UNITED NATIONS

ECONOMIC AND SOCIAL COUNCIL

Distr.
GENERAL
E/ESCWA/SDP/87/5/Rev.1
E/ESCWA/NR/87/11/Rev.1
13 October 1988
ORIGINAL: ENGLISH

ECONOMIC AND SOCIAL COMMISSION FOR WESTERN ASIA

Social Development, Population and
Human Settlements Division

Natural Resources, Science and Technology Division

INTRODUCTION OF BIOGAS TECHNOLOGY IN DEMOCRATIC YEMEN A CASE STUDY

ESCWA/UNIFEM Project PDY/86/W01

August 1987

E/ESCWA/SDP/87/5/Rev.1
E/ESCWA/NR/87/11/Rev.1

88-0475

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EXPLANATORY NOTES

The following symbols have been used in tables:

Two dots (..) indicate that no information is available.

A dash (-) indicates that the amount is nil or negligible.

Totals may not add precisely because of rounding.

Part one

TECHNO-ECONOMIC ASPECTS*

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INTRODUCTION

1. Purpose and scope of the study

Based on the terms of reference set by the United Nations Development Fund for Women UNIFEM-ESCWA (annex I), this report covers the techno-economic part of the assignment. A separate report is presented on sociological aspects, where particular emphasis is placed on the role of women, their responsibilities and the impact of introducing biogas technology (BGT).

The basic purpose of this study is to assess the prospects of biogas technology in Democratic Yemen.

An intensive field visit by a group of consultants to Democratic Yemen constituted the basic fact-finding and data collection phase of the study.

An interim preliminary short report has been submitted for follow-up purposes.

2. Contents

The contents of this report can be roughly divided into six parts:

1. An overview of BGT which provides the subject background and fundamentals;

2. A general presentation of the major characteristics of Democratic Yemen;

3. More specific coverage of the two foremost relevant aspects of energy and animal production;

4. An overall estimate of the potential and prospects of BGT in rural areas of Democratic Yemen, based on the results of field visits and an analysis of the available data;

5. A preliminary appraisal of the feasibility of a number of proposed biogas systems that seem promising under rural conditions in Democratic Yemen;

6. A proposed demonstration phase.

3. Key findings, conclusions and recommendations

BGT seems to have reasonably good prospects in rural areas of Democratic Yemen, both for energy production and sanitary waste disposal; the latter may even have a more pronounced impact. The utilization of digested effluent as a fertilizer or animal feed (under certain conditions) constitutes an additional benefit. It is certainly an appropriate technology for women, both in terms of their role and the benefits to be gained.

A combination of family size, community-shared facilities and large-scale biogas plants attached to governmental animal-raising farms seems necessary for realizing the optimum potential of BGT in Democratic Yemen.

The realistic potential of BGT in the rural areas of Democratic Yemen is estimated to be around 60,000 digesters, with sizes varying from 0.5 to 170 cubic metres (m^3). These would produce about 27 million m^3 of biogas per year, which could save about 17 per cent of the oil estimated to be used in rural areas. The share of family-sized units would represent about 64 per cent, while communal units would contribute around 22 per cent and the rest would be produced by large-scale plants.

Based on preliminary estimates for the use of biogas, about 12,000 rural households could become energy self-sufficient, while another 60,000 families could use biogas energy to cover part of their needs.

The possibility of incorporating a human waste sanitary disposal system within the biogas scheme would have an even greater impact. It is estimated that more than 180,000 families could connect domestic or public latrines to either family or community biogas units.

Preliminary cost estimates indicate the viability of biogas systems on a family, community or large-scale level under assumed conditions. Reliable estimates, however, can only evolve from actual field demonstrations, when site specific conditions and data would be available. Social cost-benefit analyses could also be attempted at that stage in an effort to reflect the beneficial societal impact of BGT.

At the earliest opportunity field demonstrations of a number of promising biogas systems are recommended as a follow-up. This can be achieved in two steps: the first covers family and communal biogas units, while the second encompasses large-scale digesters attached to governmental animal and poultry-raising farms. The demonstration phase will provide evidence of the viability and appropriateness of this technology and its consequences for rural and bedouin Yemeni women.

I. BIOGAS TECHNOLOGY (BGT)

A. An introductory review of basic principles and prospective designs

1. Biogas technology

BGT involves the anaerobic digestion (fermentation in the absence of air) of organic waste materials such as animal dung, human excreta, agricultural residues and certain industrial and municipal wastes. It is a microbial process that produces a gas called biogas, in addition to a left-over stabilized sludge; it must be carried out under controlled conditions and in the absence of certain toxic substances.

Biogas is a clean fuel. It is basically a mixture of methane and carbon dioxide, plus a number of minor constituents. The general composition of biogas produced from farm wastes is usually: CH_4 54-70 per cent, CO_2 27-45 per cent, N_2 0.5-3 per cent, H_2 0-2 per cent, and H_2S 0.1-0.5 per cent. On average its calorific value is around 5,500 Kilocalories (kcal)/m^3.

The digested sludge contains most plant nutrients (humus, nitrogen, phosphorus, potassium and trace elements such as zinc, copper, calcium and boron). Therefore, it is usually used on land as a soil conditioner and fertilizer. It is also safe to handle, since anaerobic treatment considerably reduces the number of pathogenic bacteria and parasites.

Although biogas was first discovered in the seventeenth century, the first reported practical application was in 1896, when gas from sewage was used to light a street in Exeter, England. Recently, however, rural biogas systems have attracted much attention in view of their potential for waste recycling, pollution control and the improvement of sanitary conditions, in addition to providing fuel and fertilizer. Though China and India are the leaders in this regard, many other developing countries have instituted BGT programmes at various levels of development and size.

