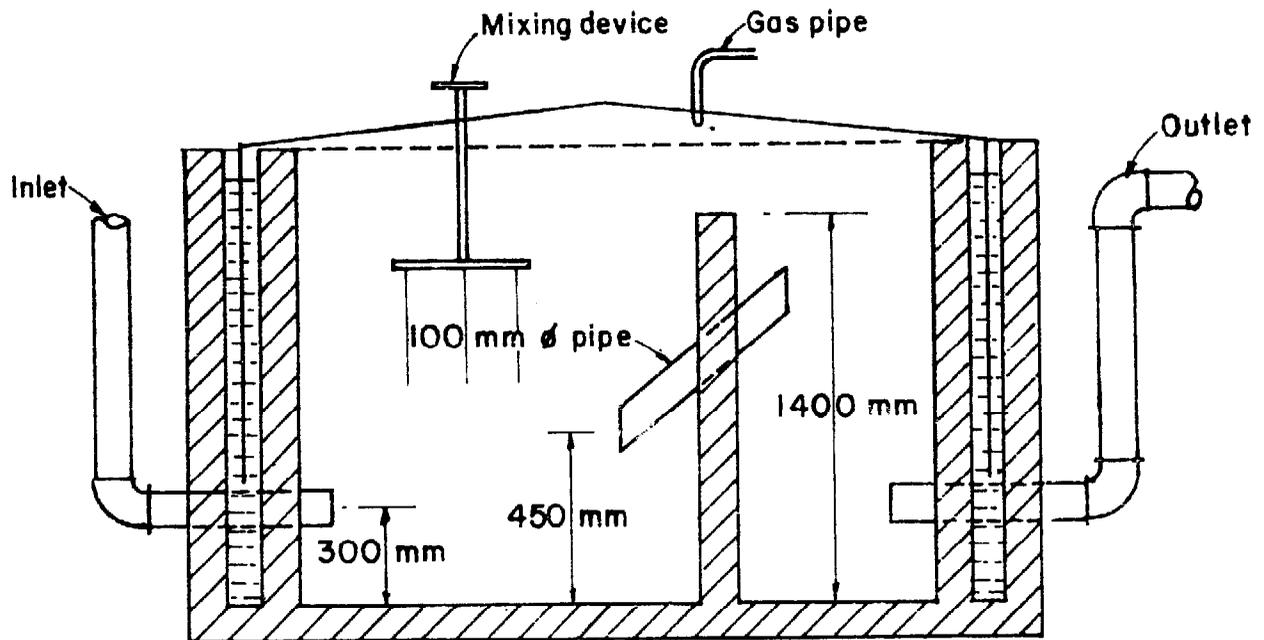


Figure 6. Two-chamber rectangular digester with floating gas holder and water seal (Philippines)

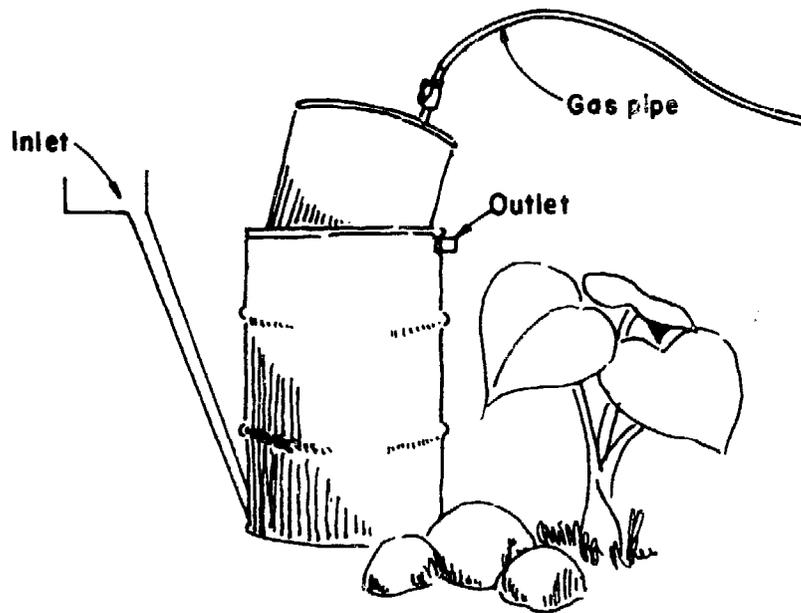


Figure 7. Oil drum digester (Indonesia)

(e) *Jar digester with separate gas holder (Thailand)*

This type (see figure 8) is cheaper than the floating gas digester and is easier to construct and maintain. However, it tends to leak and fails easily owing to cracking.

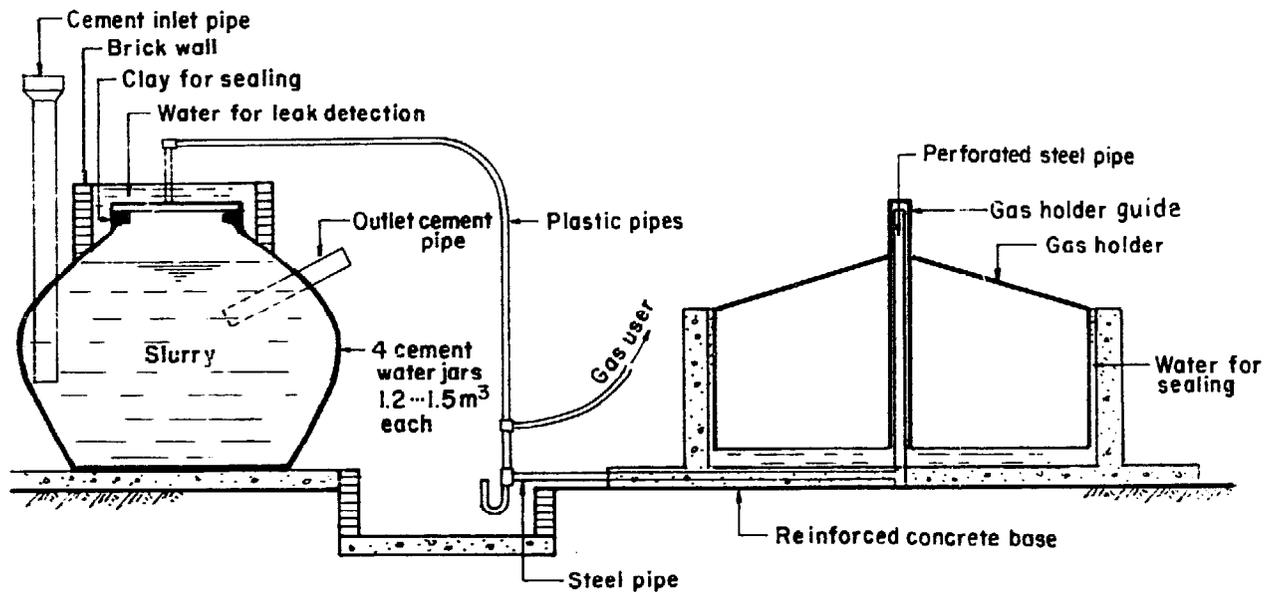


Figure 8. Jar digester with separate gas holder (Thailand)

(f) *Fixed dome digester with separate gas holder (China)*

The digester (see figure 9) in this plant is subjected to a less but more constant pressure. Additional work and cost are, however, involved in building the water tank and the gas holder.

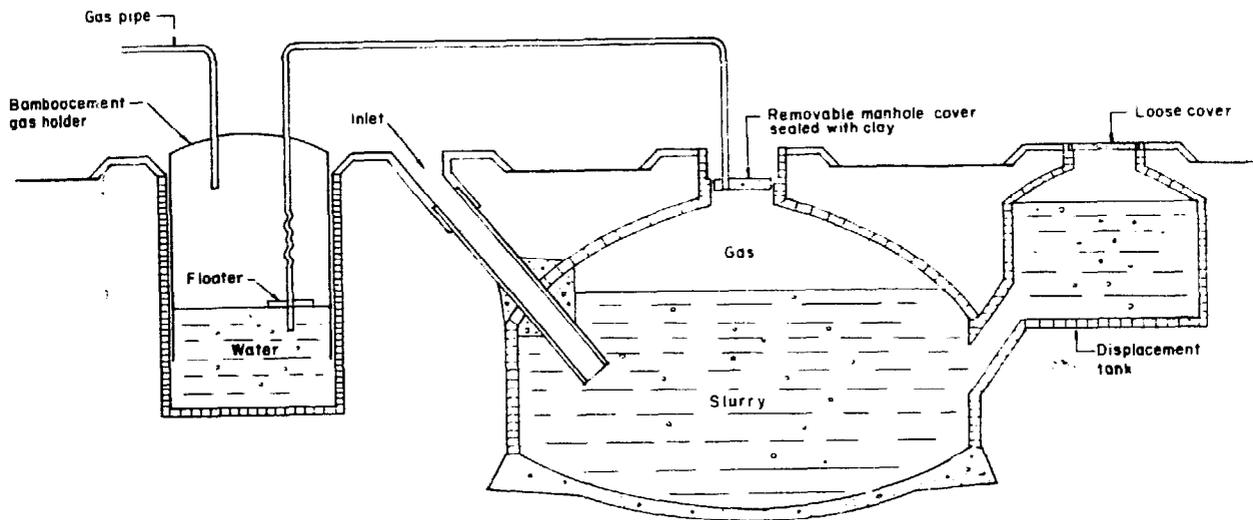


Figure 9. Fixed dome digester with separate gas holder (Sichuan, China)

B. THE REST OF THE BIOGAS PLANT

1. Gas removing system

This usually consists of a flexible pipe made of rubber or plastic (see figure 10). A hooked pipe or a pipe passing through the gas holder could be also used.

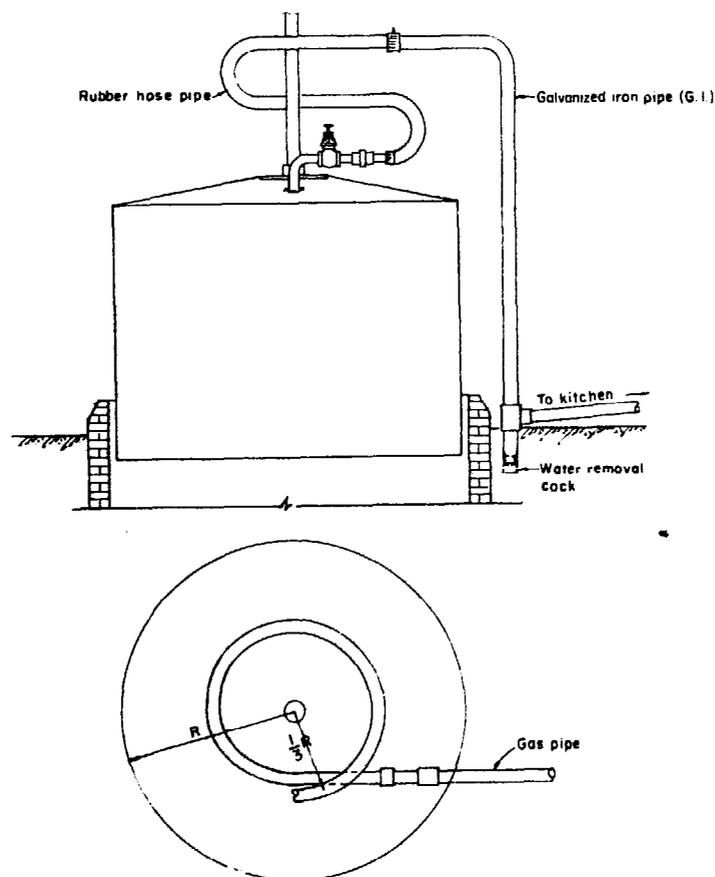


Figure 10. Gas removing system through a flexible pipe

2. Gas holder support system

This system is necessary only in the floating gas holder types. The most common systems are the internal and the external ones (see figure 11). The other systems like the wheel and the counter balance systems are not trouble-free.

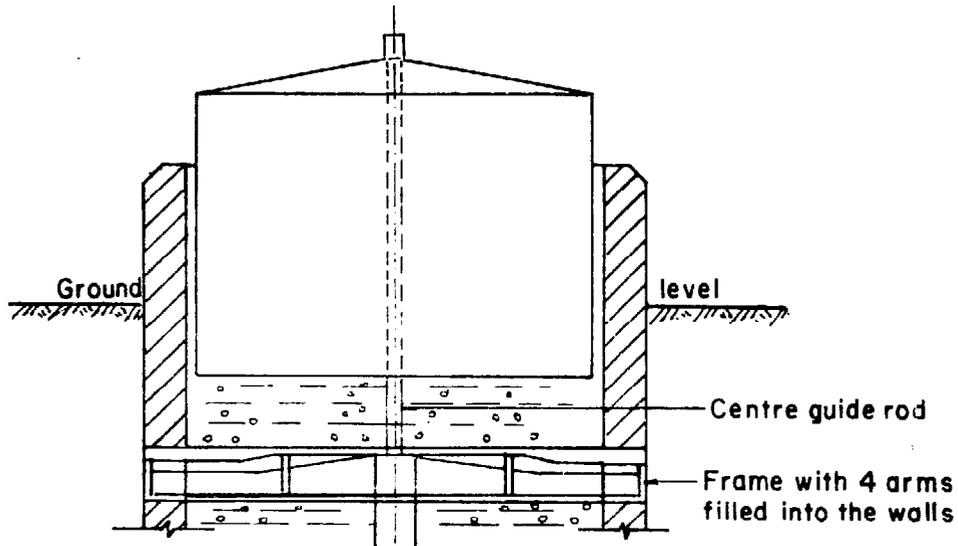


Figure 11a. Gas holder internal guide system

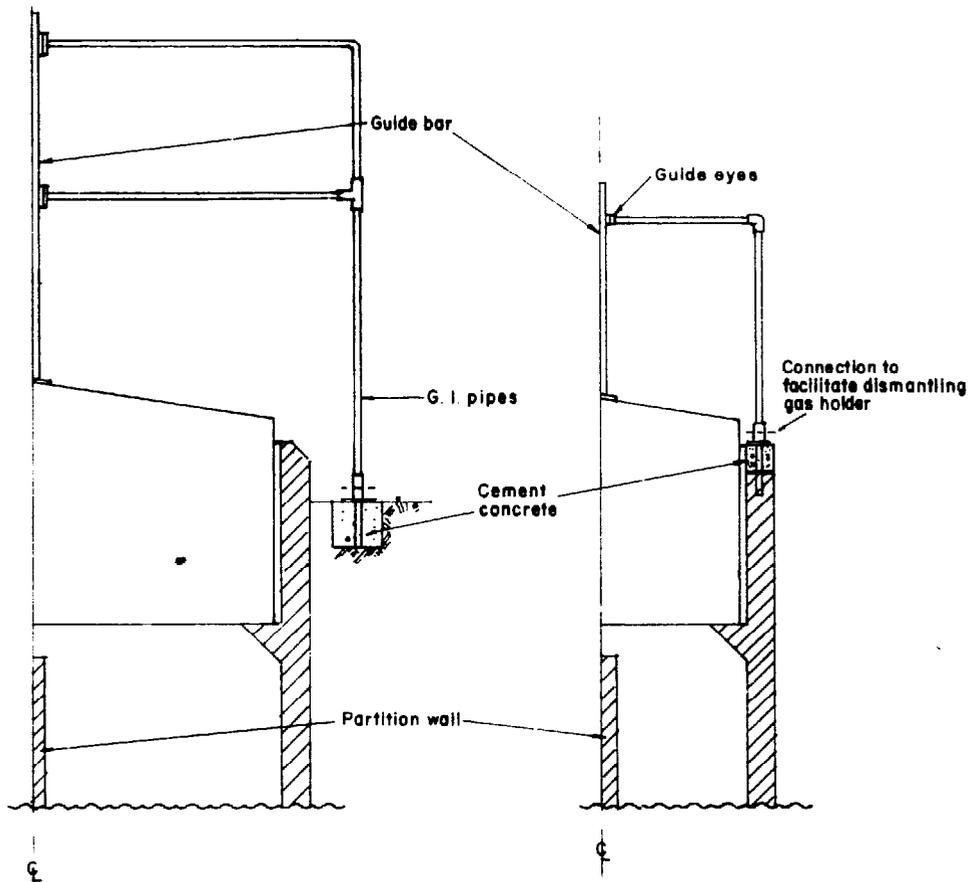


Figure 11b. Gas holder external guide system fixed to the earth (for large sizes)

Figure 11c. Gas holder external guide system fixed to digester wall

3. Monometer

This device is one of the typical attachment of the fixed dome (Chinese) digester (see figure 12). In addition to its use as indicator of pressure, and thus of the amount of the gas in the digester, it functions also as a safety device in case of excess increase of the gas pressure.

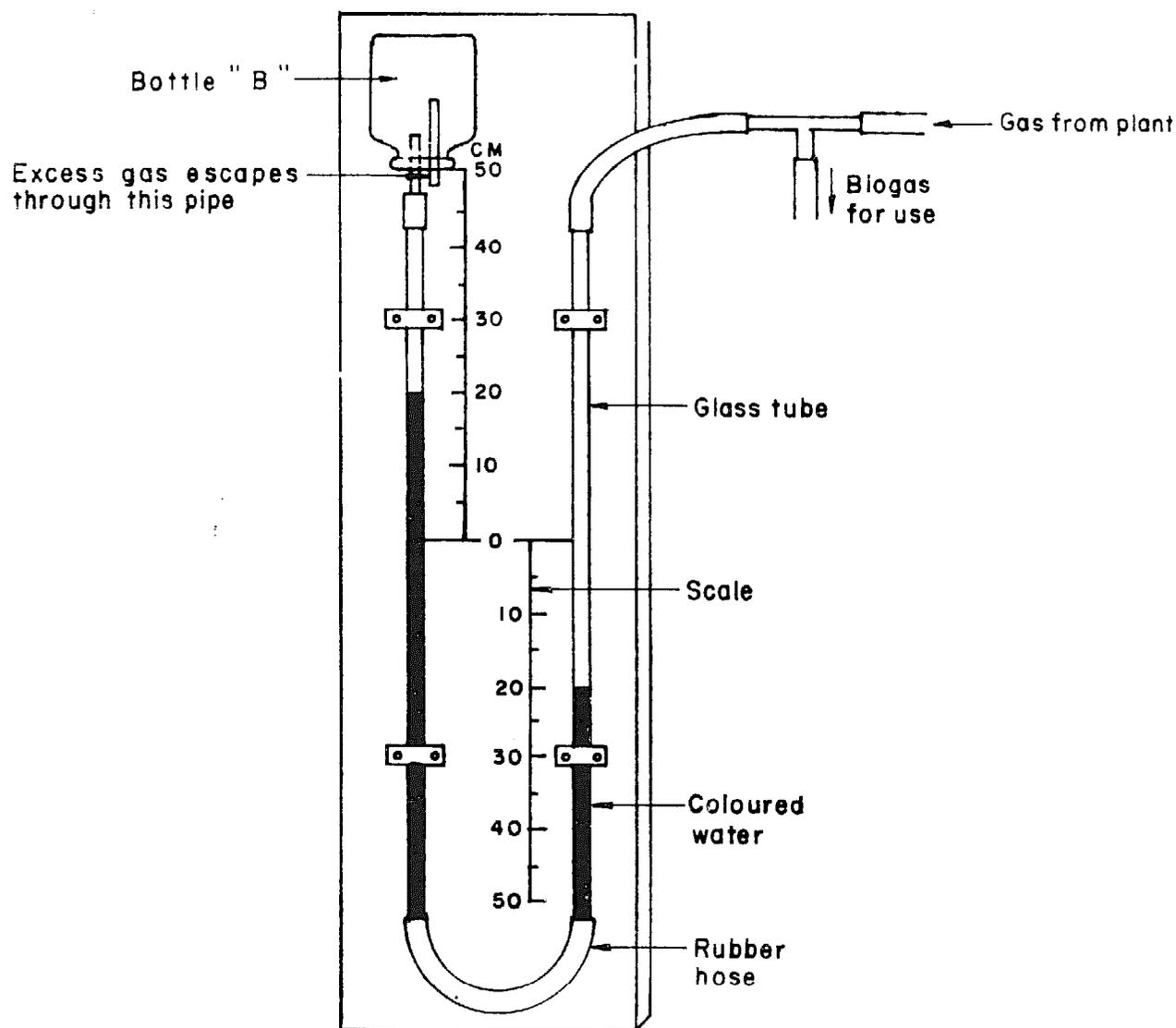


Figure 12. Monometer and safety valve combined

4. Biogas stoves

Biogas can be used like any other inflammable gas; LPG or natural gas. Air must be thoroughly mixed with the gas before it reaches the flame ports. In order to burn, the air to biogas ratio should be in the range of 1:1 to 4:1. The optimum area of the flame ports to the gas jet is between 80:1 and 200:1. There are many different types of stoves usually locally made from cast iron, mild steel or clay (see figure 13).

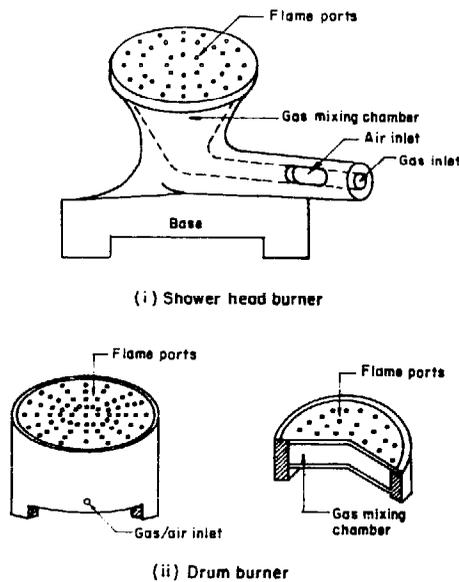


Figure 13. Clay burners (China)

5. Biogas lamps

The most efficient use of biogas in lighting is by generating electricity and using an electric bulb: 1 m³ of biogas can generate 1.25 kWh and would be sufficient to ignite a 60 W electric bulb for 20 hours. The same amount of biogas will ignite a mantle gas lamp, equivalent to 60 W for about seven hours only. In most cases, however, the cost of the engine and generator may not be justified; hence a simple gas lamp can be used in spite of its low efficiency. There are also different types of biogas lamps; some are commercially made and others are village made (see figure 14).

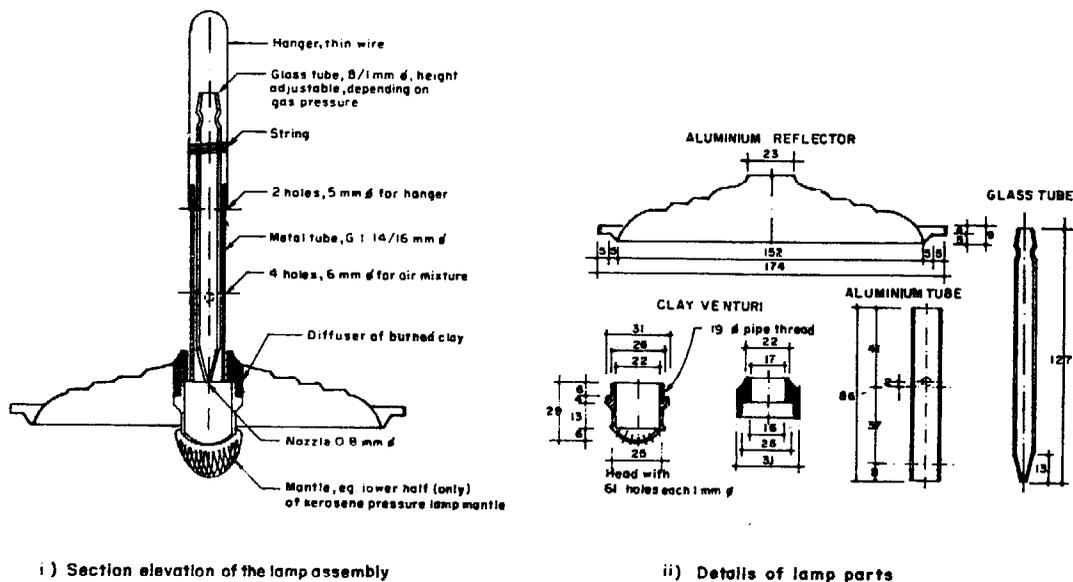


Figure 14. Simple biogas lamp (China)

5. Composting around the digester

The idea is to use the heat generated in aerobic digestion to heat the digester by constructing composting pits around and against the digester sides. It is important to empty and refill the compost pits regularly in rotation to avoid temperature fluctuation of the slurry.

B. MECHANICAL METHODS

The mechanical methods include stirring (mixing) and recycling of slurry.

1. Stirring (mixing)

Stirring is effective in helping to bring the bacteria closer to the digestion sites. A few minutes of stirring several times a day is desirable. Stirring also helps to break up any scum and to release the trapped gas bubbles. A number of mechanisms has been suggested for different digesters. A simple manual one with a minimum number of moving parts is desirable.

2. Recycling of slurry

In this method about 2 litres of old slurry are added to the new slurry in order to seed it with bacteria and increase gas production.

C. CHEMICAL AND MICROBIOLOGICAL METHODS

In these methods urine, urea fertilizer, molasses, sugar waste products etc. are added to increase gas production. One litre of urine per 1.4 m³ of digester volume may be added every day. If urea is used a teaspoon per 3 m³ of digester volume per day will be sufficient. About 70 grams per m³ of molasses or sugar waste may also be added per m³ of digester volume per day. Chopped water hyacinths and algae were also found to give significant increase in gas production.

IV. ACTIVITIES IN THE ESCAP REGION

Several countries in the region are undertaking and/or initiating projects on the research, development, demonstration and promotion of biogas. The information available is summarized below.⁶

1. Plant construction and operation

In Bangladesh research and development is being carried out on both the fixed dome and the floating gas holder digester. Investigation is also going on for optimizing the cost and efficiency of the different designs.

In China an extensive programme for testing different types of digesters including floating gas holder digester, separate gas holder and fixed dome digester are being undertaken. At present more than 8 million biogas units have been constructed in the

⁶ For full details see the entries under individual expert and institution.

various provinces with more than 4 million units in Sichuan Province. The present goal is to bring the total number of the plants to 100 million units, thus utilizing the major part of human, animal and plant wastes in the country. In addition, the units that are out of function are under repair; the reasons for their malfunctioning are being investigated and the digesters are being renovated.

In Fiji research and development work is being undertaken by the University of the South Pacific. About 20 units have already been constructed. Small digesters utilizing animal, agricultural and vegetable waste are being investigated.

In Indonesia biogas plants are being considered as part of village energy development studies being undertaken by seven universities and one research institute, covering approximately 400 villages.

In India a major programme of biogas development has been underway for a number of years under the auspices of the Khadi and Village Industries Commission. Several educational and research institutions have been engaged on various aspects of biogas plant design, simpler construction, installation and maintenance techniques and cheaper materials such as ferrocement for gas holders etc. Two types of designs – one floating drum type and the other fixed dome type – are being pursued. So far approximately 80,000 plants of the floating drum type designs have been installed and about 2000 fixed dome type designs have also been introduced mainly in the northern provinces. A few community type biogas plants have also been set up and more of such types are envisaged. During the next five years India plans to reach a target of 500,000 plants.

In Malaysia a movable gas holder digester is being tested.

In Pakistan, plans have been drawn up for providing 160 villages with compact (community-type) biogas systems as part of the rural energy project, on which work has been initiated. Prefabricated ferrocement biogas plants are under investigation.

In Papua New Guinea large biogas systems have been designed for the conversion of human waste and coffee pulp into fuel and fertilizer.

In the Philippines industrial-size batch and continuous digesters with floating gas holders are being designed and constructed. Small biogas plants with separate digesters and gas holders are also being constructed. Regional biogas demonstration plants are being established for promotion purposes.

In the Republic of Korea about 24,000 family size biogas plants were built from 1969 to 1975. Owing to problems arising from low temperature, modified designs of underground digesters are under consideration.

In Sri Lanka the fixed dome digester is under investigation in view of its comparatively low cost. In addition promotional work for biogas plant is also continuing.

In Thailand about 600 biogas plants of the floating gas holder type have been constructed. Jar and fixed dome type digesters are also being experimented with.

2. Gas production and utilization

In Bangladesh gas yield from animal, agricultural and vegetable wastes is under study.

In China the gas is being used in cooking, for lighting, for running tractors, trucks and buses, for running engines and for electricity generation. The biogas after being compressed in bottles and put in the buses is released to a large neoprene balloon usually placed on the bus roof, then connected to the engine. A wide range of biogas lamps and stoves has been developed and manufactured in villages.

In India biogas is mainly used for cooking and lighting and for running engines for water pumping in agriculture, drinking water supply and in small agro-industries. Research is progressing on the use of biogas in welding and on increasing gas yield through techniques of maintaining optimum temperature conditions in the digester.

In Indonesia the utilization of biogas in refrigeration and for cooling is being studied.

In the Philippines biogas is being used in engines for pumping water, electricity generation and processing of meat.

In the Republic of Korea biogas is used in the rural areas mainly for cooking and space heating.

In Samoa, Sri Lanka and Thailand the gas is used mainly for cooking.

In Thailand a study on gas production using different plant wastes is being undertaken.

3. Microbiological aspects

In Bangladesh a study is planned for the identification and isolation of active methanogenic bacteria.

In China various microbiological studies are being undertaken in a number of institutions, e.g. bacteria production for village biogas plants, fermentation kinetics, use of enzymes, bacterial decomposition and use of additives to increase biogas production etc.

In India various microbiological studies involving fermentation kinetics in the mesophilic and thermophilic ranges, isolation of specific microbiological strains, development of techniques for production and maintenance of enriched cultures of methanogenic bacteria and on enzyme hydrolysis of hemicellulosic materials etc. are being carried out.

In the Philippines studies are being undertaken on the microbial actions on biodegradable materials for improving the gas yield.

In the Republic of Korea microbiological research on isolation of specific bacteria and improving their effectiveness with particular reference to low temperature operations are being undertaken.

In Thailand studies are planned and/or being undertaken on the effluent from biogas plant as a source for single cell protein production and kinetic and population studies of methanogenic micro-organisms.

4. Effluent and its uses

In China the aspects being investigated include fertilizing efficiency and effectiveness of the bio-plant effluent and sludge, and potentiality of various uses of biogas plant fermentation residue.

In India investigations are being carried out on the effluent for enhancing its manurial value and on aspects relating to slurry handling and application as farm manure.

In the Philippines and Thailand the use of effluent for mushroom production is being studied. The utilization of digested slurry with local rock phosphate to increase crop yield is also being investigated in Thailand.

V. ECONOMIC, SOCIAL AND ENVIRONMENTAL ASPECTS⁷

Like any renewable source of energy, socio-economic evaluation of biogas systems faced problems in quantification, particularly of indirect costs and benefits of the economic, social and environmental aspects of biogas technology.

A. SOCIAL FACTORS

The socio-economic aspects of biogas economy included:

- (a) Employment created in biogas construction work and related industries;
- (b) Improving facilities in villages, thus decreasing migration to urban areas;
- (c) Positive effects on the health of the farmers by improving hygiene in the village, providing better lighting and decreasing smoke hazards;
- (d) Income redistributive effects, where access to biogas technology utilization is limited to comparatively affluent farmers;
- (e) Costs involved in promotion and extension of biogas technology.

B. ENVIRONMENTAL FACTORS

The main environmental factor associated with the biogas is the introduction of a substitute to firewood which could mean conservation of forests and decrease in air pollution.

⁷ For full discussion, see "Guidebook on biogas development", *op cit.*, chap. XV, pp. 95-97. For actual applications in a specific country's context, see the following chapter.

II. USE OF PRODUCTS OF BIOGAS PLANT

As was mentioned before the main products of the biogas plant are the gas and the slurry. Both products are valuable and arrangements should be made to make use of both of them.

A. USE OF BIOGAS

A summary of the possible uses of the biogas is given in figure 15.

1. Cooking and lighting

A brief account was given in the last chapter on biogas stoves and lamps. Cooking and lighting represent over 90 per cent of the main uses of the biogas in developing ESCAP countries. The use of biogas in engines for motive power and electricity generation and for refrigerators will be considered briefly in what follows.

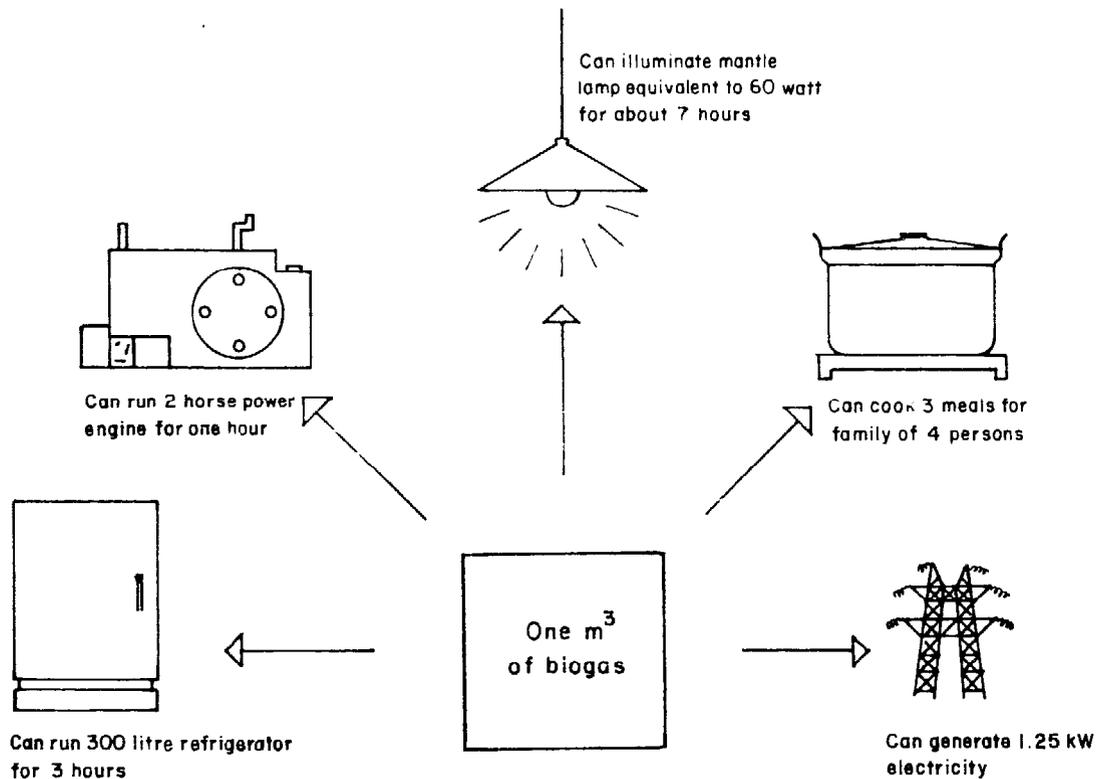


Figure 15. Possible applications of biogas

2. In engines

A petrol engine can run on 100 per cent biogas. It is common, however, to use a little petrol for starting up. The biogas is simply supplied to the intake pipe either through a venturi (see figure 16), without any modifications in the carburettor, or by replacing it by the gas carburettor shown in figure 17 if the engine is to run continuously on petrol.

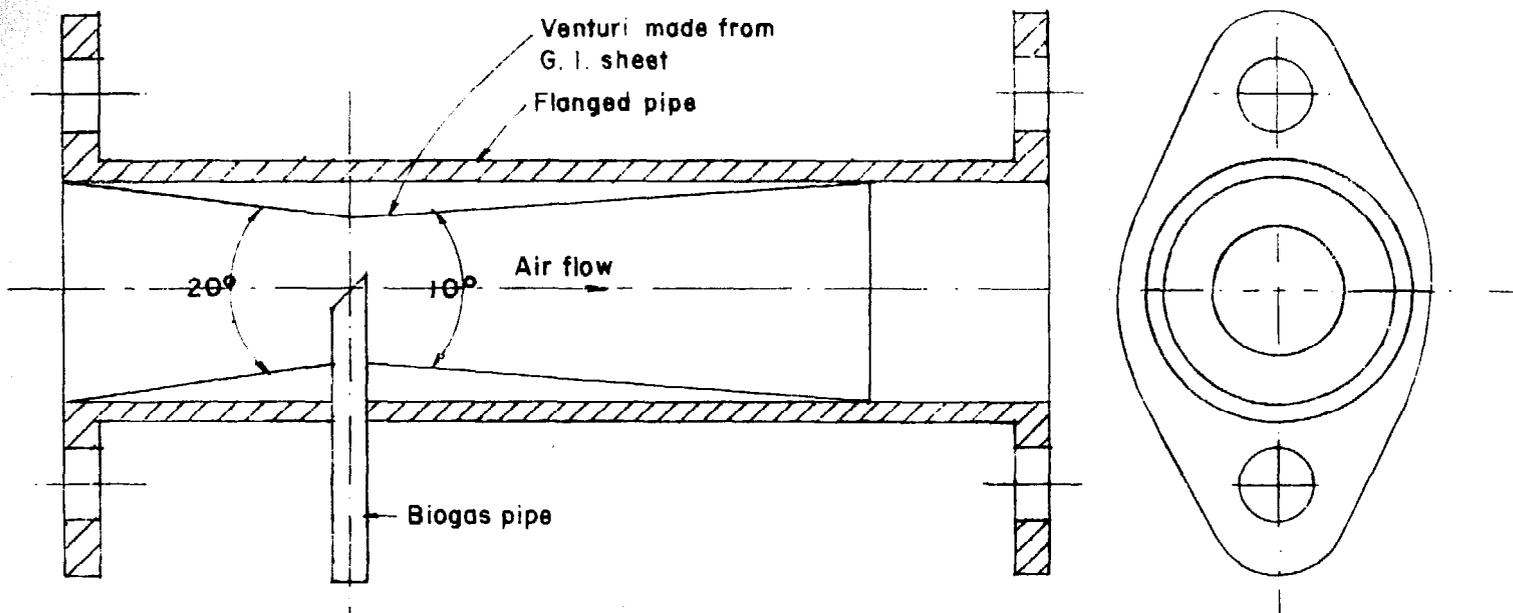


Figure 16. Gas venturi (Pakistan)

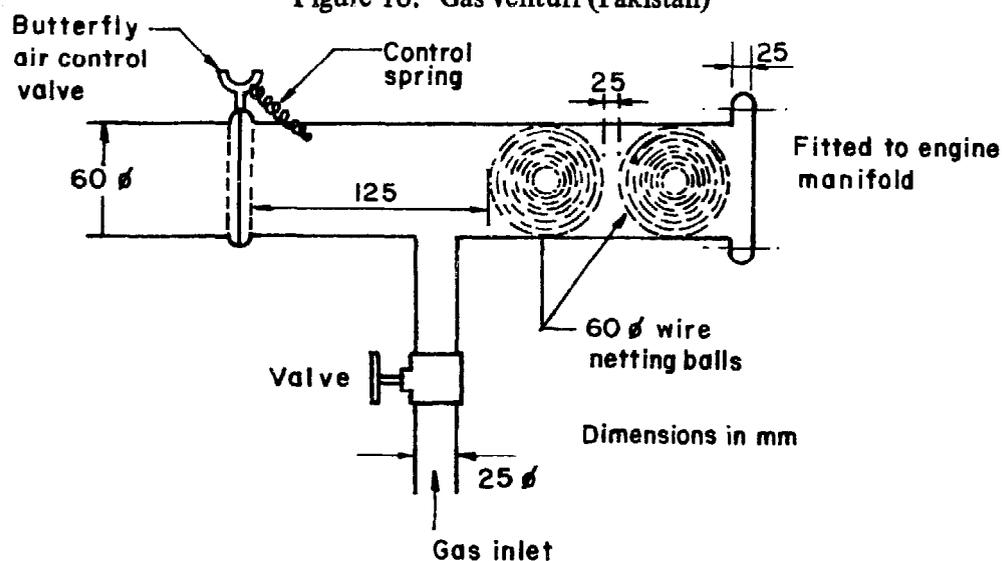


Figure 17. Carburettor for 10 bhp petrol engine running on biogas

In diesel engines the temperature at the end of the compression stroke is usually not more than 700°C , whereas the ignition temperature of the biogas/air mixture is 814°C . Hence the injection of a little diesel fuel just before the end of the compression stroke, to ignite the gas mixture, can ensure the normal running of the engine. Arrangements to take care of this are already included, as all types of diesel engines are normally set with an advance injection angle. Accordingly, it is usually enough to connect the biogas pipe to the air intake of the diesel engine (see figure 18). Some users in the Philippines have noticed that diesel engines run more smoothly on dual fuel when the compression ratio is lowered. Others in China added spark plugs. These optional solutions may increase the amount of the biogas used but will also decrease the rated power of the engine. Two connexions are given in figures 18 and 19 for the biogas pipe to the engine intake pipe.

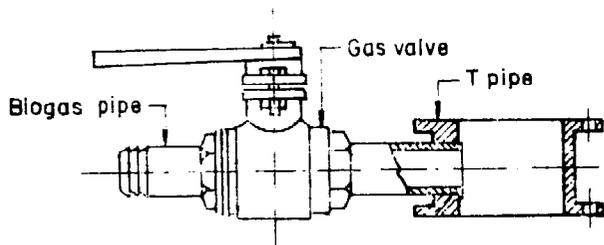


Figure 18. Direct connexion of biogas pipe to inlet pipe (China)

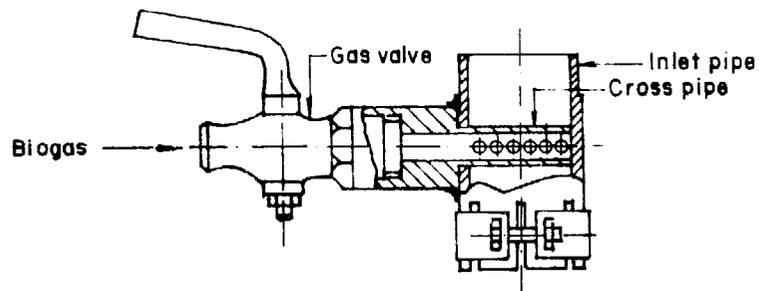


Figure 19. Cross flow connexion (China)

3. In refrigerators

Absorption type refrigerators can be run on biogas by adjusting a modified burner, e.g. Bensin or Telcu, to give the correct amount of heat.

B. USE OF SLURRY

In the floating gas holder digester the slurry consists of the effluent that comes out from the outlet pit. In the fixed dome digester, where plant wastes are usually added, the slurry consists of the effluent and the sludge which precipitates at the bottom of the digester and is formed mostly of the solid substances of plant wastes.

1. Use of effluent

The effluent can be used directly as fertilizer on plants. In China, it is sometimes diluted by irrigation water which carries it to the field. In India it is often used in composting. This is done as follows: a layer of straw or plant waste is first put in the pit then a layer of effluent. Again a layer of plant waste or straw is added followed by another layer of effluent and so on until the pit is full. In the Philippines a part of the effluent is recycled and mixed with the feed of the pigs as it contains vitamin B16.

2. Use of sludge

The sludge which is obtained twice, or more frequently from the fixed dome digester, is usually composted as above or mixed with chemical fertilizers as it contains a higher percentage of parasite and pathogens than the effluent.

III. METHODS OF IMPROVING PLANT PRODUCTIVITY

The methods that are generally adopted for improving plant productivity could be divided into thermal, mechanical, chemical and microbiological.

A. THERMAL METHODS

Gas production increases significantly when the temperature of the slurry is raised. The optimum temperature for the types of plant discussed earlier is about 35°C. At temperatures lower than 10°C gas production is insignificant. It is also necessary to maintain the temperatures constant within $\pm 1^\circ\text{C}$, as the bacteria cannot tolerate fluctuating temperatures.

1. Insulation of the digester

In this method the whole plant is insulated, including the gas holder. Insulating materials such as straw are usually used and they should be kept dry. The thickness of the insulating layer is about 5 to 8 cm. Experimental work on this subject was undertaken in India.

2. Heating of input slurry

In this method the input material is heated either by solar energy or by using a part of the gas produced. Excessive heating of the slurry, which would kill the bacteria, should be avoided. This technique was experimented with in different countries.

3. Glasshouse

In this method, a plastic tent is erected over the gas plant. This gives a greenhouse effect, provided the joints are made airtight. Plastic sheets deteriorate usually after one year due to aging under sunlight conditions. In some reports from Pakistan it is mentioned that this method increases gas production by about 50 per cent.

4. Solar heating of digester

Attempts to incorporate a solar water heater and heating coil in the digester were made in China and India. The idea is technically feasible and could be adopted if economically justifiable. One example of this technique, which has been tried in India, is illustrated in figure 20.

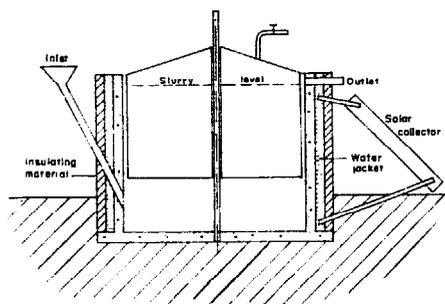


Figure 20. Solar-heated digester

C. METHODS OF QUANTIFYING SOCIO-ENVIRONMENTAL FACTORS

The social and environmental factors mentioned above are difficult to quantify at the level of the individual farmer. However, in carrying out comprehensive studies at the community or country level they should be taken into account. A few methods have already been suggested to quantify these factors. For example, the environmental factors may be accommodated by adding the capital cost to the costs of devices etc., needed in the case of conventional resources, in order to obtain the same environmental conditions prevailing when the biogas plants are used. Also, the cost of reforestation of an area that would have been deforested had firewood been used instead of biogas may be added to the capital costs.

Methods of quantifying the social factors may be also introduced by evaluating the possible social expenditure on non-employment should the labourers who are engaged in the construction work remain unemployed. Also the possible savings in foreign currency resulting from decreasing fossil fuel imports may be evaluated and taken into account.

As mentioned earlier these factors may be taken into account only in a large-scale comprehensive analysis. If the only interest is an analysis seen from the farmer's point of view, it would be enough to enumerate these factors in addition to a simple economical analysis.

D. ECONOMIC ANALYSIS

The two products of the biogas plant that should be evaluated at the individual farmer's level are the biogas and the fertilizer. There exist different approaches for the evaluation of the products of the biogas plant. A review of some of these methods may be found in the literature. One possible way of carrying out this analysis will be described below: the figures used are for illustrative purposes only.

1. Value of biogas

The gas should be compared with the fuels that it substitutes. Thus, in cooking it may be compared with firewood, butane, or charcoal. In lighting it may be compared with kerosene. It may be taken that 12.3 kg of dried dung cakes is equivalent to 61.5 kg wet dung, assuming 20 per cent solids in the wet dung.

If this dung were processed in a gas plant, it would be expected to produce 2 m³ of gas (calorific value about 20 MJ/m³) which is double the amount of heat obtained from the dung cakes (calorific value about 8.8 MJ/kg), taking into account the efficiency of the biogas stove which is about 60 per cent in comparison to the efficiency of the cattle dung stove (open hearth) which is usually less than 10 per cent. Besides, there is the further direct advantage of the subsequent fertilizer value of the effluent.

A few assumptions that simulate the conditions in rural areas and simplify the calculations will be made with illustrative figures to compare the cost against the benefits.

It will be assumed that the farmer obtains a loan for building the plant. The interest on the loan will be calculated using the annuity factor, but the effect of inflation will be ignored. The method can be illustrated with numerical examples.

(a) *Capital cost*

The total cost of the floating gas holder digester in India was from \$US 50 to 60 per m³ of digester volume. The volume of a 3 m³/day biogas plant is about 8.5 m³. Thus the total cost of the plant could be about \$US 500.

Assuming that the farmer receives a loan at 10 per cent interest to be repaid over 10 years, the annual payment may be calculated from the formula:

$$C_a = \frac{C_c}{a} \dots\dots\dots (1)$$

Where: a = the annuity factor, and is calculated from:

$$a = \frac{1 - (1 + i)^{-n}}{i} \dots\dots\dots (2)$$

i = interest rate (percentage)

n = repayment period in years

Substituting i = 10 per cent and n = 10 in equation (2).

We find $a = 6.14$

Therefore $C_a = \frac{500}{6.14} = \$US 81$

The total cost of the loan including the interest will be 81 x 10 = \$US 810.

(b) *Annual cost*

Assuming that the life of the gas plant is 20 years and that the repairs and maintenance costs are about 2 per cent of the capital cost, the annual cost will be

$$\frac{810}{20} + \frac{2 \times 500}{100} = \$US 50$$

(c) *Cost of energy*

It will be assumed that 70 per cent of the gas will be used, instead of wood, for cooking and 30 per cent, instead of kerosene, for lighting. Using the figures given in (a) for the calorific value of biogas (20 MJ/m³), kerosene (38 MJ/litre) and firewood (20 MJ/kg), and assuming stove efficiencies of 60 per cent for the biogas and 10 per cent for the firewood and the same lamp efficiency for biogas and kerosene it is possible to arrive at the figures of the effective heat equivalent to 1 m³ biogas. For firewood in cooking this will be 6 kg and for kerosene in lighting 0.53 litre.

Assuming further an average cost of \$US 0.20/litre for kerosene and \$US 0.02/kg for firewood, the cost of equivalent effective heat using 1 m³ of biogas will be

0.2 x 0.53 = \$US 0.10 for kerosene
 and 6.0 x 0.02 = \$US 0.12 for firewood.

From these figures it is easy now to calculate the annual benefits of using biogas instead of kerosene and firewood as follows:

Kerosene	0.1	x	3	x	0.3	x	365	=	\$US	32.80
Firewood	0.12	x	3	x	0.7	x	365	=	\$US	<u>92</u>
Total benefits of biogas as energy source								=	\$US	124.80

2. Value of fertilizer

In order to set a value for the effluent as fertilizer in comparison to the raw or the coke dung, it will be assumed that (a) all elements except nitrogen remain constant no matter how they are used; (b) the fresh dung has initially 0.12 per cent nitrogen and that for each m³ of biogas produced 32 kg of cattle dung is used per day, i.e. 11,700 kg/year.

Accordingly, in 11,700 kg dung at 0.12 per cent nitrogen there is 14.1 kg nitrogen. This is equivalent to about 31 kg of urea fertilizer which has normally about 46 per cent nitrogen. If urea costs about \$US 0.20/kg and contains 46 per cent nitrogen then 1 kg nitrogen is \$US 0.44.

From the above it follows that in the example of the last section the value of nitrogen in cattle dung for 3 m³/day biogas plant = 14.1 x 3.0 x 0.44 = \$US 18.60/year.

In the current method of making manure (piling the dung for 30 days before use) the manure value of nitrogen decreases by about 50 per cent, hence the value of nitrogen = 18.6 x 0.5 = \$US 9.30/year.

If the new practice of drying the effluent is adopted, then only 15 per cent of the nitrogen will be lost. Accordingly, the value of nitrogen = 18.6 x 0.85 = \$US 15.80.

The improved nitrogen value of the manure = 15.8 - 9.3 = \$US 6.50/year.

3. Benefit/cost ratio

Continuing with the preceding example the benefits to total cost ratio can be calculated:

Total benefit	=	124.8 + 6.5	=	\$US 131.30/year
Total cost	=	\$US 50		
Benefit/cost	=	$\frac{131.3}{50}$	=	2.6/1

It is clear in the above example that the benefits from using biogas instead of firewood was the main factor affecting the above analysis. In many cases in the rural areas of the region all the firewood or part of it is being collected by family members, making it rather difficult to fix a value for it, even excluding the cost of the damage caused by deforestation to the society which is much higher than the value of the fuelwood given above. The benefits of not using firewood in the farmer's view in the above example may thus vary between \$US 0 and 92/year. Consequently the benefit/cost ratio may accordingly vary between 0.77/1 and 2.6/1 depending on the ratio of firewood collected by family members to that purchased.

4. Case studies

Some comprehensive studies on biogas economics are being undertaken in the region. A survey of cost-benefit evaluation techniques as carried out in a developing ESCAP country is given in the next chapter, illustrative of their practical application in the context of a developing mixed economy, and of the methodological problems faced not only in a particular context but of general interest. It is hoped that more case studies will be available for other developing ESCAP countries, providing an expanding basis for interchange of knowledge and experience in this vital area.

VI. SCOPE FOR ECDC AND TCDC

Biogas technology has evolved as a mature technology in the developing countries largely as a result of their own efforts and under conditions obtaining in their rural areas. Hence there can be ample scope for fostering TCDC and ECDC activities among interested developing countries. Significant developments in biogas technology have taken place in developing ESCAP member countries, notably in China and India where its application has already become quite widespread. Considerable interest in it exists in Fiji, Indonesia, Nepal, the Republic of Korea, Pakistan, the Philippines and Thailand. A series of co-operative activities among developing countries can be envisaged and some illustrations are provided below.

There can be sharing of knowhow in areas such as biogas plant design, construction techniques, alternative construction materials, operation with different feedstocks and under different agro-climatic conditions, techniques for enhancement of gas production, and maintenance. This could be facilitated through:

- (a) Interchange of drawings, specifications, design details, technical and socio-economic reports and other relevant information;
- (b) Exchange of scientific and technical personnel;
- (c) Offer of consultancy services under concessional terms for adaptation of existing designs to suit individual country's skills and raw materials;
- (d) Mutual sharing of training facilities and training programmes.

Areas for mutual extension of technical assistance can include:

- (a) Strengthening planning and programming capabilities at various levels including socio-economic evaluation techniques of biogas systems;
- (b) Developing appropriate schemes for popularization of biogas programme;
- (c) Strengthening of local institutions responsible for implementation;
- (d) Developing appropriate financial institutions for administering loans, subsidies and other incentives.

Economic co-operation in this field can take place through grants for purchase of hardware such as biogas stoves, lighting mantles, biogas engines, biogas-operated tractors equipped with plastic bags (for storing biogas), valves and fittings, paints and others. There can also be promotion of trade in such hardware.

Joint ventures can be established among developing countries for production of prefabricated components for the construction of biogas plants, and for the manufacture of biogas stoves and other appliances such as space heaters, ovens, lighting mantles, plastic sheets and bags, repair and maintenance kits, small engines and other accessories.

There can be technical and economic assistance for setting up facilities for the testing, standardization and quality control of hardware/materials used for construction of biogas plants, for the measurement of the performance of gadgets for using biogas such as stoves, heating and lighting devices and engines, and for the study of fermentation kinetics, microbiological aspects etc. Biogas experimental stations can also be established through such co-operation.