2. Basic principles

Excellent descriptions of the principles and state of the art of biogas have been published, and a number of these are included in the keyed reference (1-12). As these reviews cover the essential features of BGT, only a concise outline will be presented here.

(a) The microbiology of anaerobic digestion

The biochemistry and microbiology of anaerobic digestion is extremely complex. In general terms there are three steps. In the first, the polymeric compounds of carbohydrates, proteins and fats are broken down into soluble monomers by a group of facultative[1/] bacteria through enzymatic hydrolysis.

1/ Bacteria that can adapt to living or without oxygen. For aerobes, oxygen is essential, whereas strict anaerobes can only live in the absence of oxygen.

In the second, these monomers are converted through the action of acid-producing bacteria into acetic, propionic and lactic acids. Carbon dioxide and hydrogen are also formed. In the third step, methanogenic bacteria produce methane from acetic acid and carbon dioxide and hydrogen. The bulk comes from acetic acid.

(b) Operating conditions

Optimum operating conditions will depend to some extent on the materials being digested. Almost any organic waste material serves as a component of the substrate for an anaerobic digester. The suitability of materials for gas production, however, depends on several factors such as biodegradability, nitrogen availability which is usually expressed in terms of the carbon to nitrogen (C/N) ratio, and the absence of toxic or inhibitory constituents. If the nutritional requirements of the micro-ogranisms are met by a suitable mix, most types of organic matter can be used. The carbon to nitrogen ratio needs to be in the region of 30 to ensure the best results. Possible substrates include: animal manure, human excrement, crop residues, aquatic and terrestrial vegetation, food processing and organic factory wastes, or even kitchen wastes. In all cases, the balance between acids and basis is extremely important, with an optimum pH level of around 7.

The methanogenic bacteria are obligate anaerobes and highly susceptible to environmental change. Temperature is crucial. There are two sets of methane-forming bacteria: mesophilic and thermophilic. Mesophilic bacteria grow in a temperature ranging from about 20 to 45°C, with an optimum of 35°C. Above 45°C these bacteria begin to die off. Thermophilic bacteria are active from about 50°C to 65°C, with an optimum of 55°C. Digestion tends to take place more rapidly at thermophilic rather than mesophilic temperatures. The pathogen kill rate is also higher. However, in practice thermophilic digestion appears to be more sensitive to temperature shocks than mesophilic digestion. Another argument against the use of the thermophilic operation is the extra energy required. Normally, then, agricultural digesters are run under mesophilic conditions.

The retention time, and hence the size of the digester at a given loading rate, are partly determined by kinetics and partly by the pathogen kill rate. Under mesophilic conditions, a retention period of 30-50 days is normally required.

3. The biogas system

The biogas system is not just a digester. Rather, it is an integrated sequence of processes involving waste feed management, digestion, effluent and gas handling and usage. Thus, the whole system is not quite as simple as it first appears to be.

The first step entails the collection of organic wastes and water (needed for dilution), transport, preparation and feeding. Common organic wastes that are normally produced from rural household activities include livestock and poultry wastes, night soil and vegetable wastes. These need sanitary handling and delivery to the digester.

Agricultural residues such as straw and stalks usually need to be shredded to facilitate their loading into the digester, as well as to increase the effeciency of bacterial action. The storage of these residues in a damp and confined space for about 10 days is recommended in order to reduce the time required for digestion. Generally, for better digestion, the feed should be a homogeneous slurry with a total solids concentration of 8-11 per cent by weight. This normally requires dilution with water.

The second step, which takes place in the digester, is the core of the biogas system. It consists of an oxygen-free container with a gas collection device. In certain cases agitation devices and controlled heat input systems are included. The process can be batched with the digester being filled and the materials being left to digest for a certain time before being opened, emptied and the next batch processed. Alternatively, the digester design may include input and output ports in which case it can be set to operate semi-continuously. Feed is added periodically (usually daily) and an equivalent portion of the digested slurry is removed. This leads to uniform gas production, whereas in the batch method, several batch digesters, loaded alternately, are needed to achieve uniform production.

The management of digested slurry depends on local conditions. The slurry is normally used as a fertilizer. Several alternatives exist: direct use as a slurry dilution with irrigation water, after drying, or used as an ingredient in compost. The latter is probably the best, since it resembles the traditional technique used by the villagers. In this case, the digested slurry is absorbed into silt and/or agricultural and household solid wastes. The compost can be stored till needed, and it is easier to handle than liquid slurry.

The use of the biogas is the final step in the process. Because of the low working pressure of biogas, the gas user should be located near the generation unit. Like other types of gaseous fuels, biogas can be used on household scale for cooking, lighting and heating. Suitable devices should, however, be designed for efficient gas use in rural areas. Otherwise, normal liquified petroleum gas (LPG) burners can be modified for use.

A small village-type domestic digester operated in conjunction with three large animals and a toilet would normally produce sufficient gas to meet the energy needs of a family (cooking and lighting). In addition, on further composting with agricultural wastes, it would produce sufficient digested slurry of good manurial value to serve a small family land-holding (around 3-4 acres).

Technically, the success or failure of a biogas system depends on whether the different design parameters are adequately taken into consideration (13). These parameters include the following: gas production, consumption patterns and storage capacity, fermentation temperature, digester internal flow patterns, gas pressure and its stabilization, scum formation and mixing. Local situations should be considered when setting the design parameters. Satisfying the needs of the end user and giving due consideration to socio-economic factors (which will be discussed later) should also constitute major objectives of the diffusion of this technology.