In addition to regional workshops/seminars and other group meetings for interchange of knowledge and experience, joint research and development programmes either on a bilateral or multilateral basis can be developed. A regional network can be established of leading agencies, institutions and field-level organizations for exchange of experiences on plant operation with different feedstocks, maintenance problems etc. for collection and dissemination of information on scientific and technical developments and for facilitating exchange of technical personnel. Regional demonstration projects can be usefully evolved, involving village-level biogas plants supplying energy for cooking, lighting, agricultural pumping and agro-industries.

COST-BENEFIT ANALYSIS OF INDIAN BIOGAS SYSTEM: A CASE STUDY*

I. COST-BENEFIT ANALYSIS AND SOME EMPIRICAL RESULTS

A. USEFULNESS OF COST-BENEFIT ANALYSIS

In recent times there has been increasing emphasis in discussion among researchers of the development and expansion of not only commercial fossil fuel sources but also of new and renewable sources of energy such as solar energy, biogas, wind and tidal power, mini-hydro electric plants and power alcohol.

The use of biogas (popularly known as gobar gas in India) plants to generate methane gas from animal and plant wastes has been studied in India for over thirty years. The Government of India has been promoting biogas plants as alternative technology for energy supply in rural India through such measures as government subsidy and institutional credit. Until recently, the biogas technology being extended in India has been a simple KVIC (Khadi and Village Industries Commission) design named Gramalaxmi. To date about 70,000 small, family-size biogas plants, with a capacity range of 60-400 cu ft of gas per day, have been installed around the country. So far the very few large-size community plants installed have been for use in organized institutions. It is only recently that the Government of India has undertaken a programme to install large-size community plants in actual village situations on a pilot basis with a view to their popularization. During the last two to three years there have been attempts to popularize the fixed-dome biogas plant, popularly known as the "Janata" model.

The various studies made in India on the cost-benefit analysis of biogas plants are basically related to the small, family-size technology of KVIC design. Similar analysis of village-community plants as well as of Janata plants are constrained by a lack of adequate field data. However, even with the limited available data, some attempts are made to develop a framework of cost-benefit analysis of large-size community plants.

Broadly speaking, the cost-benefit analysis is an integral part of the process of project planning for decision-making over time. In essence, however, it examines the stage of feasibility in the project cycle limiting the alternatives to a few of the most promising ones. Thus, the cost-benefit analysis is an evaluation process for elimination in order to maximize the benefits by choosing the best alternatives for investment and minimize the incidence of unproductive and nonviable investments.

* Based on a study, prepared for this publication, by T.K. Moulik, Professor, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, Gujarat, India.

Theoretically, a project is identified during the planning process itself. In the planning exercise a set of output targets for various sector-wise commodities, such as, energy, can be projected over the next five-year period considering the expected rate of growth of the economy and the pattern of income distribution. With sectoral targets known, the investment plan is determined in relation to domestic production or imports. It is this sectoral target which forms the basis of project identification. However, a mere identification of a project does not help in making final investment decisions. There are always several alternatives in terms of choice of technology, location, size, foreign exchange requirement, allocation of skilled manpower and other resources and welfare effects etc., which need to be examined before a final decision for investment is made. Even when there is only a single version of a project, there are two implicit alternatives: to do or not to do the project. The cost-benefit analysis is one of the most commonly used methodologies to determine the economic and financial viabilities of various alternatives of a project.

In general, any developmental project assumes a complex nature, particularly, in resource-constrained developing countries. With the help of cost-benefit studies, a project's viability and efficiency with respect to the economy-wide use of resources can be conveniently established. The next stage in the project cycle in terms of final investment decisions, implementation of the project and monitoring can follow after the feasibility of the project is evaluated and established through cost-benefit analysis.

A caveat should be added here about the use of cost-benefit analysis as the sole criterion for investment decision. The cost-benefit analysis is basically an exercise in predicting outputs and inputs in quantitative terms, which are more often than not subject to margins of error due to various assumptions, the nature of data base and other unforeseen circumstances. Nevertheless, the cost-benefit analysis provides some useful messages for investment decisions. A high internal rate of return (IRR), for example, signifies a good investment. An IRR somewhat below but approaching the opportunity cost of capital deserves tolerance since there are several other secondary benefits of social importance that cannot be measured. Low and very low IRRs, however, may signal an ineffective project, wrong priorities and the possibility of non-viability.

B. APPROACH OF COST-BENEFIT ANALYSIS

The cost-benefit analysis as conventionally applied to appraise a project investment is basically concerned with calculating costs and benefits. The enumeration and quantification of costs and benefits, however, differ according to the point of view from which profitability is being considered. "Primary benefits and costs" refer to project outputs and inputs. "Secondary costs and benefits" are related to more efficient alternative uses of resources.

Financial, economic and social evaluation are the three basic aspects of project appraisal. While the financial analysis deals with the profitability of the project at market prices, economic analysis is concerned with the determination of a set of prices reflecting "efficiency" benefits to the nation, that is, an analysis at efficiency

prices. Social analysis refers to social profitability in terms of welfare implications, such as, equity and distribution of income. The basic parameter in all the three aspects of cost-benefit analysis is to work out actual flows of income and expenditure in order to determine the financial, economic and social rates of returns out of the project investment.

Operationally, the conventional cost-benefit analysis is broken down to a number of measures of investment performances, such as:

- (a) Financial cash flow or economic net benefit stream or social net benefit stream;
- (b) Net present value (NPV) or the discounted net benefits;
- (c) IRR;
- (d) The payback period or capital recovery;
- (e) The present value of capital or the benefit-cost ratio (PV/K).

C. APPLICATION

The performance measures in cost-benefit analysis, given above, are applied here to the small, family-size, KVIC-design biogas plants. The data for this analysis were obtained through a field survey of 173 small individual biogas plants of varying sizes distributed over four States of India, Madhya Pradesh, Uttar Pradesh, Haryana and Andhra Pradesh.¹

1. Analysis of costs

Following the usual tradition, the costs of biogas plants are broken down into investment and operating cost components. The investment (or capital) costs of a biogas unit cover capital expenditure items, such as, cost of land and compost pits, cost of civil construction of the digester well, and costs of gasholder, pipes and appliances. The operating costs of a biogas unit are divided into variable and fixed components, the former covering items like cost of cowdung used as major inputs, the cost of labour for dung collection and for operating the plant, and cost of water, while the latter includes the cost of painting, repairs and replacement of the component parts.

In calculating the cost streams of the sample biogas units, the KVIC estimates² are used with necessary modifications derived from field observations. In the KVIC estimates, the capital costs of a biogas unit cover only the cost of gasholder, the cost of civil construction and the cost of pipeline and appliances. All the three items of capital costs are derived through component-wise break-down. Since the land area required for biogas installation and for compost pit construction is small (e.g. only 342 sq ft of land area for a 60 cu ft plant), it is assumed that it would have insignificant alternative economic use and therefore its cost can be taken as zero. Similarly,

¹ T.K. Moulik, U.K. Srivastava and P.M. Shingi, *Biogas System in India: A Socio-Economic Evaluation* (Ahmedabad, Centre for Management in Agriculture, Indian Institute of Management, 1978).

² Khadi and Village Industries Commission, *Gobar Gas Plants: Why and How* (Bombay, KVIC, 1975).

Table 1. Capital costs of biogas plants (in Rs)

Plant size	Cost of gasholder	Cost of civil construction	Cost of pipeline and appliances	Total initial cost
60	932	1 143	256	2 331
100	1 207	1 478	331	3 016
150	1 344	1 646	370	3 360
200	1 670	2 055	450	4 175
250	1 920	2 352	528	4 800
300	2 000	2 450	550	5 000
500	3 400	4 165	935	8 500

the cost of compost pit construction is taken as zero assuming that the cost of cement and labour used for this purpose would be the same as in the case of the usual process of composting manure without a biogas unit.

The major components of the operating costs of biogas plants are: the costs of cowdung, the labour costs for collecting cowdung and for operating and maintaining the plant, and the repair and replacement costs of various components of the plant. Using the KVIC estimate of conversion ratio, 1.3 cu ft of gas to 1 kg of wet dung, the total annual requirement of wet dung for a biogas unit is estimated. The values of this wet dung are assessed on the basis of its use as farmyard manure (FYM). Taking the estimated price of FYM as Rs 40 per ton, the cost of dung is included into the cost stream. Since the villagers do not usually hire labour exclusively for biogas plant operation, it is difficult to calculate the labour cost for maintenance and operation. However, following the KVIC estimate, Rs 100 per annum is taken as the labour cost for maintenance and operation. The costs for repair and replacement are calculated on the basis of the following observations in the field:

(a) Biogas plants are usually painted to prevent corrosion and rust every second year. The average cost of paint for each size is taken into the cost stream.

(b) The gasholder is repaired every fifth year and finally replaced after eight years. Thus, the average life of a gasholder before it becomes corroded beyond repair is taken to be eight years as against the KVIC estimate of 10 years. Similarly, hosepipes are replaced every third year and the pipelines are repaired during the third year. The central guide-pin is replaced every third year and burners every fifth year. The market prices for the repair and replacement of the component parts are included in the cost stream of the economic life of the plants.

(c) The KVIC estimate of the economic life of the plants is 40 years. However, the economic life of digester, pipelines and appliances vary between 20

and 40 years. For the purpose of our analysis, the economic life of the plant is taken as 30 years.

The cost stream taking into account both capital costs and operating costs of various sizes of biogas plants over the economic life of 30 years is presented in table 2.

Table 2. The cost stream of varying plant sizes (in Rs/year)

Economic life	Size of plant in cu ft/day							
	60	100	150	200	250	300	350	500
0	2 332	3 016	3 360	4 175	4 800	5 000	6 100	8 500
1	368	487	648	850	1 018	1 188	1 375	1 861
2	268	381	521	662	802	942	1 083	1 504
3	401	517	668	839	993	1 148	1 312	1 766
4	272	385	525	666	806	946	1 087	1 508
5	447	564	714	885	1 040	1 195	1 359	1 812
6	494	607	748	888	1 028	1 168	1 309	1 730
7	322	438	589	760	914	1 069	1 233	1 687
8	268	381	521	662	802	942	1 083	1 504
9	1 334	1 724	2 012	2 509	2 913	3 148	3 752	5 166
10	297	410	550	691	831	971	1 112	1 533
11	461	577	727	899	1 053	1 208	1 372	1 825
12	351	464	604	745	885	1 025	1 166	1 587
13	427	542	693	865	1 019	1 174	1 338	1 791
14	268	381	521	662	802	942	1 083	1 504
15	427	542	693	865	1 018	1 173	1 337	1 791
16	415	528	668	809	949	1 089	1 230	1 651
17	1 251	1 641	1 929	2 426	2 830	3 065	3 669	5 083
18	351	464	604	745	885	1 025	1 166	1 587
19	322	438	589	760	914	1 069	1 233	1 687
20	293	406	546	687	827	967	1 100	1 529
21	791	764	915	1 086	1 240	1 395	1 559	2 013
22	272	385	525	666	806	946	1 087	1 508
23	318	434	585	756	910	1 065	1 229	1 683
24	351	464	604	745	885	1 025	1 166	1 687
25	1 280	1 670	1 958	2 455	2 859	3 094	3 698	5 112
26	411	524	664	805	945	1 085	1 226	1 647
27	401	517	668	839	993	1 148	1 312	1 766
28	272	385	525	666	806	946	1 087	1 508
29	318	434	585	756	910	1 065	1 229	1 682
30	268	381	521	662	802	942	1 083	1 504

2. Analysis of benefits

Quantification of the benefits of a biogas system is a crucial step in the cost-benefit analysis. It is equally a difficult process given the existing situations in villages in India. The two major outputs of the biogas unit, the biogas and digested manure, are not usually traded commodities in Indian villages and therefore no market prices are readily available. Hence, it becomes essential to find an alternative way to evaluate these two benefits. In addition, there are genuine problems of quantifications of various secondary or indirect benefits of the biogas system, just as in the case of various indirect costs. For the present, however, let us consider the benefits from a small, family-size plant in relation to two major outputs, biogas and manure.

The average rate of manure production from a biogas unit is an imputed figure from the average input-output data in KVIC research stations.

According to the KVIC estimate, the manure obtained through the biogas plant is about 45 per cent more than the quantity obtained from the compost pit. With this assumption, the total value of annual manure production through a biogas unit is calculated in monetary terms at the average price of manure per cartload (i.e. 0.5 ton) as observed in the survey area.

In the valuation of biogas, the first problem is the seasonal variation in the rate of gas production. Taking into account the seasonal variation, the total quantity of gas produced by a biogas unit is converted into firewood equivalent using the conversion factor as given by KVIC.³ Taking an average price of firewood as 20 paise per kilogram, as observed in some parts of the survey area, the estimated annual value of biogas from various sizes of plants are calculated.

Table 3. Seasonal variation in the rate of gas production

Seasons	Average rate of gas production (in percentage of plant capacity)
Summer (122 days)	100
Winter (120 days)	78
Monsoon (123 days)	86

It is now possible to present the estimated streams of benefits derived from the two major outputs of biogas plants.

³ The KVIC estimate is: 1 kg firewood = 3.474 m³ biogas.

Table 4. The benefit stream of varying plant sizes (in Rs/year)

Size of plant (in cu ft/day)	Value of gas (at Rs 0.20/kg of firewood equivalent of gas)	Value of manure	Total annual revenue (in Rs)
60	379.36	316.00	695.36
100	632.29	526.00	1 158.29
150	948.44	790.00	1 738.44
200	1 264.58	1 053.00	2 317.58
250	1 580.73	1 316.00	2 896.73
300	1 896.88	1 579.00	3 475.88
350	2 213.03	1 843.00	4 056.03
500	3 161.47	2 632.00	5 793.47

It should be pointed out here that in a large part of rural India, firewood is still obtained at zero private cost; the villagers do not purchase firewood and therefore there is no available market price for firewood in many villages. The price of 20 paise per kg of firewood used in the present analysis is, in fact, the observed average price of firewood prevailing in or around the survey areas, mostly in the nearby towns. Yet the social cost of indiscriminate cutting of firewood is certainly greater than the market price used in the analysis although many may not realize this. It may perhaps be more rational to use a varying level of prices of firewood starting from zero considering the private individuals' villager's point of view of investment decisions for biogas plants. The implication of the varying firewood prices on the benefit stream of biogas units is quite obvious.

3. Cash flow

Having worked out the inflow of income (benefit stream) and outflow of expenditure (cost stream), the financial cash flow stream of varying sizes of biogas plant can be analysed, taking the economic life of the plants as 30 years. The cash flow for 60 cu ft size plants is shown as an example.

4. Net present value (NPV)

Having established the financial or net economic flows, as shown in table 5 in relation to a 60 cu ft plant size, the problem now is to derive a present value by discounting all items in the net cash flow back to year 0. Denoting P_0 for the present value and P_1, P_2, \dots, P_t for the stream of payments accruing from years 1 to t , the general form of the discounting expression becomes:

$$NPV = \sum_{t=0}^T P_t (1+R)^t$$

Table 5. Cash flow for biogas plants of 60 cu ft (in Rs)

Year	Costs	Revenue	Cash flow
0	2 332	0	-2 332.00
1	368	695.36	327.36
2	268	695.36	427.36
3	401	695.36	294.36
4	272	695.36	423.36
5	447	695.36	248.36
6	494	695.36	201.36
7	322	695.36	373.36
8	268	695.36	427.36
9	1 334	695.36	-638.64
10	297	695.36	398.36
11	461	695.36	234.36
12	351	695.36	344.36
13	427	695.36	268.36
14	268	695.36	427.36
15	427	695.36	268.36
16	415	695.36	280.36
17	1 251	695.36	-555.64
18	351	695.36	344.36
19	322	695.36	373.36
20	293	695.36	402.36
21	791	695.36	-95.64
22	272	695.36	423.36
23	318	695.36	377.36
24	351	695.36	344.36
25	1 280	695.36	-584.64
26	411	695.36	284.36
27	401	695.36	294.36
28	272	695.36	423.36
29	318	695.36	377.36
30	268	695.36	427.36

What is important to remember here is that the use of a single discounting parameter, R , assumes that the time value of benefits falls at a constant rate, where R is an annual rate of interest. For financial analysis, the discount rate is normally the interest rate at which bank loans are available, that is, the opportunity cost. However, for the present analysis, three different discount rates, 10 per cent, 13 per cent and 15 per cent, are considered in view of the effect of likely inflation rates. It is assumed that the inflation rate is identical for costs and benefits.

The calculation of NPV at different discount rates can be shown by considering the cash flow stream for a 60 cu ft biogas plant.

Table 6. Discounted cash flow^a and NPV for 60 cu ft plant (in Rs.)

Year	Cash flow	Discounted cash flow (10 per cent)	Discounted cash flow (13 per cent)	Discounted cash flow (15 per cent)
0	-2 332.00	-2 332.00	-2 332.00	-2 332.00
1	327.36	297.57	289.71	284.80
2	427.36	352.99	334.62	323.08
3	294.36	221.06	203.99	193.69
4	423.36	289.15	259.52	242.16
5	248.36	154.23	134.86	123.43
6	201.36	113.57	96.65	86.99
7	373.36	191.53	158.68	140.38
8	427.36	199.58	160.69	139.75
9	-638.64	-270.78	-212.67	-181.37
10	398.36	153.77	117.52	98.39
11	234.36	82.03	61.17	50.39
12	344.36	109.85	79.55	64.40
13	268.36	77.82	54.75	43.74
14	427.36	112.40	77.35	60.26
15	268.36	64.14	42.94	33.01
16	280.36	61.12	39.53	30.00
17	-555.64	-110.02	-69.45	-51.67
18	344.36	61.98	38.22	27.89
19	373.36	61.23	36.59	26.13
20	402.36	59.95	35.00	24.54
21	-95.64	-12.91	-7.36	-5.07
22	423.36	52.07	28.79	19.47
23	377.36	42.26	22.64	15.09
24	344.36	35.12	18.25	12.05
25	-584.64	-53.79	-27.78	-17.54
26	284.36	23.89	11.94	7.39
27	291.36	22.37	10.89	6.77
28	423.36	29.21	13.97	8.47
29	377.36	23.77	10.94	6.41
30	427.36	24.36	11.11	6.41
NPV		137.52	-294.32	-512.56

^a The discounted cash flow at interest rates of 10, 13 and 15 per cent over 30 years are obtained by multiplying the cash flow figures in column 1 by the multipliers in any standard set of discount tables.

Following the above example, the NPV for different sizes of biogas plants are worked out at 10, 13 and 15 per cent discount rates as shown in table 7.

The NPV provides a very simple investment decision rule which is to "accept if $NPV > 0$ ". In other words, an investment in a biogas plant of particular size is deemed acceptable if the value of NPV is positive.

Table 7. Net present values of investment in plants of various sizes

Size of the plant (cu ft/day)	Discount rate (percentage)	NPV (without deducting subsidy from initial cost) (Rs)	NPV (20 per cent subsidy deducted from initial cost) (Rs)
60	10	137.64	524.20
	13	-299.40	105.95
	15	-512.50	-98.38
100	10	2 558.28	3 166.82
	13	1 497.38	2 103.96
	15	938.80	1 589.51
150	10	6 204.33	6 876.33
	13	4 332.35	5 004.35
	15	3 427.98	4 099.98
200	10	9 108.66	9 943.65
	13	6 488.71	5 004.35
	15	5 223.48	4 099.98
250	10	12 362.90	13 323.5
	13	8 960.89	9 921.29
	15	7 318.53	8 278.83
300	10	16 157.8	17 157.8
	13	11 939.2	12 939.2
	15	9 903.62	10 903.6
350	10	18 748.9	19 950.3
	13	13 796.8	15 000.6
	15	11 407.0	12 612.0
500	10	27 883.2	29 583.2
	13	20 621.4	22 321.4
	15	17 117.0	18 817.0

Considering the government subsidy towards the cost of biogas plant installation, the whole analysis is done into two ways:

(a) Economic analysis, in which the entire cost of the biogas plant is entered into the cost stream;

(b) The financial analysis in which the government subsidy of 20 per cent is deducted from the initial cost.

In terms of an investment decision, it is clear that except in the case of 60 cu ft plant, the NPV is positive for all other plant sizes at varying discount rate. For a 60 cu ft plant, the NPV is negative at 13 per cent and 15 per cent discount rates in the case of economic analysis (without subsidy) and at the 15 per cent discount rate in the case of financial analysis (with subsidy). Even at a 10 per cent discount rate, the

NPV for a 60 cu ft plant, even though positive, comparatively smaller than in the case of other plant sizes. It is also clear from the analysis that the value of NPV increases with the increase in size of the biogas plants. One more significant point from the policy point of view is the observation that both the economic and financial analyses (with and without subsidy) show a similar trend in NPV. That raises the question of the rationale for giving a subsidy, particularly for a flat rate of subsidy. Since the valuation of biogas is at firewood equivalent, it would be relevant to find out the opportunity cost of firewood at which the NPV turns positive indicating the financial viability of the investment.

The IRR value implies that if the investor perceives the opportunity cost of firewood below the break-even level, the investment in a biogas plant does not seem financially viable for him. Yet it is clear from table 8 that except for a 60 cu ft plant, the larger size plants remain viable at an opportunity cost of firewood less than the market price of 20 paise per kg. In fact, the required opportunity cost of firewood at which NPV turns positive decreases with the increase in the size of plants. Following the trend it was observed⁴ that a plant size of 3000 cu ft or above is viable even at zero opportunity cost of firewood at varying discount rates. If the perception of an investor about the opportunity cost of firewood is zero, as is most often the case in the rural areas, then a smaller size biogas plant does not seem to be viable for investment. It is on this basis that the case for a large-size, community plant and a subsidy for small family-size plants rest.

5. Internal rate of return (IRR)

Being a "pure number", IRR is widely used in project appraisal allowing projects of different size to be compared directly.

To define operationally, IRR is that discount rate at which NPV for a project is exactly zero. The decision rule corresponding to IRR is to accept the project if IRR is greater than the cost of capital ($R > C$).

Like NPV, IRR also shows a similar pattern in the sense that the values of IRR increase with the increase in plant size. Thus, even using IRR as criterion for making a decision for investment, the relatively larger plant sizes get preference over the smaller ones. Again, whether with or without considering the subsidy into the cost stream, the trend of IRR values remain the same except the fact that IRR with a subsidy (financial analysis) are greater in values than their corresponding values without a subsidy (economic analysis).

6. Capital recovery

One of the commonly used criteria for assessing the relative desirability of two or more projects is the payback period or the capital recovery criterion; the decision rule is to choose that project which recovers its capital costs in the shortest period.

⁴ T.K. Moulik, U.K. Srivastava and P.M. Singi, *op. cit.*

Table 8. Opportunity cost of firewood at which NPV turns positive

Plant size (cu ft)	Discount rate (percentage)	Opportunity cost of firewood (paise/kg)
60	10	20
	13	Not even at 20
	15	Not even at 20
100	10	12
	13	14
	15	16
150	10	7
	13	8
	15	9
200	10	5
	13	7
	15	8
250	10	4
	13	5
	15	6
300	10	3
	13	4
	15	5
350	10	3
	13	4
	15	5
500	10	3
	13	4
	15	5

Table 9. Internal rates of return (IRR) for plants of various sizes (in percentages)

Size of the plant (cu ft)	Economic analysis (without subsidy)	Financial analysis (with subsidy)
60	10.82	13.98
100	20.74	26.63
150	32.19	40.76
200	35.75	45.09
250	40.03	50.36
300	47.10	59.09
350	45.28	56.82
500	47.52	59.59

The calculation of the payback period of a project investment is normally done by dividing the capital cost by the cumulative sum of the undiscounted net cash flow. However, for the present analysis the discounted cash flow is used, which does not alter the ranking of the projects except that it leads to longer payback periods.

As table 10 indicates, the payback period also reveals a scale economy. This means that the capital recovery period is shorter as the size of the plant increases. The most interesting aspect is that the recovery period for a small, family size plant of 60 cu ft is too long to be recovered in the life of the plant, particularly at the discount rates of 13 per cent and 15 per cent in the case of economic analysis (without subsidy) and 15 per cent in the case of financial analysis (with subsidy). However, with the exclusion of subsidy into the cost-stream (financial analysis), the payback period reduces slightly.

Table 10. Payback period for biogas plants of varying sizes (in years)

Size of the plant (cu ft)	Discount rate (percentage)	Payback period (without subsidy)	Payback period (with subsidy)
60	10	23	13
	13	—	20
	15	—	—
100	10	7	5
	13	8	5
	15	8	6
150	10	4	3
	13	4	4
	15	5	4
200	10	4	3
	13	4	3
	15	4	3
250	10	3	3
	13	4	3
	15	4	3
300	10	3	2
	13	3	2
	15	3	3
350	10	3	2
	13	3	2
	15	3	3
500	10	3	2
	13	3	2
	15	3	3

7. Benefit-cost ratio (PV/K)

Another crude index of investment efficiency, popularly used by the economic planners is output-capital ratio, defined as the average (undiscounted) value-added produced per unit of capital expenditure. The PV/K or benefit-cost ratio is simply a discounting version of the above. The benefit-cost ratio compares the discounted net revenue stream with the discounted capital costs. Thus, the numerator (PV) does not include initial capital costs and may be taken as a gross rather than a net present value. The decision rule in this case is to accept the project if $PV/K > 1$. However, it must be noted that any project with a positive NPV will automatically have PV/K greater than unity. Hence, the criterion of benefit-cost ratio does not provide any extra information except that it may be additionally useful as a capital rationing device where the available public funds do not get exhausted at the discount rate used for planning purpose.

As expected, the PV/K ratios given in table 11 also confirm the scale economy for investment in biogas plants.

Table 11. Benefit-cost ratio of biogas plants of various sizes

Size of the plant (cu ft)	Rate of discount (Percentage)	PV/K
60	10	1.02
	13	0.94
	15	0.89
100	10	1.30
	13	1.20
	15	1.14
150	10	1.60
	13	1.49
	15	1.42
200	10	1.71
	13	1.59
	15	1.52
250	10	1.82
	13	1.70
	15	1.62
300	10	1.96
	13	1.83
	15	1.74
350	10	1.96
	13	1.83
	15	1.74
500	10	2.04
	13	1.90
	15	1.81

8. Sensitivity analysis

In the preceding section the measures of cost-benefit analysis, such as NPV, IRR and PV/K, are obtained under some specific valuation of some important parameters under certain assumptions. It is likely that the estimates of the key parameters used in the foregoing cost-benefit analysis will vary according to location, time-period, technological development and various other extraneous factors. Hence it is useful to analyse the effect of varying the key parameter values on the social profitability of a biogas unit.

It will be noted that the measures of cost-benefit analysis as presented above are calculated by varying the plant sizes and depreciation rates. However, in order to provide a more realistic basis for making an investment decision, the results of varying other key parameter values need to be examined to take account not only of differential impacts of optimistic and conservative assumptions, but also of the likely impact of the ongoing research and development efforts. To illustrate, an earlier study⁵ carried out its analysis by valuing biogas at the market price of kerosene equivalent (instead of firewood equivalent as used in the present case) and using separately the KVIC estimates and observed sample estimates. The results of the analysis are shown in tables 12, 13 and 14.

It is interesting to note that the results obtained with kerosene equivalent valuation of biogas are similar to those obtained with firewood equivalent price used in the present case. However, there are some differences in the results obtained with KVIC data and the sample data. With the KVIC data, the payback period for various sizes of biogas units, for example, is shorter than those estimated with the sample data. Similarly, NPVs are smaller with the sample data as compared to those estimated with the KVIC data. Thus, the results indicate clearly the optimistic estimates of KVIC as compared to those obtained in the field situations.

One of the most crucially important sensitivity analyses should be in relation to the capital costs of biogas technology. There is considerable research and development effort going on to reduce the capital costs of biogas technology. The use of ferro-cement or polythene bag instead of mild steel for gasholder has direct effect on capital costs of the plants. Similarly, the use of fixed-dome Chinese-type Janata plant has direct bearing on the capital cost structure of biogas plants. By replacing the movable steel gasholder of the KVIC model by the fixed dome of brick and cement, the Janata model of biogas plant is reported to reduce the costs (both capital and maintenance costs) by as much as 20 to 40 per cent. The effect of this cost reduction on the results of cost-benefit analysis is quite apparent. Bhatia⁶ carried out a sensitivity analysis under two assumptions: 20 per cent and 30 per cent reduction of capital costs of biogas units. Bhatia observed that, "even if capital costs were reduced by 30 per cent, investment in a biogas unit would continue to be socially unprofitable if gas is mainly

⁵ T.K. Moulik and U.K. Srivastava, *Biogas Plants at the Village Level: Problems and Prospects in Gujarat* (Ahmedabad, Indian Institute of Management, 1975).

⁶ Ramesh Bhatia, "Economic appraisal of biogas units in India: framework for social benefit cost analysis", *Economic and Political Weekly* (Bombay), vol. XII, Nos. 33-34, August 1977.

Table 12. Payback period and net present value of investment in plants of various sizes

Size of the plant (cu ft)	Discount rate (percentage)	Economic analysis						Financial analysis					
		Using KVIC data			Using sample data			Using KVIC estimates with 25 per cent subsidy on initial cost			Using sample data with 25 per cent subsidy on initial cost		
		payback period (years)	Net present value (Rs)	payback period (years)	Net present value (Rs)	payback period (years)	Net present value (Rs)	payback period (years)	Net present value (Rs)	payback period (years)	Net present value (Rs)	payback period (years)	Net present value (Rs)
60	10	9	1 402.97	13	628.12	6	1 985.97	7	1 211.13	6	1 985.97	7	1 211.13
	13	10	638.35	23	77.24	7	1 221.35	8	660.24	7	1 221.35	8	660.24
	15	16	280.39	-	-190.72	7	863.40	12	392.28	7	863.40	12	392.28
100	10	5	4 406.55	6	2 788.45	4	5 160.56	5	3 542.45	4	5 160.56	5	3 542.45
	13	6	2 850.56	7	1 671.74	4	3 604.56	5	2 425.74	4	3 604.56	5	2 425.74
	15	6	2 125.13	8	1 130.58	4	2 879.13	5	1 884.58	4	2 879.13	5	1 884.58
150	10	4	8 695.68	4	6 638.47	3	9 535.67	3	7 478.47	3	9 535.67	3	7 478.47
	13	4	6 131.29	4	4 670.14	3	6 971.29	3	5 510.14	3	6 971.29	3	5 510.14
	15	4	4 938.56	5	3 718.63	3	5 778.56	3	4 558.62	3	5 778.56	3	4 558.62
200	10	3	12 203.60	4	9 857.84	3	13 247.60	3	10 901.80	3	13 247.60	3	10 901.80
	13	4	8 708.47	4	7 080.35	3	9 752.47	3	8 124.36	3	9 752.47	3	8 124.36
	15	4	7 083.59	4	5 738.39	3	8 127.59	3	6 781.39	3	8 127.59	3	6 781.39
250	10	3	16 074.70	3	12 651.50	2	17 274.70	3	13 851.50	2	17 274.70	3	13 851.50
	13	3	11 608.20	4	9 187.92	2	12 808.20	3	10 387.90	2	12 808.20	3	10 387.90
	15	3	9 532.64	4	7 514.95	3	10 732.60	3	8 714.95	3	10 732.60	3	8 714.95
300	10	3	20 541.90	3	12 651.50	2	17 274.70	3	13 851.50	2	17 274.70	3	13 851.50
	13	3	15 055.20	3	13 394.10	2	16 305.30	2	14 644.10	2	16 305.30	2	14 644.10
	15	3	12 507.20	3	11 176.50	2	13 757.20	2	12 426.50	2	13 757.20	2	12 426.50
350	10	3	23 781.40	3	18 978.48	2	25 306.40	2	20 503.40	2	25 306.40	2	20 503.40
	13	3	17 368.80	3	13 981.20	2	18 893.80	2	15 506.20	2	18 893.80	2	15 506.20
	15	3	14 390.30	3	11 568.40	2	15 915.30	3	13 093.40	2	15 915.30	3	13 093.40
500	10	3	35 002.90	3	31 535.00	2	37 127.90	2	33 660.00	2	37 127.90	2	33 660.00
	13	3	25 661.20	3	23 530.50	2	27 786.20	2	25 655.50	2	27 786.20	2	25 655.50
	15	3	21 322.80	3	19 667.30	2	23 447.80	2	21 792.30	2	23 447.80	2	21 792.30

Table 13. Internal rate of return on investment for plants of various sizes

Size of the plant (cu ft)	Economic analysis		Financial analysis (in percentage)	
	Using KVIC estimates	Using sample data	Using KVIC estimates (with 25 per cent subsidy on initial cost)	Using sample data (with 25 per cent subsidy on initial cost)
60	19.99	13.53	23.53	19.04
100	26.39	21.45	35.57	29.35
150	38.23	33.34	51.15	44.95
200	41.65	37.53	55.63	50.44
250	46.04	40.53	61.43	54.38
300	53.80	50.90	71.67	68.04
350	51.66	45.66	68.85	61.12
500	53.97	52.15	71.93	69.71

Table 14. Benefit-cost ratio of plants of various sizes

Size of the plant (cu ft)	Rate of discount (percentage)	Using KVIC data	Using sample data
60	10	1.23	1.10
	13	1.12	1.01
	15	1.05	0.96
100	10	1.55	1.34
	13	1.42	1.24
	15	1.32	1.17
150	10	1.87	1.66
	13	1.73	1.54
	15	1.64	1.47
200	10	1.97	1.78
	13	1.82	1.65
	15	1.72	1.57
250	10	2.07	1.84
	13	1.92	1.71
	15	1.82	1.63
300	10	2.23	2.07
	13	2.07	1.94
	15	1.98	1.86
350	10	2.21	1.96
	13	2.05	1.83
	15	1.95	1.75
500	10	2.29	2.16
	13	2.12	2.02
	15	2.02	1.93

Table 15. Comparative estimated costs of biogas plants (in Rs)

Size of plant (cu fit)	KVIC model	Janata model
60	2 332.00	1 650.00
100	3 016.00	2 250.00
150	3 360.00	2 910.00
200	4 175.00	3 760.00

Source: K.C. Kandelwal, *Janata Gobar Gas Plant* (New Delhi, Directorate of Extension, Ministry of Agriculture and Irrigation).

consumed for cooking purposes. Thus, in areas where electricity is already available for lighting, there is no case for providing subsidy for investment in biogas unit.”

Bhatia⁷ also did a sensitivity analysis using the varying delivered costs of soft coke and the calorific values of biogas and soft coke in determining the profitability of biogas units. Similarly, Susan Deo⁸ used varying efficiency rates of gas production with the assumption of modification of the technology in the sensitivity analysis of biogas plants. All these exercises indicate the necessity to do sensitivity analysis with varying estimates of key parameters in order to arrive at a relevant and practical criterion for decision making. Such analysis assumes a critical role not merely in relation to the estimated values of required inputs (costs) but also, and perhaps more importantly, the estimated values of outputs (benefits). The results of such analysis may change drastically in favour of investments if and when reliable estimates of some of the secondary or indirect benefits could be imputed to the benefit streams.

9. Janata plants

As mentioned earlier, there are currently two common types of biogas plants which are being popularized in India – the KVIC model and the Janata model. The Janata plant is a drumless (no steel gasholder), fixed-dome, closed-type biogas unit made entirely of brick and mortar, similar to those being used in China. The cost difference between the KVIC and Janata models is quite substantial. Since the Janata model does not require the steel gasholder the KVIC model does, the former is about 40 per cent cheaper than the latter (see table 15). It is also interesting and equally important to note that since 1978, the cost of constructing the KVIC model plant has gone up by as much as 20 per cent as against 10 per cent in the case of the Janata model.

The advantages of a reduction in the construction cost of a biogas plant as happens in the case of the Janata model are obvious for a third world country like India. Considering the cost factor alone, the Janata model may be more suitable to

⁷ Ramesh Bhatia, *loc. cit.*

⁸ Susan Ruth Rothrock Deo, “An economic analysis of biogas technology for a hypothetical village in rural India” (M.Sc. Thesis, University of Illinois, Urbana, 1980).

the large masses of the economically weaker sections for whom the KVIC model plant is mostly beyond reach. Considering the cost factor, the Government of India has been making special efforts since 1979 to popularize the Janata plants through the Ministry of Agriculture and Irrigation, New Delhi, and the Planning Research and Action Division, Uttar Pradesh.⁹ In fact, it is hoped that about 50 per cent of Indian farmers will opt for the KVIC model, while the rest of the farmers will opt for the Janata model. In Uttar Pradesh alone already 7000 such plants have been set up.

In a recent study done for the Ministry of Agriculture, Government of India, the Agricultural Finance Corporation, Bombay, compared the economic and financial viability of the KVIC and PRAD (Janata) models.¹⁰ It was found in the study that the 2 cu m and 3 cu m plants of KVIC models were not economical, while the 3 cu m plant of PRAD design (Janata model) was economically feasible. On account of cost reduction, the benefit cost ratios were found to be comparatively higher in the case of Janata plants than the benefit cost ratios of the KVIC models. The results as shown in table 16 clearly indicate that the financing of 2 cu m biogas plants would be uneconomical irrespective of models. In respect of a 3 cu m plant, the KVIC model would become financially feasible only at a 4 per cent rate of interest and with a subsidy of 50 per cent of the cost. It was also observed that the benefit cost ratios increased with the increase in size of the plants irrespective of the models. The study, however, concluded that under the existing subsidy the biogas plants of both KVIC and PRAD (Janata) models would be economical.

Table 16. Benefit-cost ratio, KVIC and Janata models (by size)

Model	Beneficiary group	(size in cu m) Benefit-cost ratio			
		2	3	4	6
KVIC	(a) General (at 11 per cent rate of interest)	0.70	0.98	1.15	1.35
	(b) Weaker section (at 4 per cent rate of interest)	0.74	1.03	1.22	1.43
Janata	(a) General (at 11 per cent rate of interest)	0.88	1.25	1.42	1.60
	(b) Weaker section (at 4 per cent rate of interest)	0.94	1.35	1.53	1.70

Some mention about the technical problems of the Janata plants must be mentioned here. First, considering the design and the building materials used, the economic life of the Janata plant is very likely to be shorter than the conventional KVIC model. In the absence of any reliable data and based on field observation, the economic life of a Janata plant can be assumed to be not more than 15 years as compared to 30-40 years in the case of KVIC plants. Secondly, it has been generally observed under field conditions that the rate of gas production fluctuates more widely between summer and winter months in the Janata plant than in the KVIC plant. Again,

⁹ In this connexion, see *Janata Biogas Model 1 Nirman Pusti Ka* (Lucknow, Uttar Pradesh, Planning Research and Action Division (PRAD), 1978) and P.B. Ghate and K.K. Singh, *Action Research in Biogas Development* (Lucknow, PRAD, 1978).

¹⁰ Agricultural Finance Corporation, *A Draft Note on National Biogas Project (1980-85)* (Bombay, September 1980).

there are no established scientific data to confirm or reject this impression. Lastly, and perhaps more serious, is the complaint usually made against the Janata plant that its gas yield is about 30 to 40 per cent lower than is the case with the KVIC model. Whether or not the lower yield is a scientifically established fact, it is a fact that the Janata plant suffers more from the leakages as compared to the KVIC model. Of late, there have been some successful experiments in tackling the leakage problem in biogas plants (both for KVIC and Janata models) by using a specially formulated paint.

However, in a few years time many of the technical problems of Janata plants will likely have been verified and scientifically established under varying field conditions in India. Meanwhile, the Government of India, the Ministry of Agriculture and PRAD in particular, have worked out plans to promote Janata plants on the same scale as the conventional KVIC units simply because of cost considerations.

10. Summary analysis

To recapitulate, the results to the cost-benefit analysis as presented above indicates that biogas units of higher than 60 cu ft. size were viable and there were scale-economies. In the economic analysis, the payback period for the 60 cu ft plant is found to be 23 years at 10 per cent, but at 13 and 15 per cent rate of discount, payback is not achieved during the life of the plant. In the financial analysis, at 10 per cent the payback is 13 years while at 15 per cent payback is not obtained during the life of the plant. The economic analysis shows a range of net present values from Rs 299.40 (for a 60 cu ft plant at 13 per cent) to Rs 27,883.20 (for a 500 cu ft plant at 10 per cent). The internal rates of return range from 10.82 per cent (for a 60 cu ft plant) to 47.52 per cent (for a 500 cu ft plant).

The corresponding range of values of NPV and IRR in the financial analysis are Rs 98.38 (for a 60 cu ft plant at 15 per cent) to Rs 29,583.20 (for a 500 cu ft plant at 10 per cent), and 13.98 per cent (for a 60 cu ft plant) to 59.59 per cent (for a 500 cu ft plant) respectively. The results are similar to those obtained when biogas is valued at kerosene equivalent market price.

It is also observed in the analysis that if the price of firewood (biogas was valued in firewood equivalent) is less than 20 paise per kg, even some of the larger biogas plants become less viable. At a 13 per cent discount rate, for example, the price of firewood has to be 14 paise per kg for the 100 cu ft plant to remain viable, while the 500 cu ft plant requires a price of only 3 paise per kg. Thus, the bigger sizes of plants can withstand quite low prices of firewood and still maintain their economic viability. From these results, it can be concluded that the small, family-size plants can be promoted only with massive subsidy, while the large-size, community plants can be a worthwhile viable investment even without subsidy, ignoring the problems of organization.

In its methodological approach and assumptions, the present analysis is to some extent different from many other studies made on the economic aspects of biogas units in India. The present analysis is largely at micro level in the sense that the costs and benefit streams are estimated from the point of view of individual private villagers.

Hardly any attempt has been made to concern itself with macro level societal or national considerations except that a subtle difference has been made between economic and financial analysis in relation to government subsidy. The economic analysis in the present study, by including the subsidy amount in the cost stream, also has covered part of the costs and benefits accruing to society or nation at large. However, financial analysis has been done mainly from the point of view of the villagers and only the cash inflows and outflows accruing to the villagers have been considered, the subsidy being treated as a reduction in cost. Even if such distinctions between economic and financial analysis, as in the study, are not conceptually and methodologically rigorous, the study has attempted to take into account a significant fact of life in terms of government policy concerning the subsidy.

At the same microlevel, the present analysis also differs from many other studies in three important aspects. First, all the costs and benefits of biogas plants have been estimated in relation to domestic market price rather than the "shadow price" or the foreign exchange equivalent price. Secondly, the present study deliberately used firewood equivalent and kerosene equivalent prices of biogas for the simple reason that these two are the most likely alternative fuels in rural India; alternatives in the form of electricity, soft-coke and other commercial fuel have been thus neglected. Lastly, the present analysis has been done by considering only one kind of functional use of biogas, that is, cooking or heating for which the dungcake and firewood are reported to be the most commonly used fuel in rural India. Hence the use of biogas for cooking or heating could save cowdung and firewood for better alternative uses and other social benefits, such as prevention of deforestation, provision of sanitation, and soil improvement through increased use of dung manure.

The methodological approach as followed in the present analysis has both advantages and limitations. How some of these limitations could be overcome have been referred to in the other cost-benefit studies of biogas systems. For the present, however, it would be interesting to compare the findings of the present study with some important similar studies on biogas systems in India.

One of the first detailed cost-benefit analyses was done by Parikh.¹¹ He evaluated the costs and benefits accruing to the national economy. The benefits were measured in terms of increase in foodgrain yield due to the use of digested manure and firewood saved. The value of the biogas was determined in relation to diesel and gasoline. Parikh also used costs of six different village situations: the 60 cu ft size with 50 plants at one plant per family; 10 plants at one plant for 5 families and 20 plants at one plant for 5 families; two 2500 cu ft plants for 50 families; one 1000 cu ft plant for 50 families and one 2000 cu ft plant for 100 families. As in the present study, Parikh also found that the larger size plants were less expensive. In another study, Parikh¹² observed that for a private owner of a biogas unit, it yielded "a gross return of 14 to 18 per cent purely in financial terms." His analysis showed that, with an

¹¹ K.S. Parikh, "Benefit cost analysis of biogas plants in India", (Ph.D. thesis, Massachusetts Institute of Technology, January 1963).

¹² K.S. Parikh, *Second India Studies: Energy* (New Delhi, MacMillan, 1976).

investment of Rs 2000 on a 2 cu m plant, the annual saving due to a biogas plant over the alternative of burning dung as cakes was Rs 298. The corresponding saving was Rs 364 when the alternative was the use of the entire dung for composting. However, it should be noted that the results of Parikh's studies were highly dependent on assumptions regarding the increase in the nitrogen-content in digested manure and the price of dung cake.

Prasad, Prasad and Reddy¹³ compared the costs and benefits of biogas plants with that of rural electrification in order to meet the energy demands for cooking, irrigation pumping, industries and lighting. They estimated that a 5000 cu ft plant with a capital cost of Rs 41,000 excluding cost of pipelines, compressors etc., would have an annual cost of Rs 12,206 and an annual benefit of Rs 19,160 from the use of 4450 cu ft gas per day and they also estimated indirect benefits in terms of 22 tons of additional foodgrains due to the use of digested manure, foreign exchange saving on 2 tons of naphtha, saving of 0.4 acres of forest per year and improvement in sanitation and health.

The results of the cost-benefit analysis as presented in an ICAR study¹⁴ were overwhelmingly positive in favour of investment in biogas plants. Ascribing cash value to dung fuel, manure and cowdung, the ICAR study found the NPVs, in all the 18 cases under consideration, positive for all sizes of biogas unit. The report also analysed the private cost-benefit of a biogas unit from the farmer's point of view, in which the additional comforts and the saving of fuel costs from the use of gas were non-monetized. The study concluded that, "from the individual farmers's point of view also, the cowdung gas plant is an economically viable proposition."

Sirohi¹⁵ one of the authors of the ICAR report, further extended the analysis to observe that the commercial benefit-cost ratio (at 10 per cent rate of interest) for a 70 cu ft plant was estimated to be 1.388 for North India and 1.504 for South India. However, considering the partly monetized benefit cost ratio, he concluded "that the monetized benefits of the gobar gas plant are not sufficient to cover the cost of gobar gas plant in the longrun."

Sanghi and Day¹⁶ did a cost-benefit analysis by separately evaluating benefits in terms of coal and electricity (both subsidized and non-subsidized). They concluded that "the monetary benefits do not outweigh the cost incurred by an individual household that constructs a 100 cu ft plant." However, they were emphatic to mention that if all the indirect social benefits could be quantified and taken into account, benefits would outweigh costs.

¹³ C.R. Prasad, K.K. Prasad and A.K.N. Reddy, "Biogas plants: prospects, problems and tasks", *Economic and Political Weekly*, vol. IX, Nos. 32-34, August 1974.

¹⁴ Indian Council of Agricultural Research, *The Economics of Cowdung Gas Plants: A Report* (Delhi, ICAR, 1976).

¹⁵ A.S. Sirohi, "Economics of gobar gas plant", *National Symposium on Biogas Technology and Usage*, Delhi, November 1977.

¹⁶ A.K. Sanghi and Dekle Day, "A cost-benefit of biogas production in rural India: some policy issues", in N. Lock Heretz (ed), *Proceedings of the Conference on Energy and Agriculture* (New York, Academic Press, 1977).

Bhavani¹⁷ published a detailed social cost-benefit study of the small 2 cu m plant. She listed the outputs of fuel and manure as benefits and the capital and operating (including the opportunity cost of dung in terms of nutrient content of FYM) as costs. Biogas was valued in terms of soft-coke. An important point made in this study was that the results of such analysis were contingent on the previous uses of the raw materials. Bhavani analysed three alternatives for previous use of dung: one third fuel and two thirds manure, all manure and all fuel. The results of the analysis indicated that if any of the dung was used previously for fuel the use of a biogas plant was cost-effective. Yet, if all the dung was used previously for manure the benefit-cost ratios were found to be lower than with other alternatives.

Bhatia¹⁸ made a significant contribution in the cost-benefit analysis of biogas plants in India by providing an outline of the range of costs and benefits to be considered and how they should or should not be included in an analysis. He also provided an illustration of how different uses of the products from biogas plants could vary in value. In his analysis, Bhatia reviewed a long list of primary and secondary benefits and direct and indirect costs of installing small biogas plants. He assumed 20 years plant's life and valued gas for lighting as kerosene equivalent and for cooking as soft-coke equivalent. He chose two cases for the value of manure: the same nutrient content as compost and a value greater than compost. With all these estimates, Bhatia found that the benefit-cost ratios for a 70 cu ft plant at a social rate of discount of 10 per cent were less than 1. At a reduction of 30 per cent in investment cost this became 1.33 for the case where additional value of manure was assumed and 20 cu ft gas used for lighting and the remaining 50 cu ft used for cooking. Bhatia made two significant observations in his analysis. He concluded, for example, that the investment in a biogas unit would "continue to be socially unprofitable if gas is mainly consumed for cooking purposes." Secondly, on the basis of some specific assumptions he also found that the investment in a biogas unit to run an irrigation pump was not economic from the point of view of the society. However, he concluded that the profitability of biogas units could improve if gas was utilized both for cooking as well as for powering other machines.

Ghate¹⁹ analysed the advantages of large-size, community biogas plants over smaller, family-size plants. Based on the ongoing experimental data on two pilot large, community-size plants (35 cu m and 45 cu m) in Uttar Pradesh, Ghate observed that "biogas based energy system is socially profitable when credit is taken for uses other than cooking and lighting." Following Bhatia, Ghate valued biogas as soft-coke equivalent for cooking and kerosene or electricity equivalent for lighting, i.e. without considering any credit for the manurial value. It turned out in the analysis that the direct gas lighting alternative was socially more profitable than the use of a generator. He, how-

17 S. Bhavani, "Biogas for fuel and fertilizer in rural India: a social benefit cost analysis", *Indian Journal of Agricultural Economics*, vol. 31, July-September 1976.

18 Ramesh Bhatia, *loc. cit.*

19 P.B. Ghate, "Biogas: a decentralized energy system: a pilot investigation project", *Economic and Political Weekly (Bombay)*, vol. XIV, No. 27, July 1979.

ever, rightly cautioned about the unreliability of the assumptions for much of the data used in the analysis.

In her recent study, Susan Deo²⁰ observed that the costs and benefits of community biogas plants were more consistently favourable than those of individual plants. Economies of size were substantial. She concluded that, "if the societal benefits, including improved health, less strain on dwindling forest resources and increased local and national energy self-sufficiency, were also incorporated the value of benefits might surpass costs in even the more questionable cases."

In two recent studies by Dandekar²¹ and Kelkar, Malhans and Sanghera,²² several social economic and cultural problems were evaluated in relation to popularization of biogas plants in rural India, with special reference to the fixed-dome Janata plant. These two studies were important in the sense that they gave insight into the socio-cultural factors that contributed to non-adoption of biogas plants at the village level.

A comparative review of the above mentioned studies *via-a-vis* the cost benefit analysis presented here clearly indicates that the profitability of biogas plants was crucially dependent on the various assumption of estimates of costs and benefits. However, all these studies seemed to confirm that inspite of various bottlenecks and substantial room for technical improvements, the investment in biogas plants even at the present level of technology was largely viable and attractive.

II. SOME METHODOLOGICAL PROBLEMS

Some basic conceptual as well as theoretical problems arise in the application of conventional cost-benefit analysis to renewable sources of energy like biogas systems, as is evident from the empirical analysis above. In comparison, many of these problems are either non-existent or are easier to solve in the case of alternative conventional non-renewable sources of energy, such as electricity generation and petroleum oil production.

Basically, the problems arise as the cost-benefit analysis is based on limited information to make predictions about the future. Any energy project and for that matter any project, involves one or more outputs and a whole series of inputs. Hence, the result of a cost-benefit analysis of a project is entirely dependent on the accuracy of a stream of calculations based on projected physical quantities and prices. It is unwise to rely excessively on the reasoning that overestimates in one place will be balanced by underestimates in another. For, there are variations in the importance of some variables in influencing the ultimate results. This means that the result of cost-

²⁰ Susan Ruth Rothrock deo, *op. cit.*

²¹ H. Dandekar, "Gobar gas plants: how appropriate are they", *Economic and Political Weekly* (Bombay), vol. XV, No. 20, May 1980.

²² G. Kelkar, N. Malhans and J. Sanghera, "Showpiece of Saidqपुरa". *Economic and Political Weekly* (Bombay), vol. 16, No. 9, February 1981.

benefit analysis is limited to the extent of reliability of available information, particularly about the key variables. While working on cost-benefit analysis of a project on renewable energy sources like biogas plants, one feels more constrained with the problems of accurate measurements of inputs and output than in the case of a project on non-renewable conventional energy sources like, say, thermal power stations. Comparatively speaking the problems of measurement of cost and revenue streams are of lesser magnitude in the case of conventional non-renewable energy sources simply because of the long tradition of experience in this sector providing a reliable basis of past trends under varying regional conditions and the far more advanced technological development aiding in reliable quantification of data based on technical judgement.

A. TECHNOLOGICAL DATA GAP

As noted earlier, many crucial technical data about the operation of biogas systems are yet to be standardized beyond any doubt. To illustrate, no clear scientific results are confirmed yet about the quality and quantity of digested manure from biogas systems as compared with compost or farm-yard-manure (FYM). It is claimed by KVIC²³ and ICAR²⁴ that the "manure obtained from a gas plant is about 45 per cent more in quantity" and contains "nearly twice as much N as compared with FYM per unit weight of dry matter." These claims have been equally forcefully contested: Sanghi and Day,²⁵ for example, have referred to the results of tests reported by Hart, which clearly indicates that the total nitrogen content of the dung does not change during digestion, even though there is a qualitative change in nitrogen.

The quality and rate of production of both digested manure and gas are affected significantly by various factors, such as, the composition of feeding materials used and its quality, the weather and temperature. Although ICAR and KVIC provide some average estimates, they do not take into account the wide-ranging situational variations.

As a result, any calculations done on the basis of the above mentioned available estimates remain merely a "second best" assumption in the absence of accurate and properly quantified scientific information.

As compared to the biogas system, the technical data on inputs and outputs of non-renewable energy sources are fairly standardized technologically. Also they are not affected by varieties of largely uncontrollable extraneous factors as is the case of renewable sources of energy. Hence, to the extent the data on non-renewable sources of energy are technologically standardized with less margin of variations, its cost-benefit analysis is easier for predicting more reliable results.