4. Relevant technologies and prospective designs

The biogas digester is a tank which can be take many designs and forms. However, it should satisfy a minimum number of technical requisites. These include being air-tight and water-proof, and having sufficient space for biological reactions to take place and for the digester slurry to form, without clogging the gas outlet with scum from the slurry surface.

A relatively large number of biogas technologies are available, varying from the simple to the more sophisticated. A wide range of scales are available, from the small family digester, community-size unit or much larger, "industrial type" plants. The degree of mechanization and mode of operation vary accordingly, with some operating as batch, semi-continuous or continuous systems.

Non-batch systems fall into two categories: suspended and immobilized. Suspended growth systems are characterized by a long retention time in the region of 20-60 days which prevents the active micro-organisms from being "washed out". Immobilized growth systems have a low retention time (sometimes only a few hours) owing to the entrapment of organisms.

Another system which is popular because of its efficiency is the two-phase or diphasic digestion system. The acid and methane production stages are separated, as the optimum conditions for the respective bacteria are quite different.

The descriptions that follow will be limited to designs that are appropriate in terms of simplicity, scale and cost. There are several basic designs including the following (10-12, 14, 15):

(a) The Indian floating cover digester, with modifications;
(b) The Chinese fixed-dome, with modifications;
(c) The horizontal-vertical digester;
(d) The plastic bag digester;
(e) The batch "dry" fermenter;
(f) The Ready-made mini-digester;
(g) Other types suitable for large-size applications.

These designs were mainly developed in developing countries. Their suitability for rural areas of many developing countries has already been demonstrated with various degrees of success.

It should be noted, however, that there is no definitive design for a digester, and there never will be. The ideal biogas plant is one that can cope with local conditions (local skills, available construction material, feed materials and climate). With some modification, the following designs would be appropriate for the conditions of target rural communities in Democratic Yemen.

(a) The Indian floating cover digester

This is the most widely used design in India and is popular in the rest of the world. It is normally called the Khadi and Village Industries' Commission (KVIC) design, and has been in use for over 40 years. A simple sketch is shown in figure I.

The digester is cylindrical in shape and has a height-diameter ratio of between 2.5 and 4. It is usually built underground and constructed of brick. The gas produced in the digester is trapped under a floating gas holder, which moves up and down on a central guide. The gasholder is normally made of mild steel, although owing to the problem of corrosion, other materials such as ferrocement, fibreglass and high-density polyethylene have been used. It is braced internally with irons angle fitted at different heights, so that when the holder is rotated around the centre guide, the surface of the slurry is agitated to break up the scum. The pressure of the available gas depends on the weight of the gas holder per unit area, which is usually in the order of 8 cm of water pressure. This can be increased by placing weights on the gas holder.

The digester often has an internal central partition to prevent short-circuiting. The digester is fed semi-continuously by means of an inlet pipe after the feed has been diluted with water and homogenized in a mixing pit that is fitted with a hand stirrer. An equal amount of digested slurry is displaced and flows through an outlet pipe.

Typical retention times vary from 30 days in warm climates to 50 days or more in cold areas. When cattle manure is diluted to 9 per cent solids, gas yields of between 0.2 and 0.4 by volume per digester volume per day are achieved.

The major drawbacks of this design are the relatively high initial capital investment needed for the steel gasholder, heat losses through the gasholder and its liability to corrosion. Several attempts have been made to cope with these problems by changing the construction material of the gasholder. Heat loss through the digester cover can be dealt with by incorporating a solar water collector into the roof of the gasholder. The hot water that is produced can then be used to charge the digester. These two modifications are claimed (11) to increase gas yield by 11 per cent.

Modifications to the conventional Indian design include the following:

The Omar Makram modified Indian-type digester developed by the National Research Centre (NRC) of Egypt, as shown in figure II (15);

The modified two-chamber BORDA-type[1/] digester and Egyptian (NRC) version, which is shown in figure III.

The main advantages of these modified types are their ease of construction and suitability for medium-level underground water-tables.

1/ Developed by the Bremen Overseas Research and Development Agency (BORDA), Federal Republic of Germany.

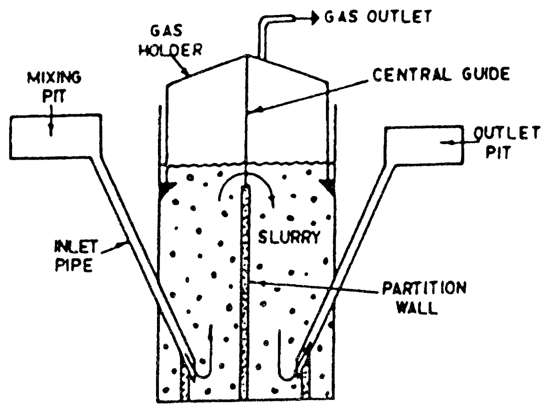


Figure I. Indian floating cover digester

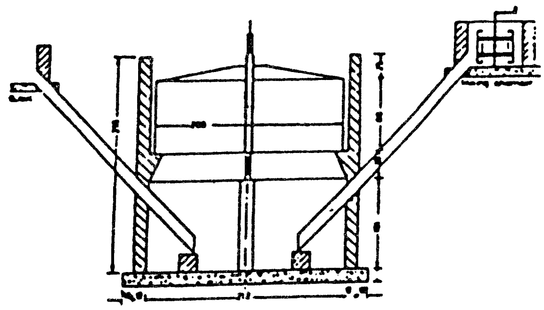


Figure II. Omar Makram modified Indian-type digester (NRC)