²³ Khadi and Village Industries Commission, *op. cit.*

²⁴ Indian Council of Agricultural Research, *op. cit.*

²⁵ A.K. Sanghi and Dekle Day, *op. cit.*

B. ECONOMIC LIFE

A problem which often causes concern is the question of how to calculate the economic life of a project, particularly in relation to renewable energy projects due to lack of data under varying conditions. Although KVIC claims the economic life of a biogas plant is of the order of 40 years, the field observations of various researchers (e.g. Moulik and Bhatia) differ. The same is true concerning the timing of repair and the replacement of various components of the biogas plant. This variation has a definite bearing on the results of any economic and financial analysis.

A project on non-renewable energy sources is usually made up of sophisticated engineering machinery, high value capital items. The economic life is simply determined at a point when borrowing money to replace it is cheaper than repairing it. As the sophisticated engineering machinery is widely used all over the world, there are sufficient data available to determine the point at which it becomes cheaper to replace equipment. However, even in this case the calculation of the economic life is becoming increasingly difficult because of the obsolescence of the old technologies by rapid technological change.

C. DECENTRALIZED VERSUS CENTRALIZED SYSTEM

Unlike the non-renewable energy sources (e.g. thermal power), which are basically a centralized operational units, the renewable sources of energy (e.g. biogas plants) are operated, by and large, at a decentralized level. Thus, assuming that there is no bottleneck on the supply side of the inputs, it is easy to estimate on the basis of technical and cost information, the input-output parameters of a non-renewable source of energy and its capacity in a fairly controlled manner. In the case of, say, a biogas plant owned by a villager, the input-output parameters will depend largely on the kinds of food eaten by his animals and their age, size and general health; whether latrines are connected with the plant; whether agricultural waste is used; the handling practices of collection of feed-stock of digesters and biogas slurry; and lastly the operating conditions and practices followed by the owner of the biogas plant. Since it is difficult to predict accurately the supply-response factors in such uncontrolled decentralized operations, the input-output parameters are usually estimated at the ideal experimental conditions, which most often are far away from the actual field situations.

Thus, for a renewable energy source like a biogas unit, the results of cost-benefit analysis tend to be more based on controlled ideal conditions than those that can be obtained in the real field situations.

D. PRICING

Like the quantification of physical input and output, the quantification of prices needs to be based on accurate prediction in order to work out a realistic cost-benefit analysis of a project. It is on this question of pricing, that those concerned with renewable energy sources face the most crucial and major problems. Interestingly, by its very technological nature, the problem of pricing in the case of non-renewable sources

of energy is relatively more difficult for both inputs and outputs. There are various seemingly insurmountable issues.

In doing financial analysis, for example, which is mainly concerned with the profitability of a project at market prices, one will take into account domestic market prices. There are two broad questions to be resolved in relation to the domestic market prices. First, whether the project itself is likely to have an impact on prices and if so, how does one take it into account. Secondly, there are likely to be price movements in the future under the influence of various extraneous factors. This is a question of price forecasting, in which the problem of inflation is one aspect since one would like to know how prices of inputs and outputs are likely to change relative to each other in relation to some base year.

In the case of economic analysis, one is concerned with that set of prices which best reflects "net efficiency" benefits to the nation. In a broader sense, the "efficiency" measure of a project output is related to the question of its contribution (actual or potential) to foreign exchange earnings (import or export). Likewise, the opportunity cost of any project input is concerned with its contribution to or claim on foreign exchange. In other words, for economic analysis, the world price rather than the domestic market price becomes relevant.

Within this broad framework of price-related issues, the most immediate and crucial problem with the cost-benefit analysis of renewable energy sources like a biogas system (in relation to both production and use) is the fact that in a large part of the rural areas in a country like India, there are no organized and stable markets for the major inputs (animal and plant waste) or outputs (biogas and digested manure). In other words, this is a typical problem of non-traded items, which also includes labour, particularly, unskilled labour. As mentioned earlier, in most Indian rural areas the inputs and outputs of a biogas plant, cowdung, plant waste, manure and cooking fuel, are obtained at zero private cost. Thus the perceived opportunity cost of these inputs and outputs for an Indian villager may be zero, while from the nation's point of view it could be substantial depending upon the way in which they are considered, such as, saving of commercial energy, of plant nutrients, of forests and also of foreign exchange.

Almost the same question arises about the valuation of the unskilled labour which again in the labour-surplus situation of Indian villages has zero opportunity cost. Yet, in principle, the economic cost of employing labour in the cost-benefit analysis is most often taken as the foreign exchange equivalent of labour consumption.

In short, the problem of pricing inputs and outputs in the renewable energy sources like biogas systems is more acute than in the case of non-renewable energy sources, like, a thermal power station, due to the preponderance of non-traded items. It is a complex question of rational and relevant estimates of "shadow prices" for most of the inputs and outputs. It must, however, be pointed out that the use of world prices as "shadow prices" in the new social cost-benefit analysis (SCBA), brings the

considerations of trade efficiency and distribution to the forefront, raising many critical questions just as it answers many others.

E. SECONDARY COSTS AND BENEFITS

Tracing through the various secondary costs and benefits of a project, irrespective of whether it is in the field of renewable or non-renewable sources of energy, is often exceedingly difficult. The problem is often insurmountable if one wants to quantify them for inclusion in the cost-benefit streams of the project. What is involved is the total impact of the project on the economy which cannot be readily identified and easily priced. To illustrate, the impact of an energy project on the generation of extra employment in the service sector, on the quality of life and environment, on the current distribution of personal incomes and on the foreign exchange situation, are important parameters for social cost-benefit analysis. Yet, in actual practice it becomes extremely difficult to obtain reliable quantified estimates.

In case of biogas units, for example, there are a number of indirect benefits one can identify, such as, improving environmental pollution and hygienic conditions, saving forests by preventing indiscriminate felling of firewood, preventing erosion and flood, making available pollution-free energy, making cooking more convenient and less laborious, saving the economic life of cooking utensils and reducing the uncertainty of commercial fuel supply. Ideally, a special premium should be attached to such benefits in cost-benefit analysis.

Similarly, on the cost side, there are indirect cost elements like the cost of benefiting the rich farmers and thereby increasing the income disparity, the likely cost of depriving the landless labourers and poorer-sections from the availability of cowdung and employment in collection of cowdung. These are broad social costs which would vary between regions. Again, for SCBA, these costs in quantified terms should ideally be incorporated.

Because of the lack of data, many of these indirect costs and benefits are ignored in the conventional cost-benefit analysis. This is perhaps one of the problems which is encountered almost with equal degrees of difficulty both in the case of renewable and non-renewable sources of energy.

F. RISK AND UNCERTAINTY

In many cost-benefit analysis exercises, often a single estimate of NPV or IRR is presented on the basis of which an "accept-reject" decision has to be made. One must bear in mind that this estimate of NPV or IRR is only one value amongst all possible values of outcomes. It is obvious, therefore, that some outcomes are more likely than others, given a particular set of assumption and estimates of variates entering the calculation of NPV. Thus, there is an implicit risk of reaching a particular outcome in cost-benefit analysis, which is formally known as "quantifiable uncertainty". Since the critical parameters of a project on energy sources, particularly renewable sources, are widely varying and are often estimated on the basis of some assumptions rather than

empirical-evidence, it is perhaps imperative to present a probability distribution of outcomes, P (NPV), rather than a single point estimates of profitability, in which the variables assume various values.

G. MULTIPLE USES OF OUTPUT

Any project on energy sources, be it renewable or non-renewable, has the potentiality of its energy output being used for multiple purposes. This means apportioning the available energy for using it into the best possible combination of functions in order to maximize benefits. For a biogas plant, for example, depending on the size of the plant, biogas can be used for cooking, lighting, operating irrigation pumps and for generating power for, say, running various small industries. The same is true for commercial non-renewable sources of energy. This point is often overlooked. For a realistic cost-benefit analysis, however, the patterns of potential multiple use of energy output should be assessed and alternative possibilities generated.

III. SOME APPROACHES TO METHODOLOGICAL PROBLEMS

The methodological problems of cost-benefit analysis as outlined above encounter varying degrees of difficulties to solve. Some of them require more research in order to generate reliable data, while others can be reasonably solved with the help of the existing state of knowledge and data. What follows are some suggested approaches to solving scientifically the methodological problems of cost-benefit analysis related to renewable sources of energy, particularly biogas system. It must be noted, however, that similar approaches are equally applicable to non-renewable energy sources.

A. TECHNOLOGICAL DATA GAP

As referred to earlier, there are conflicting claims about the quality and quantity of gas and digested manure production from biogas plants. In addition, there is still some confusion about the calorific value of biogas and cowdung cake. As a result, various estimates of values of these important parameters are used in different studies. Similarly, the knowledge about the quantified estimates of various social and economic impacts of biogas units is limited.

It is not that there are no data or estimates available for the many variables mentioned, but that there is confusion about the authenticity and source of such estimates. Given the varying experimental and field conditions in a decentralized technology system this is not totally unexpected. What is necessary is to co-ordinate and generate sufficient reliable data on the relevant variables by setting up carefully planned experiments in the field under varying conditions. For secondary costs and benefits, however, it is necessary to trace through the impact over a period of time in different field conditions.

Until such time as reliable technological data become available, one of the following approaches could be used by the analysts:

(a) Work out separate cost-benefit analysis with all available alternative estimates of the technological data or even with some reasonable hypothetical data. To illustrate, Bhatia did the analysis separately: first assuming that there was no significant additional benefit in terms of quantity and quality of digested manure from a biogas plant; secondly, by assuming that the increase in digested manure was 46 per cent (i.e. taking the KVIC estimate) and the nitrogen content of the digested manure was 1.6 per cent as compared to 1 per cent in compost manure.

(b) In the case where there are various conflicting estimates available for a particular variable, as in the case of calorific value of biogas, then one may do the analysis taking the average value. Bhavani, for example, used the median value (112 kil/cu ft) of a range of calorific values of biogas reported by Sathianathan.

B. ECONOMIC LIFE OF BIOGAS PLANTS

Bhatia, for example, assumed a 20-year plant life, while KVIC claimed 40 years and Moulik *et al* assumed 30 years. Again, given the effects of varying external conditions in which biogas plants are installed and operated, it is difficult to establish an accurate and consistent life of plant and equipment. One way to tackle this problem is to take the estimates of life of plant and equipment as observed under different conditions and then work out cost-benefit analysis separately for each assumption. A more prudent approach would be to use different rates of discount rate. In fact, if the set of discount rates used is realistic, it will make little difference to the net economic profitability with varying assumptions of economic life of the plant. The only caution one has to keep in mind in the last approach is the fact that lower discount rates, the results of the cost-benefit analysis will be more sensitive to the changes in the estimates of economic life.

C. PRICING

First is the problem of inflation. The crucial question here is whether the cost and benefit streams are given in current prices while discounting the net cash flow of a project. One way to tackle this problem is to estimate the rate of inflation and then add it to the relevant discount rate. Here the assumption is that a particular rate of inflation affects the cost and revenue of a project identically, which is hardly the case in a real situation. It is therefore a general and preferred practice to express all prices in constant terms for the purposes of financial analysis with domestic market prices. Likely movements in constant prices over time can then be determined by analysing the trend data. The most widely used prediction technique in this regard is the simple regression analysis with the historical time series data on prices. In other words, there are statistical techniques available which can solve even more complex problems encountered in price forecasting, which can be worked out by the statistician. What is, however, suggested here is that the key task of a project analyst is to properly utilize these statistical techniques for improving the financing analysis of a project.

Secondly, a more serious pricing problem is encountered in the case of economic analysis wherein it is now broadly accepted that the input and output prices of a project should be set in relation to their contribution to or claim on foreign exchange. In other words, the analysis of economic profitability is increasingly understood in relation to world price-relations rather than domestic price-relations indicating trade efficiency against which actual investment performance should be measured. In operational terms, this means the use of the shadow exchange rate (SER) to value the foreign exchange equivalent of the input and output prices expressed in home currency. SER is broadly that rate of exchange which accurately reflects the worth of an extra dollar in terms of one's own currency.

In determining the shadow prices, inputs and outputs need to be broken down into traded, potentially traded, and non-traded goods and basic factors of production including labour (both skilled and unskilled). Most projects will have these three types of goods in their input-output stream. In the case of a biogas plant in India, for example, inputs like cement, steel and bricks are easily recognised as the traded goods, whereas cowdung as input and digested manure as output can be treated at best as potentially traded goods. The agricultural wastes, if used as input, and biogas output are non-traded goods.

The practical difficulties encountered in setting the price for all the three categories of inputs and outputs can be illustrated, beginning with the case of traded goods. Traded goods are defined using the principle that the opportunity cost of any commodity, as long as it can be traded under present or predicted future conditions, is its border price. The difficulty in valuation of traded goods is solved by various methodological approaches:

(a) If the input or output is actually to be purchased from or sold abroad, price data can be obtained directly from the foreign supplier or buyer;

(b) If the input or output is domestically purchased or sold and a perfectly similar traded item cannot be found in the domestic markets, a useful approximation is to take the border price of the nearest equivalent traded goods and multiply it by the ratio of the domestic price of the home variety to the domestic price of the imported variety;

(c) Where there is a wide gap between the f.o.b. (export) and c.i.f. (import) prices of a commodity, a convenient shortcut is to take an average of f.o.b. and c.i.f. prices;

(d) In dealing with the problems of tariffs, taxes and subsidies of traded goods, the most common practice preferred is to use accounting ratios (AR) following World Bank conventions.²⁶

Various methods have been applied in the different studies cited to estimate the price of traded goods in relation to biogas units. In the present case study on the

²⁶ M.F.G. Scott, J. MacArthur and D.M.G. Newbery, *Project Appraisal in Practice: The Little-Mirrlees Method Applied in Kenya* (London Heinemann, 1976).

Indian biogas system, for example, the land, labour and capital costs are taken directly from the KVIC estimates, which seem to be based on prevalent (1975) domestic prices and therefore not adjusted to foreign exchange equivalents at future time periods. Bhatia estimated in 1977 the price of cement and steel by giving a 20 per cent premium on market price, but at the same time suggesting a method of calculating the true shadow price of the two traded goods, cement and steel, by taking the f.o.b. price adjusted for a premium on foreign exchange and adding to it the transport and distribution costs. In the same study Bhatia used a zero "shadow wage rate" for unskilled labour, the existing market wage rate for skilled labour and a zero opportunity cost for land required for installing biogas units. Verma, however, in 1976 included the cost of land at the market rate as the opportunity cost of the land.

The valuation of potentially traded goods depends on the view taken as to how the situation will hold in future. In general, the potentially traded goods should be treated as fully traded goods if there is any indication that they will develop into this category in the foreseeable future, or as non-traded goods if the opposite is the case. It is with this consideration in mind that most of the cost-benefit analysis studies on biogas plants have so far considered cowdung and digested manure from biogas units as potentially traded goods. In the case of cowdung as an input to a biogas unit, the opportunity cost is taken to be its use as FYM and/or dung-cake as fuel. With the slowly developing market for FYM and dungcake (in fact, this trend can already be observed in many parts of India, particularly, in view of the green revolution), one may value cowdung by some local market price of FYM and cowdung cake. This was the approach used in the present case study on Indian biogas plants. A still better approach is to value the opportunity cost of cowdung in terms of plant nutrient contents (NPK) of FYM. Bhavani used this method and analysed three alternatives for previous use of cowdung: one third fuel and two thirds manure, all manure and all fuel. She used the same approach in valuing digested manure from a biogas plant assuming increases in nutrient contents. Many other studies (ICAR; Prasad, Prasad and Reddy; and Bhatia) used a similar approach. The important merit of this methodological approach is that such valuation can easily be converted into a foreign exchange equivalent of commercial fertilizers and therefore fulfils the criterion of the trade efficiency of the economic analysis as discussed earlier.

Lastly, concerning the valuation of non-traded goods, that is, those goods which do not enter into trade by their very nature, a useful approach could be to work out a long-term average AR for non-traded goods and then determine a suitable range of AR values sensitive to cost-benefit analysis. In the case of a biogas plant, the non-traded goods to be considered is biogas. It has been argued that the value of biogas is best determined by using the market price of an equivalent amount of the next best alternative fuel. The difficulty arises because of the differing views about the next best alternative fuel. Many studies (e.g. ICAR; Mouluk and Srivastava; and Parikh) used the kerosene equivalent price of biogas, while an earlier case study and Susan Deo calculated the value of biogas in terms of firewood equivalent. Bhavani and Bhatia valued biogas in terms of soft coke, while Prasad, Prasad and Reddy used electricity equivalent prices of biogas. For macro level national planning, it is quite reasonable

to use soft coke or electricity equivalent values of biogas, but from the villagers' point of view at micro level such valuation perhaps has no direct relevance. The major sources of domestic fuel in rural India still remain to be dung cake, agricultural waste, firewood and kerosene. Thus, there is the divergence of interests and perceptions between the micro level villagers (beneficiaries) and the macro level planners. The task becomes still more difficult owing to extreme variation among the villages in relation to available energy sources and use patterns. The best methodological approach, therefore, could be to work out independent cost-benefit analysis taking all possible alternative fuels' equivalent values as a pricing mechanism for biogas and using the one relevant to a specific region or villages suited to its available energy resource position and use pattern.

D. MULTIPLE USE AND COST-BENEFIT ANALYSIS

The problems are directly related to the size of the plant or more specifically to larger than family-size plants. Very few studies have been done on biogas plants wherein the use of biogas is assumed to be for multiple functions, such as, cooking, lighting and generating power. Bhatia did a fairly detailed analysis for 70 cu ft and 105 cu ft per day size plants assuming various proportions of biogas being used for cooking and lighting. In a recent study by Susan Deo an interesting analysis was done by working out a total energy demand of a hypothetical village in relation to cooking, pumping water, lighting homes and industry. Taking the estimate of total energy demand of a village, she worked out the sizes most appropriate for the village and the cost-benefit ratios for combinations of community biogas systems. There is hardly any difference in methodologies for cost-benefit analysis of such systems except the higher capital and distribution costs. It is necessary to work out the basic parameters of cost-benefit analysis for such a large system based on direct observations under varying field conditions.

E. INDIRECT COSTS AND BENEFITS

The data required to predict various indirect costs and benefits, which is conventionally termed as secondary costs and benefits, particularly those related to social or welfare parameters, are formidable to collect. It is essentially a methodological problem of quantification of such data, which can either be collected over a period of time under fairly controlled conditions or at best can be hypothetical estimates. To illustrate, the effects of biogas plants constituting secondary costs and benefits would require baseline data against which the effects are to be measured and quantified. Even then, these quantified effects would have to be statistically explained in terms of the contribution due to biogas plants. Not that this is methodologically impossible, but the task is enormous and therefore in most analyses so far the substitution possibilities of these parameters are ignored. However, Prasad, Prasad and Reddy reported some of these secondary benefits in evaluating biogas plants versus rural electrification to meet the rural energy demand for cooking, irrigation pumping, industries and lighting. They estimated that a 5000 cu ft per day biogas plant would have an extra benefit stream of 22 tons of additional foodgrain from 4.4 tons of nitrogen, a foreign exchange saving

on 2 tons of naphtha for fertilizers, and a reduction of deforestation saving 0.4 acres forest per year.

In view of the reservation about the reliable estimates of various secondary costs and benefits, it is methodologically prudent to concentrate solely on those parameters for which a reliable set of quantified estimates are available. However, conscious efforts need to be made to carry out a comprehensive survey of villages and regions over a period of time where biogas plants have been installed in order to generate reliable estimates of secondary costs and benefits. Short of this survey, there cannot be any other alternative approach to tackle this particular methodological problems of social cost-benefit analysis.

F. CHOICE UNDER RISK AND UNCERTAINTY

All the above-mentioned alternative methodological approaches lead us to the problem of the probability of a particular outcome of cost-benefit analysis under different assumptions, to the problems of choice under risk and uncertainty. The calculations of cost-benefit analysis, or more precisely the values of NPV or IRR, depend largely on various assumptions under which the estimates of inputs and outputs are quantified. Given the nature of the project, particularly for a project like a biogas plant the operational parameters of which vary widely under equally varying exogenous factors, the assumptions and estimates are bound to vary. One of the most commonly used methodological approach to tackle this problem is sensitivity analysis, through essentially varying key parameter values, preferably one at a time but sometimes in combination, and then calculating a large number of NPVs. One can then assess the effect of changes in parameters on the central tendency estimate of profitability of the project. The decision rule for such analysis is to use the mean expected value as a criterion of central tendency of the probability distribution of NPV, that is, $P(NPV)$, for project evaluation.

The application of sensitivity analysis in the case of cost-benefit analysis of biogas plants can be illustrated from almost all the studies cited. The resulting NPVs taking various fuel equivalent values of biogas, different depreciation rates, sizes of plants, different valuations on inputs and outputs, and considerations of costs with and without subsidy, are some examples of such attempts.

IV. CONCLUSION

In the foregoing analysis several conceptual and methodological issues have been raised about the cost-benefit studies of biogas plants as an alternative source of energy. Given the energy crisis these issues assume added relevance and importance, particularly for the net oil-importing third world countries. Under the circumstances, for most of the third world developing countries, the biogas technology appears to offer a logical alternative source of energy with considerable potential since both a more efficient fuel and a good quality organic fertilizer can be obtained from the system.

The results of various cost-benefit studies and the arguments presented earlier have suggested that the case for investment in biogas plant lies, in general, in the probable private profitability. Also, from the point of view of social benefit-cost, biogas plants seem to be an even more attractive and viable investment, given the import content and the general scarcity of fertilizers and commercial energy. However, there has been a strong indication of substantial economies of size of biogas plants when comparing the large plants with the smaller, family-size ones.

The enormous difficulty in quantifying all the benefits of a biogas system is amply demonstrated in the foregoing analysis. Since there is hardly any direct cash flow of benefits, it is difficult for many, particularly, the villagers, to see the advantages of installing biogas plants. In spite of this difficulty, it is shown in the present study how reasonable attempts can be made at quantifying the major benefits, with particular reference to the micro-level individual villager's point of view. However, the difficulty for quantification of benefits increases many times when one attempts to quantify macro-level societal benefits of biogas system, such as, improved health and sanitation, prevention of deforestation, improved soil structure and agricultural production due to additional use of digested manure, increased local and national energy self-sufficiency leading to saving of scarce foreign exchange, increased female labour efficiency etc. From the national point of view, these long-term, macro-level benefits are crucially important in determining national plan priorities. The present study concluded that if all the societal benefits are incorporated in the cost-benefit analysis, even the most questionable cases for investment in biogas plants will become viable. Considering such possibilities, both micro- and macro-level analyses are highly useful in order to determine the private as well as the social profitability of biogas plants.

One of the critical aspects for evaluating the potentiality of biogas plants is the appropriate uses for biogas. Since fuel for cooking is by far the greatest demand for energy in rural India, and the fact that the use of biogas for cooking immediately replaces cowdung cake and firewood, the two most important fuels used for cooking, and having a more profitable and worthwhile alternative use, many cost-benefit studies have considered the use of biogas mainly for the purpose of cooking. This is quite logical and appropriate. However, various studies referred to in the report have clearly demonstrated other more profitable uses of biogas energy such as, running engines, pumping water and powering small-scale industrial operations. It is therefore reasonable to conclude that the optimum use of a biogas system should be a package of multiple functions like cooking, pumping water, lighting, powering industrial operations etc. rather than simply cooking.

The present study also brings out various methodological uncertainties and limitations of cost-benefit analysis of biogas systems. It is, therefore, suggested that the results of the cost-benefit analysis should be used with caution for taking investment decisions for postponement or rejection of biogas programmes until priorities are sorted out, and various uncertainties and limitations are overcome. Keeping these limitations in mind, the study concluded with some suggestions for some methodological improvements of cost-benefit analysis and some future research needs.

It would be worthwhile briefly to recapitulate here some of the suggested future research needs which have larger policy implications for third world countries.

First, it has been consistently and clearly established that there is a scale economy for biogas plant sizes indicating popularization of large, community-size plants. This calls for setting up a number of pilot community plants under varying conditions and then comparing them more accurately with those of the family plants. Also, it is in these pilot projects, the management and organizational parameters of the community plants are to be worked out.²⁷

Secondly, irrespective of large or small biogas plants, there is a clear and urgent need to conduct field experiments under varying conditions and regions in order to standardize or to arrive at realistic values of input and output parameters of biogas system. These field experiments should take into consideration alternative biogas technologies (e.g. KVIC and Chinese-type Janata models), use of different types of raw materials, various combinations of biogas use patterns, different plant size, different management and organizational patterns for community plants etc. It is through these field experiments under varying conditions that appropriate designs and distribution systems can be developed apart from realistically establishing the viability of the system.

Thirdly, if large-scale adoption of biogas technology is projected in the third world countries, there has to be a detailed analysis of the nation-wide changes in resource allocation, as well as, a comparative assessment of various other alternative energy sources, including a solar system, tidal and wind power, energy from forests, improving efficiency of burning current fuels etc., is required. A correct analytical comparison between various alternative energy technologies would provide the basis for choosing a particular combination of energy technologies suitable for specific communities leading to optimum available resources within the community. In other words, any future research on biogas technology should be undertaken keeping the broader objectives of rural development and energy needs in mind in which the biogas system is merely a part. In this context a most relevant question to be researched is whether allocating the current construction materials for massive development of biogas systems is an optimum use. There is, therefore, the urgent necessity for research on reduction of the use of expensive construction materials, to reduce the cost of biogas plants and to bring them within the economic reach of a wider section of the population than at present. It is in this context, the importance of the Chinese-type Janata model as compared to the KVIC model needs to be understood.

Lastly, there is an urgent need for a detailed analysis and quantification of the various secondary costs and benefits related to biogas systems. In fact, there has been a consensus among all concerned that there are important and significant secondary benefits both at private and societal levels to the extent that if properly assessed and

²⁷ The Department of Science and Technology, Government of India, has recently sponsored about 20 such pilot community plants to be set up and studied for three-year period. The present author has taken up 10 of the 20 pilot plants for action research studies. Some analytical results should be available from these pilot plants after a year.

incorporated into the conventional analysis, a biogas system becomes viable even under seriously questionable assumptions. In spite of consensus about the importance of the secondary benefits, most of them have so far remained qualitative and unmeasured. Whatever few attempts were made to quantify these benefits and incorporate them in the analysis, they were largely based on hypothetical assumptions rather than actual field observations. The problem of measuring these secondary costs and benefits lies in the fact that it requires a fairly well-planned time series data on the basis of "before and after" surveys of the project areas. Such research effort is undoubtedly costly, but equally invaluable to planners and decision makers. In fact, there has been some deliberate attempts in China to collect these kinds of data on secondary benefits and to use them in persuading the villagers to opt for a biogas popularization programme in the communes.²⁸ Similar research efforts are needed in order to measure realistically all the secondary costs and benefits of biogas systems under varying field conditions.

In conclusion, it must be emphasized again that the major decisions regarding a future biogas programme in third world countries need not necessarily wait until the concept and methodology of cost-benefit analysis and its parameters are realistically developed. Even if there are various limitations, the present stage of analysis does certainly indicate significant pointers for decision making in relation to the investments in biogas programmes. While the attempts to overcome the conceptual and methodological limitations continue, it is essential for all nations to make concerted efforts for collaborative research and development on a long-term basis for mutual sharing of information and experiences related to use of alternative energy technologies, including biogas technology.

²⁸ T.K. Moulik, "Biogas system and rural energy supply", in the author's forthcoming book, *China After Mao* (Bombay, Somaiya Publications, 1981).

ABBREVIATIONS

ADB	Asian Development Bank
AFPRO	Action for Food Production
AIT	Asian Institute of Technology
ASEAN	Association of South-East Asian Nations
BCSIR	Bangladesh Council of Scientific and Industrial Research
BUET	Bangladesh University of Engineering and Technology
CIAE	Central Institute of Agricultural Engineering
CIDA	Canadian International Development Agency
CSIR	Council of Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organization
CUSO	Canadian University Services Overseas
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FCIC	Fellow, Chemical Institute of Canada
FIE	Fellow, Institution of Engineers
FIIPHE	Fellow, Indian Institute of Public Health Engineers
FRDI	Fellow, Resources Development Institute
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IDRC	International Development Research Centre
IIT	Indian Institute of Technology
KSCST	Karnataka State Council for Science and Technology
KVIC	Khadi Village Industries Commission
MASE	Member, American Society of Engineers
MIDC	Member, International Dairy Congress (London)
MIE	Member, Institution of Engineers
MIME	Member, Institute of Military Engineers
MIPE	Member, Institute of Power Engineering
MISAE	Member, Indian Society of Agricultural Engineers

MISCA	Member, Indian Science Congress Association
MISES	Member, International Solar Energy Society
MIWWE	Member, Institute of Water Works Engineers
MRIC	Member, Royal Institute of Chemistry (London)
MSDT	Member, Society of Dairy Technology (London)
NDRI	National Dairy Research Institute
NEA	National Energy Administration
NIST	National Institute of Science and Technology
NRCP	National Research Council of the Philippines
NSDB	National Science Development Board
PAAS	Philippine Association for Advancement of Science
PPS	Philippine Phytopathological Society
PSM	Philippine Society for Microbiology
SAR	Society for the Advancement of Research
SATA	Swiss Association for Technical Assistance
SIDA	Swedish International Development Agency
SPATF	South Pacific Appropriate Technology Foundation
SPC	South Pacific Commission
SWD	Steering Committee on Wind Energy for Developing Countries
TERI	Tata Energy Research Institute
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UPCA	University of the Philippines College of Agriculture
USAID	United States Agency for International Development
USP	University of the South Pacific
VITA	Volunteers in Technical Assistance

KEY TO NUMBERS IN ENTRIES UNDER EXPERTS AND INSTITUTIONS

Experts

1. National of
2. Date of birth
3. Academic and professional qualifications
4. Languages
5. Employment record
6. Primary fields
7. Other fields
8. Projects
9. Publications*
10. Address

Institutions

I. Information on institutions

1. Address; phone no.; cable address; telex no.
2. Established in
3. Chief executive
4. Officers concerned
5. (a) Number of technical staff
(b) Number of digesters constructed/operated
6. Field station
7. Formal linkages with other institutions
8. Nature of work
9. Fields of work
10. Services
11. Training courses
12. Publications*
13. Projects

* Where publications are included in the bibliography

II. Information on biogas plants

A. *Digester type and design*

1. Gas holder
 - (a) Fixed
 - (b) Movable
2. Digester size (m^3)
3. Materials used in constructing:
 - (a) Digester body
 - (b) Gas holder
 - (c) Inlet
 - (d) Outlet

B. *Digester feed*

1. Type of feed
 - (a) Continuous
 - (b) Batch
2. Feed material most common
3. Pretreatment and mixing of feed
4. Daily quantity of feed for continuous digester
5. Quantity of feed and frequency of feeding for batch type
6. Water to feed ratio

C. *Use of digester products*

1. Quantity of gas
 - (a) Volume of gas produced/day (m^3)
 - (b) Main uses
2. Use of effluent and the amount of effluent used in each of the following purposes:
 - (a) Direct fertilizer on soil (kg/day)
 - (b) Composting (kg/day)
 - (c) Aquaculture (kg/day)
 - (d) Recycling to digester (kg/day)
 - (e) Recycling as feed to animals (kg/day)
 - (f) Waste (kg/day)
 - (g) Other applications (kg/day)
3. Effluent treatment for disease control

D. *Other information*

1. Cost of the plant in \$US
2. Outside average temperature
 - (a) Summer ($^{\circ}C$)
 - (b) Winter ($^{\circ}C$)

3. Position of plant
 - (a) Shadow
 - (b) Sun
4. Additional heating of slurry and method used
5. Troubles in digester operation, their sources and methods of overcoming them
6. Percentage of digesters in operation to the total number of digesters constructed
7. Other comments on design to assist in trouble-free operation of plants

EXPERTS

A

- | | |
|---------------------------|-------------|
| 1. Mr. Romeo V. ALICBUSAN | Philippines |
| 2. Mr. M. AMARATUNGA | Sri Lanka |
| 3. Mr. Y.P. ANAND | India |
| 4. Mr. Muchidin APANDI | Indonesia |

B

- | | |
|--------------------------|-------------|
| 5. Mr. Andreas BACHMANN | Switzerland |
| 6. Mr. Julian BANZON | Philippines |
| 7. Mr. Ajit Kumar BASU | India |
| 8. Mr. T.D. BISWAS | India |
| 9. Mr. Piyawat BOON-LONG | Thailand |

C

- | | |
|---------------------------------|------------|
| 10. Mr. CAO Guo-Qiang | China |
| 11. Mr. CAO Ze-Xi | China |
| 12. Mr. CHAI Chang-Da | China |
| 13. Mr. Sompongse CHANTAVORAPAP | Thailand |
| 14. Mr. CHEN Sheng-Geng | China |
| 15. Mr. CHONG Chok-Ngee | Malaysia |
| 16. Mr. M. Yusuf CHOWDHURY | Bangladesh |

D

- | | |
|--------------------------|----------|
| 17. Mrs. Revadee DEEMARK | Thailand |
| 18. Mr. A.K. DHUSSA | India |
| 19. Mr. J.A. D'SOUZA | India |

E

- | | |
|------------------------|------------|
| 20. Mr. Muhammad EUSUF | Bangladesh |
|------------------------|------------|

F

- | | |
|------------------------|--------|
| 21. Mr. FENG Wei-Cheng | China |
| 22. Mr. Nigel FLORIDA | Canada |

G

- | | |
|-----------------------------|-------|
| 23. Mr. H.P. GARG | India |
| 24. Mr. K.V. GOPALAKRISHNAN | India |
| 25. Mr. K.P. GOSWAMI | India |
| 26. Mr. GU Zhen-Gang | China |
| 27. Mr. Chaman L. GUPTA | India |

H

- | | |
|------------------------|-------|
| 28. Mr. Kiyonori HAGA | Japan |
| 29. Ms. HU Li-Na | China |
| 30. Mr. Ishrat HUSSAIN | India |

I

- | | |
|----------------------------|------------|
| 31. Mr. S.G. ILANGANTILEKE | Sri Lanka |
| 32. Mr. M.M. ISLAM | Bangladesh |

J

- | | |
|----------------------|-------|
| 33. Mr. R.C. JAIN | India |
| 34. Mr. S.C. JAIN | India |
| 35. Mr. D.S. JOSHI | India |
| 36. Mr. Vishnu JOSHI | India |

K

- | | |
|-------------------------------|-------------------|
| 37. Mr. Jagdish Chandra KAPUR | India |
| 38. Mr. Amrit Bahadur KARKI | Nepal |
| 39. Mr. K.C. KHANDELWAL | India |
| 40. Mr. Ghulam KIBRIA | Pakistan |
| 41. Mr. Kyun Uk KIM | Republic of Korea |
| 42. Mr. Suchart KLINSUWAN | Thailand |
| 43. Mr. C.P. KOTHANDARAMAN | India |
| 44. Mr. Savang KULAPATRAPA | Thailand |

L

- | | |
|------------------------|-------|
| 45. Mr. LI Chang-Sheng | China |
| 46. Mr. LI Fang-Qiang | China |
| 47. Mr. LI Nian-Guo | China |

- | | |
|----------------------|-------|
| 48. Mr. LING Dai-Wen | China |
| 49. Mr. LIU Ke-Xin | China |
| 50. Mr. LIU Ting-Wei | China |

M

- | | |
|-------------------------------|-------------|
| 51. Mr. Felix D. MARAMBA, Sr. | Philippines |
| 52. Mr. MEI He-Xiao | China |
| 53. Mr. T.K. MOULIK | India |
| 54. Mr. Raymonds M. MYLES | India |

N

- | | |
|----------------------------|----------|
| 55. Mr. Ram Krishnan NAIDU | Fiji |
| 56. Mr. V.P. NARAYANASWAMY | India |
| 57. Mr. S. NEELAKANTAN | India |
| 58. Ms. Watana NOPAKOON | Thailand |

O

- | | |
|-------------------------|-------------|
| 59. Mr. Enrico D. OBIAS | Philippines |
|-------------------------|-------------|

P

- | | |
|-----------------------------|----------|
| 60. Mr. V. PADMANABHAN | India |
| 61. Mr. Mohan PARIKH | India |
| 62. Mrs. P.P. PARIKH | India |
| 63. Mr. G.L. PATANKAR | India |
| 64. Mr. T.M. PAUL | India |
| 65. Mr. PENG Wu-Hou | China |
| 66. Mr. Chongrak POLPRASERT | Thailand |
| 67. Mr. G.G. PURI | India |

Q

- | | |
|---------------------|-------|
| 68. Mr. QIAN Ze-Shu | China |
|---------------------|-------|

R

- | | |
|------------------------|-----------|
| 69. Mr. S.K. RAJAPAKSE | Sri Lanka |
| 70. Mr. M.A. Sethu RAO | India |

- | | |
|---------------------------|----------|
| 71. Mr. P. Sreenivasa RAO | India |
| 72. Mr. Sermpol RATASUK | Thailand |
| 73. Mr. REN Yuan-Cai | China |

S

- | | |
|----------------------------------|----------------|
| 74. Mr. M.A. SATHIANATHAN | India |
| 75. Mr. B.R. SAUBOLLE, S.J. | India |
| 76. Mr. Iqbal Hussain SHAH | Pakistan |
| 77. Mr. J.B. SINGH | India |
| 78. Mr. Ongart SITTHICHAROENCHAI | Thailand |
| 79. Mr. Pichit SKULBHRAM | Thailand |
| 80. Mr. Koentoro SOEBIJARSO | Indonesia |
| 81. Mr. Richard K. SOLLY | Australia |
| 82. Mr. W. Robert STANTON | United Kingdom |
| 83. Mr. D.J. STEWART | New Zealand |
| 84. Mr. SUN Guo-Chao | China |
| 85. Mr. Calixto C. TAGANAS | Philippines |
| 86. Mr. Morakot TANTICHAROEN | Thailand |
| 87. Mr. Boontham TESNA | Thailand |
| 88. Mr. Y.R. TIPNIS | India |
| 89. Mr. Hiroji Narayan TODANKAR | India |
| 90. Mr. TSE Shu-Chien | China |
| 91. Mr. TU Jia-Bao | China |
| 92. Mr. Sornthep TUMWASORN | Thailand |

W

- | | |
|-----------------------|-------------------|
| 93. Mr. WANG Da-Si | China |
| 94. Mr. WANG Meng-Jie | China |
| 95. Mr. WANG Xin-Quan | China |
| 96. Mr. Myo WIN | Burma |
| 97. Mr. Dong Han WOOK | Republic of Korea |
| 98. Mr. WU Chang-Lun | China |
| 99. Mr. WU Jin-Peng | China |

X

- | | |
|--------------------------|-------|
| 100. Ms. XIAO Ying-Chang | China |
| 101. Mr. XU Jie-Quan | China |

- | | |
|----------------------|-------|
| 102. Mr. XU Ke-Nan | China |
| 103. Mr. XU Yi-Zhong | China |
| 104. Mr. XU Zeng-Fu | China |

Z

- | | |
|---------------------------|-------|
| 105. Mr. ZHANG Chang-Ming | China |
| 106. Mr. ZHANG Guo-Zheng | China |
| 107. Mr. ZHANG Wei | China |
| 108. Mr. ZHOU Meng-Jin | China |
| 109. Mr. ZOU Yuan-Liang | China |

ADDITIONS

- | | |
|-------------------------------|----------------|
| 110. Mr. J.H. FINLAY | United Kingdom |
| 110(a). Mr. M. Sohail QURESHI | Pakistan |
| 110(b). Mr. P. RAJABAPAI AH | India |
| 110(c). Mr. TIAN Feng | China |
| 110(d). Mr. B.V. UMESH | India |

INSTITUTIONS

Bangladesh

111. Bangladesh Agricultural University
112. Bangladesh Council of Scientific and Industrial Research, Institute of Fuel Research and Development

China

113. Artificial Biogas Experimental Station, Nanhui County
114. Beijing Academy of Agricultural Science, Research Institute for Soil and Fertilizer
115. Chengdu Biogas Research Institute
116. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture
117. Chengdu Biological Research Institute, Chinese Academy of Sciences
118. Chengdu Institute of Biology, Chinese Academy of Sciences
119. China Research and Designing Institute of Agricultural Engineering
120. Chongqing Teachers Training College
121. Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences
122. Hangzhou City Biogas Extension Office
123. Institute of Microbiology, Chinese Academy of Sciences
124. Jiangsu Province Wujin Biogas Research Institute
125. The Office of National Leading Group for Biogas Development, Ministry of Agriculture
126. Research Institute for Soil and Fertilizer, Academy of Agricultural Science
127. Shandong Province Energy Resource Research Institute
128. Shanghai Institute of Industrial Microbiology
129. Shanghai Science and Technology Association
130. Xinan Teachers Training College, Biogas Research Institute
131. Zhejiang Agricultural University, Laboratory of Soil Microbiology
132. Zhejiang Biogas and Solar Energy Scientific Research Institute

Fiji

133. University of the South Pacific, Institute of Natural Resources

India

134. Action for Food Production (AFPRO)
135. Agricultural Tools Research Centre
136. Centre of Science for Villages
137. Delhi Water Supply and Sewage Disposal Undertaking
138. Gobar Gas Research and Training Centre
139. Indian Agricultural Research Institute, Division of Soil Science and Agricultural Chemistry
140. Indian Institute of Management
141. Indian Institute of Technology (Bombay)
142. Indian Institute of Technology (Madras)
143. Indian Institute of Technology (New Delhi), Centre of Energy Studies
144. Kapur Solar Farms
145. Khadi and Village Industries Commission, Gobar Gas Research and Development Centre
146. L.G. Balakrishnan and Brothers Limited
147. Maharashtra Gandhi Smarak Nidhi
148. Ministry of Agriculture, Department of Agriculture and Co-operation
149. Municipal Corporation of Greater Bombay, Dadar Sewage Treatment Plant
150. National Dairy Research Institute, Indian Council of Agricultural Research
151. National Institute of Waste Recycling Technology
152. Orissa Cement Limited
153. PSG College of Technology
154. Punjab Agricultural University
155. Resources Development Institute
156. Sobic Industrial Consultants
157. Sri Parasakthi College for Women
158. Structural Engineering Research Centre
159. Tata Energy Research Institute, Field Research Unit

Indonesia

160. Development Technology Centre, Institute of Technology Bandung (DTC-ITB)
161. Industrial Research Institute, Centre for Chemical Industry.

Japan

162. Ministry of Agriculture, Forestry and Fisheries, National Institute of Animal Husbandry

Malaysia

163. Standards and Industrial Research Institute of Malaysia (SIRIM)

New Zealand

164. Invermay Agricultural Research Centre

Pakistan

165. Appropriate Technology Development Organization, Government of Pakistan
166. Merin Limited
167. Ministry of Petroleum and Natural Resources, Energy Resources Cell

Philippines

168. Liberty Flour Mills, Inc., Maya Farms Division
169. Ministry of Energy, Centre for Nonconventional Energy Development
170. National Institute of Science and Technology

Republic of Korea

171. Office of Rural Development

Samoa

172. University of the South Pacific, School of Agriculture

Sri Lanka

173. University of Peradeniya, Department of Civil Engineering

Thailand

174. Asian Institute of Technology (AIT)
175. Department of Health, Ministry of Public Health
176. Kasetsart University, Faculty of Agriculture
177. King Mongkut's Institute of Technology
178. Maejo Institute of Agricultural Technology
179. Mahidol University
180. Ministry of Agriculture and Co-operatives, Department of Agriculture
181. National Energy Administration
182. Thailand Institute of Scientific and Technological Research

ADDITIONS

India

183. Indian Institute of Science, Centre for the Application of Science and Technology to Rural Areas (ASTRA)
184. Shri A.M.M. Murugappa Chettiar Research Centre, Photosynthesis and Energy Division

Nepal

185. Development and Consulting Services

1. Mr. Romeo V. ALICBUSAN

1. Philippines
2. 28 February 1930
3. B.Sc. (Agriculture), M.Sc. (Plant Pathology)
4. Filipino, English
5. 1972 to-date Supervising Scientist (1972-1974) and then Science Research Supervisor, Microbiological Research Department, National Institute of Science and Technology, Manila
1955-1971 Assistant Instructor (1955-1960), Instructor (1961-1965) and then Assistant Professor, University of the Philippines College of Agriculture
6. Cultivation of edible mushrooms. Biogas production
7. Fermentation of food products. Alcohol production
8. Research and development towards establishing mushroom industry in the Philippines. Biogas production utilizing food wastes (ASEAN)
9. *
10. Microbiological Research Department, National Institute of Science and Technology, P.O. Box 774, Pedro Gil Street, Ermita, Manila, Philippines

2. Mr. M. AMARATUNGA

1. Sri Lanka
2. 9 February 1936
3. B.Sc. (Engineering), Ph.D.; C. Eng., FIE (Sri Lanka)
4. English, Sinhalese
5. 1963 to-date Lecturer, Senior Lecturer, Associate Professor and then Professor, Department of Civil Engineering, University of Peradeniya, Sri Lanka
1968-1969 and 1972-1973 Lecturer in civil engineering, Kingston Polytecnic, UK
1962-1963 Engineer, Felix J. Samuely & Partners, London
6. Civil engineering structures. Biogas technology
7. Low-cost housing. Solar energy
8. Development of biogas digesters for integrated systems. Development of gas burners
9. *
10. Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka

3. Mr. Y.P. ANAND

1. India
2. 12 December 1934
3. B.Sc. (Hons.) (Civil Engineering)
4. English, Hindi, German, Urdu, Punjabi
5. 1957 to-date Assistant Engineer, Executive Engineer, Deputy Director (Research), Joint Director (Research), Deputy Chief Engineer (Construction), Divisional Superintendent, Additional Chief Engineer and then Chief Engineer, Indian Railway Service of Engineers
1956-1957 Assistant Engineer (Design), PWD, Chandigarh
6. Railway engineering (track, bridges, structures, management)
7. Studies in various aspects of energy with special emphasis on solar energy and bioconversion
8. Biogas plants for disposal and recycling of domestic and vegetable wastes
9. Design, instruction sheets and drawings
10. 31, N.E. Railway Colony, Gorakhpur 273 001, India

4. Mr. Muchidin APANDI

1. Indonesia
2. 14 January 1927
3. M.Sc. (Food Technology), Ph.D. (Animal Husbandry)
4. Indonesian, Dutch, German, English
5. 1975 to-date Senior Lecturer and staff member, Development Technology Centre, Institute of Technology Bandung
1967-1975 Senior Lecturer, University Padjadjaran Bandung
1955-1967 Lecturer, Institute of Agriculture, Bogor
6. Animal husbandry. Food technology
7. Biogas technology
8. Projects on microbial enzymes for high fructose syrups, alcohol, proteins. Biogas
10. Development Technology Centre, Institute of Technology Bandung, P.O. Box 276, Bandung, Indonesia

5. Mr. Andreas BACHMANN

1. Switzerland
2. 24 February 1946
3. Dipl. San. Inst.; Member: International Solar Energy Society; Swiss Solar Energy Society
4. German, French, English
5. 1974 to-date Advisor. Swiss Association for Technical Assistance (SATA), Nepal
1969-1971 Technician, Swiss Association for Technical Assistance (SATA), Cameroon, Africa
6. Sanitary installations
7. Appropriate technology. Renewable energy resources for rural areas: solar energy, biogas
8. Information dissemination: *Biogas Newsletter*, Nepal
10. c/o Swiss Association for Technical Assistance, P.O. Box 113, Kathmandu, Nepal

6. Mr. Julian BANZON

1. Philippines
2. 25 March 1908
3. Ph.D. (Chemistry)
4. English, Filipino
5. 1973 to-date Maya Farms Division, Liberty Flour Mills, Inc.
1977 to-date Philippine Coconut Research and Development Foundation
1959-1964 Philippine Atomic Energy Commission
1930-1959 and 1964-1973 University of the Philippines
6. Chemistry. Biochemistry
7. Fermentative processes
8. Fermentative/chemical processes for energy concentration
10. University of the Philippines at Los Banos, College, Laguna, Philippines; or c/o Maya Farms Division, Liberty Flour Mills, Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

7. Mr. Ajit Kumar BASU

1. India
2. 1 January 1932
3. D.Sc. (University of Liege, Belgium); FCIC, MIChemF, FIIPHE
4. English, Spanish, French, Bengali
5. 1956 to-date Scientist-in-Charge, NEERI Zonal Laboratory, Calcutta
 Pollution Expert, FAO
 Senior Consultant, UNEP Regional Office, Bangkok
 Expert (pollution and waste water management), Asian Development Bank
6. Treatment of waste water and water pollution
7. Environmental impact assessment. Air pollution. Solid waste water treatment. Environmental planning. Teaching environmental studies
8. Recycling of agricultural wastes, with particular reference to piggery waste water treatment in the Laguna de Bay, Philippines. A demonstration biogas plant, constructed with concrete and steel with movable gas holder, continuous feed of pig manure of 5000 kg per day, 145 m³ of gas produced per day to be used for heating, cooking and lighting purposes; effluent used for fish culture, algae production and animal feed
9. About 95 scientific publications
10. Official: NEERI Zonal Laboratory, 23 R.N. Mukherjee Road, Calcutta-1, India
Residence: 59 Lake Road, Apartment No. 8C (2nd Block), Calcutta 700 029, India. Tel: 46-7753, 42-4191

8. Mr. T.D. BISWAS

- 1, India
2. 3 November 1920
3. M.Sc., Ph.D.
4. English, Hindi, Bengali
5. 1946 to-date Research Assistant (1946-1956), Assistant Soil Survey Officer (1956-1958), Soil Scientist (1958-1968), Professor of Soil Science and Agricultural chemistry (1968-1972) and then Head, Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi
6. Research in soil science (soil physics, soil chemistry, soil genesis, micronutrient)
7. Biogas technology and usage

8. Production of fuel gas and manure by anaerobic fermentation of agricultural wastes and other organic materials. Soil productivity and soil physical conditions as influenced by long term and intensive crop management practices.
9. *
10. Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi 110 012, India

9. Mr. Piyawat BOON-LONG

1. Thailand 2. 1951
3. Ph.D. (Engineering)
4. Thai, English
5. Present Lecturer, Faculty of Engineering, Chiang Mai University, Chiang Mai
Visiting Assistant Professor, Kansas State University, USA
6. Heat transfer. Renewable energy resources
8. Solar-heated biogas digesters
10. Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand

10. Mr. CAO Guo-Qiang

1. China 2. 26 June 1941
3. Graduate, Shanghai Tongji University (specialization in applied mechanics)
4. English, Chinese
5. 1980 to-date Chengdu Biogas Scientific Research Institute, Ministry of Agriculture
July - August 1980 FAO Advisor to the Philippines (Middle Lu Song University) for establishment and management of a small-scale biogas plant, with 15 m³ round-shaped water pressure style bio-digester and production capacity of 0.75 m³ per day.
1964-1979 Sichuan Construction Science and Research Institute, Structure Department
1977 Biogas digester construction in Sichuan
6. Designing and conducting experimental research on housing structure including biogas digester, its design, construction and materials; provision of techniques involving material mechanics, structural mechanics, shell mechanics etc; theory of elasticity; reinforced concrete; prestressed concrete; knowledge and capability for initiative in planning and designing various kinds of structure.

7. Further pursuit of experience in construction with regard to biogas plant structure.
8. Among the important projects completed at Sichuan Construction Science and Research Institute: improvement in light crane beam; plastic-coated pump for apertures and its practical application in structures; research test with arched crane beam; research in hoisting of structure; participation in the compilation of specifications for reinforced concrete; improvement of factory structure; reports on research on various aspects in the construction of biogas plants, as follows: (a) synthesis of the techniques of biogas plant construction; (b) synthesis of the conclusions of engineering techniques in biogas plant construction; (c) publication of rural scientific magazines introducing often used materials in construction of biogas plants; (d) publication of correspondence and writings on construction and use of round hydraulic-pressure-type biogas plant; (e) simplified diagram for making biogas plants; (f) research on chemical preparation for medium-sized medium temperature digester; and (g) research on casing of reinforced concrete with less reinforced steel.
9. Compilation of *Biogas technology study* (2nd volume), for publication by United Nations University and in China. Lectures and teaching materials for the Joint UNEP-Chinese State Department Environment Office Study Group on Biogas in 1979 at Chengdu.
10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu, Sichuan, China

11. Mr. CAO Ze-Xi

1. China
2. June 1934
3. South-West Airforce Pre-University Contingent, 5th Aviation School, (specialization in aviation machinery) (June 1950 – May 1951)
4. Ordinary ability to understand and write Russian (elementary), speak Japanese.
5. 1959 to-date Engineer, Chief, farm power and hydraulic machine, 3rd Research Office, Sichuan Province Agricultural Machinery Research Institute
1950-1951 Mechanical Engineer, Chief, Armament Contingent, 3rd Middle Contingent, 34th Regiment, 12th Army, Airforce
6. Research on techniques of practical application of biogas as motive power in rural areas.
7. Research on small-scale internal-combustion engine
8. Research on utilization rate on north-west Sichuan grasslands of waste gas propelled turbo weight attached to a tractor.