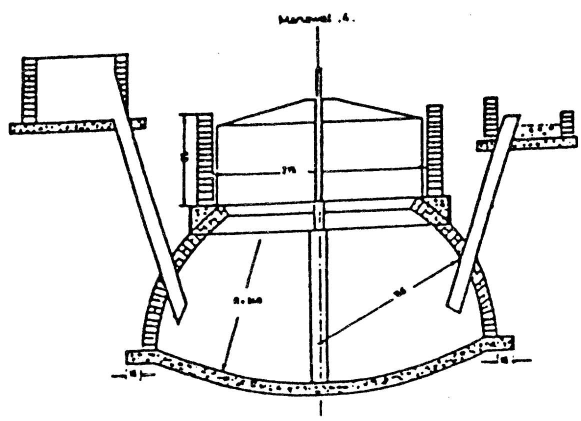


Figure III. Modified two-chamber BORDA-type digester (NRC)

(b) The Chinese fixed-dome digester

This is a low-cost digester where the expensive steel gasholder is replaced by a fixed dome. The basic features of this design are shown in figure IV.

The digester can be built of either bricks, stone or concrete. Both the top and bottom of the digester chamber are hemispherical and it has straight sides. In order to render the whole structure gas-tight, the inside surface is plastered over with several thin layers of mortar.

The digester is fed semi-continuously through a straight inlet pipe which reaches mid-way into the digester. The outlet is also located mid-way in the digester and consists of a fairly large storage tank. The gas outlet pipe ends in a relatively large manhole cover located at the top of the digester to provide access for cleaning.

The gas produced during digestion is stored under the dome. It displaces some of the contents of the digester into the effluent chamber, which produces gas pressure in the dome of around 100 centimetres (cm) of water. As the gas is used, the pressure gradually decreases. Typical gas production is in the order of 0.1-0.2 by volume per digester volume per day, with a retention time of about 60 days and temperature in the order of 20-25^{o}C.

The major drawbacks of this design are frequent gas leakage through the dome, low gas productivity and possible short circuiting.

Several Egyptian innovations have been introduced to the conventional Chinese model by NRC engineers in an effort to enhance its effectiveness or adapt and simplify its use.

Studies at the National Research Centre, for example, indicated that changes in the design of the outlet chamber could reduce the loss of gas generated from the slurry which was pushed up into the outlet chamber. The design of the NRC-modified outlet chamber which minimizes the movement of slurry is shown in figure V. Results indicate that this design assists the stabilization of gas pressure (leading to a more efficient burner design), while maintaining the required gas storage capacity. A sharp decrease in gas loss was noted.

The latest NRC innovation is the Egyptian - Chinese digester which is shown in figure VI (15).

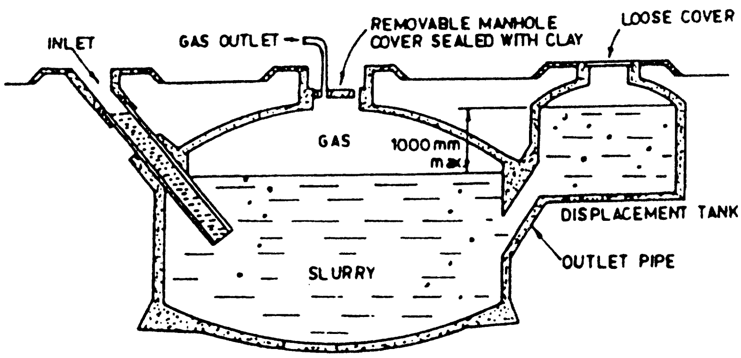


Figure IV. Chinese fixed-dome digester

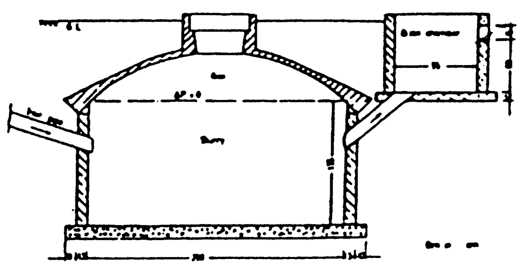


Figure V. Omar Makram modified Chinese-type digester (NRC)

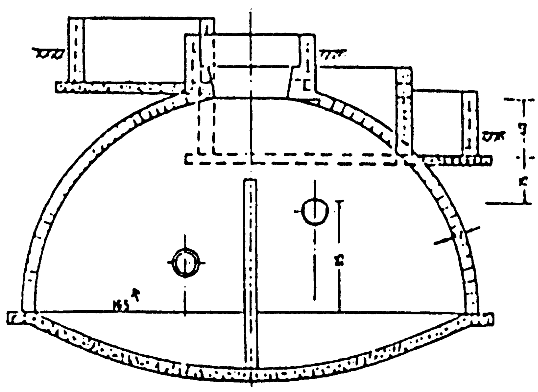


Figure VI. Egyptian-Chinese digester (NRC)

The digester is spherical in shape and has adjacent inlet and outlet chambers. Figure VI shows the main features of the digester. Passive solar heating is used to warm the slurry in both chambers. The digester volume varies in range from 5 to 30 m^3, and therefore can be used for family-sized as well as small-scale community systems. The digester is made of concrete and bricks.

The main advantages of this type of digester are that:

(a) It requires less depth underground, which makes it more suitable for prevailing high water-table conditions;

(b) The system is easier, faster and less costly to build, thus making it suitable for local village situations and skills;

(c) The gas production rate is higher than that of conventional Chinese designs;

(d) The gas storage capacity is high, while gas losses are considerably reduced;

(e) The effluent automatically flows outside under the influence of gas pressure, thus reducing operating costs.

(c) <u>The horizontal vertical digester (Philippines)</u>

This is also a modified version of the floating gasholder-type digester, though here it is classified separately. It was developed by Maya farms in the Philippines to suit conditions where the ground is hard to dig, the water-table is high and/or there is a high flood level. It has a rectangular horizontal design that slopes slightly upwards towards a floating gasholder, which only covers one third of the length (figure VII). Its recommended size is over 20 m^3. The effect of fluctuations in ambient temperature, noted in the vertical type with a floating metallic gasholder, is minimized. Construction costs, however, are higher than those of the vertical digester.

(d) <u>The bag digester (Taiwan)</u>

This digester essentially consists of a long cylinder made from a flexible membrane, either Hypalon laminated with neoprene and reinforced with nylon, polyvinyl chloride or red mud plastic. The digester and gasholder are combined in one bag. The feed inlet and outlet pipes and gas pipe are integrated into the bag. A simple sketch is given in figure VIII.

Bag digesters are now available ready-made on the market. They are mass-produced and easy to transport and install. A 50 m^3 digester weighing 270 kilogrammes (kg) can easily be installed by excavating a shallow trench slightly deeper than the radius of the digester, and it is relatively low in cost. Gas yields are said to be higher than those of previous types in view of the higher internal digester temperature. This is because the walls of the bag are thin, therefore the contents of the digester can easily be heated by external solar heat.

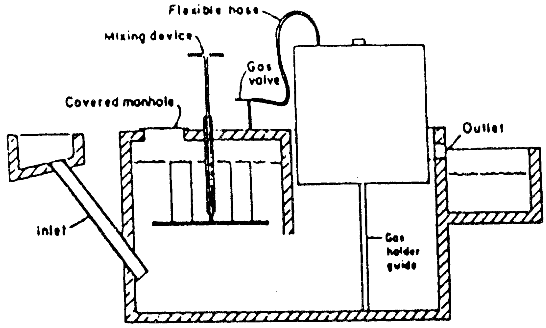


Figure VII. <u>Horizontal continuous-feed biogas digester (Maya farm, Obias)</u>

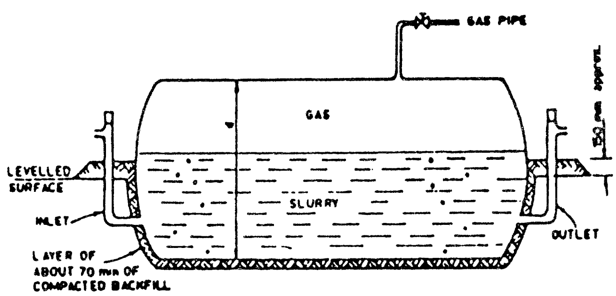


Figure VIII. <u>Bag digester (Taiwan)</u>

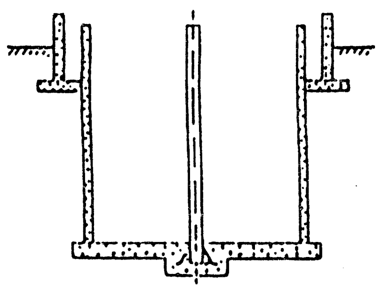


Figure IX. <u>Dry fermenter digester (NRC)</u>

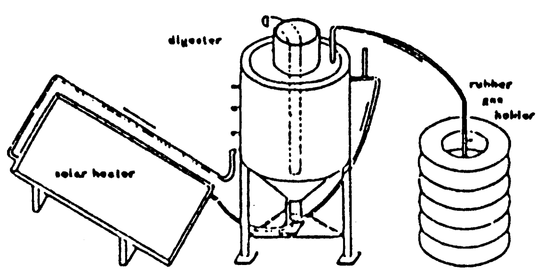


Figure X. <u>Mini digester (NRC)</u>

However, bag digesters are not easy to operate and maintain. Their major disadvantages are that they less safe, can be pierced or damaged, especially when additional weights are used to regulate the gas pressure, cannot be stirred and they have no access for cleaning.

(e) The batch "dry" fermenter(15)

Where animal wastes are in short supply, which is quite common in the rural areas of Egypt, the dry fermentation of agricultural residues is a logical solution. The process is carried out in a batch system at high solid concentrations of about 25 per cent. To ensure a continuous supply of gas, at least two digesters should be constructed and operated in unison, so that while one is operating, the second can be discharged, re-fed, etc.

The dry fermenter consists of a digester and gasholder. The digester can be cylindrical or rectangular in shape, and is made of bricks or concrete. The gasholder may be made of metal, rubber or plastic. Figure IX shows one of the designs for digesting agricultural residues.

The main advantages of this system are as follows:

(i) Gas can be produced in cases where animal wastes are in short supply;

(ii) The amount of organic fertilizer produced is increased;

(iii) The digester can be located outside a village when there is insufficient space near the house.

(f) Ready-made mini-digesters

These are small digesters with a volume of 1 - 2 m^3. They are made of prefabricated steel or plastic materials. Figure X depicts one of the models that has been developed with a solar heater to give a higher operating temperature, which produces more gas.

This type of digester has the following advantages:

(i) It can easily be erected because of its ready-made nature;

(ii) It can meet the energy needs of a rural family, as it an operate using the waste of only two large animals as a result of its relatively high productivity;

(iii) Requires only a small area for installation;

(iv) Is suitable for high water-table locations as it is erected above ground.