9. For the National Science Commission, chief editor of teaching materials on biogas for the United Nations University. "Views concerning some practical aspects of combustible fuel for farm machinery".
10. Sichuan Province Agricultural Machinery Research Institute (3rd office), Sichuan, China

12. Mr. CHAI Chang-Da

1. China 2. 12 March 1943
3. Graduate, Hangzhou Agricultural College, Agriculture Department (1961)
4. English (elementary), Chinese
5. 1974 to-date Technician, Hangzhou City Biogas Extension Office
1962-1973 Technician, agricultural microbiology, Agricultural science Research Institute, Hangzhou City
6. Biogas fermentation. Biogas digester construction techniques
7. Agricultural science
8. Design and construction of separable type gas holder for rural households
Constructional technique improvements in the moulding and hauling of biogas plants. Synthesized use of the biogas fermentation remainder in mushroom cultivation, rearing of earthworm, feeding of pig, chicken, fish etc. Experimentation on fertilizer efficiency of fermentation remainder.
9. "Effective way of extension work regarding agricultural energy resources", *Energy Resources Journal*, 1980 first issue. *Popular Science Book on Biogas*, published by Zhejiang People's Publishing House. "Report on experiment on biogas production with movable gas holder", *Means of Production*, collected edition, vol. 4.
10. Biogas Extension Office, Hangzhou city. China

13. Mr. Sompongse CHANTAVORAPAP

1. Thailand 2. 1935
3. B.Eng. (Hons.) (Chulalongkorn University, Bangkok), M.Eng. (SEATO Graduate School of Engineering, Bangkok); Engineering Professional License in the category of Fellow Engineer from the Board for the Control of the Engineering Profession
4. Thai, English
5. 1976 to-date Special grade engineer, in charge of Design and Energy Research Section; Chief, alternative energy study and development project; and Assistant

Director, USAID-Thai Government nonconventional renewable energy project, National Energy Administration, Bangkok

1970-1975 First grade engineer, in charge of Design Section and Assistant Director, Lam Dom Noi hydro electric construction project, National Energy Administration

1967-1969 Seconded by National Energy Administration to work as System Analysis Engineer at the Mekong Secretariat

1961-1966 Third grade engineer (1961-1963) and the second grade engineer, Design Section, National Energy Administration

6. Civil engineering
7. System analysis. Development planning, sectoral planning and project analysis.
8. Alternative energy study and development project in which biogas/biomass energy is included.
9. "Utilization of biogas digesters in Thailand", presented at the Expert Group Meeting on Biogas Development, ESCAP, Bangkok, 20-26 June 1978. *Biogas Handbook* (Thai version), 1978. "Cement water jars as a biogas digester for Thailand", 1979.
10. National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

14. Mr. CHEN Sheng-Geng

1. China
2. July 1938
3. Graduate, Fudan University (1964)
4. Chinese
5. 1979 to-date Shanghai Biogas Laboratory, Association for Science and Technology
- 1974-1979 Shanghai Biogas Research and Co-ordination Group
- 1964-1974 Shanghai Association for Science and Technology
6. Bio-fermentation. Biogas construction
8. Small and medium sized digesters. Automation of multi-stage mesophilic fermentation digesters.
9. *Biogas* (in Chinese)
10. Science and Technology Commission, 47 Nan Zhong Road, Shanghai, China

15. Mr. CHONG Chok-Ngee

1. Malaysia
2. 30 June 1943
3. B.Sc. (Hons.) (Chemistry), B.Ed., Ph.D.; AMIC, MRIC, C. Chem.
4. English
5. Present Head, Research Unit, Standards and Industrial Research Institute of Malaysia (SIRIM)
6. Chemistry of biologically active compounds
8. Supervise a range of projects in the fields of ceramics technology, building materials, energy technology and pollution technology.
9. Technical papers/reports covering the above fields.
10. Standards and Industrial Research Institute of Malaysia (SIRIM), P.O. Box 35, Shah Alam, Selangor, Malaysia

16. Mr. M. Yusuf CHOWDHURY

1. Bangladesh
2. 1 April 1934
3. M.Sc. (Applied Chemistry) (Dacca), M.S. (Chemistry) (New York State University), Ph.D. (Agricultural Chemistry)
4. Bengali, English, German
5. 1964 to-date Senior Lecturer (1964), Associate Professor (1973) and then Head, Department of Agricultural Chemistry, Bangladesh Agricultural University
1958-1964 Lecturer in chemistry (1958) and then Professor and Head, Department of Chemistry, AM College
6. Agricultural chemistry with special interest in utilization of agricultural wastes
7. Organic wastes in plant nutrition and fish production. Water chemistry. Fertilizer technology and chemical instrumentation.
8. Biogas production (since 1971). Effect of organic manures with and without supplemental chemical fertilizers on the yield and qualities of the agricultural produce.
10. Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, Bangladesh

17. Mrs. Revadee DEEMARK

1. Thailand
2. 17 August 1940
3. B.Sc. (Chemistry), M.Sc. (Agriculture) (College of Sweden)

4. English, Thai
5. Present Scientist/Chief, Fertilizer Research Section, Agricultural Chemistry Division, Department of Agriculture, Bangkok
6. Study of organic fertilizer including digested slurry from biogas production.
7. Chemistry and technology and chemical fertilizers.
8. Studies on the manurial value of digested slurry from biogas plant. Examination of the nitrogen balance of dung during anaerobic digestion. Studies on the manurial value of digested slurry from biogas plant on sandy loam soil. Study on industrial waste for fertilization. Utilization of biogas as alternative source of energy. (completed)
 Study on low-cost biogas digester. Biogas production from various plant wastes. Biogas production in dome digester. Biogas production by using slurry and combination plants. (ongoing)
 Cost reduction of small-scale biogas plant. Utilization of organic waste other than animal waste. Biogas-based integrated farming system. Utilization of digester manure with local rock phosphate. (planned)
10. Fertilizer Research Section, Division of Agricultural Chemistry, Department of Agriculture, Bangkok, Bangkok, Thailand

18. Mr. A.K. DHUSSA

1. India
2. 3 March 1955
3. B.Sc., B.E. (Chemical)
4. English
5. Present Research Officer/Senior Scientific Associate, Gobar Gas Research Station, Ajitmal
6. Fermentation technology. Reaction kinetics and plant design.
7. Training
8. Designing gas generation and distribution systems for large communities.
9. *Janata biogas plants: introduction and design* and a construction manual in Hindi language
10. Gobar Gas Research and Training Centre, Ajitmal 206 121, Etawah, India

19. Mr. J.A. D'SOUZA

1. India
2. 21 February 1931
3. B.Sc.
4. English
5. 1968 to-date Refining Superintendent, Madras Refineries Ltd.
1972-1974 Deputation to Sri Lanka
1966-1968 Senior Engineer, Cochin Refineries Ltd.
1954-1966 Manufacturing Assistant, Burmah-Shell Refineries Ltd., Bombay
6. Energy conservation
7. Alternate sources of energy: solar, biomass and wind energy.
8. Solar water heater. Solar cooker. Biogas plant. Windmill for pumping water.
10. 5V. N.G. Road, Madhavaram Milk Colony, Madras 600051, Tamil Nadu, India

20. Mr. Muhammad EUSUF

1. Bangladesh
2. 11 October 1936
3. M.Sc. (Chemistry) (Dacca), Ph.D. (Chemistry) (Ottawa)
4. English, German, Bengali, Urdu, Arabic
5. 1977 to-date Project Director, Institute of Fuel Research and Development, BCSIR, Dacca
1966-1977 Editor, Bangladesh Journal of Scientific and Industrial Research, BCSIR
1964-1976 Senior Research Officer (1964-1973) and then Principal Scientific Officer, Fuel Research Division, BCSIR Laboratories, Dacca
6. Fuel and energy.
7. Activated carbon. Petrochemicals.
8. Increasing gas yield. Reduction in seasonal variation of gas yield. Cost reduction. Slurry making from agricultural wastes. Development of low-cost burners and lamps.
9. *
10. Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dacca, Bangladesh

21. Mr. FENG Wei-Cheng

1. China
2. December 1932
3. Graduate, Air Force School No. 6 (1952)
4. Chinese, English (can read periodicals and manuals in own area of specialization)
5. 1964 to-date Engineer, Sichuan Province Agricultural Machinery Research Institute
- 1953-1964 Instructor (engines), Air Force School No. 10
- 1952 Teaching Assistant (engines), Air Force School No. 6
6. Research on techniques of biogas as motive power
7. Research on biogas and speed-adjustor in diesel engine moving parts
8. Research on S195 biogas and diesel engine.
9. "Practical application of biogas as motive power"
10. Sichuan Province Agricultural Machinery Research Institute (3rd Office), Sichuan, China

22. Mr. Nigel FLORIDA

1. Canada
2. 7 June 1942
3. Diploma in Technical Education (Queen's University, Canada), Diploma in Electronics Technology (Ryerson Polytechnical Institute, Toronto)
4. English
5. 1977 to-date Associate Director, South Pacific Appropriate Technology Foundation (SPATF). Organized and directed the Foundation. Initiated a nine point programme for an integrated appropriate technology development package.
- 1974-1977 Technical Officer, Technical Team, Canadian University Services Overseas (CUSO), Ottawa. Responsible for the selection and placement of prospective business and technical volunteers in CUSO overseas programmes.
- 1972-1974 Recipient of international development scholarship, sponsored by the Canadian International Development Agency (CIDA). Research topic on village or appropriate technology. Studied and implemented a number of ideas of an appropriate technology nature in a small village in rural India.
- 1969-1971 Instructor, Commission for Technical Education and Vocational Training, Zambia. CUSO contract to start Zambia's first radio and TV repair course. Entailed design and building of workshop, ordering equipment and drafting syllabus.
6. Appropriate technology administration

8. Small-scale industry in Ghana, a potential for CIDA support. Small agricultural tool production unit, under USAID/VITA in Zaire. Reconstruction project to the district of Totonicapan following the 1976 Guatemala earthquake, involving housing, mobile medical services and groundwater surveys. Collect and coordinate information on appropriate technology under CUSO in Canada.
9. *
10. c/o P.O. Box 6937, Boroko, N.C.D., Papua New Guinea (Permanent: c/o 38 St. Claire, Ottawa, Canada K2G 2A2)

23. Mr. H.P. GARG

1. India
3. M.Sc. (Physics), Ph.D. (Solar Energy); MISES
4. Hindi, English
5. 1979 to-date Professor, Centre of Energy Studies, Indian Institute of Technology, New Delhi
 1972-1978 Physicist and then Senior Physicist, Central Arid Zone Research Institute, Jodhpur
 1965-1972 Scientist, Central Building Research Institute, Roorkee
 1964-1965 Lecturer, MMH College, Ghaziabad
6. Solar energy applications for domestic, industrial and agricultural purposes
7. Wind power utilization and bioconversion. Biogas and energy conservation.
8. Design and optimization of family size biogas plants.
9. *
10. Central of Energy Studies, Indian Institute of Technology, Hauz Khas, New Delhi 110 016, India

24. Mr. K.V. GOPALAKRISHNAN

1. India
2. 25 November 1936
3. Ph.D. (Mechanical Engineering)
4. English, German, Tamil
5. 1962 to-date Lecturer (1962-1972) and then Assistant Professor, Department of Mechanical Engineering, Indian Institute of Technology, Madras
6. Development of biomass – biogas energy for rural areas of developing countries. Development of alcohols and hydrogen as alternative fuels for internal combustion engines

7. Control of air pollution from internal combustion engines
8. Investigator: project on combustion of alcohols and biogas, financed by the National Science Foundation, Washington, D.C. Alternative fuels for internal combustion engines, supported by the German Academic Exchange Service (DAAD), Federal Republic of Germany
9. *
10. Department of Mechanical Engineering, Indian Institute of Technology, Madras 600 036, India

25. Mr. K.P. GOSWAMI

1. India 2. 2 April 1938
3. B.Sc. (Agriculture), M.Sc. (Indian Agricultural Research Institute, New Delhi), Ph.D. (University of Hawaii, USA)
4. English, Hindi, Spanish, Bengali, Punjabi
5. 1974 to-date Associate Professor in soil microbiology, Soils Department, Punjab Agricultural University, Ludhiana
 1971-1973 Junior Soil Scientist, Agronomy and Soils Department, University of Hawaii
 1961-1967 Senior Research Fellow (1961-1964) and then Senior Scientific Officer, Central Fuel Research Institute, Dhanbad
 1960-1961 Research Assistant, Agricultural Chemistry Laboratory, Udaipur
6. Soil science and agricultural chemistry. Soil microbiology and biochemistry. Biogas production from fibrous plant wastes.
7. CO₂ – fertilization. Decomposition of organic matter. Nitrogen fixation.
8. Development of a kachara-gas plant for biogas and manure production from fibrous plant wastes.
9. *
10. Soils Department, Punjab Agricultural University, Ludhiana, 141004, India

26. Mr. GU Zhen-Gang

1. China 2. February 1930
3. Graduated from the Aviation Special School, from the Mathematics Department in a university and then from a class for training teachers
4. Learnt English many years ago

5. 1973 to-date Laboratory of Animal Waste Management, National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries, Japan
6. Biogas production from animal wastes
7. Animal waste management
8. Biogas production from animal wastes and its utilization
9. *
10. Laboratory of Animal Waste Management, National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries, Tsukuba Norindanchi, P.O. Box 5, Ibaraki 305, Japan

29. Ms. HU Li-Na

1. China
2. 28 December 1932
3. Graduate, Beijing Agricultural University (1954)
4. English, Chinese
5. 1958 to-date In-charge, Fertilizer Research Office and Chief, Biogas Office, Beijing Academy of Agricultural Science, Beijing
1956-1958 Assistant, Pesticides Teaching Group, Beijing Agricultural University
1954-1956 Technician, Plant Disease Quarantine Station, Shanxi Province
6. Biogas techniques (biogas fertilizer and fermentation)
7. Soil fertilizer science. Agricultural environmental protection. Botanical chemical protection
8. Farmer household-fuel biogas experimental station and consultancy and extension, Beijing suburban district. Small-scale experimental pig farm biogas power station. Research on biogas fermentation process and important changes in fertilizer effectiveness and composition. Research on the efficiency of the biogas fermentation remainder as fertilizer and its use in soil improvement. Research on types of feeding materials and the amount of gas produced.
9. *Study of Biogas Techniques* (under publishing process)
10. Beijing Academy of Agricultural Science, Ban Jin Village, Beijing, China

30. Mr. Ishrat HUSSAIN

1. India
2. 15 July 1940
4. Hindi, English

5. Present Supervisor, demonstration-cum-training of Janata biogas plants scheme, Action for Food Production (AFPRO), New Delhi
Gobar Gas Technician, Gobar Gas Research Station, U.P.
Government
6. Biogas plants
7. Drafting and civil structure (rural latrines)
8. Biogas training and extension scheme for Janata plant
9. Drawings and sketches
10. Action for Food Production (AFPRO), C-17 Community Area, Safdarjang Development Area, New Delhi, 110 016, India

31. Mr. S.G. LANGANTILEKE

1. Sri Lanka
2. 26 October 1944
3. B.Sc. (Agriculture) (Ceylon), M.S., Ph.D. (Agricultural Engineering) (Michigan State University)
4. English, Sinhalese
5. 1970 to-date Head, Department of Agricultural Engineering, University of Sri Lanka, Peradeniya
6. Post-harvest technology and energy development for rural technology
7. Farm machinery design for intermediate rural technology
8. Construction of biogas unit as a demonstrational unit for secondary schools. Evaluation of locally available materials to enhance biogas production. Determining the pressure losses in conveyance of biogas to the lighting point.
10. Department of Agricultural Engineering, University of Sri Lanka, Peradeniya, Sri Lanka

32. Mr. M.N. ISLAM

1. Bangladesh
2. 1 August 1946
3. B.Sc. (Chemical Engineering), Ph.D.
4. Bengali, English
5. 1973 to-date Assistant Professor (1973-1977) and then Associate Professor, Department of Chemical Engineering, Bangladesh University of Engineering and Technology, Dacca
- 1972-1973 Senior Research Associate, University of Newcastle-upon-Tyne
- 1968 Lecturer in chemical engineering, EPUET, Dacca

6. Chemical engineering
7. English engineering. Environmental engineering.
8. Design, construction and operation of a biogas plant suitable for the rural area of Bangladesh (1977-1979), sponsored by the University Grants Commission, Bangladesh. Social and economic evaluation of biogas technology in Bangladesh (1978-1980), sponsored by IDRC, Ottawa, Canada
9. *
10. Department of Chemical Engineering, Bangladesh University of Engineering and Technology, Dacca 2, Bangladesh

33. Mr. R.C. JAIN

1. India 2. 5 January 1950
3. B.E. (Mechanical Engineering) (Bhopal University); Member (Scholar) Director, Resources Development Institute
4. Hindi, English
5. 1979-1980 General Manager, Small-scale Industries, Chindwara District, Government of Madhya Pradesh
 1978-1979 Industries Promotion Officer, Jorhat, Assam
 1974-1978 Junior Engineer, Design Research and Computerized Inventory Centre, Irrigation Department
 1974-1979 Part-time Research Scholar, Resources Development Institute, Bhopal (Honorary)
6. Mechanical engineering. Computer systems and programming. Small-scale industries.
7. Biogas technology. Solar energy
8. Biogas technology: portable biogas plant; small biogas turbine; biogas filter, biogas conversion kit etc. Solar energy: cheap solar cookers; solar pump; aqua ammonia-absorber turbine system; reflected concentrator modified Stirling engine system.
9. *
10. c/o Resources Development Institute, E6-00, 1100 Quarters Area, Bhopal 462016, India

34. Mr. S.C. JAIN

1. India
3. B.Sc. (University of Delhi), AIC (equivalent to M.Sc. in Chemistry) (Medical College, Calcutta)
4. Hindi, English, Urdu, German
5. 1959 to-date Assistant Chemist (1959-1961), Assistant Superintendent-cum-Chemist (1961-1969) and then Assistant Chief Water Analyst, Delhi Water Supply and Sewage Disposal Undertaking, Municipal Corporation of Delhi
1958-1959 Research Chemist, CSIR Scheme attached to Delhi Water Supply
6. Water treatment and sewage treatment including biogas
7. Industrial waste water treatment
8. Sewage treatment. Industrial waste water treatment. Biogas (town supply)
9. *
10. Sewage Disposal Works, Okhla, New Delhi 110 020, India

35. Mr. D.S. JOSHI

1. India
3. B.Sc. (Bombay University); Certificate in Chromatography and Library Science. Completed short-term course conducted by Central Public Health Engineering Research Institute. William D. Hatfield Award winner (Water Pollution Control Federation, United States of America)
4. English, Marathi, Hindi
5. Present Superintending Chemist, Dadar Sewage Treatment Plant Laboratory, Bombay
22 years experience of sewage, industrial effluents, sludge and gas analysis at Dadar Sewage Treatment Plant of Municipal Corporation of Greater Bombay and also past experience in ink analysis, pathological analysis and asphalt and road materials analysis
6. Analysis of sewage, sludge, grit and gas for the control of activated sludge plant, trickling filter and biogas digesters. Administration and management of laboratory
8. Tertiary treatment. High-rate digestion. H₂O removal from sludge gas. Infiltration of sea water.

9. "Performance of activated sludge plant", *Indian Journal of Environmental Health*, 1976. "Use of Orsat apparatus in gas analysis", SGEMA Souvenir, 1976. "Upsets in biological treatment plant" (contribution to a course on industrial waste treatment). "Air pollution control in industries", Seminar on Air Pollution Control.
10. ¼, Dadar Sewage Treatment Plant, Senapati Bapat Marg, Dadar, Bombay 400 028, India

36. Mr. Vishnu JOSHI

1. India 2. 14 February 1927
3. B.E. (Bombay University). Post-graduate in structural engineering (Cambridge University). Member of Institution of Civil Engineers, London
4. English, German
5. 1973 to-date Self-employed for development of appropriate technology and as a part-time consultant to Stein and Associates, New Delhi
 1960-1973 Architect, engineer and town planner, Stein and Associates
 1956-1960 Consulting Engineer, Felix Samudy and Partners, London
 1949-1955 Construction, design, planning of National Defence Academy of India
6. Structural engineering planning and design. Civil engineering. Project planning and co-ordination. Construction management.
7. Development and application of ferrocement technology especially for benefit of rural population.
8. Rural employment in the manufacture of ferrocement, water tanks, septic tanks, grain storage bins, biogas plants and fishing boats. Agro service centre
10. Sarang, Post Pen, Kolaba District, Maharashtra 402 107, India

37. Mr. Jagdish Chandra KAPUR

1. India 2. 16 February 1920
3. B.Sc. (Mechanical Engineering and Electrical Engineering) (Punjab University); M.S. (Engineering) (Cornell University). Post-graduate studies in aeronautical engineering (Indian Institute of Science, Bangalore). Industrial and labour relations studies (Cornell University). Fellow: Nuclear Energy Society; Indian Standards Institute. Life Member, Indian Science Congress. Member: International Solar Energy Society; American Society of Heating, Refrigeration and Air-conditioning Engineering; World Future Society.
4. English, Hindi, Punjabi

39. Mr. K.C. KHANDELWAL

1. India
2. 1 January 1948
3. B.Sc. (Agriculture), M.Sc. (Microbiology), Ph.D. (specialization in soil organic matter). Participated in FAO/UNDP Study Tour on Cold Weather Biogas Plants to the Republic of Korea, May 1980.
4. English, Hindi, Russian (elementary)
5. 1976 to-date Assistant Commissioner (Biogas) (1976-1979) and then Specialist, Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi
1970-1976 Assistant Professor (Microbiology), Haryana Agricultural University, Hissar.
6. Biogas fermentation.
7. Bio-fertilizer. Soil organic matter.
8. National project on development and promotion of biogas technology.
9. *
10. Department of Agriculture and Co-operation, Ministry of Agriculture, 112, 'B' Wing, Shastri Bhavan, New Delhi 110 001, India

40. Mr. Ghulam KIBRIA

1. Pakistan
2. 1 April 1926
3. B.Sc. (Engineering); President, Pakistan Association of Electrical and Mechanical Engineers (1967-1968)
4. English, Urdu, Punjabi, Hindi, German
5. Present Development Consultant, Karachi
1974-1978 Chairman, Appropriate Technology Development Organization, Government of Pakistan, Islamabad
1953-1959 Senior Executive, Gillanders Arbuthnot & Co. (Pakistan) Ltd.
1952-1953 Training abroad: Foster Gwynnes Ltd., Lincoln, United Kingdom; Brush Group Ltd., Loughbrough, United Kingdom; Klöckner Humbölt Deutz, Köln, Federal Republic of Germany
1948-1951 Junior Executive, Volkart Brothers, Lahore
1946-1948 Lecturer in mechanical engineering, Muslim University, Aligarh, India
6. Development consultancy

7. Biogas technology and low-cost hydro technology for Pakistan
8. Biogas and low-cost hydroelectric projects.
9. *
10. 5-E, 7th Central Street, Defence Housing Society, Karachi, Pakistan

41. Mr. Kyun Uk KIM

1. Republic of Korea
3. M.S., Ph.D.
4. Korean, English
5. 1974 to-date Associate Professor, Seoul National University, College of Agriculture
January-July 1974 Food Research Institute, University of Wisconsin
6. Food and fermentation microbiology
7. Fermented foods
8. Growth and resistance of lactic acid bacteria. Bioconversion of biomass.
9. *
10. College of Agriculture, Seoul National University, Suwon 170, Republic of Korea

42. Mr. Suchart KLINSUWAN

1. Thailand
2. 1955
3. B. Eng. (Institute of Technology and Vocational Education, Bangkok)
4. English, Thai
5. 1979 to-date Alternative energy study and development project, National Energy Administration, Bangkok
6. Machine design and heat transfer
7. Auto-mechanics
8. Alternative energy study and development (biogas energy)
9. Report on experiment on engine fuelled by biogas
10. National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

43. Mr. C.P. KOTHANDARAMAN

1. India
2. 10 August 1933
3. B.E. (Hons) (Mechanical Engineering), M.S. (Heat Power), Ph.D. (Metal Fatigue)
4. English, Tamil
5. 1958 to-date Teaching and research, PSG College of Technology, Coimbatore
6. Heat power engineering.
7. Refrigeration. Solar energy. Biogas
8. Development of a turbo charger for a 100 hp diesel engine. Development of a 500 W wind power generator. Gobar gas utilization in I.C. engines. Development of devices like solar water heater, solar still and solar air heaters. CSIR research scheme on thermal fatigue. Development of refrigeration plant.
9. *
10. PSG College of Technology, Coimbatore 641 004, Tamil Nadu, India

44. Mr. Savang KULAPATRAPA

1. Thailand
2. 6 January 1949
3. B. Eng. (Chulalongkorn University, Bangkok), M.S. (Oklahoma State University, USA)
4. Thai, English
5. 1976 to-date Engineer, in-charge of Biomass Energy Unit, Alternative Energy Study and Development Project, National Energy Administration, Bangkok
1972-1974 Engineer, in-charge of Telephone Repair Section, Workshop Division, Telephone Organization of Thailand
6. Industrial engineering. Energy planning and development. Biomass energy research and development.
7. Systems planning and analysis. Engineering economics analysis. Renewable energy planning and development.
8. Biomass energy development, sub-project of alternative energy study and development project. Demonstration and promotion of biogas energy in rural areas. Pilot scale production of biogas and fertilizer from pineapple cannery waste. Biogas pumping station.
9. Numerous working papers and unpublished reports on new and renewable sources of energy.
10. National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

45. Mr. LI Chang-Sheng

1. China 2. 1941
3. Graduate, Nanjing Agricultural College, Farm Mechanization Department (1964)
4. English, Chinese
5. 1978 to-date Engineer, Research on bio-energy resources, China Research and Designing Institute of Agricultural Engineering, Beijing
1964 Scientific Researcher, China Agricultural Mechanization Science Research Institute
6. Engineering. Biogas energy resource.
7. Agricultural mechanization. Hydraulic pressure techniques.
8. Participation in a project on the state of national tractor technology: inspection techniques without dismantling. Country-wide management of design of small-scale ORBIT hydraulic pressure motor set. Currently research on large-scale design of biogas power station in Mou Mou County and on increasing the effectiveness of biogas products.
10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

46. Mr. LI Fang-Qiang

1. China 2. 1944
3. Graduate, China Chengdu Science and Technology College (1961)
4. 1979 to-date Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu
1971-1978 Sichuan Provincial Biogas Office
1961-1971 Sichuan Provincial Agricultural Science College
6. Combining techniques of manufacture with use of biogas
7. Agricultural soil chemistry
9. Chief editor: "Production and utilization of biogas for villages", Sichuan Provincial Publishers. "Building biogas plants in the villages", China National Science Publisher. "Questions and answers in establishing biogas in the village" (3 volumes), China National Agriculture Publisher (one of the volumes translated into English by the British Intermediate Technology Publishing Company)
10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu City, Sichuan Province, China. Tel: 7737

47. Mr. LI Nian-Guo

1. China
2. May 1930
3. Advanced education in College of Agriculture, Lingnan University, Guangdong
4. Chinese, English
5. Present Head, Information Division, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences
 Teacher, Fujian Pedagogic College
6. Information collection and evaluation for energy from biomass, geothermal, solar, ocean, wind and other renewable sources, as well as energy storage and conservation.
7. Foreign affairs. Editor-in-chief of publications
8. Foshan biogas pilot power plant. Fengshun geothermal pilot power plant. Hainan solar-distill pilot power plant.
9. In English, on digesters for developing countries; design, construction and operation of digesters in China; fermentation technology for Chinese rural digesters etc.
10. 81 Martyrs Road, C.P.O. Box 1254, Guangzhou, China

48. Mr. LING Dai-Wen

1. China
2. 25 March 1934
3. Graduate, Beijing Agriculture University, Department of Microbiology
4. English, Chinese
5. 1957-1980 Research Associate, Department of Bacteriology, Institute of Microbiology, Chinese Academy of Sciences, Beijing
6. Taxonomy of bacteria
8. Studies on taxonomy of bacillus, lactobacillus and coryform bacteria; taxonomy of microbes in the biogas digester (in progress)
9. Ling Dai-Wen. Identification of lactobacilli, *Acta Microbiologica Sinica*, 11(4): 600-605, 1965.
 — A new species of cellulomonas – cellulomonas variants. *Acta Microbiologica Sinica* (to be published)
 Ling Dai-Wen and Wang Da-Si. Two new species of corynebacterium – corynebacterium thermophilum and corynebacterium deparaffinicum. *Acta Microbiologica Sinica* (to be published)

Ling Dai-Wen, Jiang Shu-Qin and Fu Ta-Fuh. Identity of aerobic sporeforming bacteria. *Acta Microbiologica Sinica*, 2(6):275-288, 1960.

Wang Da-Si, Ling Dai-Wen, Zhen Like and Hond Jun-Hua. Numerical taxonomy of gram positive rod-shaped bacteria from Tianshan and other sources. *Acta Microbiologica Sinica* (to be published)

10. Institute of Microbiology, Chinese Academy of Sciences, Beijing, China

49. Mr. LIU Ke-Xin

1. China
2. October 1936
3. University of Wuhan (specialization in microbiology)
4. Russian, English, Chinese
5. 1961 to-date Engineer, Chengdu Institute of Biology, Chinese Academy of Sciences. Research in microbiology and biogas fermentation
6. Microbiology
7. Biogas fermentation
8. Technology of biogas fermentation. Enrichment, isolation and culture of methanogenesis. Improvement of anaerobic digester
10. Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, Sichuan, China

50. Mr. LIU Ting-Wei

1. China
2. October 1932
3. Graduate, Beijing Mechanical Engineering College (1960)
4. English, Chinese, Russian
5. 1979 to-date Engineer, China Research and Designing Institute of Agricultural Engineering, Beijing
1978 Design Engineer, Luoyang Area Machine Factory
6. Mechanical engineering
8. Research and testing of medium temperature village biogas fermentation engineering
10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

51. Mr. Felix D. MARAMBA, Sr.

1. Philippines 3. 7 January 1897
3. B.S. (University of Illinois), M.S. (Iowa State University), D.Sc. (Honoris causa) (Gregorio Araneta University Foundation). Registered Professional Agricultural Engineer; Registered Professional Mechanical Engineer
4. English, Filipino, Spanish
5. President and Director, Liberty Flour Mills, Inc.
Dean of engineering and graduate studies, Gregorio Araneta University Foundation
Professor of mechanical engineering, Far Eastern University
Manager, Land Settlement and Development Corporation
Director, Bureau of Plant Industry
Chief, Industrial Engineering Division, Bureau of Science
Assistant Professor, University of the Philippines, College of Agriculture
6. Bio-energy. Farm mechanization. Indigenous sources of energy.
7. Processing of agricultural products. Waste recycling.
8. Biogas works at Maya Farms. Producer gas as fuel for internal combustion engines. Straight hydrous alcohol as fuel for internal combustion engines. Biogas and waste recycling. Coconut oil as motor fuel. Recycling system for farming.
9. *
10. Official: Liberty Building, Pasay Road, Makati, Metro Manila, Philippines
Residence: 9 Magallanes Avenue, Magallanes Village, Makati, Metro Manila, Philippines

52. Mr. MEI He-Xiao

1. China 2. 15 May 1937
3. Graduate, Xian Architectural Engineering Institute, Department of Civil Engineering
4. Russian, English, Japanese
5. 1980 Wujin Biogas Research Institute, Jiangsu Province
1960-1980 After advanced study at Fudan University, engaged in construction and design
6. Construction. Design
8. Research and construction of modernized biogas plants in villages

10. Provincial Biogas Research Institute, Ben Niu Zhen, Wujin County, Jiangsu Province, China

53. Mr. T.K. MOULIK

1. India 2. 11 March 1936
3. M.Sc. and Ph.D. (Agricultural Development Extension) (Indian Agricultural Research Institute, Delhi)
4. Bengali, Hindi, English Pidgin
5. 1974 to-date Professor, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad
1970-1974 Senior Fellow, Research School of Pacific Studies, Australian National University, Canberra
1969-1970 Associate Professor, Indian Agricultural Research Institute, Delhi
1967-1969 Programme Analyst, USAID, Delhi
1965-1967 Assistant Professor, Indian Agricultural Research Institute, Delhi
1958-1960 Agricultural Extension Office, Department of Agriculture, West Bengal, India
6. Development economics
7. Sociology. Organization behaviour
8. Co-ordinator of the action research project on rural development for rural poor. Rural energy projects. Transfer of technology for backward area development
9. *
10. Indian Institute of Management, Vastrapur, Ahmedabad 380 015, Gujarat, India

54. Mr. Raymond M. MYLES

1. India 2. 31 July 1943
3. B.Sc. (Agricultural Engineering) University of Allahabad), M.Sc. (Agricultural Engineering) (University of Guelph, Canada); MASE, MISAE
4. English, Hindi
5. Present Senior Specialist (appropriate technology), Action for Food Production, New Delhi. Involved in the promotion of biogas plants.

About 17 years experience, in different capacity as engineer, specialist, consultant and manager in the field of agricultural engineering

6. Farm power and machinery. Agro engineering services and appropriate/rural technology. Utilization of alternative energy under rural conditions. Biogas technology.
7. Extension and training in agriculture and rural development field
8. Extension and systematic promotion of Janata biogas plant, through demonstration-cum-training. Field evaluation of small tractor (self helper-7 hp) under different agro-climatic conditions in India
9. "Promotion of biogas plants for small and marginal farmers on individual and community basis". "Construction of a 2 cu m (70 ft) demonstration-cum-training model Janata biogas plant in the Union Territory of Delhi". "Biogas technology: a review of approach adopted by AFPRO in the systematic promotion of Janata plant". "Field evaluation of Hinomotor tractor (7 hp)".
10. Action for Food Production (AFPRO), C-17 Community Centre, Safdarjung Development Area, New Delhi 110 016, India

55. Mr. Ram Krishnan NAIDU

1. Fiji 2. 7 July 1927
3. B.Sc. (Agriculture) (Massey), B.Sc. (Agriculture) (Allahabad)
4. English, Hindi, Fijian, Tamil
5. Present Secondment to South Pacific Commission, as consultant on integrated farming
 1976-1978 Agriculture Department, Government of Fiji
 1965-1975 Self-employed as farmer
 1953-1958 and 1961-1964 Agriculture Department, Government of Fiji
6. Animal husbandry. Tree crops.
7. Agriculture in general and fresh water fish raising (livestock and crops)
8. South Pacific Commission has projects in Tonga, Cook Islands, Tahiti, Fiji, Samoa, Solomon Islands – a total of 23 digesters
10. c/o South Pacific Commission, Department of Agriculture, Box 358, Suva, Fiji

56. Mr. V.P. NARAYANASWAMY

1. India 2. 26 April 1941
3. B.E. (Civil Engineering), M.Sc. (Structural Engineering), Ph.D. (Structural Engineering)
4. English, Tamil, Hindi, German

5. 1968 to-date Scientist, Structural Engineering Research Centre, Roorkee
July – November 1978 Fellow, Asian Institute of Technology, Bangkok
1963-1964 Associate Lecturer, Sri Venkateshwara University, Tirupati
6. Structural engineering.
7. Biogas technology
8. Development of ferrocement gas holder for biogas plants (completed). Development of ferrocement components for biogas plants (ongoing).
9. *
10. Structural Engineering Research Centre, Roorkee (U.P.) 247 672, India

57. Mr. S. NEELAKANTAN

1. India
2. 11 March 1941
3. B.Sc. (Agriculture), M.Sc. (Agriculture), Ph.D.
4. English, Tamil, Hindi
5. 1972 to-date Scientist, Dairy Bacteriology Division, National Dairy Research Institute, Karnal
1968-1972 Assistant Microbiologist, Haryana Agricultural University
6. Microbiology and chemistry of anaerobic digestion into biogas. Soil microbiology – legume inoculants. Silage microbiology – lactic fermentation
7. Composting of cattle manure. Blue green algae inoculation to rice fields.
8. Isolation of efficient rhizobium for fodder legume. Microbial and nutritional studies of some silages. Composting of dairy farm wastes with desirable fermentation. Biogas production during winter and utilization of slurry. Improved and efficient dairy farming through harnessing locally available energy sources.
9. *
10. Dairy Bacteriology Division, National Dairy Research Institute, Karnal 132 001, India

58. Miss Watana NOPAKOON

1. Thailand
2. 1949
3. B.Sc. (Chulalongkorn University)
4. Thai, English

5. 1976 to-date Scientist, Alternative Energy Study and Development Project, National Energy Administration, Bangkok
1972-1976 Scientist, Energy Research and Development Section, National Energy Administration, Bangkok
6. Chemical technology
7. Food technology
8. Experiment on: solid fuels from waste materials; biogas production from agricultural waste; analysis of solid fuels.
10. Technical Division, National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

59. Mr. Enrico D. OBIAS

1. Philippines
2. 3 October 1933
4. English, Filipino
5. 1960 to-date Chief Chemist (1960-1971), Assistant Vice President for Research and Development and Quality Control (1971-1975) and then Vice President for Operations, Maya Farms Division, Liberty Flour Mills, Inc., Manila
1959-1960 Researcher, H.G. Henares and Sons
1958-1959 Instructor, University of the Philippines
6. Food processing
7. Waste recycling
8. Biogas works at Maya Farms.
9. Co-author: "Biogas and Waste Recycling", 1978. "The Small Biogas Plants", 1977
10. 51 Fordham Street, White Plains, Quezon City, Metro Manila, Philippines; or c/o Maya Farms Division, Liberty Flour Mills Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

60. Mr. V. PADMANABHAN

1. India
2. 19 September 1923
3. Graduate in science, trained in village industries
4. English, Tamil
5. 1976 to-date Secretary (1976-1978) and then Managing Trustee, Gandhigram Trust

- 1972-1976 Special Officer (village industries), Khadi and Village Industries Commission, Bombay
- 1960-1972 Secretary, Tamil Nadu Khadi and Village Industries Board
- 1956-1960 Deputy Director, Industries and Commerce, in charge of village industries of the Tamil Nadu State
- 1952-1956 Personal Assistant to Project Executive Officer, Assistant Project Officer and Block Development Officer of Community Development Programme of Periyar Division, Madurai District, Tamil Nadu
- 1947-1952 Secretary, Gandhigram
6. Village industries. Village reconstruction and training. Village industries including biogas and other occupations like spinning, weaving, soap manufacture, leather manufacture, carpentry and blacksmithy, lime manufacture, processing of cereals and pulses, oil extraction, bee-keeping etc.
 7. Agriculture. Animal husbandry. Silk-worm rearing.
 8. Ferrocement digester and gas holder with the gas drawn from below. Ferrocement digester and gas holder with water jacket system. Ferrocement digester and mild steel gas holder, square type. Brick masonry digester with high density polyethylene gas holder. Chinese design of biogas plant with fixed dome. Conventional Khadi and Village Industries Commission design with movable floating drum.
 9. Articles on rural development and village industries in *Commerce, Khadi Gramodyog, The Mail* and other journals
 10. Gandhigram Trust, Madurai District, Gandhigram 624 302, Tamil Nadu, India

61. Mr. Mohan PARIKH

1. India
4. English, Hindi, Gujarati
5. Present Director, Agricultural Tools Research Centre, Bardoli
Director, Yantra Vidyalaya, Bardoli (an institute for rural development)
Managing Trustee, Suruchi Chhapshala, Bardoli (a school of printing technology)
6. Social service and rural development. Improved agricultural hand tools and bullock – driven implements for small and marginal farmers.
7. Biogas energy – cow dung gas plant; garbage gas plant; gas plant with fixed R.C.C. roof. Solar energy utilization – solar cooker.

8. Design and development of about 60 improved agricultural tools and implements. Prototype experimental garbage gas plant with different raw materials. Design and development of a gas plant with fixed R.C.C. roof on Chinese pattern. Conversion of conventional gas plants with iron dome to store gas into fixed R.C.C. roof gas plant.
9. *
10. Agricultural Tools Research Centre, Suruchi Campus, Post Box 4, Bardoli 394 601, India

62. Mrs. P.P. PARIKH

1. India
3. Ph.D. (Mechanical Engineering); MIE (India), MAIE (India)
4. English
5. Present Assistant Professor, Mechanical Engineering Department, Indian Institute of Technology, Bombay
6. Internal combustion engines
7. Environmental engineering. Combustion engineering
8. Utilization of biogas in diesel engines. Environmental aspects of biogas engines
9. Monogram on recent developments in gobar gas technology
10. Mechanical Engineering Department, Indian Institute of Technology, Bombay 400 076, India

63. Mr. G.L. PATANKAR

1. India
3. B.Sc. (Chemistry – Physics); A.I.C. (Fuels and Gas Water and Sewage); Diploma in advertising and public relations.
4. English, Hindi, Marathi
5. 1962 to-date Laboratory Supervisor (1962-1963), Fuel Chemist (1963-1973), Assistant Director (1973-1976) and then Deputy Director, Gobar Gas Scheme, Khadi and Village Industries Commission
6. Biogas technology
7. Solar energy for village uplift
8. Simplification in the design of biogas plant (domestic). Problems of corrosion of biogas plant. Design of community gas plant. Development of commercial

gas appliances. Gas plant for cold region. Fermentation kinetics and environment.

9. *
10. Gobar Gas Research and Development Centre, Kora Gramodyog Kendra, Borivli (West), Bombay 400 092, India

64. Mr. T.M. PAUL

1. India
2. 10 September 1916
3. B.Sc. (Chemistry), M.Sc. (Chemistry), Ph.D. (Dairy Science); MISCA, MRIC, MIDC, MSDT
4. English, French, Malayalam, Hindi, Tamil, Telugu
5. Present Director, National Institute of Waste Recycling Technology. Consultant to the Indian Institute of Technology, Madras, on community development and integrated rural development
1977-1978 Consultant to FAO on recycling of agricultural and animal wastes, Bangkok
February-July 1977 Regional Adviser on biogas, Natural Resources Division, ESCAP, Bangkok
1976-1977 Consultant to the South Pacific Commission on rural development based on integrated farming system
1967-1976 Head, National Dairy Research Institute, Bombay
1965-1967 Head, Division of Dairy Extension, National Dairy Research Institute, Karnal
1962-1965 Chief, Quality Control Officer, Delhi Milk Chem, New Delhi
6. Environmental pollution control through biogas and compost. Waste-recycling for energy as biogas and rural agricultural production and sanitation. Biogas and compost production from human and animal waste. Intensive mixed farming through use of liquid compost plants for biogas production and compost.
7. Dairy farming, biogas and compost production. Waste-land reclamation for increased agricultural production. Integrated rural development through mixed farming.
8. Rural development based on dairy-farming through integrated farming systems. Workshop on biogas for the Pacific island community. Recycling agricultural and animal wastes in the south and south-east Asian countries. Developed a system of intensive farming based on recycling of all wastes, solid, liquid and gaseous, making all agricultural practices independent of all outside-supplies of energy, chemical fertilizer etc. Developed a system for co-operative urban and rural habitation in and around cities and towns to make use of all waste-mater-

ials generated in urban areas, to develop a green-belt around, to make use of all city wastes, solid, liquid and gaseous, to produce all perishable agricultural commodities needed in the urban-centres.

9. *
10. National Institute of Waste Recycling Technology, A-18, Juhu Apartments, Juhu Road, Bombay 400 049, India

65. Mr. PENG Wu-Hou

1. China
2. 21 July 1939
3. Graduate, Shanghai Science and Technology University (specialization in biochemistry and physical chemistry) (1963)
4. English, Chinese
5. 1966 to-date In-charge, Comprehensive Research Office, Shanghai Institute of Industrial Microbiology, Shanghai
1963-1966 Research on fermentation for industries, Shanghai Light Industry Research Institute, Shanghai
6. Biochemistry
7. Microbiological fermentation
8. Research on biogas fermentation and on utilization of waste heat from power generation. Research on potential raw materials for biogas fermentation. Research on disposal of urban waste for biogas fermentation.
9. "Approaches to some aspects of increasing the volume of biogas production", *Energy Resources* No. 3, 1979. "Research on the effect of acetic acid, sodium, cellulose enzymes etc. in biogas fermentation". "Chemicals to stop formation of mildew", *Chemical World* No. 5, 1980. "Research on artificial biogas", parts I and II, *Industrial Microbiology*, December 1979 and 1980. "Report on utilization of waste heat from biogas power generation", ID/WG 321/4, June 1980.
10. Shanghai Institute of Industrial Microbiology, Shanghai, China

66. Mr. Chongrak POLPRASERT

1. Thailand
2. 25 October 1949
3. Ph.D. (Civil Engineering)
4. English, Thai
5. 1977 to-date Assistant Professor of environmental engineering, Asian Institute of Technology, Bangkok
6. Sanitation. Waste recycling.

7. Environment
8. Recycling rural and urban nightsoil in Thailand, a two-year research project sponsored by the International Development Research Centre, Canada
10. Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand

67. Mr. G.G. PURI

1. India 2. 16 August 1924
3. B.Sc. (Electrical and Mechanical Engineering). Director, Institute of Regional Analysis. Technical Member, NWWA, USA. Chairman, Institute of Engineers, Madhya Pradesh Centre
4. Hindi, English, Marathi, French, Urdu, Gujarati
5. 1974 to-date Founder/Executive Director (honorary), Resources Development Institute, Bhopal
 1973 to-date Chief Engineer, Irrigation Department, Government of Madhya Pradesh
 1977-1978 Managing Director, M.P. Lift Irrigation Corporation
 August-October 1979 Consultant, Asian Development Bank, Mission IV, agriculture credit project, Lao People's Democratic Republic
 1970-1973 Director, ground water surveys and tubewells, Government of Madhya Pradesh; also Expert, World Bank
 1968-1970 Superintending Engineer, Directorate tube wells, Madhya Pradesh; also Consultant, Development Resources Corporation, USA
 1958-1968 Executive Engineer, EIM, Irrigation Department, Government of Madhya Pradesh
 1958-1960 Consultant to Chief Engineer, Irrigation Department, Madhya Pradesh
 1950-1958 Assistant Engineer, Public Works and Irrigation Department and Bhilai Steel Plant
 1949-1950 Engineer (power), Empress Mills, Nagpur
6. Construction machinery, workshops, stores, projects construction and mechanization. Ground water development: wells, tube wells, drilling and pumping machinery
7. Resource development: all aspects including biogas technology and solar energy.
8. Research and research guidance on resource development projects, including biogas and solar energy technology. Auto-lift impulse pumps.
10. Resources Development Institute, E-3/76, Arera Colony, Bhopal, M.P., India

68. Mr. QIAN Ze-Shu

1. China
2. 1925
4. Chinese, English
5. Present Associate Professor of Microbiology, Zhejiang Agricultural University, Zhejiang
6. Soil microbiology
7. Biogas (methane fermentation)
8. Nitrogen fixation. Methane fermentation
9. "Studies of observation on methane fermentation in farmyard digesters in China". (in English)
10. Zhejiang Agricultural University, Zhejiang, China

69. Mr. S.K. RAJAPAKSE

1. Sri Lanka
2. 19 June 1952
3. National Diploma in Technology (Chemical Engineering); Specially trained in China on small and large scale biogas technology.
4. English
5. Present Chemical Engineer, Industrial Development Board, Katubedda, Moratuwa, Sri Lanka
6. Biogas and other alternate sources of energy.
8. Promotion of biogas in Sri Lanka in collaboration with World Vision International Organization. Training of technicians for construction of biogas works. Undertaking of design and construction works.
10. Industrial Development Board of Ceylon, 615, Galle Road, Katubedda, Moratuwa, Sri Lanka

70. Mr. M.A. Sethu RAO

1. India
2. 27 September 1924
4. English, Kannada
5. Present Joint Secretary, Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore
Reader in chemistry, University of Mysore, Karnataka
6. Physical chemistry

7. Science and technology. Planning. Popularization of science.
10. Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore 560012, India

71. Mr. P. Sreenivasa RAO

1. India 2. 5 July 1931
3. M.Sc., Ph.D.
4. English
5. 1961 to-date Scientist (1961-1976) and then Assistant Director, Central Salt and Marine Chemicals Research Institute, Bhavnagar
 1958-1961 Lecturer, M.R. College, Vijayanagaram
 1957-1958 Lecturer, A.C. College
 1950-1957 Demonstrator, Hindu College
 1970-1971 Reader in bioscience, Saurashtra University, Bhavnagar
6. Marine algae
7. Marine microbiology and marine biomedical
8. All-India co-ordinated project on algae – energy from sea weeds and other organic wastes
10. Central Salt and Marine Chemicals Research Institute, Waghawadi Road, Bhavnagar 364 002, India

72. Mr. Sempol RATASUK

1. Thailand 2. 18 October 1943
3. B.Sc. (Hons.) (Chemical Engineering) (Chulalongkorn University, Bangkok), M.Eng. (Environmental Engineering) (AIT, Bangkok), Ph.D. (Environmental Engineering) (University of Newcastle-upon-Tyne)
4. Thai, English
5. Present Environment and Development Department, Thailand Institute of Scientific and Technological Research, Bangkok
6. Chemical engineering. Environmental engineering.
8. Evaluation of treatment alternatives for molasses distillery stillage
9. On anaerobic filter treatment of strong organic wastes; anaerobic filter for biogas production
10. Thailand Institute of Scientific and Technological Research, 196 Paholyothin Road, Bangkhen, Bangkok 9, Thailand

73. Mr. REN Yuan-Cai

1. China
2. December 1933
3. Graduate, Chongqing Architectural Engineering Special School (1955) and Architectural Construction Special Night University (third year) (1959)
4. Self-educated in English
5. 1980 Chief, Biogas Digester Scientific Research Group, Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu
1976 In-charge, Central Experimental and Research Institute, Ministry of Construction, Third Bureau, responsible for environmental protection and scientific research, Division of Science and Technology, Urban Construction Commission, Chengdu, Sichuan
1965 Chief, Scientific Research Group, Office of Structures, Xinan Construction Science and Research Institute, Ministry of Construction, Chengdu, Sichuan
1959 Head, refining factory for reinforced concrete, Mao Ming City, Guangdong Province
6. Scientific research and management of biogas digester construction
7. Techniques of welding reinforcing bars. Techniques of practical application of concrete
8. Design and construction of standardized small biogas plants for farm households and research on collective or decentralized gas supply. Design and construction of medium-scale (60-200 m³) biogas plants. Research on power station for coordinated electricity generation and refining of by-products of agriculture. Design and construction of large-scale (300-1200 m³) biogas plants. Biogas fermentation techniques at general and medium temperatures. Research on a complete set for electricity generation.
9. "Collected fruitful scientific research results", Ninth information collection on digester construction, Sichuan Province Biogas Office compilation and publication. *Biogas techniques: design and construction of digesters*, Book II, textbook and reference for United Nations University, 1980.
10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Ren Min Nan Lu, Chengdu City, Sichuan Province, China

74. Mr. M.A. SATHIANATHAN

1. India
2. 5 January 1924
4. English, Hindi, Malayalam, French

5. 1978 to-date Co-ordinator, Energy and Environment Centre of Science for Villages; and also Director, Eco-Living Centre
 1969-1978 Secretary, Progressive Education Association; and also Vice-Chairman, Village Industrialization Association
 1967-1969 Director, Sevagram Rural Technical Training Centre (an Indo-German project)
 1965-1967 President, Rural Higher Education Institute, Sevagram
 1955-1964 Field work in Kerala and Gwalior as a village worker
 1947-1955 Head, Science and Handicrafts Department at Sevagram, Mahatma Gandhi's Village Headquarters.
6. Education. Biogas technology. Rural industrialization
7. Taking science to the villages
8. Studies on: equipment design engineering and improvement of digesters; digestion process engineering studies; feed stock processing and plant design, selection of biogas system for its use in rural industries; systems approach to biogas utilization (ongoing)
9. *
10. Kakawadi, Wardha 442 001, India

75. Mr. B.R. SAUBOLLE, S.J.

1. India
2. 1 October 1904
3. Jesuit priest
4. Hindi, English, French, Nepali, Latin
5. 1965 to-date Experimented in solar energy
 1953-1980 Experimented in biogas
 1951-1980 Education
 1940-1950 Parish work in India
6. Priesthood. Education, Primary and middle school
7. Biogas. Solar energy. Appropriate technology.
8. Introduction of biogas and solar water heaters in Nepal. Member of Editorial Board of *Biogas Newsletter Nepal*. Consultant member of periodical *Shakti* (Energy). Development of smokeless stoves.
9. On, fuel gas from cow dung, home brew, mini-technology
10. Post Box 50, Kathmandu, Nepal

76. Mr. Iqbal Hussain SHAH

1. Pakistan
2. 11 November 1934
3. B.Sc. (Mechanical Engineering), MME (Colorado State University), M.Sc. (Thermo) (University of Birmingham), Post Graduate Diploma (Industries) (Norway)
4. English, Pashto, Urdu, Persian
5. 1978 to-date Dean/Director Research, Faculty of Engineering, University of Peshawar, Pakistan
- 1976 Affiliated Professor, Colorado State University
- 1975 Visiting Professor, Sri Lanka, under UNESCO
- 1956-1969 Senior Lecturer (1956-1961), Reader (1961-1969), and then Professor, Engineering College, University of Peshawar
- 1955-1956 Assistant Engineer, Hydro-electric Project, Warsak
6. Mechanical engineering. Cryogenic engineering. Thermodynamic power in general. Refrigeration. Air-conditioning. Solar energy. Biogas
7. Appropriate technology research projects. Solar energy. Biogas
8. Design and construction of sealed type, variable pressure biogas plant. Determination of heat of temperature on biogas production. Conversion of 5 hp petrol engine to run on biogas (tested for 2 years and can be directly started with biogas). Conversion of 6 hp diesel engine to run on biogas and diesel. Design and construction of vertical type biogas pump. Utilization of solar energy in production of biogas. Biogas as a fuel for power production on agricultural farm.
9. *
10. Faculty of Engineering, University of Peshawar, P.O. Peshawar University, N.W.F.P., Pakistan

77. Mr. J.B. SINGH

1. India
2. 23 May 1926
3. M.Sc. (Agriculture) (Agro-economics)
4. English, Hindi
5. Present Executive Director, Action for Food Production (AFPRO), New Delhi
6. Agricultural economics and extension. Community development
7. Appropriate/rural technology. Biogas technology

8. Chief co-ordinator: extension and systematic promotion of Janata plant through demonstration-cum-training of Janata plants scheme; field evaluation of small tractor (self helper – 7 hp) under different agro-climatic conditions in India
9. Promotion of biogas plants for small and marginal farmers on individual and community basis
10. Action for Food Production (AFPRO), C-17 Community Centre, Safdarjang Development Area, New Delhi 110 016, India

78. Mr. Ongart SITTHICHAROENCHAI

1. Thailand
3. B.Sc. (Sanitation), MPH (Environmental Health)
4. English, Thai
5. 1970 to-date Department of Health, Ministry of Public Health, Bangkok
6. Environmental sanitation
7. Environmental health
10. Sanitation Division, Department of Health, Ministry of Public Health, Bangkok, Thailand

79. Mr. Pichit SKULBHRAM

1. Thailand
3. B.Sc. (Sanitary Science) (Mahidol University), MPH (Environmental Health) (University of Minnesota)
4. English, Thai
5. 1957 to-date Instructor (1957), Assistant Professor (1971) and then Associate Professor, Sanitary Science Department, Faculty of Public Health, Mahidol University, Bangkok
6. Environmental health, majoring in water and wastewater
7. Teaching in general sanitation
8. Biogas production from various organic matters; two research projects completed at Sanitation Region Centre 1, Prabhudtabat District, Saraburi Province.
9. Two final reports on biogas research published in the Journal of the National Research Council of Thailand (in Thai)
10. Faculty of Public Health, Mahidol University, 420/1 Rajavithi Road, Bangkok 4, Thailand