It has the following disadvantages:

(i) It needs to be erected on a sunny site if it is to maintain high gas production rates;

(ii) It requires the manual feeding of animal dung and urine.

(g) Miscellaneous designs particularly suited to large-scale applications

While some of the previous designs, particularly the Indian type, can be used for large-scale applications, they are generally employed for relatively small-scale digesters, mainly for household-scale units. Plug-flow type digesters that are fitted with mechanical devices, as well as large stirred-tank fermenters, are used for large-scale applications. The latter type is often employed in conjunction with sewage sludge digestion.

Plug-flow digesters are frequently referred to as "tunnel-type" digesters. They can have a fixed or flexible roof. Examples of both types are shown in figures XI, XII and XIII (15).

B. System products and their use

The tangible outputs of rural biogas systems include gas, digested slurry and the affected sanitary waste disposal.

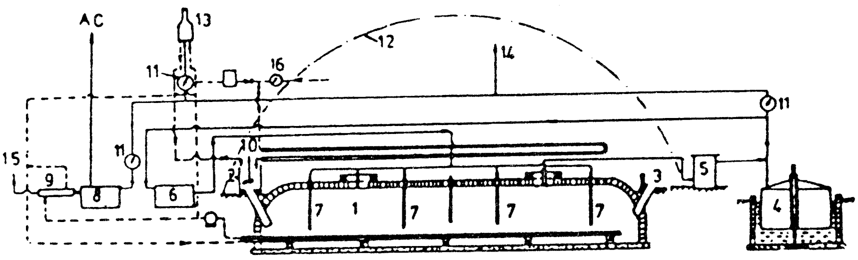
1. Uses of biogas

Biogas, which is a clean, combustible gas, can be used for domestic purposes (cooking, heating and lighting), particularly when used in family-type units. For larger plants, biogas can provide heat energy for large installations and institutions, and can be used to produce mechanical and electrical power. Biogas-fueled engines are used to pump water, as well as for rice hulling, grain threshing, chaff cutting, flour milling and feed grinding.

For domestic applications, gas-use devices can be designed and manufactured specifically for use with biogas (10), or normal gas-use devices can be modified to function with biogas. The primary modifications that can be made include the adjustment of the gas nozzle area, the air-gas ratio (air intake), as well as adjustments to the burner head and its ports through which the gas-air mixture is discharged for combustion.

The benefits derived from the use of biogas as a cooking fuel are substantial. Biogas provides a quicker, easier, cleaner and healthier fuel than the fuels it usually replaces. By reducing the time needed for fuel collection and preparation, the biogas system frees the housewife for more productive activities. The use of biogas reduces eye disease by eliminating smoke from the burning of biomass fuels. If it replaces dung cakes, the biogas eliminates the odour, disease and insect problems that are associated with the preparation of the dung cakes. If biogas replaces wood fuel, it helps to limit deforestation. It also frees straw and crop stalks for use as fodder and silage.

The use of biogas in engines required a number of modifications to be made. Spark-ignition (petrol) engines can operate entirely on biogas fuel, whereas compression-ignition (diesel) engines require that a minimum of 10-15 per cent of diesel oil be injected in the conventional manner to initiate and complete the combustion of the biogas-air mixture inducted during the suction stroke.



Notes:

1. Tunnel digester
2. Feed chamber
3. Effluent outlet
4. Gasholder
5. Gas scrubber
6. Gas compressor
7. Gas-mixing distributors
8. Electrical power generator
9. Engine waste-heat recycle
10. Solar water heater
11. Gas meters
12. Greenhouse
13. Gas heater
14. Main biogas line
15. Flue gases
16. Water meter

Figure XI. The 50 m^3 tunnel-type digester (NRC)

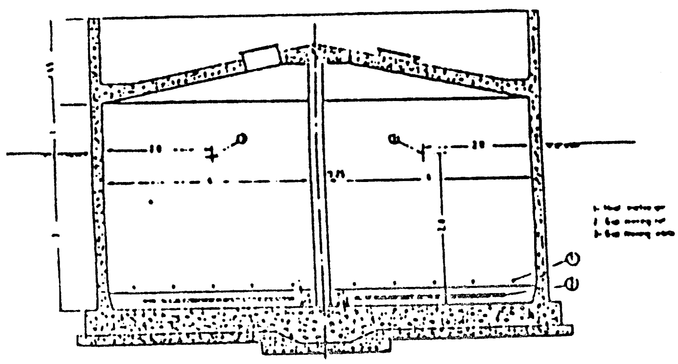


Figure XII. Tunnel-type digester with pyramidal roof (NRC)

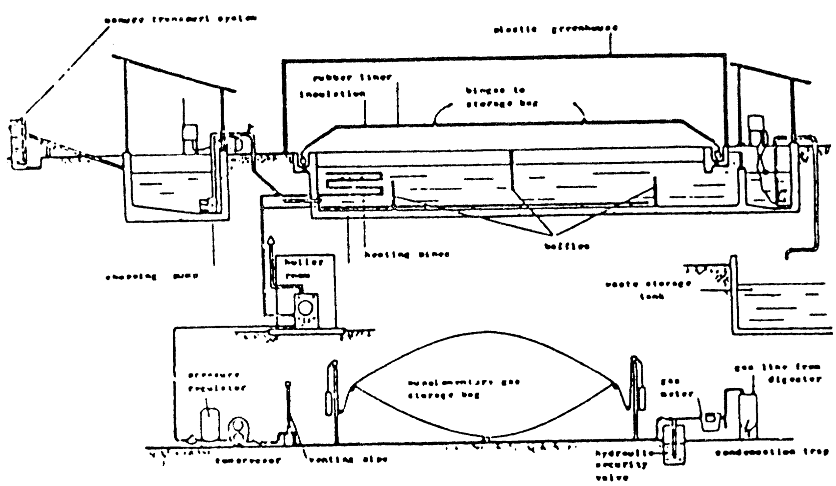


Figure XIII. Tunnel-type digester with flexible roof (Italy)

2. Use of digested slurry

The digested slurry can be used as an organic fertilizer, animal feed or for algae production; the first use is the most important. While the initial organic materials fed to the digester can be used as fertilizers, digested products are generally agreed to have a better fertilization value (10-35 per cent more). Furthermore, the digested slurry is safer to use because most of the pathogenic bacteria and parasites are killed off in the anaerobic digestion process.