80. Mr. Koentoro SOEBJARSO

1. Indonesia
3. 17 October 1944
3. Faculty of Agricultural Technology, Gajah Mada University
4. English, Indonesian
5. 1976 to-date Research staff, Laboratory of Industrial Gases, Industrial Research Institute, Centre for Chemical Industry, Indonesia
1973-1976 Research staff, Laboratory of Microbiology, Indonesian Leather Research Institute, Indonesia
6. Industrial gases.
8. Research and development of biogas and its prototype
10. Industrial Research Institute, Centre for Chemical Industry, Jalan Karanganyar 55, Jakarta, Indonesia

81. Mr. Richard K. SOLLY

1. Australia (resident of Fiji)
3. B.Sc., M.Sc., Ph.D.; ARACI
4. English
5. Present Senior Lecturer in chemistry, University of the South Pacific, Suva, Fiji
6. Investigation of mass and energy flows in the biogas system as a function of the system parameters. Development of biogas systems appropriate to the rural areas of developing countries
7. Utilization of vegetable matter in biogas systems
8. Investigation of rural digesters in the South Pacific. Installation and operation of polymer rubber biogas digesters in appropriate locations in the South Pacific. Development of simple durable biogas digesters. Utilization of water hyacinth and vegetable matter in biogas digesters. Development of integrated biogas systems
9. *
10. University of the South Pacific, P.O. Box 1168, Suva, Fiji

82. Mr. W. Robert STANTON

1. United Kingdom
2. 24 February 1923
3. B.Sc., Ph.D. (London); FIBiot, FIFST

4. French, German, Italian, Malay, English
5. Professor of Botany, University of Malaya, Malaysia
 Consultant and Member, UNEP/UNESCO/ICRO Panel for Applied Microbiology
 in south-east Asia
 Head, Microbiology Section, Tropical Products Institute, London
 Senior Botanist, Nigeria
 UK Research Institutions
6. Processing tropical and equatorial crops and by-products
7. Fermented foods
8. Vegetable oil recovery from vegetable oil processing wastes. Equatorial starches
 for establishment of food and gasohol industries – palm starches and sugar. Bio-
 gas plant, constructed with mild steel and with digester volume of 2 x 3000 m²
 at a cost of approximately US\$ 600,000, with continuous feed of about 400
 tons/day of effluent and palm oil processing, producing 9 tons/day methane, at
 present utilized for hot air drying with the effluent used as direct fertilizer on
 soil.
10. 346 Lorong 10C, United Gardens, Old Klang Road, Kuala Lumpur, Malaysia

83. Mr. D.J. STEWART

1. New Zealand
2. March 1942
3. B.Sc., M.Sc., Ph.D.
4. English, French
5. 1972 to-date Scientist, Ministry of Agriculture and Fisheries, New Zealand
 1970-1971 Assistant Professor, Dalhousie University, Halifax, N.S., Canada
 1968 Post-Doctoral Fellow, Dalhousie University, Halifax, N.S.,
 Canada
 1967 Junior Lecturer in chemistry, Victoria University, Wellington,
 New Zealand
6. Chemistry. Biochemistry
7. Physics. Engineering.
8. Effects of industrial pollution on agriculture. Production of biogas from crops
 and wastes. Energy farming. Energy in agriculture. Farm scale biogas and ethanol
 plants.
9. *

10. Section Leader, Energy and Environment Section, Invermay Agricultural Research Centre, Private Bag, Mosgiel, New Zealand

84. Mr. SUN Guo-Chao

1. China
2. January 1941
3. Graduate, Nanjing Agricultural College, Department of Agriculture (specialization in agriculture)
4. English, Chinese
5. 1968 to-date Lecturer and Deputy Chief, Biogas Group, Chengdu Biological Research Institute, Chinese Academy of Sciences
6. Microbiology
7. Biogas fermentation and biochemical analysis
8. Microbiological biogas fermentation. Biogas fermentation techniques
10. Chengdu Biological Research Institute, Chinese Academy of Sciences, Chengdu City, Sichuan, China

85. Mr. Calixto C. TAGANAS

1. Philippines
2. 21 October 1921
3. B.S.C.E., S.E.
4. English, Filipino
5. Assistant Vice President, Liberty Flour Mills, Inc., in charge of biogas works design, construction and operations and civil works
Administrative Officer and Officer-in-Charge, Civil Department, Liberty Flour Mills, Inc.
Head Miller, Liberty Flour Mills, Inc.
General Superintendent, Ysmael Wood Industries
Shift Miller, Liberty Flour Mills, Inc.
Assistant Civil Engineer, Liberty Flour Mills, Inc.
Construction Inspector, National Power Corporation
Engineer Aide, Ministry of Public Works and Communication
Instructor, Aurora College (formerly Baler Institute)
6. Design, construction and operation of biogas works. Construction of multi-rise structures
7. Flour milling, veneer and plywood manufacturer

8. Biogas works at Maya Farms and other stock farms
9. "Biogas and waste recycling". "The small biogas plant".
10. Official: Liberty Flour Mills, Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines
Residence: 149 K-6 Kamias, Quezon City, Philippines

86. Mr. Morakot TANTICHAROEN

1. Thailand 2. 13 October 1947
3. Ph.D. (Microbiology) (University of Rhode Island)
4. English, Thai
5. 1978 to-date Head, Department of Microbiology, King Mongkut's Institute of Technology, Thonburi Campus, Bangkok
1972-1977 Teaching and Research Assistant, University of Rhode Island, USA
1968-1971 Research Assistant, SEATO Medical Research Laboratory, Bangkok
6. Microbiology
7. Renewable energy (bio-energy conversion)
8. Biogas mechanism generated from plant materials. Isolation of cellulolytic micro-organism from soil and digester sludge
10. King Mongkut's Institute of Technology, Thonburi Campus, 48 Suksawad Road, Rajburana, Bangkok 14, Thailand

87. Mr. Boontham TESNA

1. Thailand 2. 19 June 1928
3. B.Sc. (Agriculture) (Kasetsart University), M.S. (Agricultural Education) (Oklahoma State University), Ph.D. (Co-operative Extension)
4. English, Thai
5. Government official, serving as an instructor in vocational agriculture school for nine years and lecturer, assistant professor, associate professor for ten years both at Khon Kaen University and Maejo Institute of Agricultural Technology
6. Agricultural education
7. Interested in biogas primarily in the interests of manure collection, sanitation and gas for cooking

8. Has encouraged many rural and farm population to build biogas units with different designs; with or without gas tanks, different shapes-round, rectangular, cubic, square; with inside outlet and outside for draining spent manure. Good units for showing to interested groups or individuals; 10 in Chieng Mai, 1 in Lumpang, 2 in Pitsanulok and 2 in Lamphoon
9. A paper presented to Universiti Pertanian Malaysia about social-economic outcome of the extension of biogas technology
10. Dean, Faculty of Agricultural Business, Maejo Institute of Agricultural Technology, Maejo, Chieng Mai, Thailand. Tel: 236-602

88. Mr. Y.R. TIPNIS

1. India 2. 19 December 1907
3. B.A., B.Sc., B.E. (Civil Engineering); Life Member: Indian Institute of Geohydrologists, Calcutta; FIE, FRDI, MIWWE, MIPE, MIME
4. English, Hindi, Marathi, Gujarati
5. 1970 to-date Trustee and Director, Rayalaseema Development Trust, Anantapur (during October 1975 – December 1976, with Pentajen Engineering as coordinating sales engineer for indented equipment)

1970-1969	Adviser, Udain Engineering Co. (contractors and builders)
1967-1970	Consultant
1965-1967	Chief Engineer, Sikkim P.W.D., Ganjtale, Sikkim
1962-1965	Chief Engineer, Indian Institute of Petroleum Research
1959-1962	Chief Civil Engineer, Gantrati Refinery Noomati, Assam
1957-1959	Chief Plant Engineer, Hindustan, Bangalore
6. Composite civil engineering and indential projects
7. Water supply survey, planning implementation, conservation and replenishment. Agro-oriented projects like biogas plants and solar cooker. Social work with emphasis on experience of work and rural education
8. Among others, construction of biogas plants and cheap solar cookers.
10. c/o Resources Development Institute, 1100 Quarters Area, Bhopal, 462016, India

89. Mr. Hiroji Narayan TODANKAR

1. India 2. 7 December 1918
3. Practical experience with nightsoil and cattle dung gas plants over the past 22 years; also learned the technique of constructing inexpensive hygenic latrines for Indian villages.

4. Marathi (mainly), Hindi and English (working knowledge)
5. 1959 to-date Organizer of the Bhangi Mukti (improved rural hygiene scheme without the hired services of scavengers) under the aegis of Gandhi Memorial Fund for the State of Maharashtra (India).
1949-1959 Social worker in Government-sponsored Sarvodaya (integrated rural development organization) at Gopuri.
6. Rural hygiene. Biogas
7. Rural education
8. Introduction in villages of improved, inexpensive hygienic latrines and nightsoil gas plants. During the past 20 years constructed over 56,000 latrines and over 100 nightsoil biogas plants. Earlier organized 14 schools on Gandhiji's model of occupation oriented basic education.
9. One informative handout on nightsoil gas plant (in English)
10. Gandhi Bhavan, Kothrud, Pune 411 029, Maharashtra, India

90. Mr. TSE Shu-Chien

1. China
4. English, Chinese
5. Present Head, Department of Soils and Agricultural Chemistry, Zhejiang Agricultural University
6. Soil microbiology
7. Biogas
9. Experimental reports
10. Laboratory of Soil Microbiology, Zhejiang Agricultural University, Hangzhou, Zhejiang, China

91. Mr. TU Jia-Bao

- 1; China
2. March 1939
3. Graduate, Beijing Agricultural University (1964)
4. Chinese
5. 1978 to-date Planning and managing biogas research and implementation
1964-1977 Planning and managing agricultural scientific instruments and equipments

6. Biogas research, planning and managing
7. Biogas implementation and administration
8. Programmes under National Biogas Office
9. Reports at UNDP/ESCAP 1978, UNAPDI 1978, FAO 1980 and UNIDO 1980
10. National Biogas Office, Ministry of Agriculture, Ho Pin Lee, Beijing, China

92. Mr. Sornthep TUMWASORN

1. Thailand 2. 25 July 1951
4. English, Thai
5. 1978 to-date Junior Lecturer, Animals Science Department, Kasetsart University, Bangkok
1977 Research Assistant, Rockefeller Foundation
6. Animal breeding and production
7. Agricultural waste management
8. Integration of biogas with agricultural system under village conditions
10. Animal Science Department, Kasetsart University, Bangkok 9, Thailand

93. Mr. WANG Da-Si

1. China 2. 23 April 1923
3. Graduate, Catholic University (1945). Post-graduate, Peking Union Medical College (1949)
4. English, Chinese
5. 1959 to-date Institute of Microbiology, Chinese Academy of Sciences
1949-1959 Institute of Forestry and Soil, Chinese Academy of Sciences
6. Bacteriology
7. Industrial bacteriology
8. Bacterial taxonomy. Bacteria in biogas production
9. "Foundation for bacterial taxonomy", Science Press, 1977
10. Institute of Microbiology, Chinese Academy of Sciences, Beijing, China

94. Mr. WANG Meng-Jie

1. China
2. 1935
3. University graduate, Herbin North-east Agricultural University (1957-1962)
4. Chinese, Japanese
5. 1978 to-date Engineer/Chief, Energy Sources Engineering Office, China Research and Designing Institute of Agricultural Engineering
1962-1978 Engineer, Farm Machinery Repairing and Research Institute, Heilongjiang Province
6. Mechanical engineering. Energy resources engineering
7. Farm mechanization. Utilization of plasma as arc heat source
8. Medium temperature biogas engineering. Standardization of small-scale biogas plants. Utilization of solar energy for seeding biogas plants through winter. New energy sources for village construction
9. "Norms for farm machinery maintenance". "Renovation of old tractors".
10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

95. Mr. WANG Xin-Quan

1. China
2. July 1940
3. Graduate, Shanghai Special School for Electrical Industry (specialization in manufacture of steam turbine)
4. Can translate written texts into English, with the help of dictionary.
5. 1963 to-date Chief Engineer (power machinery), Sichuan Agricultural Machinery Research Institute, Sichuan
6. Research on practical applications of biogas as motive power for agriculture
7. Research on forming a complete set machinery for biogas. Research on small horsepower diesel machine
8. Research on installation for stirring in biogas plant and on small horsepower diesel engine
9. "Practical applications of biogas as motive power in agriculture", in the study compiled for United Nations University on biogas engineering
10. Agricultural Machinery Research Institute, Sichuan Province, China

96. Mr. Myo WIN

1. Burma
3. B.E. (Agriculture), M.Eng.Sc. (Melb)
4. Burmese, English
5. 1979 to-date Lecturer, Agricultural Engineering Department, University of the South Pacific, Alafua, West Samoa
1965-1979 Instructor (1965-1971), Assistant Lecturer (1971-1978) and then Lecturer (1978-1979), Mechanical Engineering Department, RIT
6. Mechanical and agricultural engineering
7. Soil and water conservation
8. Supervised undergraduate and post-graduate theses. Testing of small farm implements
10. c/o Agricultural Engineering Department, University of the South Pacific Alafua, Samoa

97. Mr. Dong Han WOOK

1. Republic of Korea
3. B.S. and M.S. (Agricultural Chemistry) (Korea University), Ph.D. (Agricultural Science) (Hokkaido University, Japan)
4. English, Japanese
5. Present Agricultural Senior Researcher/Chief, Rural Energy Resources Research Division, Institute of Agricultural Science, Office of Rural Development
6. Biogas production and utilization
8. Studies on material resources for biogas production. Development of biogas plant types and biogas utilization
9. Studies on biogas generation from animal wastes. A feasibility study of village scale biogas plant during winter season
10. Institute of Agricultural Science, Office of Rural Development, Suweon, Republic of Korea

98. Mr. WU Chang-Lun

1. China
2. December 1937
3. Graduate, Beijing Agricultural Mechanization Institute (1959)

7. Botany
8. Laser induced mixing of bacteria at low temperature biogas plant. Addition of formaldehyde, acetone acid to raise the effect of the rate of gas production. Experiment with putting in bacteria. Plants as a source of energy – water hyacinth. Research on water hyacinth, green grass increasing the volume of biogas. Research on potentiality of water hyacinth for producing biogas and on methods of introducing feed materials. Comparison of results of single stage and multi-stage fermentation with respect to biogas production. Separate appraisal of methane bacteria
9. “Flora in Shandong economy”, Shandong People’s Publishing House (1978). “Water hyacinth and green grass are good raw materials for fermentation”, Chongqing Microbiology Society (1979). “Production at dew point low temperature (reddish brown requirement, 9.2): a summing up”, Sichuan Microbiology in Agriculture, second anthology
10. Microbiology Department, Chongqing Teachers College, Chongqing, Sichuan Province, China

101. Mr. XU Jie-Quan

1. China
2. March 1945
3. Graduate, University of Fudan (specialization in microbiology – biochemistry)
4. English, Chinese
5. 1968 to-date Engineer, Chengdu Institute of Biology, Chinese Academy of Sciences, research in biogas fermentation
6. Biochemistry
7. Biogas fermentation
8. Two-phase anaerobic digestion
10. Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, Sichuan, China

102. Mr. XU Ke-Nan

1. China
2. September 1927
3. Graduate, Department of Agricultural Chemistry, Sichuan University (specialization in biochemistry) (1952)
4. English (reading), Chinese
5. 1952 to-date Technician, Agricultural Technician, Deputy Chief, Research Office, Research Institute for Soil and Fertilizer, Academy of Agricultural Science, Sichuan

6. Agricultural chemistry
8. Accelerated composting. Manufacturing granulated fertilizer from urban garbage. Ground phosphate rock. Fertilizer nutrition survey. Nitrogenous and phosphatic nutrition for rapeseed and fertilizer application for high yield. Techniques of application, effectiveness and utilization of biogas fertilizers
9. "Acceleration in composting", Sichuan People's Publishing House (1956). "Methods of manufacture and use of granulated fertilizer", Sichuan People's Publishing House (1955). "Ammonia water and hydro carbonic acid", joint publication of Sichuan Province Agricultural Bureau, Fertilizer Division and Sichuan Province Agricultural Investment Corporation (1974). "Simplified method of measuring content of humic acid and carbonic acid in rational application of fertilizers for raising its effectiveness", Sichuan Provincial Information Centre for Chemical Industry Techniques (1976). "Anthology on means of production", *Research and Utilization of Biogas Fertilizer*, Sichuan Provincial Biogas Office (1979). "Severe toxic gas formation during decomposition process: examination of early signs", *Sichuan Agricultural Science and Technology*, No. 4 (1980)
10. Research Institute for Soil and Fertilizer, Academy of Agricultural Science, Chengdu City, Sichuan Province, China

103. Mr. XU Yi-Zhong

1. China
2. 15 October 1934
3. University graduate (biology)
4. Chinese
5. Present Engineer, Chengdu Biogas Scientific Research Institute, Sichuan July – August 1980 UNDP biogas consultant in the Philippines
6. Biology. Biogas digestion. Biogas fermentative bacteria
8. Some conclusions from biogas experiments (1974). Investigation of general conditions for use of biogas in the village in spring (1975). Experiments to strengthen management and increase the rate of biogas production (1975). Tests of rules for fermentation (1976). Relation between different siting of biogas plants and increase in production (1976). Experiments with production rates at various pressures (1977). Relations between different fermentation materials and fertilizers (1978). Research on absence of oxygen in the digester (1980). Use of pig manure (1980)
9. Eight articles on biogas published in Chinese biogas magazines
10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu, Sichuan, China

104. Mr. XU Zeng-Fu

1. China
2. 1921
3. Fudan University, Shanghai (1946)
4. English, Japanese, Chinese
5. Present Vice-director, Zhejiang Biogas and Solar Energy Scientific Research Institute, Hangchow
6. Biogas technology and economy
7. Solar energy application
8. Biogas drying technique. New type of mesophilic biogas plant
9. *Biogas Technology*, to be published by United Nations University, Tokyo
10. Zhejiang Biogas and Solar Energy Scientific Research Institute, Hangchow City, China

105. Mr. ZHANG Chang-Ming

1. China
2. November 1936
3. Graduate, Sian Communication University (specialization in internal-combustion engines) (1961)
4. Chinese, English, Russian
5. 1961 to-date Technician, internal-combustion engine (1961-1965) and then Engineer, internal-combustion engine, Sichuan Province Agricultural Machinery Research and Design Institute
6. Biogas application for energy in agriculture
7. Gas engines. Diesel engines
8. Gas fuelled engine. Research and manufacture of S195 – small-scale model
10. Sichuan Province Agricultural Machinery and Design Institute (3rd Office), Sichuan, China

106. Mr. ZHANG Guo-Zheng

1. China
2. 10 March 1936
3. Graduate in biology, China South-west Normal College (1961)
4. Chinese, English

5. 1959 to-date Assistant in botany (1959-1962), Assistant in microbiology and Lecturer (1963-1980), Chief of Biogas Research Section (1974-1978) and then Head of Bio-energy Research Institute, China South-west Normal College
6. Specialist in microbiology and fermentation research
8. Research on mixture ratio among fermentation materials, fermentation conditions, fermentation bacteria, fermentation materials in the city and in the village. Scientific management of small digesters
9. Experiments with activities of micro-organisms. Research on ratio of feed materials for digester. Pretreatment of feed materials. Survey of biogas development inside and outside the country
10. China South-west Normal College, Biogas Bio-energy Research Institute, Xinan, China

107. Mr. ZHANG Wei

1. China
2. October 1922
3. Graduate, University of Chongqing, Department of Architectural Engineering
4. Chinese, English
5. 1952 to-date Architect, S.W. Institute of Building Design, Chengdu, Sichuan
1979 Lecturer, Chengdu Biogas Seminar
Participant in Bremen Biogas Workshop, 1979 and in Indo/Sino/German Joint Biogas Group
6. Architecture
7. Planning. Biogas (in co-operation with National Biogas Office)
8. Information and translation of materials concerning biogas study
9. "Construction of biogas digester in Sichuan, China", *Agricultural Waste*, November 1979 (in English)
10. S.W. Institute of Building Design, 168 Jin Hwa Street, Chengdu, Sichuan, China

108. Mr. ZHOU Meng-Jin

1. China
2. 25 February 1935
3. Graduate, Department of Biology, Beijing Teacher's College (1961)
4. Chinese, English
5. 1961 to-date Teacher, Department of Biology, Beijing Teacher's College
6. Microbiology

8. Pure cultural isolation of methanogenic bacteria. Study of kinetic of methane fermentation
10. Department of Biology, Beijing Teacher's College, Beijing, China

109. Mr. ZOU Yuang-Liang

1. China
2. August 1937
3. Graduate, Shandong University, Biology Department (specialization in microbiology) (1960)
4. Chinese, Russian
5. 1978 to-date Engineer, Deputy Chief, Biological Energy Office, Energy Research Institute, Shandong Academy of Sciences
1966-1978 Chief, Chemistry Teaching Group, Shandong Special Teachers College
1960-1966 Assistant Professor, Biology Faculty, Shandong University
6. Microbiology
7. General chemistry
8. Screening and breeding of anti-cancer antibiotics. Marine actinomyces. Breeding of actinomyces 2321 amino acidic nourishment defective type. Research on management of biogas plant through winter. Biogas seeding. Research on potential of digester materials for gas production and the optimum combination of materials.
10. Shandong Province Energy Resources Research Institute, Jinan City, Shandong Province, China

110. Mr. J.H. FINLAY

1. United Kingdom
2. 3 July 1938
3. C. Eng., MI Prod. E.
4. English
5. 1974 to-date Biogas Consultant, Development and Consulting Services, Butwal, Nepal
1980 Consultant, compilation of UN ESCAP Guidebook on Biogas Development, 1980
6. Biogas plant design, Biogas appliances designs
7. Engineering

8. Design and construction of floating gas holder drum type gas plant, cu ft per day of 100, 200, 350 and 500; drumless gas plants of 10, 15, 20 and 50 m³; gas production equipment; hard go-bar mixer; 1300 mm water pressure gauge. (completed)
 Gas taps; tunnel plant; attaching small generator to biogas/diesel engine water pump for lighting 15 lamps in village. (ongoing)
 Gas lamp; large gas store; pressure regulator. (planned)
9. *
10. Development and Consulting Services, Butwal, Nepal

110(a). Mr. M. Sohail QURESHI

1. Pakistan
2. 16 September 1934
3. B.Sc. (Hons.) (Punjab), B.Sc. (Non-med) (Punjab), M.Sc. (Chemical Engineering) (Birmingham), M.Sc. (Hons.) (Punjab)
4. English, Urdu, Punjabi
5. 1978 to-date Director-General (Energy Resources), Ministry of Petroleum and Natural Resources, Government of Pakistan
 1973-1978 Principal Officer to Vice-Chairman, BIM & State Petroleum Board
 1973-1976 Chief, in charge of Economic Wing in the Prime Minister's Secretariat
6. Chemical engineering. Petroleum refinery. Development and management of energy resources
7. Marketing development. Management development
8. Installation 100 family biogas units for demonstration. Rural energy project. Rural electrification project. Solar energy development project. Conservation of energy. Biogas development project (1,200 biogas plants)
10. Energy Resources Cell, Ministry of Petroleum and Natural Resources, Government of Pakistan, Islamabad, Pakistan

110(b). Mr. P. RAJABAPAI AH

1. India
3. B.Tech. (Chemical Engineering). At present doing research for the doctoral degree in the biogas field.
4. English, Telugu, Hindi, Kannada

5. 1978 to-date Staff Member and Investigator, project on further studies in biogas technology, ASTRA (Centre for the Application of Science and Technology to the Rural Areas), Indian Institute of Science, Bangalore
Worked for two years in the research project on development of biogas technology and five years in small-scale chemical industries in Andhra Pradesh, India
6. Chemical engineering. At present specializing in the biogas fields such as process, production, construction, utilization (burners, lamps, engines and electricity generation), environmental improvement etc.
7. Interested in the treatment of wastes such as sewage wastes, alternative energies such alcohol, solar and wind energies; low-cost appropriate technologies for the rural development of India
8. Studies in biogas technology: performance of the conventional Indian biogas plant; optimization of plant dimensions; thermal analysis of biogas plants and innovation of a novel solar-heated biogas plant (completed).
Further studies in biogas technology (improvement of the solar-heated biogas plant, gas production from alternative materials for dung such as water hyacinth, recycling of water in biogas plants etc.); community biogas systems for villages (production and distribution of biogas, viz. fertilizer and water including hot water, electricity generation and small-scale industries using biogas as energy source); design and construction of ultra low-cost rural-oriented biogas plants (modified Indian and Chinese biogas plants) (ongoing).
Modelling of lowest biogas reactors (continuous, semi-continuous and batch reactors using all materials available in rural areas such as animal, human and agricultural wastes as well as industrial wastes such as from the sugar factories, fermentative industries and sewage wastes); low-cost biogas appliances (burners, lamps, engines etc) (planned).
9. *
10. ASTRA (Centre for the Application for Science and Technology to the Rural Areas), Indian Institute of Science, Bangalore 560 012, India

110(c). Mr. TIAN Feng

1. China
2. February 1927
3. Graduate, Nan Jing University (formerly Zhong Yang University), Foreign Languages Faculty (Russian)
4. Can read reference materials in Japanese and English
5. 1980 to-date Director, Sichuan Province Biogas Office
May 1980 Director, Joint FAO-China study group on biogas technology
February 1979 In charge, Sichuan Province Biogas Office

August 1974 Supervising design and operation of biogas plant, Sichuan Province Biogas Office

6. Administration of biogas extension work
7. Research on biogas plant design and operation
9. "Construction of biogas plants", *Rural Biogas: Questions and Answers*. Sichuan People's Publishing House, Agricultural Publications, 1979. pp. 4-50.
"Popularization of biogas plant construction with common materials", *Biogas*, Vol.III:23-25. Science and Technology Documentation Publishing House, Chongqing Branch.
"Greater efforts for biogas", *Farming Techniques*, 20 July, 24 July, 27 July, 31 July, 3 August, 7 August, 10 August, 1980.
"Biogas and its utilization". A statement at UNIDO discussion group on large-scale biogas, Beijing, July 1980.
10. Sichuan Province Biogas Office, Chengdu, Sichuan Province, China

110(d). Mr. B.V. UMESH

1. India
2. 22 February 1955
3. English, Tamil, Kannada
4. Post-graduate in chemical engineering, University of Madras (1979)
5. 1979 to-date Shri A.M.M. Murugappa Chettiar Research Centre, Madras
6. Low-cost designs for construction of biogas plants with major emphasis on utilizing the locally available materials and skills. Studies on anaerobic digestion of water-hyacinth without the loss of protein value
7. Mass culture of algae for food and feed purposes. Construction of solar cookers and dryers. Comfort conditioning by dehumidification process.
8. Implementation of biogas plants of the Centre's latest design. Performance data regarding gas production, life of the plant, use of the gas in diesel engines. Further studies in making a low-cost digester.
10. Shri A.M.M. Murugappa Chettiar Research Centre, Photosynthesis and Energy Division, Tharamani, Madras 600 042, India

111. Bangladesh Agricultural University

I

1. Mymensingh, Bangladesh
Tel: PBK-2191-93
Cable: AGRIVARSITY
2. 1961
3. Vice-chancellor
4. Dr. M. Yusuf Chowdhury, Associate Professor and Head, Department of Agricultural Chemistry
5. (b) 6/5
8. Teaching, research and extension of biogas in the rural areas.

II

A.

1. (a) fixed
(b) movable
2. 2-8 m³
3. (a) bricks, cement sand and gravel
(b) M.S. sheet
(c) M.S. pipe, bricks, cement, sand and gravel
(d) pipe, bricks, cement, sand and gravel

B.

1. (a) continuous
(b) batch
2. Cow dung
3. Frequently lime is added to control pH.
4. 40-50 kg
5. 40-55 kg every 2-5 days
6. Almost 1:1 (green weight)

C.

1. (a) 6-9 m³
(b) domestic and laboratory
2. (a) 30-50 kg/day

D.

1. \$US 500-700 depending on the size and design
2. (a) summer 35°C
(b) winter 10°C

3. (a) shadow
(b) sun
4. None
5. Investigation is going on to optimize cost and efficiency of biogas plants of different designs for the farmers.
6. Almost all of the biogas plants for the purpose of investigation are in operation. Those constructed for the farmers are not in constant use due to scarcity of cow dung resulting from low cattle population during certain time of the year.
7. A survey on cattle population among the farmers in neighbouring areas is being undertaken.

**112. Bangladesh Council of Scientific and Industrial Research,
Institute of Fuel Research and Development**

I

1. Dacca, Bangladesh
Tel: 315116-19/246
Cable: CONSEARCH
2. 1976
3. Dr. M. Eusuf, Project Director
4. 4
5. (a) 2
(b) 4/3
8. Research and development work on fuel, energy and allied subjects
9. Fuel, energy and allied subjects
10. Dissemination and demonstration of new technology developed through research
11. Training towards M. Phil and Ph.D. is provided.
12. Over 50 publications on fuel, energy and allied subjects; three publications on biogas and six other are under preparation.
13. Gas yield from cow dung under various conditions. Plant studies utilizing cow dung. Gas yeild from water hyacinth. (completed)

Increasing gas yield. Reduction in seasonal variation in gas yeild. Cost reduction alternatives. Slurry making from agricultural wastes. Development of cost burners and lamps. (ongoing)

Identification and isolation of active methanogenic bacteria and studies on their performances. Biogas-based integrated farming systems. (planned)

II

A.

1. (a) fixed (one)
(b) movable (three)
2. 220 cu ft (each)
3. (a) brick, cement and sand
(b) mild steel for movable and reinforced concrete for fixed holder
(c) and (d) RCC pipe

B.

1. (a) continuous
2. Cow dung
3. Mixing with water
4. 58 kg
6. 1:1

C.

1. (a) varies from 50 cu ft in winter to 90 cu ft in summer
(b) laboratory, cooking and experimental study

D.

1. \$US 650
2. (a) summer 30.4°C (fortnightly average)
(b) winter 16.6°C (fortnightly average)
5. Leakage in fixed holder
6. 75 per cent
7. Further work on fixed gas holder to make it leak-proof needed

113. Artificial Biogas Experimental Station, Nanhui County

I

1. The County Town of Nanhui County, Shanghai, China
Tel: 987660
2. 1977
3. Mr. Gu Ming-Long
4. 3
5. (a) 10
(b) 40/35
6. The County Town of Nanhui County, Shanghai, China

7. The Shanghai Research Institute of Industrial Microbiology. The Shanghai Research Institute of Plastics. The Shanghai Research Institute of Diesel Engine
8. Research and experiment on biogas production
9. Designs four types of biogas digester. Experiments for fermentation. Study on unloading the residue mechanically from the digester. Experiment in manure. Better biogas power generation. Experiment on solar energy.
10. Stress on improving the technology of household biogas digesters and small-sized biogas power stations in rural areas. Experiments on methane production from municipal wastes.
12. *Research for Biogas Production in Nanhui County, Shanghai, China* Issue No. 1 and No. 2. In these two issues some major articles are: "Effect of some additives on the rate of decomposition in biogas fermentation". "Effect of pressure and stirring on biogas productivity under ambient temperature". "Exploration of biogas productivity from conventional materials in the rural area of Shanghai suburbs". "Biogas fertilizer and experiment on its effect".
13. Household biogas digester of spherical type in rural areas. Biogas digester with a movable floating cover. Utilization of wastes from a pharmaceutical factory to produce biogas. Research on additives for biogas production. (completed)
 Research on a 56 m³ mesophilic ground biogas digester. Continuous improvement in the property of the biogas digester sealed airtight. Experiment on fertilizer effect of the fermented waste. Research on a biogas digester on integral fermentation. (ongoing)
 Two-phase fermentation method. Experiment on different kinds of concentration of the material fed into the digester. Research on the ratio of carbon to nitrogen to the digester. (planned)

II

A.

1. (a) fixed
(b) movable
2. 8 m³, 56 m³, 200 m³ etc.
3. (a) concrete, brick vault, soil mixed with lime
(b) concrete, brick vault, steel plate
(c) concrete, steel tube
(d) concrete, brick wall

B.

1. (a) continuous
(b) batch
2. Animal wastes, stalks, weeds etc.
3. First cutting stalk into pieces then making compost

4. For a 8 m³ digester feeding 10 kg a day
5. For a 56 m³ digester feeding 5 tons a week, i.e. 5,000 kg per week, every seven days
6. About 80 per cent

C.

1. (a) for a 8 m³ digester 1.6 m³ gas being produced each day
(b) for daily use and to generate electricity
2. When crops in the field need fertilizer to be applied, the residue in the digester has to be discharged. Generally speaking, farmers carry the fertilizer into the fields on a large-scale three times a year.

D.

1. About \$US80 (8 m³ digester)
2. (a) summer 27°C
(b) winter 4° – 5°C
3. (a) shadow
(b) sun
4. Through solar energy
5. Leaks sometimes occur; but the digester can still be used by fixing and maintaining it.
6. 87 per cent
7. Summing up and interchange of experiences once a year

**114. Beijing Academy of Agricultural Science, Research Institute for
Soil and Fertilizer**

I

1. Ban Jin Cun, Beijing, China
Tel: Beijing 811431-38
2. 1978
3. Mr. Hu Li-Na
4. Mr. Zhang Chun-Mei, Mr. Yuang Qing-Liang, Mr. Jiang Xiao-Xu
5. (a) 7
6. Laboratory within the organization. Experimental pond at Beijing village centre.
7. Part of National Biogas Science and Research Co-ordination Group. One of the units responsible for research on special problems of biogas fertilizer
8. At present, mainly, research on biogas fermentation techniques and use of biogas fertilizer
9. Biogas fermentation techniques. Biogas fertilizer application techniques

10. Practical application of biogas in Beijing suburban district. Research on crucial technical problems and consultancy service
11. Annual biogas training courses in the area. Responsibility for important lectures.
12. Internal materials; not formally published.
13. Beijing suburb farmer household – fuel biogas experimental station (elementary engineering design, basic fermentation technique, hygiene design for comprehensive technical innovation). Research on organic fertilizer stored up in biogas plant, important changes in its effectiveness, composition and growth. (completed)
 Research on the efficiency as fertilizer of biogas fermentation remainder and its use in soil improvement (ongoing)
 Research for fermentation at normal temperature to increase the rate of biogas production. (planned)

II

A.

1. (a) fixed
2. 10 or 100 m³
3. Cement mixed with congealed mud or brick arch, mortar
 - (a) cylindrical or circular
 - (b) hydraulic type
 - (c) slanting type
 - (d) outlet at middle layer inverted pipe and hydraulic type or vertical shaft hydraulic pressure type

B.

1. (a) continuous
(b) batch
2. Wheat straw, corn straw; pig, human and ox waste
3. Barnyard straw and waste materials mixed or barnyard straw wetted with biogas fermented liquor
4. Because of variations in season and in materials, research on appropriate volume under way
5. As above
6. 8 per cent

C.

1. (a) because of the changes in the seasons, variety of feed materials and differences in their volume, the volume at ordinary temperature can reach 0.8 m³ but, in general, 0.1 m³ to 0.3 m³
(b) directly, as fuel for daily life; research under way for its use as power

2. (a) about 30,000 kg/hectare
(b) mostly, for demonstration, no regular quantity
(d) to be used for straw digestion
3. For the middle level effluent, no need of hygienic treatment. Addition of liquid ammonia is recommended for sedimentary dregs; however, in many cases, this is not compiled with.

D.

1. About \$US 50
2. (a) summer 36°C
(b) winter -16°C
3. (a) shadow
4. At present, the methods being popularized do not heat the digester. Research is being undertaken on the use of solar energy and heat preservation in winter.
5. (i) After a few years of use the plant made in part of mortar develops cracks in the vault and the gas leaks due to the following reasons: late feeding at materials, no cover and effect of severe drought.
(ii) At many plants, the mixers cannot stir after the start of fermentation.
6. If there is a systematic way and there are men specific for the operations, more than 90 per cent in the rate of utilization can be reached.
7. (i) As set out by the realities of farm practices in China and as testified by the experience already gained, among the most important in the management of biogas is the synthesizing of its utilization. The most required is paying special and simultaneous attention to fertilizers and energy sources. Otherwise biogas energy cannot take firm root or develop.
(ii) To be assured of the technique and its reliability it is required that the design be standardized, spare parts be supplied from stock and commercialized, and installation be specialized.

115. Chengdu Biogas Research Institute

I

1. Ministry of Agriculture, Chengdu, Sichuan, China
Tel: 7737 Telex: 3049
2. 1978
3. Mr. Zheng Shou-Zhou
5. (a) 40
(b) 19/17
6. Chengdu
7. State and provincial biogas offices. Related research institutes

8. Biogas research
12. Drawings – small rural digesters construction
13. 17 (completed), 2 (ongoing), 36 (planned)

II

A.

1. (a) fixed
(b) movable
2. 6–300 m³
3. (a) concrete, masonry, lime-clay
(b) fixed, bamboo-cement
(c) and (d) cement, concrete

B.

1. (a) continuous

C.

1. (a) 0.15 – 0.3 m³
(b) domestic use; power

D.

1. \$US 20-40 (materials cost) (for 10 m³)
2. (a) summer 26°C
(b) winter 12°C
3. (a) shadow
(b) sun
4. Common method. Heated to 35°C. Mixed
5. Leakage
6. 98 per cent

116. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture

I

1. Ren Min Nan Lu, Chengdu City, Sichuan, China
Tel: 7737 Cable: 3049
2. 1978
3. Mr. Xue Bin-Kui, Director
4. Mr. Zheng Shou-Zhu, Mr. Zhang Geng-Xin, Deputy Directors

5. (a) 42
(b) In Sichuan Province, over 4 million, of which more than 70 per cent are in operation
6. At Ren Min Nan Lu, Chengdu City
7. With digester construction throughout the country. Two assistance groups for biogas fermentation
8. Specialized research institute for biogas scientific research
9. Scientific research on digester construction, biogas fermentation, all-purpose agricultural machinery. Information on means of production.
10. Priority to biogas research. Technical series. Specialized supplementary instruction on techniques
11. Within the country four times, to more than 120 persons. Twice for the United Nations, to more than 40 persons
12. Biogas, fourth issue, 1980. *Biogas Scientific Technique*, first issue, 1981
13. Medium and small scale biogas plants for farm households. Medium-sized biogas plants in Sichuan Province. A popular handbook on biogas fermentation: relationship between pressure and biogas production. (completed)

Collection of standard diagrams for medium-sized biogas plants for farm households in the whole country. Technological process and techniques for medium-temperature fermentation with large and medium scale horizontal type digester. (ongoing)

Experiments on potential digester materials. Survey of experimental norms. (planned)

II

A.

1. (a) fixed
(b) movable
2. 6, 8, 10 m³
3. Concrete, standard brick
 - (a) about 80 per cent capacity (height/diameter 1/2.5)
 - (b) 20 per cent gas holder (height/diameter 1/5.5)
 - (c) straight pipe with the dipperinserted type (25 cm diameter)
 - (d) straight pipe with hydraulic-pressure operated opening (with a volume at 1/10 of the volume of the digester)

B.

1. (a) continuous
(b) batch
2. Stems; pig, ox, human waste; partly wheat straw
3. Stems and waste, made into wet compost

4. 20 kg
5. 300-500 kg two times a year
6. Fresh waste, human to pig 1:1

C.

1. (a) at ordinary temperature: 0.2 m³/1 m³ liquid feed; at medium temperature: 1.0 m³/1 m³ liquid feed
 (b) small plants: lighting, cooking; medium and big plants: electricity generation and processing
2. (a) direct fertilizer on soil
 (b) composting
 (c) aquaculture
3. To the sediments and dross add ammonia water or ground phosphate rock etc. After composting, use as field manure

D.

1. \$US 30-40 (exclusive of wage payment to about 30 workers)
2. (a) summer 23-27°C
 (b) winter 7° - 5°C
3. (a) shadow
 (b) sun
4. Additional heating by steam, hot water, solar energy, waste heat from electrical machinery
5. Gas leakage. At present studying the use of coating. More closely knitting the gas holder. Feed decomposition rate rather low; presently improving the design of digester.
6. 60-94 per cent (in Sichuan)
7. Interchange of detailed information on construction, meetings for interchange of positive results. Area-wise co-operative working groups for construction, design of new types of digesters. A proposal for the establishment of a co-operative experimental station in Thailand for comparative experiments and conclusions with regard to the Indian and the Chinese small type digesters.

117. Chengdu Biological Research Institute, Chinese Academy of Sciences

I

1. Chengdu City, Sichuan Province, China
 Tel: 7080 Cable: 0406
2. 1958
3. Mr. Deng Guo-Biao

4. Mr. Hou Yong-Sheng
5. (a) 105
(b) 10
6. At the Institute
8. Botany. Zoology. Microbiology etc.
9. Theory and application
10. Extension of successful results of scientific research
13. Research on biogas fermentation techniques in villages in China. Research on bacteria production for village biogas plants. (completed)
Research on fermentation techniques in villages in China. Research on microbiological biogas fermentation. (ongoing)

II

- A.
 1. (a) fixed
 2. 27 – 6 m³
 3. (a) (b) (c) and (d) brick and cement
- B.
 1. (a) continuous
 2. Human and animal wastes. Stems
 3. Management of wet compost
- C.
 1. (a) 0.2 – 0.5 m³
- D.
 2. (a) summer 24° – 28°C
(b) winter 8° – 16°C
 3. (b) sun
 4. Materials which will add heat. Preserving the heat of haystack. Construction of biogas plant facing the sun and out of the wind

118. Chengdu Institute of Biology, Chinese Academy of Sciences

I

1. Chengdu, Sichuan, China
Tel: 7080 Cable: 0416
2. 1958
3. Mr. Deng Guo-Biao
4. Mr. Hou Yong-Sheng

5. (a) 103
(b) 10
6. Chengdu, Sichuan
8. Research and application
9. Animal, plant and microbiology

II

A.

1. (a) fixed
(b) movable
2. 2 – 3.3 m³
3. (a) (b) (c) and (d) brick

B.

1. (a) continuous
(b) batch
2. Manure and straw
3. Pretreatment

C.

1. (a) 0.2 – 0.4 m³

D.

2. (a) summer 33°C
(b) winter –2°C
3. (b) sun

119. China Research and Designing Institute of Agricultural Engineering

I

1. Beijing, China
Tel: 594961
2. 1978
3. Mr. Tao Ding-Lai
4. Mr. Zhang Ji-Gao
5. (a) 50
6. Beijing
7. Farm mechanization. Utilization of plasma as arc heat source
8. Research, designing and installation of large and medium sized biogas plants
9. Biogas engineering, design and servicing

10. Biogas servicing team inside and outside the country
11. Training courses on biogas plants at ordinary temperature
12. On Chinese agricultural engineering
13. Research, designing and installation of medium temperature biogas plants. Designing of biogas plants at Beijing ordinary temperature. (ongoing)

II

A.

1. (a) fixed
2. 100 m³, 10 m³
3. Brick, cement

B.

1. (a) continuous
2. Barnyard straw, waste
4. Depends on the volume, which is not uniform
6. 6 per cent

C.

1. (a) 10 m³ (small pond at normal temperature)
- (b) cooking, lighting

D.

2. (a) summer 35°C
- (b) winter -20°C
3. (b) sun
4. Gas, solar energy, heat left from the generator
5. (i) in the north, during winter the raising of temperature and heat preservation;
- (ii) sealing up of the materials

120. Chongqing Teachers Training College

I

1. Sha Ping Ba, Chongqing, Sichuan, China
Tel: 61275
2. 1954
3. Mr. Wang Hou-Fu
4. Mr. Jiang Dai; Mr. Lui Ping-Zhi
5. (b) 2,000

6. Sha Ping Ba, Chongqing
 7. National Co-ordination Group for Biogas Research
 8. Academic institution
 9. Teaching. Research
 10. For the villages
 11. For the administrative division and the communes in it
 12. On use of water hyacinth and green grass for fermentation; application to cellulose of peptone and acetaldehyde and its influence on formation of methane
 13. Laser induced mixing of bacteria at low temperature biogas plant. Experiment with putting in bacteria. Addition of formaldehyde, acetone acid to raise the effect of the rate of gas production. Application to cellulose of peptone and acetaldehyde and its influence on methane formation. (completed)
- Research on potentiality of water hyacinth producing biogas and on methods of introducing feed materials. Comparison of results of single stage and multi-stage fermentation with respect to biogas production. Separate appraisal of methane bacteria. (ongoing)

II

- A.
 2. 0.25 m³
 3. Brick
 - (c) direct pipe
 - (d) valve switch
- B.
 1. (a) continuous
(b) batch
 2. Water hyacinth often used. Pig and ox manure
 3. 2 per cent limewash to the cellulose nature of the wet compost in the digester
 4. 4 kg
 6. 50 – 88 per cent
- C.
 1. (a) 287 litre/day
(b) laboratory lighting; boiling and developing culture medium; cooking
- D.
 3. (b) sun
 5. In two experimental plants the movable cover leaked gas because of lack of adhesiveness of the mud plaster. After it was pasted with cement, the leak stopped at once

6. Nearly 100 per cent
7. (i) select a good foundation for the gas holder;
 (ii) for the construction site to preserve the quality of materials, it is important that it conforms to the norm – no leakage of water or gas;
 (iii) the digester feed should be adequate;
 (iv) strengthen management;
 (v) practicable economic policy regarding biogas

**121. Guangzhou Institute of Energy Conversion,
 Chinese Academy of Sciences**

I

1. 81 Martyrs' Road, C.P.O. Box 1254, Guangzhou, China
 Tel: 76042 Cable: 0508
2. September 1978
3. Dr. Wu Wen, Director
4. Mr. Kuang Zhe-min, Deputy Director Mr. Chen Ru-Chen, Head of Biomass Division
5. (a) 90
6. Foshan Biogas Pilot Power Plant; Xinfu Production Brigade (experimental spot) etc.
7. National Leading Group of Biogas Utilization; United Nations University etc.
8. Research and development on renewable energy conversion
9. Biomass, geothermal, solar, ocean wind energy. Energy storage and conservation.
10. Resources and development
11. Short courses for biomass and solar energy conversion techniques
12. "Renewable Energy Conversion" Prompt reports on energy
13. Foshan biogas pilot power plant and rural family digesters. Hainan solar-distill site. (completed)
 Renewable energy village from biogas and solar energy. Hainan solar dryer for rubber production. (ongoing)
 Slaughterhouse heating from biogas and solar energy. Solar-heated swimming pool. Solar refrigerator. (planned)

II

- A.**
1. (a) fixed (family digesters)
 (b) movable (power plant)

2. 4-10 m³ (family digesters)
47 m³ x 28 = 1316 m³ (power plant)
3. (a) brick and cement
(b) PVC film (power plant)
(c) and (d) brick and cement

B.

1. Semi-continuous
2. Night-soil (family digesters) Pigsty waste and waste water (power plant)
4. 50 kg (family digesters) 60,000 kg (including water) (power plant)

C.

1. (a) 1-1.2 m³ (family digesters) 363 m³ (power plant)
(b) cooking and lighting (family digesters). Power generation (power plant)
2. (a) 50 kg/day (family digesters) 60,000 kg/day (power plant)
3. Germ and parasite egg killing by heating in the digesters up to 50°C or higher

D.

1. Family digesters: \$US 30-50 (purchased material). Power plant: \$US 200,000 (estimated)
2. (a) summer 26-27°C
(b) winter 12-13°C
3. (a) shadow (family digesters)
(b) sun (power plant)
5. Family digesters: Low gas production rate with sludge and scum accumulating (also in power plant). Power plant: Acidic gas corrosion after H₂S ignited through engine. To be solved by injection stirring of sludge and scum and gas purification by desulfurization
6. Around 93 per cent
7. The only economically available way for stirring sludge and scum in family digesters is to re-inject supernatant from the digester back through the inlet pipe with agricultural artificial shower plus a plastic or rubber tube attached to its spray nozzle

122. Hangzhou City Biogas Extension Office

I

1. Yuan Sha Lu, Hangzhou, China
Tel: 26828
2. 1976
3. Mr. Zhang Jia-Zhi

4. Mr. Cai Chang-Da, Mr. Zhan Ju-Xian, Mr. Zhu Cai-Fu, Mr. Xu Shun-Cai, Mr. Huang Shu-Nan
5. (b) 59744/51193
8. Consultancy. Training of technicians
9. Biogas extension work in Hangzhou City suburb, village and the eight countries allied to it
10. Design and construction of biogas plants in villages
11. In construction of biogas plants and management of technicians
12. Technical materials
13. Design and construction of household biogas plants with movable type gas holders. Constructional technique improvements in the moulding and hauling of biogas plants. (completed)

Synthesised use of biogas plant fermentation residue. Experimentation on fertilizer efficiency of fermentation remainder. (ongoing)

Research on coating to seal up biogas plant (planned)

II

A.

2. 6–10 m³
3. Reinforced concrete materials

B.

1. (a) continuous
(b) batch
2. Human, pig, sheep and ox waste; green grass; rice and wheat straw
3. Rice straw and grass cut to pieces and wet-composted for ten to fifteen days, then mixed with human and animal waste to make feed material
4. 20 kg (pig waste)
5. Animal waste padded with straw, 250 kg once in 15 days
6. 1:1 (new waste to water)

C.

1. (a) 1.5 m³/day
(b) cooking and lighting
2. (a) 40 kg/day (8 m³ biogas plant)
(e) at present, at the experimental stage
(f) rearing earthworm
(g) cultivation of mushrooms
3. At the time of over-all change of feed materials, clear the sediments. For every 100 kg and 2 grams of dipterex for killing insect eggs. Wet-compost should be used only after being stirred for 24 hours

D.

1. \$US 40 (8 m³)
2. Monthly average:
 - (a) summer 28°C
 - (b) winter 8°C
5. Where the gas holder part is not tightly sealed there is seepage, overcome at once by plastering afresh or by pasting up by a coating paint
6. 85 per cent

123. Institute of Microbiology, Chinese Academy of Sciences

I

1. Zhongguancun, Beijing, China
2. 1959
3. Mr. Xue Yue-Gu
4. (a) 230
8. Research work
9. Research taxonomy, physiology, biochemistry, economy, cytology and genetics of microbiology.

124. Jiangsu Province Wujin Biogas Research Institute

I

1. Ben Niu Zhen, Wujin County, Jiangsu Province, China
Tel: 265
2. 1978
3. Mr. Zhu Bin
4. Mr. Shen Jie-Sheng, Mr. Gao Ya-Ping
5. (a) 18
(b) 11/9
7. Electric Construction Institute, Ministry of Electric Power. Guangzhou Energy Resources Institute. Nanjing Soil Institute, Academy of Sciences. Jiangsu Province Agricultural Science Institute. Sichuan Agricultural Machinery Institute
8. Scientific research on biogas application
9. Jiangsu Province
10. For the villages, to provide farmers with new types of biogas plants, new designs and fermentation techniques

13. Research on techniques of utilizing biogas in manufacturing CCl_4 . Research on oil gas for dynamo battery. (completed)

Designing of modernized biogas plants for villages. Research and manufacture of biogas fired dynamo battery. Research on improving the effects of fermentation materials. Research on techniques of raising the rate of biogas production. (on-going)

II

A.

1. (a) fixed
2. 8, 10, 12 m^3
3. (a) (b) (c) and (d) cement and brick

B.

1. (a) continuous
2. Human, animal wastes. Stems of crops
3. Wet-composting of stems of crops, before feeding
4. 50 kg
6. 1:7

C.

1. (a) 0.15 – 0.2 m^3
(b) in households, as fuel; big plants' gas used for lighting
2. (a) about 80 per cent
(b) about 15 per cent
(g) a small amount for cultivation mushrooms
3. Apply ammonium bicarbonate to the wet compost

D.

2. (a) summer $28^\circ - 30^\circ\text{C}$
(b) winter 10°C
3. (a) shadow

125. The Office of National Leading Group for Biogas Development Ministry of Agriculture

I

1. Ministry of Agriculture, Beijing, China
Tel: 463652
2. 1976
3. Mr. Zhang Chen-Yao, Director

7. All related biogas offices and research institutes
8. Administration and management

**126. Research Institute for Soil and Fertilizer,
Academy of Agricultural Science**

I

1. Chengdu, Sichuan China
Tel: 7761 Cable: 2814
2. 1949
3. Mr. Zhou Jing-Ying, Director
4. Mr. Chu Ti-Yun, Mr. Liao Si-Zhang, Deputy Directors
5. (a) 8 (biogas fertilizer)
6. At the Institute, at Congqing County and at Ren Shou County Village Centre (concerning biogas fertilizer)
7. Sichuan Provincial Biogas Extension Office. Biogas extension offices at Chongqing County and Ren Shou County
8. Experiment. Demonstration.
9. Co-ordination of biogas extension work in the province. Launching of biogas fertilizer and development of its effectiveness. Research on its application techniques and concerned consultancy work
11. Jointly with the United Nations and at province and county level
12. "Experiments on effectiveness of biogas fertilizers", *Soil and Fertilizer Science*, 3rd issue, 1975. "Biogas application and research", *Biogas*, Chongqing Branch of the Scientific and Technological Information Institute of China, 3rd monthly issue, 1979. "Examination of biogas fertilizer effectiveness", *Journal of Soil*, 2nd issue, 1979.
13. Effectiveness of biogas fertilizer (completed)
Biogas fertilizer application techniques (ongoing)
Establishment of a system to give priority to organic fertilizer (planned)

127. Shandong Province Energy Resource Research Institute

I

1. Jiran City, Shandong Province, China
Tel: 43449
2. 1979
3. Mr. Dong Xian-Jun, Deputy Director

4. Mr. Zou Yuan-Liang, Deputy Chief, Biological Energy Research Group
5. (a) 5
(b) 41/41
6. Jinan City
7. Guangzhou Energy, Source Research Institute, Chinese Academy of Sciences.
Chengdu Biogas Research Institute, Ministry of Agriculture.
8. Scientific research
9. Research and utilization of new energy sources
13. Research on management of biogas plant through winter. (completed)
Breeding of fermentation seeding. Research on the potential of feed materials for optimum gas production. (ongoing)
Research on household biogas plants. (planned)

II

- A. Underground. Hydraulic pressure type. Stone plate structure.
 1. (a) fixed
 2. 2 m³
 3. Stone plate and some cement
- B.
 1. (b) batch
 2. Wheat straw. Human, pig manure
 3. After mixing, pilling up and soaking for 9 days at 10° -20° C
 5. 1350 kg. every 170-180 days (nearly every half-year change of feed once; 90 per cent change and the rest for seeding)
 6. Strictly maintain solid content density with water at 10 per cent
- C.
 1. (a) winter: 0.6 m³/day
summer: 1.5 m³/day
(b) fuel
 2. (a) on an average, 7 kg/day
- D.
 1. \$US 30
 2. (a) summer 25° C
(b) winter 10° C
 3. (b) sun
 6. 100 per cent

128. Shanghai Institute of Industrial Microbiology

I

1. Shanghai, China
Tel: 565411
2. 1966
3. Mr. Shen Tien-yi
4. Mr. Tao Yi-Wen, Mr. Ru Zhung-Wei
8. Industrial fermentation
9. Research assignments by the ministry, bureau and departments
10. Research and development
13. Amino acid, organic acid, fermentation. Research on enzymes. Comprehensive research on anti-mildew formation industry and in biogas.