The digested slurry can be used directly in a wet form, or it can be dried. Alternatively, it can be absorbed into silt and mixed with other available waste materials, such as domestic refuse.

3. Sanitary waste disposal output

Sanitation, which evolves from the introduction of a proper sanitary waste disposal scheme for both animals and humans as a part of the total biogas production plant, is one by-product of the system. Successful demonstrations where the animal shed and a latrine were connected directly to a digester in Egyptian rural communities have been reported (16) by the BGT engineering group of NRC.

C. BGT status in some developing countries

BGT has gained acceptance in many developing as well as developed countries. While emphasis in developing countries has been on rural programmes, applications in developed countries are directed towards waste management, pollution control and large-scale energy schemes.

Many developing countries are firmly committed to biogas development (12). Their programmes tend to be on two different levels:

(i) The research, development and early demonstration stage where the technology is tested and replicated at field sites;

(ii) The extension and diffusion stage where a large number of digesters are constructed.

The dissemination of BGT is occurring rapidly in China, India, Thailand, the Republic of Korea and Taiwan and it is expanding rapidly in countries like Brazil, Egypt, Guatemala, Mexico and Nepal. Around 50 developing countries operate BGT programmes at one stage or another.

The following is a brief account of three case studies pertaining to China, India and Egypt.

1. China (10,11,14,17)

Although the development of BGT in China began in the early 1920s, rapid progress was not made until the early 1970s when there was widespread use of the technology. By the early 1980s, about seven million digesters had been built to supply biogas and organic fertilizer to 30 million members of rural communes. Most of these digesters were installed in Sichuan, an agriculturally productive province on the western edge of China's agricultural zone.

Biogas plants in China are generally found in regions where climatic conditions are favourable, feed materials and supplies satisfactory and fuelwood resources scarce. Most of the units that have been installed are of a spherical or oval water-pressure, fixed-dome type. Recently, the bag digester, made of red mud plastic, has gained wider acceptance owing to its reasonably low cost, ease of handling and installation, higher gas productivity and durability.

Most of the Chinese digesters are family-size plants. Manure from communal piggeries and state farms is also used for numerous large-scale plants; the gas produced is often used to provide mechanical or electrical power. Over 400 small and large generators provide electricity for domestic and industrial use, and small, two-wheel tractors powered by biogas are quite common. Some large facilities generate gas on a scale sufficient to make it economical to compress the gas for use in trucks and buses.

The number of operational plants in China has recently declined owing to certain unavoidable, mostly technical problems that require more attention and research before a solution can be found. The problems encountered include the following:

(a) Poor construction and use of cheap materials which result in gas leakages;

(b) Low gas productivity during winter;

(c) Difficulty in emptying the digesters and transporting the wet sludge.

A large number of institutes are involved in research and development activities relating to BGT. These include: the Chengdu Institute of Biology, the Chengdu Research and Training Centre for Biogas Development and Extension, the Beijing Institute of Solar Energy, the Agricultural University of Zhejiang Province, the Shanghai Institute of Industrial Microbiology, the Sichuan Biogas Extension Office and the Guangzhou Institute of Energy Conversion. Recent research in China has been directed towards improving the efficiency and economy of various designs and operating methods that will meet the needs and resources of the Chinese countryside (18).

The measures taken to popularize BGT in China are impressive. Recent analysis (19) suggests that the secret of China's success can be attributed to the following:

(i) The expansion of problem-oriented research programmes;

(ii) Strong and well-defined organizational support for training in construction, installation and the management of plants;

(iii) Strong and effective biogas popularization campaigns;

(iv) A sound policy of financial assistance for beneficiaries;

(v) The organizational system of rural China, with its strong links between commune, brigade team and individual households.

Research and development (R and D) is appraised in widely-publicized conferences that also provide an opportunity to exchange detailed research experiences. In addition, meetings of the directors of the biogas offices of major provinces and cities are held every year, in which detailed discussions and planning for future courses of action take place.

Extensive efforts have been made to train BGT technicians. The Government finances regular training courses lasting 2-4 weeks, which cover basic theory, as well as practical experience in building several digesters. The courses are aimed at the training of trainers. Two or three people from an area are trained; they then return to their villages to train others.

In order to disseminate information on biogas to technologists (11) and provincial and local officials, a comprehensive institutional infrastructure has been established within the State Leading Group on Biogas Construction. It is composed of representatives from various departments of the State Council. The executive institution SOBUE holds annual meetings for the directors and staff of biogas implementation agencies and research institutions in which projects are discussed and activities in biogas are co-ordinated. Meeting of technical panels dealing with fermentation, digester construction, biogas utilization, digested slurry utilization and sanitation are also held annually.