II

A.

1. (a) Fixed
2. 56 m³
3. (a) steel reinforced cement
(b) materials reinforced by steel and retempered
(c) and (d) brick and cement

B.

1. (b) batch
2. Pig, ox waste
5. 6000 kg. every seven days

C.

1. (a) 20 – 30 m³
(b) lighting

129. Shanghai Science and Technology Association

I

1. 47 Nan Zhong Road, Shanghai China
2. 1958
3. Mr. Jiang Zheng-Fan
5. (a) 230

II

- A.
- (a) fixed
(b) movable
 - 4.5 – 129 m³
 - (a) concrete
(b) steel, ferrocement, porcelain
- B.
- (a) continuous
(b) batch
 - Human and animal waste; crops
- C.
- (a) 0.25 – 0.8 m³
(b) domestic use, sewerage treatment
- D.
- US\$ 70-1000
 - (a) summer 26°C
(b) winter 13°C
 - (a) shadow
(b) sun
 - Heating from generators (using steam)

130. Xinan Teachers College, Biogas Research Institute

I

- Xinan, China
- Mr. Zhang Guo-Zheng, Head
- (a) 4
(b) 16
- Research, experiment and extension
- Research office and agricultural production experimental station
- Extension of small-scale rural biogas plants, provision of research data for use and demonstration of ways of increasing biogas production
- Can provide training courses and lectures
- Experiments: on biogas fermentation conditions; with sieving of activated mud before its insertion in the biogas plant; on additions to raise the rate of biogas

production. Communications on experiments with the rate of utilization of biogas feed materials. (completed)

Research on: increasing the rate of production of small rural biogas plants; on gas production potential of all kinds of organic materials; on bacteria decomposition. (ongoing)

131. Zhejiang Agricultural University, Laboratory of Soil Microbiology

I

1. Hangzhou, Zhejiang, China
4. Prof. Tse Shu-Chien, Head, Department of Soil and Agricultural Chemistry

II

A.

1. (a) fixed
(b) movable
2. 8–10 m³
3. All concrete

B.

1. (b) batch
2. Stable manure and nightsoil
5. 3,500 kg every 180 days
6. 1:1 (about 90 per cent water content)

C.

1. (a) 1.6 m³/day
(b) as fuel
2. (a) direct fertilizer on soil

D.

1. \$US 30–40
2. (a) summer 30°C
(b) winter 10°C
3. (a) shadow
6. 80 per cent (in Chekiang province)

132. Zhejiang Biogas and Solar Energy Scientific Research Institute

I

1. Hangchow, China
Tel: 2291 Ext. 459
2. 1980
3. Mr. Mie Wen-Hai (Director, Zhejiang Biogas Development Office)
4. Mr. Xu Zeng-Fu, Vice-Director
5. (a) 40
(b) 364900/32500
6. Zhejiang Province
7. United Nations University, Use and Management of Natural Resources Programme Office
8. Research and Development
9. Information. Research. Training
11. Biogas technique training
12. Biogas, Zhejiang Press and Publishing Commission. Biogas Technology, United Nations University.
13. Biogas drying technique of crops. New type of mesophilic biogas plant

II

- A.
1. (a) fixed
(b) movable and separated
 2. 8-10 m³
 3. (a) and (b) brick and cement or lime-clay with soil
(c) and (d) cement tube
- B.
1. (b) batch
 2. Swine, human feces
 3. Feed material pretreatment in various ways such as composting etc.
 4. The amount of raw material added and fermentation circle greatly vary.
 5. Every 40 days
 6. 1:9
- C.
1. (a) 0.15 - 0.3 m³
(b) cooking; power for fabricating agriculture products; generating electricity for lighting

D.

1. \$US 35-40
2. (a) summer 35° - 39°C
(b) winter 0° - 5°C
3. (a) shadow
(b) sun
4. Solar energy. The vast heat from dual-fuel engine
5. There is more attention paid to digester building, but less to management. A lot of digesters do not yield sufficient gas. Scientific research also has not been followed up.
6. 88 per cent

133. University of the South Pacific, Institute of Natural Resources

I

1. P.O. Box 1168, Suva, Fiji
Tel: Suva 313900
Cable: UNIVERSITY SUVA
Telex: FJ 2276
2. 1969
3. Vice-Chancellor
4. Dr. Richard K. Solly
5. (a) approx. 48 (whole University)
(b) 17 (all-Fiji)
6. University is adjacent to rural areas
7. Associated with University campuses in 11 South Pacific countries and respective Departments of Agriculture
8. Development of biogas technology
9. Laboratory and field investigation of biogas systems
10. Information Research and development. Advisory. Consultancy. Education. Training. Problem solving.
11. Run under the sponsorship of international organizations
12. Installation and operation of biogas bag digesters. A study of methane digesters in the South Pacific region. Biogas production from water hyacinth
13. Manual for installation and operation of biogas bag digesters. Investigation of field digesters in the South Pacific region. (completed)
Biogas production from water hyacinth and other vegetable matter. Development of low-cost durable biogas systems. (ongoing)

Manual for livestock food production from the effluent from biogas systems.
(planned)

II

A.

1. (a) fixed (one or two)
(b) movable (main type)
2. 5 – 25 m³
3. (a) largely concrete brick, some polymer rubber
(b) largely welded steel, some concrete brick, some polymer rubber
(c) and (d) generally PVC pipe

B.

1. (a) continuous (mostly)
(b) batch (one or two experimental)
2. Pig wastes
3. Washings of pig pens
4. Variable
5. Variable

C.

1. (a) 0.1 m³ per pig per day
(b) ring burner
2. (a) a few digesters
(c) none viable
(f) most digesters
3. None except exodation ponds

D.

1. \$US 500 to 3,000
2. (a) summer 28° – 32° C
(b) winter 18° – 22° C
5. Two problems predominate: blockage of the digester inlet pipes and leakage of the gas holder
6. Approximately 70 per cent in Fiji; 0–10 per cent in the other South Pacific island countries
7. A reliable low-cost durable digester is not generally available, especially for the digestion of vegetable matter

134. Action for Food Production (AFPRO)

I

1. C-17 Community Centre, Safdarjang Development Area, New Delhi 110 016, India
Tel: 667445, 660319 Cable: AFPRO
2. 1966
3. Mr. J.B. Singh, Executive Director
4. Mr. J.B. Singh, Chief Co-ordinator, Biogas Programme, Mr. Raymond M. Myles, Co-ordinator, Biogas Programme
5. (a) 7
(b) 9
7. AFPRO provides technical assistance to its several grass-root level voluntary agencies operating throughout India, in biogas and other agricultural and rural development fields.
8. Construction of demonstration-cum-training Janata plants and training of rural masons, selected by AFPRO related voluntary agencies operating throughout India.
9. Technical Services in the field of agriculture, livestock, water resources and appropriate/rural technology
10. Information. Advisory. Consultancy. Extension. Training. Promotion. Seminars etc.
11. All-India course on biogas technology – with special emphasis on the construction of Janata biogas plant, 1979, for senior project staff. Regional courses on biogas technology for grass-root level workers of voluntary agencies. Training of masons on the construction of Janata plant at the time of construction of demonstration-cum-training Janata plants. Several training workshops for rural masons during 1980 and 1981 in different regions of India.
12. A Janata model gobar gas plant. Community biogas plant. Promotion of biogas plant for small and marginal farmers on individual and community basis. A 2 cu m (70 cu ft) Janata plant constructed in Union Territory of Delhi. Biogas technology: a review of approach adopted by AFPRO in the systematic promotion of Janata plant.
13. Nine demonstration-cum-training Janata plants (2, 3, 4, 6 and 15 cu m capacities) (completed). Two Janata plants one 6 cu m (210 cu ft) and another 2 cu m (70 cu ft) using stones (ongoing). Six more by 1980 (planned).

II

A.

1. (a) Fixed
2. 2, 3, 4, 6, 9 and 15 m³
3. (a) (b) (c) and (d) bricks and cement

B.

1. (a) continuous
2. Cattle dung
3. Dung mixed with water in the ratio of 1:1
4. Average quantity of dung required for different size of Janata plants:

Size of plant (gas production per day) cu m (cu ft)	Approximate number of cattle	Daily requirement of wet dung (kg)	Gas utilization for cooking (number of persons)
2 (70)	3 - 4	45 - 50	6 - 8
2 (105)	4 - 5	70 - 75	10 - 12
4 (140)	5 - 7	75 - 90	12 - 16
6 (210)	7 - 10	100 - 120	16 - 20
9 (315)	14 - 18	140 - 180	30 - 35
15 (525)	25 - 30	250 - 300	50 - 60

6. 1:1 (for cattle dung)

C.

1. (b) Cooking and sometimes lighting
2. (c) composting

D.

1. All the Janata plants constructed by AFPRO so far are 30 to 40 per cent cheaper than the conventional plants with movable steel gas holder, according to AFPRO.
5. The main trouble reported is leakage of gas because of faulty construction. Proper training of masons can correct the situation; supervision and right type of construction material is also necessary.
6. 100 per cent

135. Agricultural Tools Research Centre

I

1. Suruchi Campus, Post Box 4, Bardoli 394601, India
Tel: 95258
2. 1959
3. Mr. Mohan Parikh, Director
4. Mr. Rahul Parikh
5. (a) 3
(b) 4

6. Suruchi Campus, Bardoli
7. Gujarat State Khadi Board
8. Appropriate technology. Rural development. Training centre.
9. Agricultural tools and implements. Solar energy. Biogas energy.
10. Youth training for rural development work. Technical advisory and consultancy service
12. On agricultural tools, design of a flat-plate solar cooker, garbage gas plant, biogas, fertilizer gas plant, agricultural hand tools for small and marginal farmers
13. Prototype experiments on garbage gas plant with different feed stock. Gas plant with fixed RCC roof – prototype. Double digester gas plant with fixed RCC roof.

II

A.

1. (b) movable
2. 17 m³
3. (a) RCC
(b) iron
(c) and (d) cement pipe

B.

1. (a) continuous
2. Cow dung
3. Homogeneous mixture of cow dung and water with a churner
4. 120 kg
5. 4500 kg every 60-90 days
6. 1:1

C.

1. (a) 4m³
(b) cooking
2. (a) direct fertilizer on soil

D.

1. \$US 500 (in March 1979)
2. (a) summer 32°C
(b) winter 20°C
3. (b) sun
6. 95 per cent
7. Application of some anticorrosive paint or bituminous paint on outer surface of iron gas holder gives trouble-free operation for longer periods.

136. Centre of Science for Villages

I

1. Magawadi, Wardha 442 001, India
Tel: 2412 Cable: GRAM VIGYAN
2. 1976
3. Mr. Devendra Kumar, Director
4. Mr. M.A. Sathianathan, Co-ordinator, Energy and Environment Department
5. (a) 17
(b) 76 in the area
6. Dattapur with eight plants. Four more under construction
7. All other Gandhian Institutions. The Department of Science and Technology, Government of India
9. Biogas system. Animal and manpowered devices for rural industries. Solar energy and wind power energy balance studies on rural industries and designing of appropriate energy systems
10. Information. Research and development. Advisory. Consultancy. Education. Training.
11. In biogas technology, pulp and paper from agricultural residues, construction techniques, construction materials and heavy pottery.
12. Monthly bulletin *Science for the Villages*. Occasional publications
13. Studies on equipment design engineering and improvement of digesters; digestion process engineering studies; feed stock processing and plant design, selection of biogas system for its use in rural industries, systems approach to biogas utilization (ongoing).

137. Delhi Water Supply and Sewage Disposal Undertaking

I

1. M.C.D. Link House, Bahadur Shah Zafar Marg, New Delhi 110002, India
Tel: 274333 Cable: WATER
2. 1938 (Delhi Sewage Disposal Works, Okhla)
3. Mr. M.N. Jain, Chief Engineer
4. Mr. Jai Narain, Superintending Engineer
5. (a) 3 engineers and 7 assistants
(b) 15/10
6. Sewage Disposal Works, Okhla, India
7. Central Public Health Environmental Engineering Organization (CPHEEO), Ministry of Works and Housing, Government of India. National Environmental

Engineering Research Institute, Nagpur. Central Board for Prevention and Control of Water Pollution.

8. Sewage system
9. Collection, treatment and disposal of city waste water
10. Information. Advisory. Education. Training
11. Sewage supervisors training courses, sponsored by CPHEEO, Ministry of Works and Housing, Government of India
13. 125 MGD – complete sewage treatment plant. Biogas for domestic use, 1000 families. 66 MGD sewage treatment plant. Biogas for 500 families. 22 MGD primary sewage treatment plant. (completed)
Biogas for 1000 families. 125 MGD – complete sewage treatment plant. (ongoing)
Biogas for 10,000 families (planned).

II

A.

1. (b) movable
2. 200,000 cu ft
3. (a) RCC structure
(b) mild steel plates 8 mm thick
(c) and (d) cast iron pipes range 6 in to 10 in diameter

B.

1. (b) batch
2. Sludge from primary sedimentation of raw-sewage
5. 0.3412×10^6 kg in every 3 days in each digester
6. 94–95 per cent moisture at 105°C

C.

1. (a) 14300 m^3
(b) domestic fuel supply and power generation (standby)
2. (a) 136.5×10^6 kg/day
(f) 204.7×10^6 kg/day

D.

1. \$US 2.5 million
2. (a) summer 40°C
(b) winter 20°C
3. (b) sun
5. Frequent chockages due to incoming grit. Grit chamber flow to be regulated every day. Application of back pressure with raw sewage to remove chockages
6. 66 per cent

7. To have at least 8 in to 10 in diameter C.I. pipe for withdrawal of digesters sludge and one central screw pump for mixing effectively.

138. Gobar Gas Research and Training Centre

I

1. Ajitmal, Etawah, India 206121
2. 1957
3. Director, Planning Research and Action Division, Government of Uttar Pradesh, Lucknow
4. Senior and other research officers
5. (a) over 20
8. Planning, research and extension of biogas technology
9. Biogas
10. Research and development. Training
11. On constructional methodology and technical details of biogas digesters.
12. On action research in biogas technology; design and introduction of Janata biogas plants; Janata biogas plants; biogas.
13. A community biogas plant completed. Three ongoing. More planned.

II

A.

1. (a) fixed
2. 6-18 m³ (common range)
3. (a) (b) (c) and (d) brick and cement

B.

1. (a) continuous
2. Cattle dung
3. Mixed with same quantity of water
4. 25 kg/m³ of gas
6. 1:1

C.

1. For family-size digesters
 - (a) 2-10 m³
 - (b) cooking and lighting
2. (b) (c) and (d) composted and applied twice a year

D.

2. (a) summer 35°C
(b) winter 15°C
3. (b) sun
5. As long as digesters are fed with requisite quantity of dung fixed with water it runs trouble free. If feeding is not proper and other things (agricultural wastes etc.) are also fed then the problems of scum formation and sedimentation arise.
6. Over 90 per cent.

**139. Indian Agricultural Research Institute,
Division of Soil Science and Agricultural Chemistry**

I

1. New Delhi 110 012, India
Tel: 581494 Cable: KRISHIPUSA
2. 1905
3. Dr. T.D. Biswas, Head
4. Drs. R.K. Chibber, M.C. Jain, P.K. Chhonkar, O.P. Chawla, Sushil Kumar
5. (a) 6
(b) 6 in farmers premises and 6 in institutions
6. Delhi
7. Co-ordination of research on biogas in universities and institutes, including pilot studies and feed back
8. Research on biogas technology and usage
9. Chemical, biological engineering and extension
10. Research and development. Information. Advisory. Consultancy. Training
11. For individual scientists. Seminar etc. Extension
12. *
13. Kinetics of gas production in relation to different physical, chemical and biochemical parameters. Screening of various additives for stimulating production etc. (completed)

Survey and possibility of utilization of various cellulosic waste materials for better production and investigations on the biochemical changes in the substrate, particularly the extent of cellulose decomposition to be taken up in the second phase. Detailed investigations on the residual slurry for enhancing its manurial value and easier handling will then be carried out in the third phase. Microbiological aspects: (a) Development of techniques for production and maintenance of enriched cultures of methanogenic bacteria. (b) Production of enriched culture of metha-

nogenic bacteria from various habitats including hilly areas for naturally selected cold adapted strains. These above experiments will be carried out in the first year. (c) Development of techniques for monitoring methane producing efficiency of enriched cultures and physiological investigations on selected strains for thermal sensitivity and identification of stimulatory parameters will follow in the second phase. (d) Investigations on commensural relationship between non-methanogenic cultures and fermentation kinetics of various cellulosic waste materials, will be taken up in the third phase. (Ongoing)

Installation of a community gas plant in Holombi Kalan Village of Delhi and study of the various socio-economic parameters. (planned)

II

A.

1. (b) movable
2. 3 m³ and 9 m³
3. (a) bricks and cement
(b) mild steel sheet
(c) cast iron pipe
(d) brick lined channel at the top

B.

1. (a) continuous
2. Cow dung
3. Dung and water in equal volume thoroughly mixed to form uniform slurry
4. 50/150 kg
6. 1:1 (by volume)

C.

1. (a) 3 m³ and 9 m³
(b) cooking, lighting and running engines
2. (b) 40-100 kg (wet)/day

D.

1. \$US 300 for 3 m³ and
\$US 500 for 9 m³
2. (a) summer 33°C
(b) winter 17°C
3. (b) sun
5. During summer, whenever the slurry dries out to form a hard scum on the surface, a few buckets of water are directly added to the thickened slurry around the gas holder and stirred well with a pole. Dirt and straw which form scum should be removed from the dung slurry. Precaution should be taken so

that scrapings of earth from the cowshed are not introduced in the digester otherwise there may be a silting up of the digester.

6. 100 per cent
7. Twice a week or more frequently the condensed moisture in the gas pipe must be removed; otherwise the burner flame will flicker. Once in a year, preferably after the monsoon, the gas holder and other iron components must be painted with anti-corrosive paint.

140. Indian Institute of Management

I

1. Vastrapur, Ahmedabad-380015, Gujarat, India
Tel: 450041 Cable: INDINMAN
Telex: 012-351 IIMA IN
2. 1962
3. Prof. V.S. Vyas
4. Four faculty members
5. (a) 100 (faculty), 50 (research staff)
6. Action programmes in Dharampur Taluka of Gujarat and Jawaja Block and Deogarh Blocks of Rajasthan
8. Post-graduate teaching, training, research and consultancy in the field of management
9. Agriculture and rural development. Industrial development. Industrial management. Planning and control system in private and public sectors etc.
10. Information. Research and development. Advisory. Consultancy. Education. Training.
11. Apart from regular post-graduate courses, the Institute offers about 50 different training course in a year for various levels of functionaries in various field of activities.
12. Reports on project completed.
13. Biogas: a socio-economic evaluation for Gujarat State. Biogas in India: a socio-economic evaluation (completed). Socio-administrative aspect of community size biogas plants. Rural energy demand/supply balance (ongoing).

141. Indian Institute of Technology (Bombay)

I

1. Department of Mechanical Engineering, Powai, Bombay 400076, Maharashtra, India.
Tel: 581421, 584141
2. 1959
3. Prof. A.K. De, Director
4. Dr. (Mrs.) P.P. Parikh
5. (a) 2 (b) 1
6. At the Institute
7. In contact with KVIC, Gobar Gas Research Centre, Ajitmal, Itawa; NDRI
8. Investigations of parameteric influence on generation of biogas and its utilization in engines and otherwise, research aspects
10. Research and development. Advisory. Consultancy. Education.
11. The topic of biogas is given full coverage in the energy courses for B.Tech. students.
13. Utilization of biogas in small diesel engines: conversion of existing machine (completed). Study of biogas cum kerosene engine (ongoing). Use of heavy fuels (residual fuels) with biogas in compression ignition engines (planned).

II

- A. KVIC design
 1. (b) movable
 2. For 35 m³
 3. (a) cement concrete
(b) mild steel
(c) and (d) cement pipe
- B.
 1. (a) continuous
 2. Cow dung and sometimes water hyacinth
 4. 500 kg
 5. 1:1
- C.
 1. (a) 35 m³
(b) in engine and for cooking canteen
 2. (b) composting

D.

1. SUS 500
2. (a) summer 32°C
(b) winter 28°C
3. (a) shadow
6. Only one digester

142. Indian Institute of Technology (Madras)

I

1. Madras 600 036, Tamil Nadu, India
Tel: 414342 Ext. 236 Cable: TECHNOLOGY MADRAS
Telex: TECHMAS-MS (041)7362
2. 1959
3. Prof. P.V. Indiresan, Director
4. Dr. S. Radhakrishna, Department of Physics, Dr. K.V. Gopalakrishnan, Department of Mechanical Engineering
5. (b) 2
6. Taramani House, IIT, Madras; Narayanapuram, 10 km from the Institute.
8. Research and development. Extension of biogas technology
9. Development of biogas engines. Design and development of biogas digesters. Development of comprehensive biomass biogas energy systems.
10. Research and development. Extension of biogas technology
11. Graduate and post-graduate degree courses
13. Improvement of dual-fuel engines using biogas. Demonstration and popularization of different implements working with biogas. (completed)
Cultivation of water hyacinth as biomass for biogas. Design and development of new digesters. (ongoing)
Development of comprehensive biomass systems. (planned)

II

A.

1. (b) movable
2. 8 m³ and 50 m³
3. (a) brick and cement
(b) mild steel
(c) and (d) asbestos cement pipe

B.

1. (a) continuous
2. Cow dung and water hyacinth
3. Solid impurities are removed, an equal amount of water added and a smooth slurry prepared.
4. 100 kg of wet dung (for 8 m³)
500 kg of wet dung (for 50 m³)
6. 1:1 (by volume)

C.

1. (a) 4 m³ (for 8 m³) and 20 m³ (for 50 m³)
(b) to run engine, lamps and pumpsets
2. (a) 60–70 kg/day (for 8 m³) and 200–300 kg/day (for 50 m³)
(c) 30–40 kg/day for (50 m³)
(d) 10–20 kg/day (for 8 m³) and 40 kg/day (for 50 m³)

D.

1. \$US 500 (for 8 m³) and \$US 1,250 (for 50 m³)
2. (a) summer 35°C
(b) winter 25°C
3. (b) sun
5. Blocking, cleared with bamboo poles
6. 100 per cent
7. The inlet and outlet passages should be made much larger in diameter

**143. Indian Institute of Technology (New Delhi)
Centre of Energy Studies**

I

1. Hauz Khas, New Delhi 110016, India
Tel: 654054 Cable: TECHNOLOGY
2. 1962
3. Prof. O.P. Jain, Director
4. Prof. H.P. Garg
5. (a) 10
(b) 3
8. Research and development
10. Research and development. Education. Consultancy
11. M. Tech. Course in Energy Studies
12. Several

II

A.

1. (b) movable
3. (a) masonry
(b) steel
(c) and (d) cement pipe

B.

1. (b) batch
2. Cow dung
4. 100 kg
5. 100 kg/day
6. 1:1

C.

1. (a) 3 m³/day
(b) cooking and lighting
2. (a) direct fertilizer on soil

D.

1. \$US 300
2. (a) summer 33°C
(b) winter 17°C
3. (b) sun
4. In winter slurry was made with solar heated water
5. Gas holder corrosion is a problem. Cleaning of digester well is required because of the settling of other things like small stones, sand etc.
6. 100 per cent
7. Gas holder should be made of some cheaper but durable material. Suitable trap for the moisture in the gas line should be designed. Cleaning of digester is a problem. In winter some simple and effective heating of slurry arrangement should be devised.

144. Kapur Solar Farms

I

1. Bijwasan Najafgarh Road, P.O. Kapas Hera, New Delhi 110 037, India
Tel: 391747
2. 1968
3. Mr. J.C. Kapur

5. (a) 5 (b) 1
6. New Delhi
8. Solar energy and bioconversion systems
9. Integration of solar energy and bioconversion systems
10. Research and development
13. Integrated solar energy and bioconversion systems

II

A.

1. (b) movable
2. 3-20 cu ft
3. (a) brick lined with cement plaster on both sides. Insulated with 2" insulating materials
- (b) mild steel drum
- (c) and (d) RCC pipe

B.

1. (a) continuous
2. Cow dung, at present
3. Feed being mixed with water in mixing tank before feeding
4. 125 kg
6. 1:1

C.

1. (a) 200-250 cu ft
- (b) cooking of food
2. (b) composting

D.

1. Nearly \$US 8000 (including instrumentation)
2. (a) summer 40°C
- (b) winter 5°C
3. (b) sun
4. Heating of slurry in winter by passing hot water from solar conductors through a heat exchanger

145. Khadi and Village Industries Commission, Gobar Gas Research
and Development Centre

I

1. Kora Gramodyog Kendra, Borivli (West), Bombay 400 092, India
Tel: 662485
2. July 1962
3. Mr. G.L. Patankar, Deputy Director
5. (a) 5
(b) 80,000 (In India)
7. National Environmental Engineering Research Institute, Nagpur. Bhabha Atomic Research Centre, Bombay. Planning Research and Action Institute, Lucknow. Indian Agriculture Research Institute, New Delhi
8. Research and development on biogas
10. Advisory on biogas (India and other developing countries)
11. On biogas plant construction.
12. Recent Development in Gobar Gas Technology (monogram)
13. Designing of domestic gas appliances including gas lamps, conversion kits for engines (completed).
Light weight gas holders (plastic and galvanised iron). Liquid jacked gas holder. (ongoing)
Designing of prefabricated domestic biogas plant, digester and gas holder. (planned).

II

A.

1. (b) movable
2. 3 m³
3. (a) bricks, stones
(b) mild steel (galvanized iron, PVC on small scale)
(c) and (d) cement asbestos

B.

1. (a) continuous
2. Cattle dung, human excreta
3. Mixing the feed in 1:1 proportion by weight with water
4. 80 kg
6. 1:1 or 1:1.25 for 16 per cent, 18 per cent solids respectively

C.

1. (a) 3 m³
(b) cooking and lighting
2. (a) 50% 60 kg/day (limited scale)
(b) 50% 100 kg/day (limited scale)

D.

1. \$US 550
2. (a) summer 30°C
(b) winter 20°C
3. (a) shadow
(b) sun
5. The digester works normally unless there is heavy acidity due to a particular type of feed
6. Exact number is not known, but 10 per cent of the 80,000 plants might be working
7. Prefabricated design of gas plant will solve a number of problems. Proper laying of gas pipe-line requires careful consideration. Technicians should be trained properly, so that accumulation of water condensate should not become a frequent source of trouble in operation.

146. L.G. Balakrishnan and Brothers Lintied

I

1. India House, Trichy Road, Coimbatore 641 018, India
Tel: 30355 (10 lines) Cable: CONVEYANCE
Telex: 085-222
2. 1956
3. Mr. L.G. Varadaraj, Managing Director
5. (a) 16
6. Coimbatore
8. Promotion of information on biogas, assistance in developing low-cost plants and encouraging use of plants to conserve energy.
10. Research and development

II

A.

1. (a) fixed (one plant)
(b) movable (three plants)
2. 6 m³ (fixed), 15 m³, 11.5 m³ and 3.5 m³ (movable)

3. (a) bricks
- (b) bricks for fixed type mild steel for movable type
- (c) and (d) asbestos pipes

B.

1. (a) continuous
2. Cattle dung
3. Mixed with water
4. 75 kg for fixed type
6. 1:1 (by weight)

C.

1. (a) 2.5 m³ for fixed type. 4.3 m³, 4.5 m³ and 2.15 m³ for movable type
- (b) experimental
2. (a) 686 kg/day of wet slurry
- (b) 147 kg/day of wet sludge

D.

1. \$US 108 (fixed)
\$US 500, 365 and 259 (movable)
2. (a) summer 27°C
- (b) winter 20°C
3. (b) sun
4. For a small 60 cu ft/day Indian (movable) type of plant (3.5 m³ is the digester volume), solar heating method is being tried.
5. (i) movable type: scum formation, which is taken by rotating the gas holder. Corrosion which is minimized by painting very often. (ii) Fixed type: sealing inside the dome (using gas proofing compound), painting etc. Moisture in gas, with water forming in pipe-lines and trapping of water.
6. 100 per cent
7. (i) Movable type: Ferrocement gas holders may solve to some extent the corrosion problems. Moisture removal from gas is an important problem.
- (ii) Fixed type: Perfect sealing inside the plant to prevent gas leakage. Pressure should be maintained uniformly at least in a certain definite range.

147. Maharashtra Gandhi Smarak Nidhi

I

1. Gandhi Bhavan, Kothrud, Pune 411 029, Maharashtra, India
Tel: 56905
2. In 1949 as a branch of Central Gandhi Smarak Nidhi; in 1969 as an autonomous body

3. Mr. T.S. Bharde, Chairman
4. Mrs. Savitribai Madan, Executive Member; Mr. H.N. Todankar, Organizer
5. (a) 28 technical assistants all over the State of Maharashtra
(b) 100 night soil and cattle dung gas plants constructed. In operation 95. 56,000 latrines constructed
6. In 16 districts of Maharashtra
7. Grant-in-aid from the Government of Maharashtra. Collaboration with Khadi and Village Industries Commission
8. Gandhi Smarak Nidhi itself is an organization engaged in propagating the Gandhian philosophy. Propagation of rural hygiene and biogas. Also village industries with special emphasis on training-cum-production programme
10. Consultancy. Training. Publication of Gandhian literature
11. Short-courses of one month each in construction of biogas plant and inexpensive hygienic rural latrines. Training for self-employment in village industries
12. Over 60 publications in Marathi on Gandhian philosophy, and small booklets on biogas and rural latrines
13. Construction of 56,000 rural latrines and 110 biogas plants. (completed)
Survey of the village oil-pressing industry in Maharashtra and Rajasthan. Establishment of rural industrial estate near Poona. (ongoing)
Establishment of dairy for breeding of cows. (planned)

II

- A. Digester is constructed underground with a steel or fibre-glass collector floating on the digesting slurry. Water jacketed to avoid odour.
 3. (a) bricks in cement mortar, duly plastered
(b) steel or fibre-glass and piping GI or PVC
(c) and (d) asbestos cement pipes
- B.
 1. (a) continuous
 2. Night soil and cattle dung
 3. With night soil no mixing is done. With cattle dung water and dung are hand-mixed in the proportion of 5:4.
 4. Will vary according to number of latrines and cattle. Most common sizes require night soil of 40 persons and droppings of 11-12 animals. There are smaller and bigger sizes also. Per cubic meter of gas requires cattle dung equal to 18 kg or night soil of 30 persons per day.
- C.
 1. (a) according to size of plant, 2 m³ to 35 m³ per day
(b) Gas from smaller-size plants is used mainly for kitchen. Occasionally also for lighting. From large plants gas is used for fuel in industry.

2. Used as such in the farm along with irrigation water or converted with other vegetable to refuse

D.

1. \$US 375, the smallest (2 m³) plant
2. (a) summer 40°C
(b) winter 8°C
3. (b) sun
5. Occasionally the pH of the slurry goes down and use of lime to correct the pH is required. In winter, owing to low temperature gas production is depressed some time to even less than half the normal quantity. No simple remedy has so far been found.
7. Water jacketed plants are necessary to avoid odour and flies in case of night soil gas plants. Rapid rusting of steel gas holders could be avoided with the use of glass fibre reinforced polyester gas holders

**148. Ministry of Agriculture, Department of Agriculture and
Co-operation (India)**

I

1. Krishi Bhavan, New Delhi 110 001, India
Tel: 388911 Cable: AGRINDIA
2. 1947
3. The Honourable Minister of Agriculture
4. Commissioner (Fertilizer Promotion), Specialist (Biogas).
5. (a) 4
(b) over 80,000
6. A large number under the auspices of State Governments and Khadi and Village Industries Commission
7. State Governments, Khadi and Village Industries Commission
8. Planning, programming, co-ordination and monitoring of biogas programme at national level
9. Planning, financing in the form of subsidy, arranging of finances from banks, supply for raw materials etc.
10. Information. Advisory. Consultation.
11. Regional training courses are being organized in collaboration with the Directorate of Extension, New Delhi.
12. A Gobar Gas Plant for You (1978). Janata Gobar Gas Plant (1979). Organic Recycling in Agriculture (1979).

13. About 80,000 biogas plants have been set up in the country. Programme for the year 1980-81 with a target of setting up of 40,000 plants is in progress. A national project on development and promotion of biogas for years 1980-85 is being planned.

II

A.

1. (a) fixed
(b) movable
2. Fixed gas holder: 2, 3, 4 and 6 m³; Movable gas holder 2, 3, 4, 6, 8, 10 to 85 m³
3. (a) bricks, stone slabs.
(b) steel
(c) and (d) bricks, stone slabs

B.

1. Semi-continuous
2. Cattle dung
4. Minimum of 50 kg/day for a small size i.e. 2 m³ gas production capacity plant.
6. 1:1.

C.

1. (a) 2 to 85 m³ depending upon size.
(b) cooking
2. (b) 85-95 kg/day (including water)
(g) sun drying and its use as compost: 15-20 kg/day

D.

1. \$US 200 to 10,000 depending upon size
2. (a) summer 30-35°C
(b) winter 10-20°C
3. (b) sun
5. Accumulation of water in the pipe-line which can be overcome by installation of a tap at the lowest level in the pipe-line and its periodic use to remove water. Corrosion of gas holders can be overcome by painting of gas holder at least once in two years.
6. It is estimated that about 80-90 per cent of 80,000 plants installed in the country are in operation at any one given time.
7. In gas plants having steel gas holder, designing for insulation and heating may be included. In gas plants having fixed dome, designing should be perfected to make it gas-leak proof.

**149. Municipal Corporation of Greater Bombay,
Dadar Sewage Treatment Plant**

I

1. Senapati Bapat Road, Dadar, Bombay 400 028, India
Tel: 451158
3. Executive Engineer (Mechanical) Sewerage, Western Suburbs
4. Assistant Engineer (Mechanical); Superintending Chemist (Purification)
5. (a) 35
(b) 2/2
6. Dadar, Bombay
8. Sewage treatment
9. Gas distribution and sewage treatment. Manure production

II

- A.
2. Two digestion tanks having 63' diameter and total depth 70' hopper bottom type – 4700 cu m of each unit.
 3. (a) RCC
(b) mild steel
(c) and (d) cast iron
- B.
1. (a) continuous
 2. Raw sludge (primary sludge having 5 per cent to 6 per cent solids)
 3. Consolidation for increasing the solids contents
 4. 12,500 kg
 6. 19:1
- C.
1. (a) 3000–3500 m³
(b) domestic fuel, fuel for running hospitals, and fuel for running hotels
 2. (f) 70 million litres per day
- D.
1. \$US 1 million
 2. (a) summer 33-34°C
(b) winter 18-20°C
 5. Pipe choking and screw pump jamming overcome by water recirculation. Scum formation, by moving the screw pump in forward and backward directions.
 6. 100 per cent

**150. National Dairy Research Institute,
Indian Council of Agricultural Research**

I

1. Karnal 132 001, Haryana State, India
Tel: 2851 Cable: DAIRYSEARCH, KARNAL
2. 1923 (formerly known as Imperial Dairy Research Institute, Indian Dairy Research Institute.)
3. Dr. D. Sundaresan, Director
4. Joint Director, Heads of Divisions, Scientists.
5. (a) 240 scientists
(b) 3
6. Regional stations in the south (Bangalore), west (Bombay) and east (Kalyani).
7. The Dairy Science College attached with NDRI is affiliated to Kurukshetra University and offers B.Sc. (Dairy Science), M.Sc. and Ph.D. degree. Recognized as centre of excellence for dairy production and processing by UNDP.
8. Research on dairy production with cattle, buffalo and goats, dairy processing and dairy management. Teaching for B.Sc. (Dairy Science), M.Sc. and Ph.D. and guidance for research. Collaborative research with national and international institutions.
9. Increasing milk yield of cattle. Production of good quality milk and milk products. Better management of dairy farm and mixed recycling of dairy farm wastes and of farms for fodder cultivation.
10. Research. Education. Training. Advisory
11. In addition to degree courses, short term courses: 13 in dairy production, 10 in dairy processing, and 4 in dairy management
12. Annual Report. Quarterly Newsletter. Research and Technical Bulletins and Monthly Documentation on Dairy Science.
13. 393 (completed) and 52 (ongoing).

II

- A. Khadi and Village Industries Commission design
1. (b) movable
 2. 7 m³
 3. (a) cement, brick
(b) galvanized iron
(c) and (d) cement brick and asbestos cement pipe

B.

1. (a) continuous
2. Cattle dung
3. Mixed dung with water in inlet trough
4. 125 kg (dung)
6. 1:1

C.

1. (a) 3-7 m³ (winter and summer months)
(b) cooking and lighting
2. (a) 250 litres digested slurry/day

D.

1. \$US 600
2. (a) summer 28-33°C
(b) winter 13-15°C
3. (b) sun
5. Less gas yield during winter. The gas yield can be slightly increased by charging the dung during winter months with warm water at noon. Besides 20 per cent urine addition will supplement nutrient deficiency
6. 100 per cent

151. National Institute of Waste Recycling Technology

I

1. A-18, Juhu Apartments, Juhu Road, Bombay 400 049, India
Tel: 543517 Cable: RECYCLING BOMBAY, Scz. 400 049
2. 1978 (Registration in the process)
3. Dr. T.M. Paul, Executive Directory (Honourary)
4. A band of honourary, part-time technical officers, both Indian and foreign.
5. (a) 12 Indian and 12 foreign
(b) 1
7. The Bharathiya Vidya Bhavan, Bombay. The Kosbad Agricultural Institute, Maharashtra. The Municipal Corporation, Bombay.
8. Designing and operating a pollution – free system of waste-recycling, to produce compost for manurial use, biogas for energy and reclaimed water for irrigation, industrial and domestic uses of flushing and washing and for rearing fish etc.
9. Redesign of a pollution free septic tank (completed and is under application for a patent in India and UK). Designing a simple biogas plant, without any metallic or domeshaped gas holder, but pollution-free (completed and under issue of a patent in India and UK)

10. Research and development. Consultancy, on non-profit basis
12. Liquid Compost Plant for Rural Sanitation: Part A: Basic Principles and Objectives (Under publication in International Reference Centre for Waste Disposal News No. 15, WHO.) Part B will publish the design of the new plant, after the patent is issued.
13. Pollution free septic tank. Liquid compost plant. drumless and domeless biogas plant (completed).
Field trials of the designs (ongoing).

II

A.

1. (b) movable
2. 35 m³
3. (a) brick and cement
(b) brick, cement and mild steel
(c) and (d) 3 in size asbestos pipe

B.

1. (a) continuous
(b) batch
2. Cow dung (other wastes also under trial)
3. Only mixing
4. Up to 5000 kg (approximately)
5. 10 kg every 30 days
6. 1:1

C.

1. (a) 100 m³
(b) running an irrigation pump, on a fodder farm, for about 8 years.
2. (b) up to 5000 kg/day (used for feeding chicks and calves)
3. Only compost (treatment) making is recommended

D.

1. \$US 625 (in 1967) (approx.)
2. (a) summer 35°C
(b) winter 25°C
3. (b) sun
4. Not necessary
5. None experienced in Bombay, where the annual rainfall has been about 100 in compost making could be carried out even in the rainy season.
7. Drum-free and dome-free digester will be trouble-free, but needs field trials which are under consideration.

152. Orissa Cement Ltd.

I

1. Rajgangpur 770 017, District Sundargarh, Orissa State, India
Tel: 32-RGP Cable: ORISACEMENT
Telex: 0635 240
2. Gobar gas plant established in 1977
3. Mr. M.L. Chand, General Manager
4. Mr. K.S. Singh, Horticulture Officer
5. (a) 2 (b) 3/2
6. Rajgangpur
7. Khadi Village Industries Commission, Bombay. Khadi Research Institute, Sewa-puri, Varanasi.
8. Industry
9. Rural development and welfare
10. Research and development
13. 2 (completed), 1 (ongoing) and 1 (planned).

II

A.

1. (b) movable
2. 1000 cu ft and 300 cu ft
3. (a) brick, cement and sand
(b) steel sheet
(c) and (d) brick, sand, cement and asbestos pipe

B.

1. (b) batch
2. Cow dung, cutgrass, waste cattle feed, fodder etc.
3. Mixing water, chopping grass in small
5. 1000 kg every day
6. 1:1 \pm 10 per cent

C.

1. (a) 1300 cu ft
(b) cooking food, boiling water etc.
2. (b) 1000 kg/day
(g) as fertilizer for flower pots, lawns etc.

3. (a) brick masonry
(b) M.S.
(c) and (d) stoneware pipe

B.

1. (b) batch
2. Cow dung
5. 150 kg every 7 days
7. 1:10

C.

1. (a) 8 m³
(b) running of diesel/petrol engines
2. (b) 40 kg/week

D.

1. \$US 1200
2. (a) summer 35°C
(b) winter 30°C
3. (a) shadow
7. The inlet and outlets should be of adequate size. Sand, stones etc. should be removed from the feed.

154. Punjab Agricultural University

I

1. Ludhiana, Punjab 141 004, India
Tel: 22960 Ext. 242 Cable: AGRIVERSITY LUDHIANA
2. 1962
3. Vice-Chancellor
4. Associate Professor, Soil Microbiology
5. (a) 3 (b) 1
6. In the University
7. Recognized by the University Grants Commission and the Indian Council of Agricultural Research, Government of India.
8. Research, teaching and extension
9. Agricultural, veterinary and animal science. Horticulture. Forestry etc.
10. Teaching. Research and extension.
11. B.Sc., B.Tech. B.V.Sc. M.Sc. M.Tech. Ph.D.
12. *

13. Two ongoing in biogas: Development of kachara-gas plant; cheaper materials for construction of biogas plants.

II

A.

1. (b) movable
2. 20 m³
3. (a) bricks and cement mortar
(b) and (c) mild steel sheet 18 gauge
(d) masonry tank

B.

1. (a) continuous
2. Dry paddy straw, wheat straw
3. Straw is chopped to less than 8 cm pieces.
4. 10 kg
6. 18:1 (water:straw)

C.

1. (a) 1 m³
(b) farm labour makes tea and cooks food; rest is just burnt off.
2. (a) 200 kg used for an experiment.

D.

1. \$US 1,000
2. (a) summer 27.5°C
(b) winter 14°C
3. (b) sun
5. The plant design can use any material that is of non-liquified plant origin, chopped to 8 cm size. The digester has stirring arrangement. The load on the stirrer needs to be reduced. The installation cost is higher than the KVIC design. It requires more space than the KVIC design.
6. Constructed: two. Operating: two

155. Resources Development Institute

I

1. 1100 Quarters Area, Arera Colony, Bhopal 462 016, India
Tel: 62361 Cable: SADHANVIKAS
2. 1974
3. Mr. G.G. Puri, Executive Director

4. Board of Directors (Chairman: Shri R.P. Norohna; Secretary: Professor S.D. Dube)
 5. (a) 7 researchers, 3 technicians, 3 co-ordinators.
(b) 5 constructed (one high pressure, portable, one overground on rock, one conventional, one all clay, and one in concrete)
 6. Bhopal
 7. Independent, voluntary society, recognized by the University Grants Commissions and Bhopal University as research centre
 8. Research and development. Extension and application of technology to rural poor. Consultancy
 9. Biogas technology. Solar energy. Rural – housing. Appliance and tools
 10. Research and development. Information and training. Extension. Consultancy
 12. Propose to publish a quarterly or technique which will be a journal of the RDI dealing with research, resource development, technology extension and integrated development
 13. Biogas – conversion kit for diesel engines Biogas filter. Substitution of acetylene by biogas in welding. Biogas turbine. High pressure portable biogas plants. (completed)
- Cheap solar cookers – clay and local materials costing \$US 2 to 3. Solar pumps – reflection concentrator modified Sterling engine system. Rural cold storage – aqua-amonia-absorber- and gas turbine system. Solar-cum-wind energy converter. Complete clay biogas plants. Clay ring wells for small farmers. (nearly completed)
- Baked clay – pre-fab houses for rural poor. Strain – relieving and effort boosting mechanism for hand carts. (ongoing)
- Fibre from plantain stalks. Solar cycle. Chemical storage of solar energy. Development of cheap solar cells. F. low-burnt clay bricks. Fertilizer and soil fertility boosters from manganese wastes. (planned)

II

A.

1. (b) movable
2. 4 m³
3. (a) baked clay: rings assembled
(b) baked clay
(c) clay – pipe
(d) rubber or plastic pipe – secured in clay

B.

1. \$US 50
2. (a) summer 40°C
(b) winter 25°C
3. (b) sun

156. Sobic Industrial Consultants

I

1. 5, V.N. G. Road, Madhavaram Milk Colony, Madras 600051, Tamil Nadu, India
Tel: 647102
2. 1979
3. Ms. L.M. D'Souza, Director
4. Ms. Christine D'Souza, Farm Manager
5. (b) 10/2
6. 5, V.N.G. Road, M.M.C., Madras 600 061
10. Research and development. Advisory. Consultancy. Education. Training
11. Non-formal training to village children mainly in the form of exposure by joining in the operation of feeding the plant and using effluent.
13. Biogas plant, one for S.O.S. children's village, one for Mother Teresa's orphanage, three for poor educational institutions and five for individuals (completed).
12 biogas plants for a rural housing project based on a radial design. (ongoing)
Biogas plant for a factory having 2000 workers. Low-cost biogas plants for village applications. (planned)

II

A.

1. (b) movable
2. 7.8 m³
3. (a) brick and cement mortar
(b) mild steel
(c) 4 in A.C. pipe, bottom entry, seperated by partition wall
(d) 6 in A.C. pipe, bottom exit, seperated by partition wall

B.

1. (a) continuous
2. Night soil, chicken dung, cowdung pig dung, chicken entrails, kitchen peelings, straw, cut grass, banana plant stalks, spoiled fodder, chicken deep litter
4. 25 kg approx.
6. Average 1:1

C.

1. (a) 2.8 to 3.0 m³
(b) cooking
2. (a) 30 kg/day approx.
(b) very marginal
(d) 10 kg/day approx.

3. Have tried it and found to be effective for vegetable e.g. brinjals, cluster beans etc.

D.

1. \$US 500
2. (a) summer 40°C
(b) winter 27°C
3. (b) sun
5. Setting up of inlet lines due to sand accumulation at digester bottom. Light component of feed floating due to poor feed slurry mixing. High rates of water to feed where digester is connected to sewage system. Cracks in digester feed lines and digester walls.
6. 100 per cent
7. Development of a good feed slurry mixer is very important. Arrangements to be made for removing sand from feed. At least the digester will silt in course of 2-4 years. Arrangements should be made to desilt without taking digester out of service. Good follow-up is necessary at construction stage to make sure that digester and associated pipes/lines are leak-tight.

Larger digesters to be provided with a stirrer to provide agitation which will promote good digestion.

157. Sri Parasakthi College for Women

I

1. Courtallam 627 802, Tamil Nadu, India
2. 1970
3. The Principal
5. (b) 5
6. Courtallam
11. Five batches of training courses
13. Indian Council of Agricultural Research scheme on biogas technology

II

A.

1. (b) movable
2. 2.9, 4, 14.5, 10 and 17 m³
3. (a) brick and cement
(b) (c) and (d) steel

B.

1. (b) continuous
2. Cow dung, urine, waterhyacinth

4. 200 kg of dung

6. 1:1

C.

1. (a) 20 m³
(b) cooking, lighting and laboratory uses.

2. (b) 150 kg/day
(c) 100 kg/day

D.

1. \$US 4450 (5 plants)

2. (a) summer 39°C
(b) winter 31°C

3. (b) sun

5. The gas holders often get corroded due to the gas contaminants in the biogas. Hydrogen sulphide has to be eliminated from the constituents of biogas

6. 100 per cent

7. The design should be modified in such a way that it should work even during winter.

158. Structural Engineering Research Centre

I

1. Roorkee, U.P., India

Tel: 480

Cable: SERCENTER

2. 1965

3. Dr. S.P. Sharma, Scientist-in-charge

4. Dr. S.P. Sharma, Dr. V.P. Narayanaswamy, Dr. G.V.S. Kumar, Dr. P.C. Sharma and Dr. S.S. Jain

5. (a) 4 (b) 6

7. Through the All-India Co-ordinated Project on Biogas sponsored by Department of Science and Technology, Government of India

8. Research and development relating to structural engineering and construction technology

9. Structural analysis and design. Construction materials and technology.

10. Information. Research and development. Consultancy. Training

11. On ferro-cement technology in June 1979

12. *

13. On biogas, one completed and one ongoing

II

- A.
 - 1. (b) movable
 - 2. 3.6 m^3
 - 3. (a) brick in cement mortar
(b) ferrocement
(c) and (d) brick in cement mortar
- B.
 - 1. (a) continuous
 - 2. Cattle dung
 - 3. Mixing of dung and water manually
 - 4. 66 kg
 - 6. 1:1 (by weight)
- C.
 - 1. (a) 2 m^3 (average)
(b) demonstration of use for cooking and lighting
- D.
 - 1. \$US 250
 - 2. (a) summer 35°C
(b) winter 15°C
 - 3. (a) shadow
 - 6. 50 per cent

159. Tata Energy Research Institute, Field Research Unit

I

- 1. 7 rue Suffren, Pondicherry 605 001, India
Tel: 3483 Cable: AUROBINDO
- 2. 1975
- 3. Dr. C.L. Gupta, Director
- 5. (a) 12
(b) 4 constructed; 3 designs finished; construction to start
- 6. 1 (10 km away)
- 7. IIT, Delhi, Centre of Energy Studies and TERI Headquarters, Bombay
- 8. Research in alternative sources of energy
- 9. In biogas field: small-scale biogas plants
- 10. Research and development. Consultancy. Education. Advisory
- 13. Cook stoves and small biogas systems (ongoing). Biogas system for field station (planned)

D.

1. \$US 500 (5 m³), \$US 1,000 (15 m³)
2. (a) summer 25° – 30°C
3. (b) sun
6. 50 per cent

161. Industrial Research Institute, Centre for Chemical Industry

I

1. Jalan Karanganyar 55, Jakarta, Indonesia
Tel: 625980
2. 1938
3. Ir. Koentoro Soebijarso
4. Ir. Karsini
5. (a) 10 (b) 2
6. Jakarta, Central Java and East Java
8. A five-year development plan project
9. Design and construction of small and medium biogas plants
10. Research and development
12. Annual reports. Research papers.
13. A biogas digester at West Jakarta, with a capacity of 1.50 m³ (completed).
A biogas digester at Semarang (Central Java), with a capacity of 10 m³ (ongoing).
A biogas digester at Klaten (Central Java), with a capacity of 20 m³ and a biogas digester at East Java, with a capacity of 30 m³ (planned).

II

A.

1. (a) fixed
2. 1.5 m³
3. (a) concrete tube
(b) steel plate (3 mm thick)
(c) and (d) concrete tube

B.

1. (a) continuous
2. Pig excrement and eichhornia crassipes.
3. Putrefaction of eichhornia crassipes by soaking in water (30 days)
4. 20 kg.
6. 1:1

C.

1. (a) 1 m³
(b) lighting and cooking
2. (a) 10 kg/day

D.

2. (a) summer 35°C
3. (b) sun
6. 100 per cent
7. A sprayer for cleaning biogas digester and a stirrer for homogenizing sludge, both of them constructed together with biogas dome.

**162. Ministry of Agriculture, Forestry and Fisheries,
National Institute of Animal Industry**

I

1. Tsukuba Norindanchi, P.O. Box 5, Ibaraki 305, Japan
Tel: 02975-6-8600
2. 1916
3. Dr. Takeo Abe
4. 236 (Researchers: 118, biogas 3)
5. (a) 67 (biogas: 1) (b) 1
7. Other governmental research institutes. (For biogas, with Fermentation Research Institute, Agency of Industrial Science and Technology, Ministry of International Trade and Industry)
8. Basic research
9. Animal science. Animal husbandry. Animal waste management. Animal products processing.
10. Research and development.
12. Research papers in "Bulletin of National Institute of Animal Industry" and other scientific journals: "J. Anim. Sci.", "J. Nutr.", "J. Sci. Food Agric.", "Jpn. J. Zootech. Sci.", "Endocrinol. Jpn.", "Agric. Wastes", "J. Dairy Sci.", "Agric. Biol. Chem." and the like.
13. On animal waste management: Activated sludge process for swine wastewater; High-rate animal wastewater treatment by contact aeration. (completed)
Biogas production from animal wastes and its utilization. Aerobic composting of animal wastes. Control of odours from animal wastes. (ongoing)
System analysis and standardization of animal waste management. More efficient utilization of biological resources including animal wastes. (planned)

II

A.

1. (b) movable (separated from the digester)
2. 0.2 m³
3. (a) FRP (Fibre-glass reinforced plastic)
(b) iron
(c) FRP pipe
(d) vinyl pipe

B.

1. (a) continuous
2. Swine wastes
4. 10 kg
6. 3:4

C.

1. (a) 0.2 m³
(b) fuel
2. (a) 10 kg/day

D.

2. (a) summer 27°C
(b) winter 4°C
3. (a) shadow
4. A submersible pump in the digester stirs and heats slurry simultaneously.
5. Main trouble is clogging of the submersible pump by gross organic residues such as straw mixed in the wastes. The method of overcoming is the removal of these residues before feeding digester.

163. Standards and Industrial Research Institute of Malaysia (SIRIM)

I

1. Lot 10810 Phase 3, Federal Highway, P.O. Box 35, Shah Alam, Selangor, Malaysia
Tel: 362601-4 Cable: SIRIMSEC
2. 1975
3. Mr. Abdullah bin Mohd Yusof, Controller
4. 2
5. (a) 156 (b) 1
6. Selangor
8. Standards and industrial research

10. Information. Research and development. Advisory. Consultancy.
12. Malaysian Standards. Technical Report (research and development)
13. On biogas: one completed and two ongoing.

II

A.

1. (b) movable
2. 4 m³
3. (a) concrete – bricks and cement
(b) mild steel
(c) and (d) PVC pipe

B.

1. (b) batch
2. Chicken droppings
5. 30 kg every 7 days
6. 1:1

C.

1. (a) 100 ft³
(b) cooking and lighting
2. (a) 10 kg/day

D.

1. \$US 400
2. (a) summer 31°C
3. (b) sun
5. Due to a defect in the design, difficulty was encountered in the discharge of the digested by-products. To overcome this problem an outlet pipe of a bigger diameter was used together with an inclined concrete screed to ease flow.
6. About 50 per cent
7. In the present design adopted, feeding is done manually, hence it is necessary that the opening of the inlet (or feed) pipe be within reach of the operator. With this, a digester embedded in the ground is found most fitting besides the fact that the digested material can be maintained at a constant temperature.

164. Invermay Agricultural Research Centre

I

1. Private Bag, Mosgiel, New Zealand
Tel: Mosgiel 4132

Telex: INV

2. 1950
3. Dr. A.J. Allison, Director
4. Dr. D.J. Stewart, Mr. M. Badger and Mr. M. Bogue
5. (a) 2
(b) 1 farmscale
6 laboratory
6. At the Centre
8. Research and development
10. Information. Research and development. Advisory
13. Effects of industrial pollution on agriculture. Production of biogas from crops and wastes. Energy farming. Energy in agriculture. Farm-scale biogas and ethanol plants

II

- A.
1. (b) fixed
 2. 45 m³
 3. (a) steel frame holding insulating panels, rubber liner
(b) butyl rubber bag, steel frame
(c) and (d) pump
- B.
1. (a) continuous
 2. Crops: maize, oats, kale, straw
 3. Storage as silage (chopped) and mixed with recycled effluent
 4. 200 kg
 5. 250 kg DM every day
 6. No water added
- C.
1. (a) 75 m³
(b) vehicle fuel
 2. (a) 50 per cent at 1500 kg/day at 2 per cent T.S.
(b) 50 per cent at 1500 kg/day at 2 per cent T.S.
- D.
1. \$US 17,500
 2. (a) summer 14°C
(b) winter 6°C
 3. (b) sun
 4. Gas heating/water heat exchange or electric hot water heating/heat exchanger

6. In New Zealand, 7 operating, 8 constructed and 5 under construction
7. Design of mixing system must suit material to be used.

**165. Appropriate Technology Development Organization
Government of Pakistan**

I

1. 1-A, 47 Street, F-7/1, Islamabad, Pakistan

II

A.

1. (a) fixed
2. 10, 50 and 100 m³
3. (a), (b), (c) and (d) cement, steel bars, bricks

B.

1. (b) batch
3. Cow and buffalo dung
5. 50 to 70 kg every day
6. 50 per cent

C.

1. (b) cooking
2. (c) 50 kg/day

D.

3. (b) sun

166. Merin Limited

I

1. Dada Chambers, M.A. Jinnah Road, Post Box 4145, Karachi 2, Pakistan
Tel: 221783, 231332, 233595 Cable ORGANISE
Telex: PAK 24675
2. 1948
3. Mr. Mahmood Futehally, Managing Director
4. Miss Shama Futehally, Adviser; Mr. S.A. Rahman, Manager
5. (a) 2 (b) 2
6. Sohana Bagh, Block 2, Gulshan-e-Iqbal, Karachi

7. Appropriate Technology Development Organization, Ministry of Science and Technology, Government of Pakistan; Intermediate Technology Development Group, Ltd., London; SWD Steering Committee on Wind Energy for Developing Countries DHV Consulting Engineers, Amersfoort, the Netherlands
8. Manufacture and sale of windmills, prefabricated biogas plants and propagation of productive plants and trees
9. Manufacture, sale, publicity, plant nursery services
10. Information. Research and development. Training
12. Paper presented at the 19th All Pakistan Annual Science Conference, 1979
13. Seven 12ft diameter windmills installed at various places in Pakistan. (completed)
Repair of old windmills belonging to the Government at various parts of Pakistan. (ongoing)
Development, manufacture and sale of 10 ft, 12 ft, 18 ft and 24 ft windmills. Development, manufacture and sale of prefabricated biogas plants of 10 cu m capacity. Development of water-proof fabric for construction of water-storage ponds. Development of "Ipil" forests along the roads and streets of Karachi. (planned)

II

- A. Experiments are being made with the construction of ferrocement digesters made of prefabricated sections which can be easily transported to site, quickly assembled and charged with feed within a day or two. One of the important requirements is to have a very impervious plastering substance which would make the whole structure leak-proof with only a single coat. A plaster has been produced and a small experimental plant constructed wherein this type of plaster has been used, and which has been producing since the last six months. A bigger plant of 10 m³ capacity is shortly to be installed. When this also has proved successful, its manufacture on a commercial scale is planned.
- C. So far the sole use of effluent has been for fertilizer.

167. Ministry of Petroleum and Natural Resources, Energy Resources Cell

I

1. H. No. 3, St. 88, G-6/3, Islamabad, Pakistan
Tel: 21416
2. 1973
3. Director General
4. Director, Deputy Director, Assistant Director, Research Investigators
5. (a) 13 (b) 100 family biogas units and two community biogas plants
6. Islamabad

8. Recommendation on national energy policy. Development and demonstration of renewable sources of energy. Conservation of energy
13. Installation of 100 family units for demonstration purposes and two community biogas plants (45 m³ gas/day and 90 m³ gas/day) (completed).

Projects on rural energy, rural electrification and solar energy development (on-going).

Installation of 1200 biogas plants (planned).

II

A.

1. (b) movable
2. 18 m³
3. (a) bricks, cement and sand
(b) M.S. sheet
(c) and (d) bricks, cement and sand

B.

1. (a) continuous
2. Dung
3. Dung is mixed with water in the form of slurry in the inlet tank
4. 90 kg
6. 1:1

C.

1. (a) 4.3 m³
(b) cooking
2. (a) 80 kg/day

D.

1. \$US 80
2. (a) summer 35°C
(b) winter 20°C
3. (b) sun
6. A few units were out of operation because of defective masonry work

168. Liberty Flour Mills, Inc., Maya Farms Division

I

1. Liberty Building, Pasay Road, Makati, Metro Manila, Philippines
Tel 86-50-11
Cable: LIBFLOUR
2. 1972

3. Dr. Felix D. Maramba, Sr.
4. Dr. F.D. Maramba, Sr., Dr. E. Obias, Dr. C. Taganas, Dr. J. Banzon
5. (a) 18 (b) 68
6. Angono, Rizal, Philippines
8. Integrated animal raising – meat processing – waste processing/recycling – and biogas energy utilization
9. Design, construction and operation of biogas works. Operation of integrated farming
10. Consultancy. Research and development
12. On small biogas plant; biogas and waste recycling
13. Design, construction, testing of 2 sets of industrial-size batch-fed digesters. Design, construction, testing of 4 sets of industrial continuous digesters with gas holder and sludge conditioning systems. (completed)
Design, construction of industrial-size (set of 6) digesters for continuous operation with gas holder and sludge conditioning system. (ongoing)

II

A.

1. (a) movable
2. Total volume 2753 m³
3. (a) concrete, hollow blocks, reinforcing bars
(b) concrete, reinforcing bars, steel sheet, pipes
(c) and (d) concrete or polyethelene pipes

B.

1. (a) continuous
(b) batch
2. Hog waste
3. Admixture with water
4. 20,000 kg (total)
5. Total 10,000 kg every day, but 2 out of 48 batch digesters charged each day
6. About 2:1

C.

1. (a) 1700 m³
(b) pumping water, generation of electricity, needs of meat processing and canning plants
2. (e) 3,000 kg/day
3. Prolonged aeration and settling

3. Wastes and washings only
4. 200 kg/digester
6. 1:2

C.

1. (a) 10-21.5 m³
(b) 1 gas range, 1 gas burner and 1 refrigerator
2. (a) 1 kg/day/plant (for vegetables)
(c) 8 kg/day
(e) 5,000 kg/day/algae seeding
(f) 0.2 kg/day/animal (sludge as animal feed)

D.

3. (b) sun
5. Lack of sufficient manure coming from the dairy parlor. Cattle manure is being collected from animals in the cattle shed, the wastes placed in drums and mixed with water to form a slurry.
7. The split designs offer more trouble than the continuous integrated ones

✎

170. National Institute of Science and Technology

I

1. Pedro Gil Street, Ermita, Metro Manila, Philippines
Tel: 50-30-41
3. Commissioner
4. Project Leader
5. (a) 6 (b) 72
6. 13 regional offices of NSDB
7. Technical support to Bureau of Animal Industry and Human Settlement in their biogas project.
8. Research and development. Extension
9. Designs and construction. Operation and utilization
10. Research and development. Information. Consultancy. Training
11. Biogas and mushroom production
12. On biogas technology with emphasis on microbial actions on the substrata to improve the yield and quality of gas produced.
13. Four projects (completed). One big project supported by ASEAN (ongoing)

II

B.

1. (a) continuous
2. Hog manure
3. 3 days of aerobic fermentation prior to changing
4. 20 kg
6. 3:1

C.

1. (a) 1.5 m³
(b) cooking
2. (a) 10 kg/day
(c) 5 kg/day
(f) 3 kg/day

D.

1. \$US 470
2. (a) summer 33° C
(b) winter 28° C
3. (b) sun
5. Leaks in the joints of sidings and flooring. Poured monolithic concrete is advised.
6. 95 per cent

171. Office of Rural Development

I

1. Rural Energy Resources Research Division, Institute of Agricultural Science, Suweon, Republic of Korea
Tel: Suweon 6-1057
2. 1977
3. Dr. Young Dae Park
5. (a) 9 (b) 3/3
6. Yu Name Livestock technical College
7. Farm Machinery Institute. Livestock Experiment Station. Horticultural Experiment Station.
8. Study feasibility of village scale biogas plant in the Republic of Korea
9. Gas production, utilization of effluent, reduction methods of BOD in effluent.
10. Research and development

12. Studies on biogas generation from animal wastes. A feasibility study of village scale biogas plant during winter season.
13. Studies on material resources for biogas production. Development of biogas plant types and biogas utilization. Solar energy utilization. (ongoing)
Integrated biogas research. (planned)

II

A.

1. (b) movable
2. 100 m³
3. (a) cement concrete
(b) iron made
(c) and (d) cement concrete

B.

1. (a) continuous
2. Animal manures (pig)
3. Pretreatment: manure mixed with small amount of water and keeping it as it is for one day for melting the manures
4. 1900 kg/day
6. Manure 2: water 3

C.

1. (a) 185 m³
(b) cooking and heating the rooms

D.

1. About \$US 23,450 in 1979
2. (a) summer 19°C
(b) winter -8°C
3. (b) sun
4. Digester temperature was controlled at 35°C as much as possible by heating with biogas produced
6. This digester is operating as prototype-village scale biogas plant

172. University of The South Pacific, School of Agriculture

I

1. Alafua Campus, P.O. Box 890, Apia, Western Samoa
2. 1977
3. Dean and Head of School

4. Lecturer in Agricultural Engineering
5. (b) 1
7. As a regional university linkages with many institutions worldwide.
8. Degree and diploma training. Research and extension
9. Agriculture and related fields
10. Education. Training. Research. Extension
11. Degree in Agriculture. Diploma in Tropical Agriculture.

II

A.

1. (b) movable
2. 1.57 m³
3. (a) reinforced concrete tank
(b) G.I. sheet
(c) and (d) ceramic pipe

B.

1. (a) continuous
2. Pig waste
3. Wastes washed down and screened to prevent big lumps going into digester.
4. 30 kg
6. 15:1 (including washing water)

C.

1. (b) cooking
2. (g) fish/duck pond

D.

2. (a) summer 85° C
(b) winter 80° C
3. (b) sun
4. Not necessary
5. This digester was constructed in 1977, but no record is available about its performance. It has recently been repaired by students as part of their project. It has started to operate in April 1980 and the gas is coming out fairly well.
6. Only one digester in USP.
7. The inlet and outlet pipes need to be modified. Excess water going into the digester should be properly regulated.

173. University of Peradeniya, Department of Civil Engineering

I

1. Peradeniya, Sri Lanka
Tel: 08-8029
2. 1950
3. Head of the Department
4. Professor M. Amaratunga
5. (a) 1 (b) 4
7. Ceylon Electricity Board; In-service Training Centre, Department of Agriculture
8. Research. Teaching
9. Development of burners. Integrated systems
10. Consultancy. Education
11. A short course on biogas technology is taught in B.Sc. (Engineering)
13. Collaboration with In-service Training Centre, Department of Agriculture in establishing an integrated system. Survey of biogas potential of a district in Sri Lanka. (completed)
Setting up biogas units in Matale District based on the survey. (ongoing)

II

- A.
1. (a) fixed (This type is now being used in view of prohibitive costs of steel movable holders.)
 3. (a) and (b) brick work
(c) and (d) clay pipes
- B.
1. (a) continuous
 2. Cattle dung
 4. Depends on digester. Usually 1 lb of cattle dung is used to obtain 0.5 cu ft of gas produced.
 6. 1:1
- C.
1. (b) cooking
 3. A layer retention time (about 60 days) is often used in the design for purposes of disease control.
- D.
1. About \$US 200 for a 10 m³ fixed-dome unit
 2. (a) summer 25°C

3. (b) sun
5. Gas leaks. Inadequate feeding and attention to maintenance
6. Only about 50 have been constructed in the country. Of these about 20 per cent may be said to be working.

174. Asian Institute of Technology (AIT)

I

1. P.O. Box 2754, Bangkok, Thailand
Tel: 5168311-5 Cable: AIT BANGKOK
3. Dr. Robert B. Banks, President
4. Dr. Chongrak Polprasert
5. (a) 3 (b) 4
6. AIT Campus
7. With various local and international institutions
8. Teaching graduate levels and research
9. Civil engineering
10. Education. Research and development. Advisory. Consultancy
13. Recycling rural and urban nightsoil in Thailand (ongoing)

II

A.

1. (a) fixed
2. 3.5 m³
3. (a) and (b) ferrocement
(c) and (b) PVC pipe

B.

1. (a) continuous
2. Nightsoil with water hyacinth and straw
3. Mixing twice a day
4. 5.8 kg (mixture dry weight)
6. 11.5:1

C.

1. (a) 1.5 m³
2. (c) 270 kg/day (4 fish ponds)

D.

1. \$US 200
2. (a) summer 35°C
(b) winter 20°C
3. (b) sun

175. Department of Health, Ministry of Public Health

I

1. Sanitation Technique 2, Sanitation Division, Department of Health, Ministry of Public Health, Bangkok
Tel: 2828117, 2819461
3. Mr. Chit Chaiwong
4. Mr. Udom Churnoi
5. (a) 10
6. Sanitation centre, Region 1-9
7. Faculty of Public Health, Mahidol University. The National Institute of Energy. Department of Agriculture, Ministry of Agricultural and Co-operatives
8. Environmental sanitation
9. Public health
10. Demonstration of biogas plant in public, health centers, temples and schools. Technical assistance. Equipment: casing molds.
11. Training local health officials
12. The production of biogas from animal excreta.
13. Support for construction of 517 biogas plants (completed). Experimental project on fixed-dome type, as earlier designs leaked gas (ongoing). Research on production of biogas by anaerobic digestion of human wastes and other organic materials (planned).

II

A.

1. (b) movable
2. 3.4-9.4 m³
3. (a) concrete tank
(b) metal
(c) and (d) asbestos pipe

B.

1. Semi-continuous
2. Pig excreta

4. 20 kg (for semi-continuous digester)

6. 1:1

C.

1. (a) depend on excreta used

(b) cooking

2. (a) 20 kg/day

3. No effluent treatment, because the digestion of excreta in the biogas tank greatly reduces the health hazard by killing pathogenic bacteria, parasite eggs and so on.

D.

1. \$US 250

2. (a) summer 37°C

(b) winter 25°C

3. (b) sun

5. There are several problems in digester operation: pH, toxicity, temperature and mixing.

6. 68.9 per cent digesters are in operation to the total number of digesters constructed (517 units)

7. Movable design is too expensive for rural people

176. Kasetsart University, Faculty of Agriculture

I

1. Animal Science Department, Bangkok, Bangkok, Thailand

Tel: 5790113 Ext. 350

2. 1978

3. Prof. Phaitoon Ingkasuwan, Rector

4. Dr. Pravee Vijchulata

5. (a) 2

(b) 44 (big scale 2, medium 4, small 38)

6. Kamphaeng Saen

7. Division of Chemical Agriculture, Department of Agricultural Technology, Ministry of Agriculture and Co-operatives

8. Applied research for development

9. Biological science

10. Information. Education. Consultancy. Training.

11. Provided for undergraduate, graduated students and others interested.

13. Ongoing and planned.

II

- A.
- (b) movable
 - 200 m³
 - (a) brick, cement and sand
(b) metallic and bamboo sheet
(c) and (d) cement
- B.
- (a) continuous
 - Manure
 - 800 kg
 - 10, 50, 100 kg/m³ every 1 and 3 days
 - Cattle and buffalo = 1; Chicken and swine = 3
- C.
- (a) 30 m³
(b) electricity
 - (a) 400 kg/day
(b) 100 kg/day
(c) 50 kg/day
(d) 50 kg/day
(e) 100 kg/day
(g) 100 kg/day (gardening)
- D.
- \$US 900
 - (a) summer 31°C (b) winter 23°C
 - (a) shadow
 - Gas outlet should be connected at the digester wall itself. For the small scale say 6-8 m³ of digester volume, bamboo sheet should be used as container. This will certainly be well adapted for the low income small farmers.

177. King Mongkut's Institute of Technology

I

- Thonburi Campus, Bangkok 14, Thailand
Tel: 462-5719 Ext. 73
- 1978
- Dr. Morakot Tanticharoen
- (a) 4 (b) 1
- King Mongkut's Institute of Technology, Thonburi

8. Basic research. Research and development. Pilot testing
9. Microbiology. Engineering design of digester.
10. Research and development. Education.
12. Biogas from plant material
13. Biogas from plant material. Microbial populations in methanogenesis (ongoing)
Effluent from biogas digester as a source of single cell protein production (planned).

II

A.

1. (a) fixed
2. 2.40 m³
3. (a) fibre-glass reinforced plastic
(b) FRP
(c) PVC pipe with brassgate valve
(d) FRP cover bolts.

B.

1. (b) batch
2. Aquatic weeds
3. Mechanical mixer
5. 80(dry) kg every 21 days
6. 20:1 (dryweight of weed)

C.

1. and 2. under investigation

D.

1. \$US 350
2. (a) summer 40°C
(b) winter 30°C
3. (a) shadow
5. Leakage and seepage of gas through joints of tank and materials. These problems may be overcome by vacuum injection method in fabrication of tank.

178. Maejo Institute of Agricultural Technology

I

1. Maejo, Chiangmai, Thailand
Tel: 236602
2. 1934

3. Prof. Vipata Boonsri Wangsai, Rector
5. (a) 3 part-time voluntary
(b) 20
6. At the Institution
10. Training. Demonstration. Servicing directly. Advisory.
11. Integrated agricultural technologies like mushroom culture, crops etc.
12. Many in Thai, as handouts
13. Ongoing.

II

A.

1. (a) fixed: 3 (b) movable: 17
2. 10-12 m³
3. (a) brick and cement
(b) iron sheet
(c) and (d) cement tube or brick and cement

B.

1. (a) continuous (b) batch
2. Swine or cow-buffalo dung
4. one to four buckets
5. 10-30 kg every day and other days
6. Half and half generally

C.

1. (a) 3-12 m³
(b) cooking
3. No, the process already kills everything, except the thriving anaerobic bacteria

D.

2. (a) summer 30° C
(b) winter 22° C
3. (a) shadow (b) sun
6. 85 per cent
7. No design is trouble-free. The design without gas holder is most trouble-free but less efficient in thorough turn-over of old spent manure than design with gas holder but the latter is more expensive.

179. Mahidol University

I

1. Faculty of Public Health, 420/1 Rajavithi Road, Bangkok 4, Thailand
Tel: 2827827
2. 1949
3. Dr. Debhanom Muangman, Dean
5. (a) 148
6. Phyathai, Bangkok
7. Providing technical advice to the Health Department and Provincial Health Offices. To do research projects with Sanitation Divisions.
8. Teaching and research in public health science
9. Environmental health science. Sanitary science
10. Teaching. Advisory. Consultancy. Research and development
12. Environmental sanitation. School health environment. Biogas from animal manures. Biogas from various organic materials. Fibre-glass – sanitary utensils
13. Biogas from animal manures and from various organic materials. Fibre-glass – sanitary utensils. (completed)
Biogas engine. (ongoing)
Socio-economic survey of digesters in rural areas of Thailand. (planned)

II

A.

1. (b) movable
2. 1.50 – 2.00 m³
3. (a) concrete, casing rings and masonry
(b) iron sheet, galvanized iron sheet, fibre-glass cement
(c) 4 in diameter as minimum
(d) 2 in diameter for over flow and 3 in diameter for sludge drainage pipe with gate valve

B.

1. (a) continuous
(b) batch (for research project in some aspects)
2. Animal manures
3. None for animal manures, cutting and grinding or pounding for grass and water-hyacinth
4. 30-80 kg (for 2.5 m³ digester)
5. 1/30 of total volume of digester (daily feeding)
6. 1:1 by volume

C.

1. (a) 2 m³ (from 2.5 m³ digester volume)
(b) cooking
2. (a) 30-80 kg/day
3. The human excreta had been used as feeding material for research project in 1979. The over flow liquid was treated by sand filter before use. The digested sludge, after completed digestion (about 2 months), was put in the sun for 2-3 days for drying on sand beds before use.

D.

1. \$US 150-200
2. (a) summer 33.88°C
(b) winter 24.44°C
3. (a) shadow
5. Slurry feeding must be loaded to desirable amount. Space between digester and gas holder must be optimum (1" as min.), if smaller than 1" it will cause clogging. The digested sludge remaining at the bottom of the digester must be drained out periodically to provide the optimum volume for slurry as food of the organisms to produce biogas.
6. 100 per cent
7. The fibre-glass cement is being used as the new approach to solve corrosion problem and cheaper material. Chinese dome design is being used to get more and more experience. The Chinese dome type may be useful for the biogas project in rural areas in Thailand

**180. Ministry of Agriculture and Co-operatives,
Department of Agriculture**

I

1. Bangkok, Bangkok 9, Thailand
Tel: 5790159, 5791994
2. Biogas research work in 1975
3. Mr. Paderm Titatan
4. Mrs. Revadee Deemark
5. (a) 4 (b) 11
6. Rice experimental stations at Supanburi, Rajburi, Sanpatong (Chiengmai), Kongan
7. National Research Council. National Energy Administration. Health Department. Agricultural Extension Department.
8. Organic fertilizer production and utilization for farmers' self-sufficient and better crop yield

9. Research on appropriate technology: biogas application from crop waste and as manure
10. Information. Research and development. Consultancy. Advisory
12. Bi-monthly publication by the Department of Agriculture. Annual reports.
13. Studies on manurial value of digested slurry from biogas plants and from plant on sandy loam soil. Examination of the nitrogen balance of dung during anaerobic digestion. Utilization of biogas as alternative source of energy. (completed)
 Study on low-cost biogas digester. Biogas production from various plant wastes. Biogas production in dome digester. Biogas production by using slurry as seeding with plant wastes. (ongoing)
 Utilization of organic waste other than animal waste in biogas plant. Utilization of digested slurry with local rock phosphate to increase crop yield. (planned)

II

A.

1. (a) fixed (b) movable
2. 6 m³ (fixed); 4, 5, 7 m³ (movable)
3. (a) brick masonry (fixed) concrete (movable)
 (b) brick masonry (fixed); galvanized iron sheet, ferrocement (movable)
 (c) and (d) precast concrete pipe (fixed and movable)

B.

1. Semi-continuous
2. Cow dung, buffalo dung, pig and water-hyacinth
3. No pretreatment, completely mixed with water
4. 10 kg fresh dung/m³
6. 1:1 by volume

C.

1. (a) 0.3 – 0.5 m³/m³ digester
 (b) cooking
2. (a) direct fertilizer on soil
 (b) 1:1 by weight
 (d) on trial
3. Ammonium fertilizer addition

D.

1. Movable 5 m³ digester: \$US 200 (excluding labour cost);
 Fixed type 6 m³ digester: \$US100 (excluding labour cost)
2. (a) summer 32°C (b) winter 28°C
3. (b) sun

Microbiology of methanization. Integrated system. Biogas pumping station.
Popularization of rural biogasification. (planned)

182. Thailand Institute of Scientific and Technological Research

I

1. 196 Paholyothin Road, Bangkhen, Bangkok 9, Thailand
Tel: 5791121-30 Cable: RESCORP BANGKOK
2. 1964
3. Dr. Samith Kampempool
5. (a) 5 (b) 2
7. Department of Health
8. Research and development
10. Information. Research and development. Advisory. Consultancy
12. Pre-feasibility study of the biogas application in rural areas of Thailand. Production of biogas from wastes using anaerobic packed digester. Anaerobic filter for biogas production
13. Production of biogas from animal wastes using anaerobic packed digester. Pre-feasibility study of the biogas technology application in rural areas of Thailand. (completed)
Production of biogas using horizontal plug-flow digester. (ongoing)

II

A.

1. (b) movable
2. 0.2 m³
3. (a) 200 l oil drum
(b) galvanized sheet
(c) and (d) steel pipe

B.

1. Semi-continuous
2. Pig waste
3. Screened and diluted
4. 1.34 kg (semi-continuous digester)
6. 14 litres

C.

1. (a) 0.1 m³
(b) lighting

D.

1. \$US 35
2. (a) summer 34°C
(b) winter 25°C
3. (a) shadow
5. There were, a few times, blockage problems due to the solid accumulation at the bottom part of the digester. The problems were overcome by opening the drainage pipe at the digester bottom.
7. Feed materials should be free from sand and soil

183. Indian Institute of Science, Centre for the Application of Science and Technology to Rural Areas (ASTRA)

I

1. Bangalore 560 012, India
Tel: 3441 Ext. 447
Cable: 043 326
2. 1974
3. Professor A.K.N. Reddy
4. Mr. P. Rajabapaiah
5. (a) 10 (b) 4
6. Bangalore, India and Ungra village (extension centre), Karnataka, India
8. Research
9. Development of appropriate biogas systems for Indian villages. Low-cost modified Indian and Chinese type of plants. Community and family size plants. Usage of all possible materials for biogas production. Proper utilization of biogas process development (optimum gas production)
10. Research and development. Advisory. Consultancy. Information. Education. Training
11. In the formulation stage
12. *
13. Studies on biogas technology: performance of the conventional Indian biogas plant; optimization of plant dimensions; thermal analysis of biogas plants and innovation of a novel solar-heated biogas plant. (completed)
Further studies on biogas technology: improvement of the solar-heated biogas plant, gas production from alternative materials for dung such as water hyacinth, recycling of water in biogas plants etc. Community biogas systems for villages (production and distribution of biogas, viz. fertilizer and water, including hot water, electricity generation and small-scale industries using biogas as energy source). Design and construction of ultra low-cost rural-oriented biogas plants (modified Indian and Chinese biogas plants). (ongoing)

II

A.

1. (a) fixed (b) movable
2. 3.5 to 100 m³
3. (a) bricks, cement, sand etc.
(b) mild steel, ferrocement etc.
(c) and (d) bricks, cement, sand, A.C. pipes etc.

B.

1. (a) continuous (b) batch
2. Cattle dung
3. Mixing of water and dung, pretreatment for feed such as water hyacinth
4. Depends upon the size
6. 1:1 (by weight) for cattle dung

C.

1. (a) depends upon the size
(b) mainly for laboratory use; in the extension centre, for cooking, lighting, engines etc.

D.

1. Floating type: \$US 300
Fixed type: \$US 125 (family size)
2. (a) summer 30°C
(b) winter 20°C
3. (b) shadow
4. Solar heating
5. Floating type: corrosion is minimized by proper painting.
Fixed type: leakage is overcome by proper scaling.
6. 100 per cent

**184. Shri A.M.M. Murugappa Chettiar Research Centre
Photosynthesis and Energy Division**

I

1. Tharamani, Madras 600 042, India
Tel: 41 19 37 Cable: WELDABLE
Telex: MCRC CARE TUBEIND 041 301
2. 1977
3. Dr. C.V. Seshadri

4. Dr. B.V. Umesh, Dr. C.V. Seshadri
5. (a) 5 (b) 8/5
6. Tharamani, Madras
7. With other institutions involved in the development of biogas plants
8. Research and development, fabrication and field level demonstration of biogas plants
9. Solar, wind and biomass for village level self-reliance
10. Research and development. Consultancy. Training
11. 2-week programme under consideration
12. A monograph on MCRC design of biogas plant is under preparation
13. Field testing of the present design. (ongoing)
Incorporation of water-hyacinth utilization in the present design.
(planned)

II

A.

1. (a) fixed
2. 6 m³
3. (a) bricks, cement, sand and blue-mental jelly
(b) wooden geodesic frame, low density polyethylene sheet 1000 gauge
(c) and (d) ceramic pipe

B.

1. (a) continuous
2. Cattle dung
4. 100 kg
6. 1:1 when the dung is fresh or 2:1 to 3:1 depending on the age of the dung

C.

1. (a) 4 m³
(b) laboratory purposes and cooking for staff
2. (b) 50 kg/day
(g) 50 kg/day (for algal ponds)

D.

1. \$US 250
2. (a) summer 30-38°C
(b) winter 20-28°C
3. (b) sun
5. (i) The LDPE sheet is vulnerable for damages especially from playful child-

ren in villages. This requires protective cover over the balloon and can be of thatched or bamboo structure.

(ii) Removal of scum is required once in 8 or 10 months. However the simplicity with which the gas holder can be removed does not make it a problem. The whole process of cleaning and replacing the dome hardly takes 2 hours and again by evening the plant is ready for supplying the gas.

(iii) Punctures caused accidentally can be easily located with soap water and patched up with any self-adhesive tapes available in the market.

6. 62.5 per cent

7. (i) It is desirable to remove any fibrous material prior to charging the digester.

(ii) Proper protection of the LDPE sheet would save plenty of trouble in locating the punctures and can give trouble-free service for a long time

185. Development and Consulting Services

I

1. Butwal, Nepal Cable: DSC BUTWAL
2. 1971
3. Mr. Martin Arnhorn, Director
4. Mrs. M. Wong, Mr. D. Fulford, Mr. A. Bulmer, Mr. J. Finlay
5. (a) 2 (b) 500
6. Butwal
7. Butwal Technical Institute; United Mission to Nepal
9. Biogas. Small turbines. Solar water heaters. Grain processing. Village electrification
10. Information. Research and development. Advisory. Consultancy. Education. Training
11. As requested
12. *
13. Design and construction of floating gas holder drum type gas plant, cu ft per day of 100, 200, 350 and 500; drumless gas plants of 10, 15, 20 and 50 cu m; gas production equipment; hard gobar mixer; 1300 in water pressure gauge. (completed)
Tunnel plant. Maximizing gas production in village gas plants. Gas taps for high pressure gas. Attaching small generator to biogas/diesel engined water pump for lighting 15 lamps in village. (ongoing)
Gas lamp. Large gas store. Pressure regulator. (planned)

SUBJECT INDEX – BY PROJECTS
(numbers refer to the serial number of the entries)

Acetic acid,	65
Acetone acid,	100, 120
Activated-sludge plant, control and performance,	35
Agricultural waste, management,	92
utilization,	8, 16
Algae production,	7,
Anaerobic digesters,	103, 182
improvement, in,	49
two-phase,	101
Anaerobic digestion,	57, 175
Anaerobic fermentation,	8
Anaerobic filter,	72
treatment of strong organic waste,	72
Animal waste management,	28, 162
utilization,	8
Application of biogas, domestic use, cooking,	115, 116, 119, 120, 121, 122, 123, 129, 132, 134, 135, 139, 141, 143, 144, 145, 147, 148, 149, 150, 152, 154, 156, 157, 161, 163, 165, 167, 169, 170, 171, 173, 175, 178, 179, 180.
electricity generation,	115, 116, 119, 121, 132, 137.
fuel,	114, 124, 127, 130, 131, 137, 147, 149, 162, 164, 171.
laboratory,	111, 112, 146, 157.
lighting,	116, 119, 120, 121, 122, 123, 124, 128, 134, 138, 139, 142, 143, 145, 150, 157, 161, 163, 182.
motive power,	13, 21, 95, 139, 141, 142, 153.
power generation,	115, 116, 121, 132, 137.
pumping,	142, 151, 168.
sewerage,	129

Agriculture,	16
Artificial biogas production,	26, 65
Automation of mesophilic digester,	14
Bacteria,	
in biogas production,	93, 103, 117, 139.
Bioconversion,	33, 37, 41, 86
Biogas,	38, 43, 59, 89, 90
combustion,	24
digesters,	35, 73
drying techniques of crops,	104, 132
engines,	42, 105, 179, 181
energy,	8, 23, 24, 42, 60, 61, 64, 83, 180.
fermentation,	11, 14, 39, 49, 50, 65, 84, 101, 117
fermentation techniques,	29, 73, 114, 118
filter,	35, 155
implementation and administration,	91
Biogas plant,	19, 30, 36, 53, 54
construction of,	18, 32, 51, 52, 69, 73, 76, 86, 88
construction materials for,	10
construction techniques,	10, 11, 14, 69, 123
Biogas plant design,	18, 76, 86, 119
large size,	73
family size,	23, 123, 145, 167
farm size,	83
medium size,	59, 73
rural area,	32, 46, 52, 81, 87, 97, 124
Biogas plant operation,	32, 51, 86
Biogas plant optimization,	23, 111
Biogas power production,	76
Biogas power station,	29, 45, 47
waste heat utilization, from,	65
Biogas production,	1, 16, 44, 46, 57, 64
agricultural wastes,	58
animal wastes,	28, 97, 112, 162, 179, 182
cow dung,	61, 169
chemistry and microbiology of,	57
fibrous plant waste,	25

food waste,	1
increasing rate of,	100, 103, 114, 124
increasing volume of,	20, 65, 100, 103
organic matter,	79, 179, 180
pig manure,	103, 169, 170
plant waste,	86, 177
slurry and combination plants,	17, 180
vegetable matter,	81
winter in,	57, 79, 94, 127
Biogas research and planning,	91, 175
Biogas seeding,	109
Biogas system development,	32, 53
Biogas system selection,	
for rural use,	74
Biogas pumping station,	44, 181
Biogas technology,	8, 24, 29, 33, 40, 53, 54, 66, 74, 77, 104
Biogas turbine,	33
Biogas usage,	8, 46, 97
Biogas utilization,	
systems approach,	74
Biogas water heaters,	75
Biogas yield	
increasing of,	21, 112
reduction in seasonal variations,	21, 112
Biological active compounds,	15
Blue-green algae,	38, 57
Burners, biogas,	2, 20, 112, 133, 169
Carbondioxide,	
absorber,	7
fertilization,	25
removal,	8
Chinese design biogas plants,	60
with R.C.C. roof,	61, 135
C:N. ratio,	113
Community plant design,	63, 138, 139, 141, 167
Collective gas supply,	
for farm households,	73

Compost,	38
liquid,	64
Composting,	
accelerated,	102
cattle waste,	57
dairy farm waste,	57
Corrosion in biogas plant,	63
Coryform bacteria,	48
Cost reduction,	112
in small biogas plants,	17
Cow dung,	
assessment and availability,	57
gas plant,	8
Diesel engine,	
conversion to biogas,	21, 62, 76, 95, 105, 141, 153, 155.
Development of biogas,	
commercial appliances,	63
digester,	2, 81
plants,	32, 97, 106
projects,	12
technology,	39
Digester,	
construction,	73, 107
design,	73
design with integral fermentation,	26
Digester body, construction materials for,	
brick,	111, 113, 114, 115, 116, 117, 118, 119, 120, 121, 132, 133, 134, 138, 139, 141, 142, 143, 144, 146, 147, 148, 150, 151, 152, 154, 156, 158, 160, 163, 164, 167, 173, 176, 178, 180.
cement,	111, 112, 114, 117, 119, 121, 132, 134, 138, 142, 147, 150, 151, 152, 154, 156, 157, 164, 167, 169, 176, 178.
clay, baked,	155
concrete,	113, 115, 116, 129, 130, 141, 161, 168, 171, 175, 179, 180.
ferrocement,	160, 174

fibre-glass reinforced plastic,	162, 177
lime clay,	115, 132
polymer rubber,	133
R.C.C.,	119, 122, 128, 135, 137, 149, 172
sand,	111, 112, 152, 167, 169
steel,	128, 164, 165
stone,	127, 148
Digester feed,	
batch type,	111, 113, 114, 116, 118, 120, 122, 128, 129, 130, 132, 137, 143, 151, 152, 153, 163, 165, 168, 177, 178, 179.
continuous type,	111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 122, 124, 129, 133, 134, 135, 138, 139, 141, 142, 144, 145, 146, 147, 149, 151, 154, 156, 157, 158, 160, 161, 162, 164, 167, 168, 169, 170, 171, 172, 173, 174, 176, 178, 179
Digester size,	
medium,	14, 116
small,	14, 116
Digester slurry,	
manurial value,	17
Dome-shape biogas plant,	39
Economics of biogas,	32, 83, 104
Effectiveness of biogas products,	45, 126
Effluent use,	
algae production,	7
animal feed,	7, 133, 168, 169, 176
aquaculture,	16, 111, 115, 116, 126, 142, 157, 169, 170, 176
composting,	111, 116, 126, 134, 141, 142, 144, 148, 151, 152, 153, 156, 157
direct fertilizer,	111, 116, 126, 130, 133, 135, 142, 143, 154, 156, 161, 162, 163, 165, 167, 169, 170, 176, 179

fertilizer,	11, 16, 17, 114, 126, 152, 166
fish culture,	7, 11, 172
recycling to digester,	111, 113, 126, 142, 156, 165, 176
waste,	111, 133, 170
Effluent value,	11, 17, 29
Effluents,	17
Electric generating set,	73
Energy farming,	82
Environmental effects, biogas engines,	62
Evaluation of materials, biogas production,	31, 171
Farm size biogas plant,	23
Farm waste for fuel and manure,	25
Feed materials,	29, 100, 127
agricultural waste,	164
animal waste,	113, 117, 124, 129, 171, 179
cattle dung,	122, 134, 138, 145, 146, 147, 148, 150, 158, 160, 169, 173.
cow dung,	111, 112, 114, 116, 120, 122, 135, 139, 141, 142, 143, 144, 151, 152, 153, 156, 157, 165, 178, 180
human waste,	114, 116, 117, 122, 124, 127, 129, 145
horse dung,	119
manure,	118, 130
method of introducing,	100
municipal waste,	160
night soil,	121, 130, 147, 156, 174
pig waste,	114, 116, 119, 120, 121, 122, 127, 133, 161, 162, 168, 170, 172, 175, 178, 180, 182.
poultry waste,	156, 163
ratio of,	106
vegetable matter,	81, 124
water hyacinth,	81, 100, 141, 142, 157, 174, 180
weeds,	113, 122, 177
wheat straw,	127, 154

Fermentation,	
bacteria,	106
materials and fertilizers relations,	103
material mixing ratio,	106
microbiology,	41
processes,	6
single and multi-stage,	100, 120
technology,	18
test rules,	103
Fertilizer,	
application technique,	102
composition,	29
effectiveness,	11, 29, 102
utilization,	102
Fertilizer production,	
pineapple and cannery waste,	42
urban garbage,	102
Ferrocement,	36, 166
digester,	60
gas holder and components,	56
gas holder with water jacket,	60
Fish culture,	11, 55, 172
Formaldehyde addition,	
effect on rate of biogas production,	100, 120
Fuel,	
from agricultural wastes,	25
from animal waste and grass,	83
Garbage gas plant,	25, 61, 135
Gas holder,	
fixed,	111, 112, 113, 114, 115, 116, 117, 118, 119, 121, 124, 127, 128, 129, 130, 133, 134, 138, 146, 148, 161, 164, 165, 173, 174, 177, 178, 180
movable type,	111, 112, 113, 115, 116, 118, 121, 129, 130, 133, 135, 137, 141, 142, 143, 144, 145, 146, 148, 150, 151, 152, 153, 154, 155, 156, 157, 158, 160, 162, 163, 167, 168, 169, 171, 172, 175, 176, 178, 179, 180, 182.

Gas holder, construction materials for,	
brick,	113, 115, 116, 117, 118, 119, 120, 132, 134, 138, 144, 146, 151, 165, 173.
butyl rubber bag,	164,
cement,	115, 117, 132, 134, 138, 151, 165
clay, baked,	155
concrete,	113, 116, 119, 130, 168
ferrocement,	129, 158, 160, 174, 180
fibre-glass,	147, 177
galvanized iron,	145, 147, 150, 169, 172, 179, 180, 182
lime clay,	132
mild steel sheet,	111, 112, 135, 139, 141, 142, 144, 146, 149, 150, 152, 153, 154, 156, 162, 163, 167, 169, 171, 178, 179.
polymer rubber,	132
P.V.C.,	121, 145, 147
R.C.C.,	112, 122, 128
steel plate,	113, 129, 133, 137, 143, 147, 148, 157, 161.
stone,	127
Gas generation and distribution system,	18
Gobar gas,	
as an engine fuel,	24
development in technology,	63
disposal of slurry,	64
Gobar gas diesel oil dual fuel engine,	62, 142
combustion characteristics,	24
performance,	24, 43
test,	24
Gobar plants,	23, 25, 39, 61, 63, 64
corrosion in,	63
High rate digestion,	35
Hydraulic pressure type biogas plant,	10
Hydrogen sulfide, removal of,	35

Inlet pipe, material of,	
brick,	111, 116, 117, 118, 119, 121, 128, 134, 138, 148, 150, 152, 158, 160, 165, 170
cast iron,	137, 139, 149
cement, asbestos,	111, 115, 117, 119, 121, 128, 132, 135, 138, 141, 142, 143, 145, 146, 147, 150, 151, 152, 156, 165, 167, 169, 175, 176, 178.
ceramic pipe,	172
clay-pipe,	155, 173
concrete,	113, 115, 116, 130, 134, 161, 167, 171, 180.
fibre-glass,	162
M.S.,	111, 154
P.V.C.,	133, 163, 168, 174, 177
R.C.C.,	112, 122, 144
sand,	111
steel,	113, 157, 182
stone,	153
Integrated biogas system,	2, 81, 171, 181
Integrated farming system,	17, 112, 169
Integrated solar and bioconversion projects,	37, 144
Integration of biogas with agricultural system,	92
Intensive mixed farming,	64
Internal combustion engines,	13, 31, 43, 153
prospects and problems,	62
Jar, cement water,	12
Jar digester,	12
Kinetic methane fermentations,	108
KVIC design,	60, 141, 142, 150
with movable floating drum,	60
Lactic acid bacteria,	
growth and resistance,	41
Lactic fermentation,	57
Lamp, biogas,	20, 112, 142, 145

Laser induced mixing of bacteria,	100, 120
Leakage of gas,	116, 133, 173, 177
Liquid composting,	64, 151
Low-cost biogas digester,	17, 180, 181
Low temperature biogas plant,	100
 Manure,	
collection,	87
production from fibrous plants,	25
Mass and energy flow in biogas systems,	81
Marine algae,	71
Mechanical unloading of digester residue,	26
Medium temperature biogas plant,	10, 94, 119
Mesophillic digester,	14, 113, 132
Methane,	
bacteria,	100, 108, 139
fermentation,	68, 99
Microbial fermentation,	65
Mild-dew formation,	65, 128
Mild steel square gas holder,	60
Mixed farming, use of liquid compost in,	64
Multi-state mesophillic fermentation digester, automation of,	14
Mushroom cultivation using biogas effluent,	1, 11, 122, 124
 Night soil biogas plant,	89
Nitrogen fixation,	25, 68
 Optimization of digester materials,	109
Organic fertilizer,	17, 126
Organic wastes	
decomposition of,	6, 25
utilization of,	16, 17, 180
Outlet pipe, materials, for,	
brick,	111, 113, 116, 117, 118, 119, 121, 128, 134, 138, 139, 148, 150, 152, 158, 160, 165, 167.

cast-iron,	137, 149
cement, asbestos,	111, 117, 119, 121, 128, 132, 134, 135, 138, 141, 142, 143, 145, 146, 147, 150, 151, 152, 156, 165, 167, 169, 175, 176, 178.
ceramic,	172
clay pipe,	173
concrete,	113, 115, 116, 130, 161, 171, 180
gravel,	111
fibre-glass reinforced plastic,	162
plastic,	155
P.V.C.,	133, 162, 163, 168, 174
R.C.C.,	112, 122, 144
rubber,	155
sand,	111, 152, 167
steel,	157, 182
stone,	153
vinyl pipe,	162
Petrol engine, conversion to biogas,	76, 153
p ^H control,	111
Piggery waste water treatment,	7, 162
Planning in biogas plant,	107
Plant position, shadow,	111, 113, 114, 124, 129, 132, 141, 145, 152, 153, 158, 162, 176, 177, 182
sun,	111, 113, 117, 118, 119, 120, 127, 129, 132, 135, 138, 139, 142, 143, 145, 146, 147, 151, 152, 154, 155, 156, 163, 165, 167, 168, 169, 170, 171, 173, 174, 175
Plastics for gobar gas plants,	63
Pollution control, through biogas and compost,	64
Polyethylene gas holder,	60
Polymer rubber biogas digester,	81
Portable biogas plant,	33, 155

Pressure losses in conveyance of biogas,	31
Pretreatment of feed materials,	106
Raw materials for biogas production,	65
Recycling,	
agricultural waste,	7, 44
animal waste,	64
night soil,	66
Research and development in biogas,	21, 80, 91
Sludge,	
digester,	168
Slurry,	
making from agricultural waste,	20, 112
utilization in biogas production,	57
Small-scale biogas plant,	22
management,	106
standardization,	94
Sodium cellulose enzymes,	
effect on biogas fermentation,	65
Solar energy utilization in biogas production,	76, 94
Solar heated biogas digester,	9
Taxonomy,	
of bacteria,	48, 93
of bacillus,	48
of microbes in biogas digester,	48
Temperature effect on biogas production,	57
Toxic gas formation,	102
Urban waste disposal for biogas fermentaiton,	65
Utilization of biogas digesters,	12
Variable pressure biogas plant,	
design and construction of,	76
Vertical biogas pump,	76
Village level biogas plant,	53

Waste,	
management,	92
recycling,	6, 51, 59, 64, 66
Waste heat utilization,	65
Water hyacinth,	24, 100, 112, 121, 157, 174,
	180.

BIBLIOGRAPHY*

	<i>Page</i>
A. Theory and practice of anaerobic digestion	247
B. Biogas plant construction	256
C. Biogas plant operation	261
D. Biogas utilization	263
E. Utilization of effluent and sludge recycling	266
F. Social, environmental and economic aspects	268

* This bibliography is not intended to be comprehensive. Along with the entries under experts and institutions, it is aimed at indicating current trends in research and development of biogas in regional member countries of ESCAP.

A. Theory and Practice of Anaerobic Digestion

(General background and theory of anaerobic digestion, factors affecting biogas production, type of materials used as feed, with the basic information on type of processes)

Acharya, C.N. Decomposition of plant substances of varying composition. *Biochemical Journal* 29:1459-1467, 1935.

_____ Decomposition of rice straw under anaerobic, aerobic and practically aerobic conditions. *Biochemical Journal* 29(5):1116-1120, 1935.

_____ Preparation of fuel gas and manure by anaerobic fermentation of organic materials. Indian Council of Agricultural Research Series No. 15, New Delhi, 1958.

_____ Some factors influencing the anaerobic decomposition of rice straw. *Biochemical Journal* 29(4):953-960, 1935.

_____ Studies on the anaerobic decomposition of plant materials. *Biochemical Journal* 29(3):528-541, 1935.

_____ Your home needs a gas plant. *Indian Farming (New Delhi)* 6(2):27-30, 1956.

Acharya, C.N. and P.L. Juneja. Studies on the production of combustible gas and manure from cattle dung. *Proceedings, 41st Indian Science Congress* 3:246, 1954.

Alicbusan, R.V. Microbiology of fermenting organic wastes in biogas production. Paper presented during Second International Workshop on Biogas Technology and Utilization, Manila, 13-18 October 1975.

Amaratunga, M. Integrated biogas systems. RCEHMT and UNESCO Workshop on Energy from Biomass and Wastes, Peradeniya, November 1979.

_____ On a scientific approach to the popularization of biogas technology. Expert Group Meeting on Biogas, Bangkok, June 1978

_____ A rational approach to biogas technology based on the concept of an integrated farming system. *Journal of Agricultural Engineering Society of Sri Lanka* 1(1):6-15, July 1977.

Anand, K.M. and S.K. Sampath. Effective utilization of cow dung in organized form: a case study. Seminar on Utilization of Farm Wastes for Rural Industrial Growth, NDRI, Bangalore, December 1975.

Badger, D.N., M.J. Bogue and D.J. Stewart. Biogas production from crops and organic wastes: result of batch digestion. *New Zealand Journal of Science* 22: 11-20, 1979.

- Banerjee, M.K. and L. Jayprakash. Community factor in community biogas plant. *Urja (New Delhi)* 6(1,2):53-55, 28 July 1979.
- Bansal, M.L. and others. Biogas production during anaerobic digestion of livestock excreta. *Indian Journal of Dairy Science (Bangalore)* 30(4):338-340, 1977.
- Bhattacharyya, B.C. Improvements in or relating to gobar gas or biogas plant. Indian Patent No. 142363.
- Biogas plants: performance and prospects in India. *Science Technology Bulletin (New Delhi)* 1(4):25-26, 32, 1975
- Biswas, T.D. Cow dung gas plant for energy and manure. *Fertilizer News* 19(9):3-7, 33, 1974.
- _____ Utilization of animal excreta and other agricultural wastes for manure and fuel. Proceedings, 64th Indian Science Congress 3, 1977. 116 p.
- Biswas, T.D. and O.P. Chawla. Biogas as an alternative source of energy. Paper presented at the Workshop on Biogas Technology and Utilization, 1975. pp. 16-22.
- Biswas, T.D., A.R.S. Kartha and R. Pundarikakshudu. Removal of carbon dioxide from biogas. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 37-38.
- Can biogas provide energy for India's rural poor. *Nature (London)* 281(5726), September 1979.
- Chawla, O.P., R.D. Laura and M.A. Idnani. Note on stimulation of anaerobic fermentation of dung in the cow dung gas plants. *Indian Journal of Agricultural Science (New Delhi)* 39(11):1040-1043, 1969.
- Chhonkar, P.K. Microbiological aspects of biogas production. National Symposium on Biogas Technology and Usage, New Delhi, November 1977
- Das, B., P.K. Chhonkar and A. Bose. Effect of fermentation temperature and additives on efficiency of biogas production. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 21-23
- Datta, S.N. and V. Iswaran. Effect of decomposition of easily nitrifiable leafy matter on the nitrification of cow dung gas plant slurry. *Science and Culture (Calcutta)* 30:407-409, 1974.
- Desai, B.P. Combustible gas from cattle dung. *Agricultural College Magazine (Poona)* 42:74-82, 1951.
- Desai, S.V. Combustible gas from cow dung. *Indian Farming (New Delhi)* 6(2): 140-143, 1945.
- Desai, S.V. and S.C. Biswas. Manure and gas production by anaerobic fermentation or organic wastes. *Indian Farming (New Delhi)* 6(2): 67-71, 1945.

- Eusof, M. Prospect of biogas industry in Bangladesh. BCSIR Fuel Division Laboratories, Dacca, 1975.
- FAO. China: Azolla propagation and small-scale biogas technology. FAO Soils Bulletin (Rome) 41, 1978.
- _____ China: recycling of organic wastes in agriculture. FAO Soils Bulletin (Rome) 40, 1977.
- _____ Organic recycling in Asia and the Pacific. FAO Soils Bulletin (Rome) (in print).
- FAO, UNDP and Biogas Promotion Office, Sichuan Province. Home-made biogas. FAO, Rome (speaker's notes for the single-frame colour filmstrip)
- Finlay, J.H. Night soil (sewerage) gas plant. United Mission Development and Consulting Services, Butwal, Nepal. 1980.
- Fulford, David. Biogas in Nepal: the state of the art. United Mission Development and Consulting Services, Butwal, Nepal. 1978.
- Fulford, David and Nick Peters. Survey of present gobar gas work in India. United Mission Development and Consulting Services, Butwal, Nepal. 1978.
- Ganesh, S. Biogas technology: the next phase. Urja (New Delhi) 1(4): 19-23, April 1977.
- Ghosh, S. and D.L. Klass. Feasibility analysis of the biological gasification of solid wastes. Chicago, Institute of Gas Technology, December 1972.
- Ghosh, T.K. Utilization of wastes. Science and Culture (Calcutta) 25(3):175-179, 1958.
- Goel, B.B.P.S. and others. Availability and disposal of dung in India. Indian Journal of Animal Sciences (New Delhi) 43(8):671-676, 1973.
- Golueke, C.G. Biological reclamation of solid wastes. Rodale Press, Emmaus, PA, USA, 1977.
- Gopalakrishnan, K.V. and B.S. Murthy. The potentiality of water hyacinth for decentralized power generation in developing countries. Paper presented at the Workshop on Energy from Biomass and Waste, organized by UNESCO at University of Sri Lanka, Peradeniya, Sri Lanka, November 1979. Also published in Journal of Energy, Heat and Mass Transfer 1(4):349-357, 1979.
- Goswami, K.P. Batch fermentation studies of paddy straw for biogas production. National Symposium on Recycling of Residues of Agriculture and Industry, Punjab Agricultural University, Ludhiana, 28-29 March 1980. Department of Microbiology, PAU, 1980.
- _____ A continuous fermentation karchara-gas plant for producing biogas and manure from straw-like wastes. India/FAO/Norway Seminar on the Development

of Complementary Use of Mineral Fertilizer and Organic Materials in India, Vigyan Bhavan, New Delhi, 14-19 September 1978.

- _____ Farm wastes can yield fuel gas and manure. *Indian Farming* (New Delhi) April 1967.
- _____ Fuel gas from agricultural and industrial wastes. *F.R.I. News* 15(3), 1965.
- Grewal, N.S. and B. Sagar. Possibilities of biogas as an energy supplement during peak hours. 1975.
- Harinathan, K. and others. Gobar gas plants. Fifth Conference of Orissa Association for the Advancement of Science, Bhubaneshwar, December 1975.
- Idnani, M.A. Some improvements in the biogas plant. *Indian Farming* (New Delhi) 12(11):24-25, 1963.
- _____ Why the biogas plant has not caught on with farmers. *Indian Farming* (New Delhi) 14(3), 1964.
- Idnani, M.A. and N.P. Dutta. Gobar gas plants. *Khadi Gramodyog*, 1963. pp. 256-264.
- India. Ministry of Agriculture and Irrigation, Directorate of Extension, Farm Information Unit, New Delhi. Install a cow dung gas plant. New Delhi, 1976.
- Islam, M.N. Development of biogas system in Burma. WHO Consultancy Report, SEA/EH/193, February 1978.
- _____ Production of biogas from different type of wastes. Paper presented at the Seminar on Food and Energy from Unconventional Sources with Application to Nuclear Technology, Bangladesh Atomic Energy Commission, Dacca, 29-30 July 1976.
- _____ A report on biogas programme of China. Review Paper, Chemical Engineering Department, Bangladesh University of Engineering and Technology, Dacca, October 1979
- _____ Study of the problems and prospect of biogas technology as a mechanism for rural development study in pilot area of Bangladesh. Progress Report. IDRC, Ottawa, Canada. Research Project No. 3p-77-0076-20, November 1978.
- _____ Systematic development of a biogas plant. Expert Group Meeting on Biogas Development, ESCAP, Bangkok, June 1978
- Iwai, S., A. Honda and Chung Chin-Yuan. Experimental studies on high rate digestion of night soil. *Advances in Water Pollution Control*, 2. pp. 267-304. Eckenfelder, ed. (1964). Proceedings of the International Conference held in London, 1962. Pergamon Press, London, UK.
- Jasper, A.W. and J.D. Patel. Methane digester: a source of bioenergy. All India Seminar on Technology for Rual Development, Allahabad Polytechnic, July 1977

- Jayachandran, S. and R. Kasturi Bai. Influence of different organic wastes on gobar gas production. 19th Annual Conference of Microbiologists in India, Baroda.
- Kasturi Bai, R. and others. Influence of different organic wastes on the intermediate products of fermentation, gobar gas production and manurial value. International Seminar on Management of Environment, Bombay, February 1980.
- Khandelwal, K.C. Community biogas plant. New Delhi, Department of Agriculture, Ministry of Agriculture and Irrigation, June 1979.
- _____ Directory of organizations involved in research and development of biogas. New Delhi, Agriculture and Co-operation, Ministry of Agriculture, 1979.
- _____ Influence of pH on gobar gas production. 15th Annual Conference of Association of Microbiologists of India, Bangalore, December 1974.
- _____ Janata model gobar gas plant. Published by the Directorate of Extension, Ministry of Agriculture and Irrigation, New Delhi, July 1979.
- _____ Ministry of Agriculture's biogas scheme in renewable energy research in India. Tata Energy Research Institute, Bombay, June 1980.
- _____ Some information about biogas technology and development in India. Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi, 1978. (mimeographed)
- Khadi and Village Industries Commission, Bombay. Scheme for the intensive popularization of gobar gas. Bombay, 1973.
- Laura, C. and M.A. Idnani. Note on the use of anaerobic fermentation of dung in the cow dung gas plant. Indian Journal of Agricultural Sciences 39(1):1040-1048, 1969.
- Liu, Ke-Xin and Li Nian-Guo. Fermentation technology for rural digesters in China. Paper presented at Bio-Energy '80 World Congress, Atlanta, Georgia, USA, 1979. pp. 21-24.
- Makhijani, Arjun. Energy policy for the rural third world. International Institute for Environment and Development, London, September 1976.
- Makhijani, Arjun and A. Poole. Energy and agriculture in the third world. Report to the energy policy project of the Ford Foundation. Ballinger Publishing Company, Cambridge, 1975. XV. 168 p.
- Maramba, F.D. Biogas in an integrated agro-industrial enterprise. Proceedings of International Workshop on Biogas, Bremen, Federal Republic of Germany, 16-20 May 1979.
- _____ Waste recycling and the biogas works at Maya Farms. Proceedings of 14th Pacific Science Congress, Khabarovsk, USSR, 1979.

- Martin, G.A. and D.J. Stewart. Energy: biogas utilization of methane produced by anaerobic digesters. *Farm Production and Practice*, Aglink 1/3000/6/80:FPP 425. Media Services, Ministry of Agriculture and Fisheries, Wellington, New Zealand.
- McGary, M.G. and J. Stainforth (eds). Compost, fertilizer and biogas production from human and farm wastes in the People's Republic of China. IDRC-TS8e. International Development Research Centre, Ottawa. (translation from Chinese)
- Mishra, U.P. Biochemical studies on the production of combustible gas and manure from bullock dung and other organic materials. Assoc. IARI thesis, 1954.
- Mohan Rao, G.J. Scientific aspects of cow dung digestion. *Khadi Gramodyog* 20(7): 340-347, 1974.
- Moulik, T.K. Biogas system in India: a socio-economic evaluation. Centre for Management in Agriculture, Ahmedabad, 1978.
- Mudri, S.S. Some observation in the anaerobic digestion of night soil. *Environmental Health (Nagpur)* 9(2):133-136, 1967.
- Mukherjee, J.K. Gobar gas plant: a study. New Delhi, Gandhi Peace Foundation, 1974.
- National Academy of Sciences. Making aquatic weeds useful. Washington, D.C., 1976
- National Environmental Engineering Research Institute, Nagpur. Digestion of night soil and cow dung. Technical Digest No. 8, 1970.
- Neelakantan, S. Assessment of the availability of cow dung for potential gobar gas production in India. *Agriculture Situation in India (New Delhi)* 30(9):633-637, 1975.
- _____ Microbiology and chemistry of biogas production. Bombay, Summer Institute on Waste Management by Recycling, June 1976.
- Neelakantan, S. and A. Manocha. Anaerobic digestion of plant residues into biogas. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 19-20.
- Neelakantan, S. and S.C. Sarma. Bioenergy in state of art report in microbiology. Published by NCST, Department of Science and Technology, New Delhi, 1980.
- Neelakantan, S., H.S. Sondhi and C.P. Mittal. Effect of temperature inoculum and agitation on biogas production from cattle dung. *Indian Journal of Dairy Science (Bangalore)* 29(3):226, 1976.
- Pakistan. Appropriate Technology Development Organization. Gobar gas: an alternate way of handling the village fuel problem. *Journal of Fertilizer and Fuel*.
- Paramasivam, R. Economic utilization and disposal of cattle dung in rural communities. Symposium on Community Water Supply and Waste Disposal, Nagpur, December 1966. Vol. 2. pp. 62-67.

- Parikh, J.K. and K.S. Parikh. Potential of biogas plants and how to realize it. United Nations Institute for Training and Research Seminar on Microbial Energy Conversion, Federal Republic of Germany, October 1976.
- Park, Y.D., J.H. Lin and N.J. Park. Studies on biogas generation from animal wastes. Institute of Agricultural Engineering and Utilization, Office of Rural Development, Suweon, Republic of Korea, October 1979.
- Park, Y.D., N.J. Park and J.H. Lin. A feasibility study of village scale biogas plant during winter season. Institute of Agricultural Engineering and Utilization, Office of Rural Development, Suweon, Republic of Korea, October 1979.
- Patankar, G.L. Recent developments in gobar gas technology. Khadi and Village Industries Commission, Bombay, July 1977.
- _____ Role of gobar gas plants in agro-industries. Khadi Gramodyog (Bombay) 20(7):351-352, 1974.
- Patel, J.J. Case study of cow dung gas plant at Rajendernagar. Khadi Gramodyog (Bombay) 10:818-820, 1964.
- _____ Gobar gas plant at Dattapur, Jeper Colony. Khadi Gramodyog (Bombay) 8:674-675, 1962.
- _____ Present position of gas plant research. Wardha, Jamanalal Bajaj Central Research Institute for Village Industries, 1959.
- Patel, S.N. Performance of biogas plants in Gujarat. Khadi Gramodyog (Bombay) 21:493-502, 1975.
- Paul, T.M. An appraisal of gobar gas plants in India. Seminar on Appropriate Technology, Poona, 25 February 1975.
- _____ Studies on biogas sources. Current Science (Bangalore) 45(10), 20 May 1976.
- Prasad, C.R. Changes in biochemical constituent of some organic waste materials under anaerobic methane fermentation. Indian Agricultural Research Institute, October 1969. Reprinted in Indian Journal of Agricultural Sciences (New Delhi) 40(10):921-924, 1970.
- _____ Studies on production of biogas and changes in the chemical constituents of organic materials during anaerobic fermentation. Ph.D. thesis, Indian Agricultural Research Institute, New Delhi, 1964.
- Prasad, C.R. and S.R.C. Satyanarayan. Studies in biogas technology, part III: thermal analysis of biogas plants. Proceedings, Indian Academy of Science, Vol. C2, Part 3, September 1979.
- Prasad, H. Gobar gas plant: an empirical study. Khadi Gramodyog, July 1967.

- Prasad, S. and S.V. Dikshit. Production and distribution of cow dung gas. Seminar on Energy Conservation, Pune, October 1975.
- Rajabapaiah, P. Biogas technology. Paper presented at the "Energy" short-term course, 15-30 November 1979. ASTRA, Indian Institute of Science, Bangalore, India.
- Rajabapaiah, p. and others. Studies in biogas technology, part I: performance of a conventional biogas plant. Proceedings, Indian Academy of Science, Vol. C2, Part 3, September 1979. pp. 357-363.
- Rajagopal, G. and B.W. Pathak. Effect of volatile acid accumulation in dung digestion. Environmental Health (Nagpur) 8(3):194-199, 1966.
- Ramamohanrao, J. Laboratory studies on thermophilic digestion of night soil. Thesis, M.E. (PH), Nagpur University, 1971.
- Rao, C.E.S. Treatment of distillery wastes for production of fuel gas. Seminar on Water and Industrial Waste Treatment, Bombay, March 1976.
- Reddy, A.K.N. Studies in biogas technology, part IV: a novel biogas plant including a solar water heater and solar still. Proceedings of Indian Academy of Science, C2, Part 3, September 1979.
- Research on biogas (methane) in developing countries: farm waste recycling, Philippines, India, Africa. Compost Science 19(2):24-27, March-April 1978.
- Sagar, B. and N.S. Grewal. Gobar gas: an alternative source of energy. Symposium on Rural Development, Chandigarh, September 1974.
- Sanra, R. Studies on the utilization of waste materials for production of biogas and manure. M.Sc. thesis, Postgraduate School, IARI, 1965.
- Sarma, S.C. Bioconversion of solar energy into fuel gas. 18th Annual Conference of the Association of Microbiologists of India, December 1977.
- Sathianathan, M.A. Research project on biogas. Wardha, Centre of Science for Villages, 1979. 11p.
- Sharma, U.P. Energy from wastes. Bombay, Summer Institute on Waste Management by Recycling, June 1976.
- Shukla, J.P. Biogas plant. Kanpur, National Sugar Institute, 1965.
- Singh, P.N. Biogas solution to the rural energy problems. Urja (New Delhi) 4(9): 218-220, December 1979.
- Singh, R.B. Some experiments with biogas. Ajitmal, Gobar Gas Research Station, 1971.
- Solly, R.K. Biogas production from water hyacinth. Institute of National Resources, University of the South Pacific, Suva, Fiji.

- _____ A study of methane digester in the South Pacific region. *Appropriate Technology* 3:23-25, 1977.
- Stewart, D.J. Energy: biogas. Paper presented at the New Zealand Irrigation Association Conference, Oamaru, New Zealand, 17 April 1980.
- _____ Energy: biogas. Production from crops at the Invermay Energy Farm. *Farm Production and Practice*, Aglink:FPP 375. Media Services, Ministry of Agriculture and Fisheries, New Zealand, 1980.
- _____ Energy crops to methane. Paper presented at the first International Symposium on Anaerobic Digestion, University College, Cardiff, Wales, 17-22 September 1979.
- _____ Methane production from crops and organic wastes. *Proceedings of the First Biotechnology Conference on Biomass and Energy*, Massey University, Palmerston North, New Zealand, May 1978.
- Srinivasan, H.R. History of development of gobar gas plant. *Khadi Gramodyog (Bombay)* 20(3):176-181, 1973.
- Srinivasan, S.N. and R.H. Richharia. Utility of cow dung gas plants. *Bihar Academy of agricultural Science. Proceedings* 6/7, 1957/58.
- Subrahmanyam, P.V.R. and others. Anaerobic digestion: a unit operation for waste treatment and biogas production. 18th Annual Conference of the Association of Microbiologists of India, 1977.
- Subramanian, D.K., P. Rajabapaiah and Amulya Kumar N. Reddy. Studies in biogas technology, part II: optimization of plant dimensions. *Proceedings, Indian Academy of Science, Vol. C2, Part 3, September 1979.*
- Subramanian, S.K. Biogas systems in Asia: a survey. *Biogas Technology in the Third World: A Multidisciplinary Review*. IDRC-103e, 1978.
- Taiganides, E.P. *Animal wastes*. Applied Science Publishers Ltd., London, 1977.
- Tejnarayan, S.D. and R. Moorthy. Case study of cow dung gas plant. *Khadi Gramodyog (Bombay)* 10:815-817, 1954.
- Trivedi, R.C. Anaerobic digestion of night soil. Thesis, Ph.D., Nagpur University, 1976.
- United Nations. Guidebook on biogas development. *Energy Resources Development Series No. 21*. United Nations publication, Sales No. E.80.II.F.10, ST/ESCAP/96, 1980.
- Venkataraman, G.S. and B.O. Kaushik. Stimulation of gas production from cow dung by algal supplementation. *Current Science (Bangalore)* 44(22):807-808, 1975.
- Vimuktananda (Swamy). Fuel gas from cow dung. *Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants*, New Delhi, 1961. pp. 402-403.

B. Biogas Plant Construction

(Design criteria and alternative method of construction of biogas plants)

- Acharya, C.N. Cow dung gas plants. *Indian Farming* 3(9):16-18, 28, 1953.
- _____ Prospect of compost manure from town-wastes. New Delhi, Indian Council of Agricultural Research, 1954.
- _____ With this change the cow dung gas plant works better. *Indian Farming* (New Delhi) 6(9):10-13, December 1956.
- _____ Your home needs a gas plant. *Indian Farming* (New Delhi) 6(2):27-30, 1956.
- Agrawal, P.K., K.A. Prabhu and Vishwanathan. Microbial fermentation of agricultural wastes into biogas and biomanure by a semi-wet process. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 29-30.
- Alone, B.Z. Anaerobic digestion of city refuse and dung. *Indian Journal of Environmental Health* (Nagpur) 20(2):134-140, 1978.
- Ambalkar, S.S. Management of cattle yard wastes by recycling. *Livestock Advis* 2(9):5-10, 1977.
- Appa Rao, V. Gobar gas plant: source of people's power. *People's Action* (New Delhi) 7(3):42-43, 1973.
- Bhattacharyya, B. Economic design of gobar (or bio) gas plant for rural communities. *Chemical Age of India* (Bombay) 29(5):301-303, May 1978.
- Bhide, A.D. Energy from solid wastes. *Journal of the Institute of Public Health Engineers* (India) 3 and 4:14-18, 1976.
- Chawla, O.P. Bioconversion of agricultural wastes: recent trends. National Symposium on Biogas Technology and Usage, New Delhi, November 1977.
- _____ Cow dung gas plants. *Yojana*, Annual No. 26, January 1974.
- _____ Gobar gas plant. Summer Institute on Waste Management by Recycling, Bombay, June 1976. pp. 28-34.
- _____ Winter and the cow dung gas plant. *Indian Farming* (New Delhi) 23(8):29-30, 1973.
- Chiranjivi, C. Design analysis of small-scale anaerobic digesters in India. Institute of Gas Technology Symposium Clean Fuels from Biomass and Wastes, Washington, D.C., August 1978. pp. 449-464.
- D'Rozari, R. Gobar gas: it's time for second look. *Science Today* (Bombay) 9(11):37-46, 1975.

- Damodar Rao, T. and B.S. Charles. Methane recovery studies on cow dung and distillery spent wash by anaerobic digestion. Second National Convention on Environmental Engineering, New Delhi, February 1976.
- Desai, S.V. Combustible gas from cow dung. *Indian Farming* (New Delhi) 6(2): 140-143, 1945.
- Desai, S.V. and S.C. Biswas. Manure and gas production by anaerobic fermentation of organic wastes. *Indian Farming* (New Delhi) 6(2):67-71, 1945.
- Finlay, J.H. Report on first inspection visit to 95 gobar gas plants constructed in Nepal. United Mission Development and Consulting Services, Butwal, Nepal. 1976.
- _____ Report on second inspection visit to 95 gobar gas plants constructed in India. United Mission Development and Consulting Services, Butwal, Nepal. 1977.
- Florida, N. Small-scale biogas plants. Appropriate Technology Series, Bardoli, India. December 1973.
- Fulford, David and Nick Peters. Preliminary trials of cement gobar gas plant designs. United Mission Development and Consulting Services, Butwal, Nepal. 1980.
- Fulford, David and Prakash Chandra. Report on first inspection visit to Chinese biogas plants constructed to Pokhara, Nepal. United Mission Development and Consulting Services, Butwal, Nepal. 1980.
- _____ Report on third inspection visit to 95 gobar gas plants constructed in Nepal. United Mission Development and Consulting Services, Butwal, Nepal. 1979.
- Garg, H.P. Family size biogas plant. *Invention Intelligence* (New Delhi) 12(1, 12): 149, 1977.
- Garg, M.K. Pilot project on gobar gas. Lucknow, Planning Research and Action Institution, 1962.
- Ghose, T.K. and others. Biochemical engineering feasibility of biogas production as an appropriate technology. Second National Convention on Environmental Engineering, New Delhi, February 1976.
- Goswami, K.P. Development of a kachra-gas plant for biogas and manure. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 27-28.
- Gotaas, H.H. Composting. Monograph Series No. 31, World Health Organization, Geneva, Switzerland, 1956.
- Grewal, N.S. and Budhi Sagar. Efficient layout for a gobar gas (animal dung) plant: waste disposal structures. *Progressive Farming* 12(11): 12-13, July 1976.
- Guha, B.R. and others. Fuel gas and compost manure from water hyacinth. *Khadi Gramodyog* (Bombay) 22(11):483-486, 1976.

- Idnani, M.A. and C.N. Acharya. Biogas plants, their installation, operation, maintenance and use. New Delhi, Indian Council for Agricultural Research, 1963.
- Idnani, M.A. and O.P. Chawla. The cow dung gas plant is in the news again. *Indian Farming* (New Delhi) 1(4):9-11, July 1959.
- _____. Improve the performance of your biogas plant in winter. *Indian Farming* (New Delhi) 19:37-38, 1969.
- Jain, H.K. Cow dung gas plant: instruction for installation, operation and maintenance. Indian Agricultural Research Institute, 30 April 1979.
- Kalia, A.K. and R.B. Singh. Introduction of plastics in biogas. *Popular Plastics* (Bombay) 23(4):852-855, 1978.
- Kanaksabapathy, T. Gobar gas holder built of ferrocement. *Indian Concrete Journal* (Bombay) 49(12):355-359, 1975.
- Khadi and Village Industries Commission. Gobar gas: why and how. Khadi and Village Industries Commission, Directorate of Gobar Gas Scheme, Bombay, 1975.
- Khandelwal, K.C. Dome-shaped biogas plant. *Compost Science* 19(2):22-23, 1978.
- _____. A gobar gas plant for you. New Delhi, Directorate of Extension, Ministry of Agriculture and Irrigation, 1978.
- _____. Janata model gobar gas plant. New Delhi, Directorate of Extension, Ministry of Agriculture and Irrigation, 1979.
- _____. Technical feasibility of dome-shaped biogas plant. National Symposium on Biogas Technology and Usage, New Delhi, November 1977.
- _____. This biogas plant is for you. *Intensive Agriculture* 16(12):28-30, 1979.
- Kothandaraman, C.P. Prospects of producer gas as I.C. engine fuel. Workshop on Alternative Fuels, Institute of Technology, Banaras Hindu University, Varnasi, February 1979.
- Laura, R.D. Studies on utilization of waste material for the production of biogas and manure. M.Sc. thesis, Indian Agricultural Research Institute, New Delhi, 1965.
- Laura, R.D. and M.A. Idnani. Increase in the production of biogas from cow dung, adding other agricultural wastes. *Journal of the Science of Food and Agriculture* (London) 22:164-167, 1971.
- Leo, Pyle. Anaerobic digestion: the technical options. *Biogas Technology in the Third World: A Multidisciplinary Review*, 1978. IDRC-103e.
- Makhijani, A. and A. Poole. Energy and agriculture in the third world. Ballinger Publishing Co., Cambridge, Mass., USA, 1975.

Maramba, F.D. The small biogas plant: its construction, operation and use. Manila, Chamber of Commerce of the Philippines.

Matsumoto, J. and I. Endo. Anaerobic digestion of night soil. Advances in Water Pollution Research. Proceedings, Second International Conference in Tokyo, 1964. J.K. Baars, ed. London, Pergamon.

Menon, T.C.K. Biogas from weeds and plant litter. Seminar on Selected Cases of Work in Progress on Adaptive Technology, Ullor, July 1977.

Myles, R.M. Biogas technology: a review of the approach adopted by AFPRO in systematic promotion of the Janata biogas plant. New Delhi, Action for Food Production, 9 May 1980. 14p.

_____ Construction of 2 cu m (70 cu ft) demonstration-cum-training model Janata biogas plant in the Union Territory of Delhi. New Delhi, Action for Food Production, 1980. 11p.

Narayanswamy, V.P. and others. Optimum design of biogas plants. National Symposium on Technology for Agricultural Development, Chandigarh, April 1977.

National Sugar Institute, Kanpur. Production of bio fertilizer and biogas from agricultural wastes. Khadi Gramodyog (Bombay) 20(7):358-360, 1974.

Neelakantan, S. Bioconversion of solar energy into fuel gas. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 40-41.

Parikh, M. Gobar gas plant without iron gas holder. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979.

Parikh, M. and M. Kakalia. Garbage gas plant. Khadi Gramodyog (Bombay) 24(6): 310-317, 1978.

Patankar, G.L. Plastics in setting up of a gobar gas plant. Bombay, Khadi and Village Industries Commission.

_____ Substitute material for biogas holder. Khadi Gramodyog, July 1979. pp. 452-455.

Patel, J.B. and R.B. Patel. Biological treatment of poultry manure reduces pollution. Compost Science 12(5):18-20, September 1975.

Pathak, B.N. and others. Effect of gas recirculation in a pilot scale and dung digester. Environmental Health (Nagpur) 7:208-212, 1973.

Paul, T.M. Gobar gas plant for Bombay suburbs. Khadi Gramodyog (Bombay) 21(2), November 1974.

Pawar, V.P. Construction of gobar gas plant. Journal of the Institution of Military Engineers 28(3):19-20, 1976.

Raman, N.V. and others. Ferrocement gas holder for biogas plants. Paper presented at the International Conference on Materials of Construction for Developing Countries, Bangkok, 1978.

Sathianathan, M.A. Biogas: achievement and challenges. New Delhi, Association of Voluntary Agencies for Rural Development, 1975.

_____ Discussion paper on research planning for biogas technology. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979. 5 p.

Sen, A. and others. Production of combustible gas from cane mollasses. Science and Culture (Calcutta) 11:562-564, 1954.

Shah, I.H. Design and construction of 110 cu ft day biogas plant. University of Peshawar, Pakistan

Shanta, S. and G.J. Mohanrao. Anaerobic digestion of night soil and cow dung mixtures in reducing ammonia toxicity. Proceedings and abstracts, Society of Biological Chemists, Bangalore, India, 33, 1974.

Sichuan Provincial Institute of Industrial Buildings. Construction of marsh gas producing tanks (digesters) in simple ways. 1978.

Singh, K.W. Extension aspects of cow dung gas plant. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 48-51.

Singh, R.B. Biogas plant: designs with specifications. Ajitmal, Gobar Gas Research Station, 1973.

_____ Biogas plant: generating methane from organic wastes. Ajitmal, Gobar Gas Research Station, 1971. Also appeared in Compost Science 13(1):20, January-February 1972.

_____ Building a biogas plant. Compost Science 13(2):12, March-April 1972.

_____ Some experiments with biogas. Ajitmal, Gobar Gas Research Station, 1971

Singh, R.B. and B.K. Gupta. Practical aspects of gober gas productions. Symposium on Perspective in Industrial Microbiology, Bombay, April 1977.

Singh, R.B. and K.K. Singh. Janata biogas plants: preliminary report on design and cost. Lucknow, Planning Research and Action Division, April 1978.

Small-scale biogas plant. Appropriate Technology Handbook, Canadian Hunger Foundation, 1977.

Srinivasan, H.R. Design, construction and maintenance of gober gas plants. Bombay, Summer Institute on Waste Management by Recycling, June 1976.

Stewart, D.J. Fuel from animal waste and grass: a review of the possibilities. Invermay Technical Report No. 3, New Zealand, 1975. 12 p.

Studies in biogas technology. Part II: optimization of plant dimensions. Proceedings, Indian Academy of Science, C2, Part 3, September 1979.

Subramanian, T.V. Design of a gobar gas plant. Chemical Age of India (Bombay) 28(10):805-807, 1977.

United Nations. Economic and Social Commission for Asia and the Pacific. Design and construction of biogas plant: site selection, digester and gas holder. Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978. (NR/EGMBD/1).

_____ Operation and maintenance of biogas plant. Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978. (NR/EGMBD/2)

Yaduraju, N.T. and V.S. Mani. Water hyacinth has its uses. Science Today (Bombay) 13:51-54, October 1979.

C. Biogas Plant Operation

(Operation, installation, maintenance, nature of problems and servicing of biogas digester)

Biswas, T.D. Biogas plants: prospects and limitations. Invention Intelligence (New Delhi) 12(1,2): 71-78, 1977.

_____ Cow dung gas plant: instructions for installation, operation and maintenance. New Delhi, Indian Agricultural Research Institute, 1979.

Finlay, J.H. Operation and maintenance of gobar gas plants. United Mission Development and Consulting Services, Butwal, Nepal. 1978.

Ghosh, A.B. Research and development of cow dung plant. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961. pp. 364-369.

Grewal, N.S. and Malvinder Singh. Maintenance of gobar gas plants. Progressive Farming.

Idnani, M.A. IARI study shows why the biogas plant has not caught on with farmers. Indian Farming (New Delhi) 14(3), 1964.

_____ Some improvements in the biogas plant. Indian Farming (New Delhi) 12(11):24-25, 1963.

Idnani, M.A. and C.N. Acharya. Biogas plants: their installation, operation, maintenance and use. New Delhi, Indian Council of Agricultural Research, 1963.

Joshi, K.G. Cow dung gas plant: farmer's point of view. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961.

Joshi, V.K. Cow dung gas plant: a farmer's experience. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961.

- Khandelwal, K.C. Implementation of biogas programme at village level: a case study. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 44-45.
- Moulik, T.K. Promoting biogas technology in the villages: experience in Gujarat. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 52-53.
- Moulik, T.K. and U.K. Srivastava. Biogas plants at the village level: problems and prospects in Gujarat. CMA Monograph No. 59, Indian Institute of Management, Ahmedabad, 1975. 149 p.
- Parikh, P.P. Problems and prospects of utilization of biogas in I.C. engines. Proceedings, Workshop on Biogas Utilization in I.C. Engines, 19-20 April 1978.
- Patankar, G.L. Corrosion in gobar gas plant. Khadi Gramodyog (Bombay) 24(11): 541-545, 1978.
- Patel, J.J. On constructing a gobar gas plant. Khadi Gramodyog (Bombay), 1963.
 _____ Installation of biogas plant. Bombay, Khadi and Village Industries Commission, 1964.
- Pathak, B.N. and G. Rajagopal. Effect on volatile acid accumulation in dung digestion. Environmental Health (Nagpur) 8:194-199, 1972.
- Pathak, B.N. and others. Anaerobic digestion of night soil: seasonal variations in the volatile matter reduction and gas production. Environmental Health (Nagpur) 4(1):202-207, 1965.
- Prasad, C. Popularizing biogas (gober gas) production. Khadi Gramodyog (Bombay) 12:661-663, 1966.
- Rana, K.N. Problems of gober gas technology and its utilization in Nepal. 14 p. (for discussion only)
- Srinivasan, H.R. Gober gas plants: promises and problems. Indian Farming (New Delhi) 23(2):29-33, 1974.
 _____ Gober gas scheme. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 46-47.
- Stewart, D.J. Control of lakeweed by harvesting for fuel and fertilizer. Proceedings, Symposium on Lakeweed - Friend or Foe, Hamilton, New Zealand, July 1977. 8 p.
- United Nations. Economic and Social Commission for Asia and the Pacific. Operation and maintenance of biogas plant. Expert Group Meeting on Biogas Development, Bangkok 20-26 June 1978. 17 p. (NR/EGMBD/2)

D. Biogas Utilization

(Uses of biogas for cooking, lighting, power generation etc.)

- Alicbusan, R.V. Production and utilization of biogas in Republic of the Philippines. *Modern Agriculture and Industry – Asia*, August 1976. pp. 20, 46.
- Amaratunga, M. Application of biogas technology to rural upliftment. International Conference on Appropriate Technology in Rural Societies. Freetown, Sierra Leone, 3-7 July 1978.
- Bhavani, S. Biogas for fuel and fertilizers in rural India: a social benefit cost analysis. *Indian Journal of Agricultural Sciences (New Delhi)* 31(3): 219-231, 1976.
- Biswas, T.D. Biogas in India: retrospects and prospects. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 13-18.
- Biswas, T.D., A.R.S. Kartha and R. Pundarikakshudu. Removal of carbon dioxide from biogas. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 37-38.
- Car runs on biogas. *Bulletin of the Institution of Engineers (India)* 24(8):42-43, 1974.
- Das, R. Gobar gas and potential for its utilization. *Allahabad Farmer* 36(1):17-21, 1962.
- Dass, R.S. and others. Biogas as a replacement fuel to diesel engines. *Agricultural Engineering Today* 2(2), March-April 1978.
- Gopalakrishnan, K.V. Biomass energy for rural area. Paper presented at International Solar Energy Society Congress, New Delhi, July 1978.
- _____ Combustion characteristics of gobar gas diesel oil dual-fuel engine. Paper published in the fourth National Conference on I.C. Engines and Combustion, Madras, December 1977.
- _____ Energy for internal combustion engines from wastes and biomass. Paper presented at the Workshop on Energy from Biomass and Waste, organized by UNESCO at the University of Sri Lanka, Peradeniya, November 1979. Also published in *Journal of Energy, Heat and Mass Transfer*, 1979.
- _____ Performance of gobar gas diesel oil dual-fuel engine with high compression ratio. Third ISME Conference on Mechanical Engineering, Delhi, February 1980.
- _____ Some tests with gobar gas diesel oil dual-fuel engines. Paper presented at the fifth National Symposium on I.C. Engines and Combustion, Warangal, India, December 1978.
- _____ Use of gobar gas as an engine fuel. Paper presented at the third National Conference on I.C. Engines and Combustion, Roorkee, India. December 1976.

Gopalakrishnan, K.V. and B.S. Murthy. Energy for internal combustion engines from wastes and biomass. *Journal of Energy, Heat and Mass Transfer*, 1:265-279, 1979.

_____ Potentiality of water hyacinth for decentralized power generation in developing countries. *Journal of Energy, Heat and Mass Transfer*, 1:349-357, 1979.

Goswami, K.P. and Samar Choudhury. Fuel-gas and manure from agricultural wastes. *Get-together on Science and Industry*, CSIR, New Delhi, October 1966.

Gupta, R.K. and N.V. Iyer. Use of biogas in diesel engines. *Agricultural Engineering Today* 1, May-June 1977.

Gyan, Sagar. Cooking gas, manure from community latrines for rural areas and slums. *Annual Meeting of the Institution of Engineers (India)*, Environmental Engineering Division, Nagpur, 1977.

Jain, M.C. Conversion of petrol engine to run on biogas. *National Symposium on Biogas Technology and Usage*, New Delhi, November 1977.

_____ Low-cost burners for biogas. *National Symposium on Biogas Technology and Usage*, New Delhi, November 1977. pp. 33-35.

Joshi, M.V. Dual use of some cow dung: fuel and manure. *32nd Indian Science Congress*, Pt. 2, 1945.

Kasturirangan, K. and others. Use of gobar gas diesel engine fuel. *Third National Conference on I.C. Engines and Combustion*, University of Roorkee, India, December 1976. pp. 177-178.

Khandelwal, K.C. Free-fuel and fertility gobar gas plant. *Haryana Farming* 3(12):1-3, 1974.

Kothandaraman, C.P. Performance of 5 hp diesel engine under minimal cooling conditions. *Fifth National Conference on I.C. Engines and Combustion*, Warangal, December 1978.

_____ Some investigations into the use of gobar gas I.C. engines. *Fourth National Conference on I.C. Engines and Combustion*, College of Engineering, Guindy, Madras, December 1977.

Kothandaraman, C.P. and S. Krishnamurthy. Performance of a diesel engine with increasing proportion of gobar gas induction. *Fifth National Conference on I.C. Engines and Combustion*, Warangal, December 1978.

Maramba, F.D. Biogas for rural and industrial use. *Animal Husbandry and Agricultural Journal*, April 1980. •

Massey, V. Utilization of biogas in running engines for chopping hay. *National Symposium on Biogas Technology and Usage*, New Delhi, November 1977.

- Mehta, M.M. and others. Biogas utilization in tractor diesel engines for stationery applications. Escorts Scientific Research Centre, Faridabad, India, 1978. 12 p.
- Parikh, P.P. and C.K. Jain. Gobar gas as supplementary fuel for diesel engines. *Urja* (New Delhi) 1(4):27-29, April 1977.
- Patel, H.C. and M.V. Narasimhan. Small I.C. engines for gobar gas utilization. *Khadi Gramodyog* (Bombay), 1966. pp. 598-600.
- Patel, J.J. and G.L. Patankar. Burner design for biogas. *Khadi Gramodyog* (Bombay), 1966. pp. 406-413.
- Prasad, C.R. and others. Studies in biogas technology. Part III: thermal analysis of biogas plant. *Proceedings, Indian Academy of Science, Vol. C2, Part 3, September 1979.* pp. 377-386.
- Production of biofertilizer and biogas from agricultural wastes. *Khadi Gramodyog* (Bombay) 20(7):358, 1974.
- Nao, E.G.H. Generation of power from biogas. *Symposium on Radioisotopes, Fertilizers, and Cow Dung Gas Plants, New Delhi, 1961.* pp. 381-390.
- Shah, I.H. Biogas as a fuel for power production on agriculture farm. *International Seminar and Workshop on Low Cost Farm Structures for Rural Development, Peshawar, 1978.*
- _____ Conversion of petrol engine to run on biogas. University of Peshawar, Pakistan.
- _____ Design and construction of lamp to work on biogas. University of Peshawar, Pakistan.
- Singh, A.K. and B.P. Pundit. Dual-fuel operation of a diesel engine with sewage gas. *Agricultural Engineering Today* 2(2), March-April 1978.
- Srivastava, U.K. and T.K. Moulik. Energy consumption in rural households and biogas plants: tasks ahead. *Vikalpa* 2(1), January 1977.
- United Nations. Economic and Social Commission for Asia and the Pacific. Biogas as a fuel for power production on agricultural farms. *Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978.* 8 p. (NR/EGMBD/5)
- _____ Use of products of biogas plant. *Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978.* 16 p. (NR/EGMBD/3)
- Viswanathan, G. and others. Combustion characteristics of gobar gas in gobar diesel oil dual fuel engine. *Fourth National Conference on I.C. Engines and Combustion, Vol. 1, E2-51-60. December 1971.*
- Wandrekar, D.N. Gas for village households. *Khadi Gramodyog.*

E. Utilization of Biogas Effluent and Sludge Recycling

(Agricultural uses, aquacultural uses and sludge recycling)

- Acharya, C.N. Organic manures. New Delhi, Indian Council of Agricultural Research, 1952.
- Alicbusan, R.V. Biogas and agricultural development. Paper presented during the Consultation Meeting of Regional Development Council of Region IV held at the Development Academy of the Philippines, Tagaytay City, 7-9 November 1975.
- Chawla, O.P. Gobar gas plant: its efficiency and manurial returns. Khadi Gramodyog (Bombay), July 1972.
- Dart, P. Recent developments in the field of biological nitrogen fixation. ICRISAT, Hyderabad, 1976.
- FAO. Organic materials and soil productivity. Soils Bulletin 35, 1977.
- _____ Organic materials as fertilizers. Soil Bulletin 27, 1975.
- Ghosh, A.B. and M.N. Dutta. Manurial efficiency of the digested slurry from the cow dung gas plant. National Symposium on Biogas Technology and Usage, New Delhi, November 1977. pp. 59-61.
- Ghosh, A.B. and others. Use of digested cow dung slurry in improving the soil structure. Science and Culture (Calcutta) 34:307-308, 1968.
- Goldstein, H. Sensible sludge: a new look at a wasted natural resource. Rodale Press, Emmaus, PA, USA, 1977.
- Goswami, K.P. and Samar Choudhury. Farm wastes can yield fuel gas and manure. Indian Farming (New Delhi), April 1967.
- Idnani, M.A. and O.P. Chawla. Biogas plant slurry is now easier to dispose of. Indian Farming (New Delhi) 13(11):6, 1964.
- Idnani, M.A. and others. Utilizing the spent slurry from cow dung gas plant. Indian Farming (New Delhi) 19(1):35, 1969.
- Kak, V.N. Cow dung gas plant: its utility to the farmer. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1966.
- Karki, A.B. and J. Baral. Status of bio-fertilizers in Nepal: a review. IAAS Journal, 1(1):155-169. (Presented at FAO/SIDA Regional Workshop on Organic Fertilizers in Asia, Bangkok, Thailand, 26 October to 5 November 1976.)
- Laura, R.D. and M.A. Idnani. Composting of agricultural waste materials with spent slurry as a starter for decomposition. Indian Journal of Agricultural Sciences (New Delhi) 42:246-250, 1972.

- _____ Effect on wheat yield and nitrogen uptake from manure made from slurry. *Pl. Soil*, 37:283-295, 1972.
- _____ Mineralization of nitrogen in manures made from spent slurry. *Boil Biochem* 4:239-243, 1970.
- Maramba, F.D. *Biogas and waste recycling*. Regal Printing, Manila, 1978.
- Munde, A.V. Energy through gobar gas for small farmers. *Khadi Gramodyog (Bombay)* 23(12):546-548, 1977.
- Nagar, B.R. and C. Tietjen. Status report on the use of biogas technology for increasing fuel and soil productivity. *Journal of Scientific and Industrial Research (New Delhi)* 37(9):445-448, 1978.
- Patel, J.J. Gobar gas plant fuel and manure from organic wastes. FAI/FAO National Seminar on Optimizing Agricultural Produce under Limited Availability of Fertilizers, 1974.
- Paul, T.M. Disposal of gobar gas slurry. Khadi and Village Industries Commission Seminar on Gobar Gas, Varanasi, 18-21 March 1971.
- _____ Role of biogas in the recycling of plant, animal and human wastes. Lecture delivered at the V.J.T.I., Bombay, 12 October 1977.
- Phadnis, B.A. Cow dung gas plant. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961. pp. 398-399.
- Rao, K.S. Role of cow dung gas plant in agricultural development. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961. pp. 373-380
- Shelat, R.N. and G.L. Karia. Utilization of biogas in South Gujarat: a case study. National Seminar on Technology for Agricultural Development, Institution of Engineers (India), Chandigarh, April 1977.
- Shende, P.Y. Development and extension work with cow dung gas plant. Symposium on Radioisotopes, Fertilizers and Cow Dung Gas Plants, New Delhi, 1961. pp. 370-372.
- The Soil and Fertilizer Research Institute, Shandong Province, China. Compost and its effects on soil and crops in China.
- United Nations. Economic and Social Commission for Asia and the Pacific. Biomass culture with digester effluent. Workshop on Biogas Technology and Utilization, Manila, 13-18 October 1975. 17 p. (IHT/BG/2/5)
- Venkataraman, G.S. Algal bio-fertilizers for rice cultivation. Indian Agricultural Research Institute, New Delhi, 1977.

F. Social, Environmental and Economic Aspects

- Agarwal, K.C. and others. Ecological effects of production of biogas from human excreta on the enteriopathogens. 18th Annual Conference of Association of Microbiologists of India, Madurai, December 1977.
- Awasthi, R.K. Biogas (gobar gas) plant in perspective. *Financing Agriculture* 7(3): 1-7, 1975.
- Bahadur, S. Role of biogas in rural development. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979, 11 p.
- Barnett, A. A social and economic assessment of biogas technology. Institute of Development Studies, University of Sussex, Mimeo, November 1976.
- Barnett, A., Leo Pyle and S.K. Subramanian, Biogas technology in the third world: a multi-disciplinary review. International Development Centre, Ottawa, Canada, 1978. IDRC 103e.
- Berger, R.L. Economics of gobar gas. Division of Consulting Services, United Mission to Nepal, United Mission Economic Development Agency, Butwal, Nepal, January 1976.
- Bharde, T.S. Gobar gas to energize village economy. *Khadi Gramodyog* 20(7):335, April 1974.
- Bhatia, R. Economic appraisal of biogas units in India: framework for social benefit cost analysis. *Economic and Political Weekly* 12(32&33): 1503-1518, 1977.
- Bhavani, S. Biogas for fuel and fertilizers in rural India: a social benefit cost analysis. *Indian Journal of Agricultural Economics* 31(3): 219-231, 1976.
- Biogas plants: performance and prospects in India. *Science Technology Bulletin* 1(4), 1975.
- Biswas, D.K. Biogas plant for environmental improvement. *Khadi Gramodyog* 23(1):63-72, 1976.
- Biswas, T.D. Biogas technology and rural development. Dr. Baradananda Memorial Lecture, 1979. pp. 1-22.
- Biswas, T.D. and O.P. Chawla. Biogas as alternative sources of energy. Paper presented at Workshop on Biogas Technology and Utilization, New Delhi, 1975.
- Boss, S.P. Relative influence of socio-economic factors on the acceptance of cow dung gas plant by the farmers exposed to extension teaching. M.Sc. thesis, IARV, 1960.
- Can biogas provide energy for India's rural poor? *Nature* 281(5726), September 1979.
- Bulmer, Andrew. Community gobar gas feasibility study for Madhubasa village. United Mission Development and Consulting Services, Butwal, Nepal. 1979.

Dalal, H.J. Economics of gobar gas plants. Khadi Gramodyog, Bombay, 1963.

Dandekar, H. Gobar gas plants: how appropriate are they? Economic and Political Weekly 15(20):887-893, 17 May 1980.

_____ Rural development: lesson from a village in Deccan Maharashtra, India. Ph.D. dissertation, University of California, Los Angeles, 1978.

Deo, Susan Ruth Rothrock. An economic analysis of biogas technology for a hypothetical village in rural India. M.Sc. thesis, University of Illinois, Urbana, United States of America, 1980.

Disney, R. The economics of gobar gas versus fertilizer: A critique of intermediate technology. Department of Economics, University of Reading, United Kingdom, June 1976.

D'Rozari, R. Gobar gas: it's time for a second look. Science Today 9(11), 1975.

Financing of gobar gas plants by banks. Reserve Bank of India Bulletin, Bombay, 1976.

Ghate, P.B. Biogas: a decentralized energy system — a pilot investigation project. Economic and Political Weekly 14(27):1132-1136, 1979.

Indian Council of Agricultural Research, New Delhi. Economics of cow dung gas plant: a report. ICAR, New Delhi, 1976. iii, 66.

Khadi and Village Industries Commission, Bombay. Gobar gas (methane) industry. A Commerce feature, Commerce, 13 January 1973.

_____ Gobar gas: why and how. KVIC, Bombay, February 1975.

Khandelwal, K.C. Janata gobar gas plant. Directorate of Extension, Ministry of Agriculture and Irrigation, New Delhi.

Makhijani, A. Energy policy for rural India. Economic and Political Weekly 12(33-34), August 1977.

_____ Energy policy for the rural third world. International Institute of Environment and Development, London, September 1976.

Makhijani, A. and A. Poole. Energy and agriculture in the third world. Cambridge, Ballinger Publishing Company, 1975.

_____ Energy and development policy, useful energy and bio gasification (appendices). Ford Foundation Energy Policy Project Report: Energy and Agriculture in the Third World, 1975. pp. 133-159.

Mishra, S.P. Economic feasibility of gobar gas plant: a case study. Khadi Gramodyog, 21:286-289, 1975.

- Mitra, A.K. Economics of biogas plants: problems and prospects. Gokhale Institute of Politics and Economics, Poona, 1978. (manuscript)
- Moulik, T.K. Biogas system and rural energy supply. China After Mao, Somaiya Publications, Bombay, 1981.
- Moulik, T.K. and U.K. Srivastava. Biogas plants at the village level: problems and prospects in Gujarat. Ahmedabad, Indian Institute of Management, 1975.
- Mukherjee, S.K. and A. Arya. Comparative analysis of social cost-benefit studies of biogas plants. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979. 10 p.
- National Council of Applied Economic Research. Domestic fuel consumption in India. Delhi, 1965.
- Neelakantan, S. Project proposal on research and action planning for biomass and biogas technology. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979.
- Pai, K.K. Role of commercial banks in promoting gobar gas plants. Khadi Gramodyog (Bombay) 20(7):353-357, 1974.
- Panditrao, Y.A. Energy crisis and gobar gas. Khadi Gramodyog (Bombay) 23(4), January 1977.
- Parikh, J.K. Energy systems and development. Oxford University Press, Delhi. 1980.
- Parikh, J.K. and Kirit S. Parikh. Mobilization and impacts of biogas technologies. Energy (New York) 2(4):441-455, December 1977.
- Parikh, K.S. Benefit-cost analysis of biogas plants in India. Ph.D. thesis, Massachusetts Institute of Technology, January 1963.
- _____ Second India studies: energy. New Delhi, MacMillan, 1976.
- Parikh, K.S. and J.K. Parikh. Potential of biogas plants and how to realize it. H.G. Schlegel and J. Barnea (eds). Microbial Energy Conversion, Gottingen, Germany. Erich Goltze KG, October 1976.
- Patel, A.R. Wealth from wastes gobar gas obtained through the fermentation of cattle dung anaerobically: potential source of energy. Agriculture and Agro-Industries Journal (Bombay) 10(10):3-7, October 1977.
- Patel, J.B. and R.B. Patel. Biological treatment of poultry manure reduces pollution. Compost Science 12(5):18-20, 1971.
- Patel, J.J. Digestion of waste organic matter and organic fertilizer and a new economic apparatus for small-scale digestion. Poona Agricultural College Magazine 42(3):150-159, 1951.

- _____ Gobar gas plant: its various uses and impact on society. Khadi Gramodyog (Bombay) 10(11):738-740, 1964.
- _____ Improved cow dung gas plants and their economics. Symposium on Radioisotopes, Fertilizers, Cow Dung Gas Plants, New Delhi, 1961.
- Pathak, B.N. and G. Rajagopal. Studies on the anaerobic digestion of night soil at Eranakulam. Environmental Health (Nagpur) 4(1):68-73, 1962.
- Paul, T.M. Potentialities of gobar gas under Bombay conditions. Eighth Dairy Industry Conference, Trivandrum, 1970.
- _____ Role of biogas in rural development. Lecture at the Seminar on Education in 2001 at the Indian Institute of Technology, Madras, 12-14 March 1976.
- Prasad, C.R., K.K. Prasad and A.K.N. Reddy. Biogas plants: prospects, problems and tasks. Economic and Political Weekly (Bombay) 9:32-34 (special number), August 1974.
- Pyakuryal, K.N., A.B. Karki and N.W. Axinn. Techno-socio-economic study of biogas plants in Chitwan District, Nepal. IAAS Journal 2(3), 1978.
- Rajagopal, L.S. Biogas plant for rural India. Summer Institute of Waste Management by Recycling, Bombay, June 1976. pp. 112-116.
- Ramaprasad, T.N.C. and others. Role of biogas plants in pollution control. Second UGC sponsored Seminar on Environmental Pollution Control Problem of Gujarat, Ahmedabad, February 1977.
- Rao, R.V. and others. Some of the factors for reduction of cost of the biogas plant. Seminar on Utilization of Farm Wastes for Rural Industrial Growth, Bangalore, December 1975.
- Rawat, B.S. Economic aspects of cattle-yard waste recycling. Summer Institute on Waste Management by Recycling, Bombay, June 1976.
- Reddy, A.K.N. Karnataka's biogas potential. Paper presented at Energy Planning for Karnataka 1980 Technical Seminar, 10-11 November 1979.
- Reddy, A.K.N. and K.K. Prasad. Technological alternatives and the Indian energy crisis. Economic and Political Weekly (Bombay) 12(33-34), August 1977.
- Reddy, A.K.N. and P. Rajabapaiah. Biogas energy for Karnataka State. Paper presented at Animal Energy for Developing Countries, 6 March 1980. Indian Society of Agricultural Engineers, Bangalore and Indian Institute of Management, Ahmedabad, India.
- Reddy, A.K.N. and others. A community biogas system for Pura Village. Bangalore, Karnataka State Council for Science and Technology, August 1979.
- Revelle, R. Energy use in rural India. Science, 192, 1976.

Sanghi, A.K. and Dekle Day. A cost-benefit analysis of biogas production in rural India: some policy issues. N. Lock Heretz (ed). Proceedings of Conference on Energy and Agriculture. Academic Press, New York, 1977.

Santerre, M.T. and Kirk R. Smith. Application of the FLERT approach to rural household and community anaerobic digestion system. ERD Programme Report II-80-2: USA II-2.

Sathianathan, M.H. Biogas: achievements and challenges. Sagar Printers and Publishers, New Delhi, 1975.

Schlegel, C.C. and James Tarrant. Thinking about energy and rural development: methodological guidelines for socio-economic assessment. ERD Programme Report I-80-3, USA I-2.

Sethna, H.N. Development of energy sources. Khadi Gramodyog (Bombay) 20:331-334, 1974.

Shelat, R.N. and G.L. Karia. Biogas technology for rural development: a case study. International Conference on Rural Development Technology: An Integrated Approach, Asian Institute of Technology, Bangkok, June 1977.

Sirohi, A.S. Economics of gobar gas plant. National Symposium on Biogas Technology and Usage, New Delhi, November 1977.

Srinivasan, T.G. and Utpaul Ghosh. Social benefit-cost appraisal of community gobar gas plant. Energy Management (New Delhi) 1(4):243-248, 1977.

Srivastava, U.K. Economic aspects of biogas plants. Research Planning Workshop on Energy for Rural Development, Ahmedabad, December 1979.

Stewart, D.J. Economics of biogas production from specifically grown plant material. Invermay Technical Report No. 5, New Zealand, 1977.

Subramanian, S.K. Biogas system in Asia. Management Development Institute, Delhi, February 1977.

United Nations. Economic and Social Commission for Asia and the Pacific. Biogas technology and its economic impact. Workshop on Biogas Technology and Utilization, Manila, 13-18 October 1975. (IHSP/BG/2/9)

_____ Economic aspects, over-all management and recommended subjects for research. Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978. (NR/EGMBD/4)

_____ Introduction of solar energy in biogas systems. Expert Group Meeting on Biogas Development, Bangkok, 20-26 June 1978. (NR/EGMBD/12)

_____ Report on Manila workshop on biogas technology and utilization. Workshop on Biogas Technology and Utilization, Manila, 13-18 October 1975.

_____ Socio-economic aspects of various biogas systems. Workshop on Biogas Technology Utilization, Manila, 13-18 October 1975. (IHT/BG(2)/2)

US-China Relations Programme. China's energy policies and resource development. Report of a seminar, Stanford University, 1976.

Verma, Indu. Benefit-cost analysis of rural industries project. Paper presented in Indian Economic Society Seminar, Institute of Economic Growth, Delhi, October 1976.

Verma, O.S. Gobar gas-cum-compost making cost-benefit analysis. Economic Times 16(5,8), December 1976.

_____ Gobar gas plants: rate of return. Economic Times 7(12), 1976.

Vishnoi, S.L. and S.P. Bose. Effect of educational exposures on the acceptance of cow dung gas plant by farmers. Indian Journal of Agronomy 5:284-291, 1961.

ESCAP ECDC-TCDC PUBLICATIONS

In its efforts to promote and support co-operation among developing countries, the ESCAP secretariat continues to produce a number of publications as listed below.

General series

Training courses available in developing ESCAP countries (first and second editions, out of stock), third edition, 1979

Consultancy services available in developing ESCAP countries (first edition, out of stock), second edition, 1977

Experts of developing ESCAP countries, 1978; Supplement (mimeographed), 1979

Identification of opportunities for interregional ECDC TCDC: report of consultations between India and Latin American countries, 1979

Inter-country institutional arrangements for economic and technical co-operation among developing Asian and Pacific countries

Vol. I : Intergovernmental institutions, 1980 (TCDC/IIA/1)

Vol. II : Non-governmental and national institutions, 1980 (TCDC/IIA/2)

Vol. III: Pacific institutions, 1981 (TCDC/IIA/3)

Technological research and development institutions in Asia and the Pacific (under preparation)

Sectoral series

National standards bodies in the ESCAP region, 1980 (ESCAP/TCDC/SRD/1, out of stock)

ECDC-TCDC directories on renewable sources of energy:

Vol. I : Solar energy, 1980

Vol. II : Biogas, 1981

Vol. III: Wind energy, 1981

Vol. IV: Mini-hydro plants, 1981

ECDC-TCDC directory: Machine tools (under preparation)

ECDC-TCDC directory: Leather technology (under preparation)

ECDC-TCDC directory: Industrial utilization of agro-wastes (under preparation)

The above publications can be obtained, subject to availability, from ECDC-TCDC Services, ESCAP secretariat, The United Nations Building, Rajadamnern Avenue, Bangkok 2, Thailand.