Most of the finance for biogas plants in China comes from three sources (10):

<u>a</u>. Farmers' own incomes (and contributions made in kind), which usually cover between 20 to 50 per cent of total costs in rural areas;

<u>b</u>. The investment funds of the team, brigade or commune, which cover 20 to 50 per cent of total costs;

<u>c</u>. Central Government funds in the form of subsidies, which range from 30 to 40 per cent of total costs.

China's programme for propagating BGT is well-conceived and institutionally-structured, and integrates R and D, implementation, financing and extension within a cohesive, national biogas policy and plan.

2. <u>India</u> (10,11,12,14 and 17)

The history of biogas in India dates back to 1897 (10) when one of the first biogas plants in the world was built at the Matunga Homeless Lepers' Asylum near Bombay. Biogas R and D has been taking place in India since the late 1930s. In the 1960s, the Indian biogas programme gained impetus with the involvement of a number of institutions in R and D and limited field promotion.

In particular, government encouragement of the Khadi Village Industries' Corporation (KVIC) to take up BGT as one of its rural development programmes, by which it provided subsidies and incentives (about 50 per cent of the cost) was instrumental in maintaining interest in India in this technology (20).

In the 1970s, biogas was identified as a potential renewable source of energy. Co-ordinated research and its promotion on a national scale led to the establishment of about 100,000 biogas plants, most of which were individually owned, family-size plants that used cow dung. Most of the digesters were of the floating gasholder KVIC design, while the remainder were mainly of the Janata type (modified Chinese fixed-dome design).

Further promotion and infrastructural institutional development has taken place in the 1980s. By 1983, the total number of biogas plants in India rose to about 0.28 million (20). A programme was begun to install 0.15 million plants by 1985, the final year of the sixth plan. In the seventh plan period, a target of six million plants has been proposed.

The Indian Government now gives greater priority to the development of community-sized plants designed to spread the benefits of BGT among the lower social strata of the rural community. Similarly, and concurrent with use of larger scale plants, there has been increased interest in using biogas as a propulsion fuel for pumping, power-generating and threshing, and a number of engineering industries have entered the market to manufacture dual-fuel engines and generating sets.

The Indian biogas programme encountered a number of problems. The main constraints include the following:

(a) A reduction in gas production during the cold season;
(b) Slurry disposal;
(c) Microbial efficiency;
(d) Rich-poor differentials in the beneficiaries of biogas;
(e) Cost of the biogas plant;
(f) Operating failures of installed units.

Many of these problems can probably be tackled through research, a massive effort in manpower training, emphasis on the fertilization value of the digested slurry and a well-planned and executed programme for large scale village-community and/or institutional plants.

3. Egypt

Egypt's first experience with BGT was in 1938, when a 750 m^3 sewage-sludge digester and 1,500 m^3 separate gasholder were installed at Al-Gabal al Asfar in Cairo. Though research commenced at the laboratories of the Ministry of Agriculture, R and D and demonstration activities only began in 1978/1979, when three major biogas programmes were initiated at the Agricultural Research Centre (ARC) and the Fayum Faculty of Agriculture at Cairo University. The major objectives of these programmes were to demonstrate and assess the feasibility of BGT in the rural areas of Egypt.

Apart from experimental-scale units, at present there are more than 50 field demonstration units of various designs and scales. Although the initial designs were adopted or adapted from Indian and Chinese models, newer Egyptian innovations were introduced later.

The following major conclusions were reached (15,16,21):

(a) Field demonstrations manifested the technical feasibility of suitably designed and installed rural biogas systems. Implementation and operation can be managed through the use of local resources, most of which are available in the village setting;

(b) There are indications that rural biogas systems are socially acceptable if they are properly demonstrated. The benefits of the system are visible and perceptible, particularly when there are improvements in the general level of sanitation and quality of life;

(c) Despite the relatively high initial cost of investment, these systems are economically viable if applied to appropriate situations and if all of the tangible benefits are realized. The benefits include fuel gas, organic fertilizer and the sanitary disposal of waste;

(d) Currently available designs for household units are viable if they fulfil two-main prerequisites:

(i) There is sufficient space within the house unit to install a biogas plant, including the ancillary treatment equipment;

(ii) Ownership of at least four large animals;

(e) Large units attached to animal-rearing operations should be mechanized and preferably heated;

(f) The widespread propagation of BGT in the rural areas of Egypt requires the development of modified and new designs that provide:

(i) Large-scale prefabrication of whole or partial units in order to reduce costs and alleviate leakages and other construction problems that result from the poor workmanship which often exists under village conditions;

(ii) A relatively shallow underground structure which avoids the problem of prevailing high water-tables;

(iii) An appropriate heating system which will raise gas productivity, particularly during winter;

(iv) The possibility of using agricultural residues where there is insufficient manure substrate;

(v) A minimum space requirement;

(g) On the basis of the technology currently available, it would be possible to install some 400,000 units throughout rural Egypt, provided that the proper institutional infrastructure is developed and that endeavours are made at all levels. Any attempt to exploit biogas should be carefully considered;

(h) BGT prospects can be enhanced if new designs are developed in such a way that the major constraints of lack of space and insufficient animals are alleviated. The NRC programme emphasizes this important concept in its future engineering development work;

(i) Government support, especially in terms of financial incentives, grants and soft loans, is indispensable for the propagation of BGT, particularly in view of the existing highly-subsidized fuel pricing structure.

D. Major constraints to technology diffusion

Despite its multiple output and benefits, BGT has not achieved the rate of propagation that was expected in many developing countries. This can be attributed to various technical, economic, socio-cultural and organizational constraints that will be presented here. However, these constraints would seem to stem from the inability of the concerned developmental and promotional agencies to integrate BGT into the target social systems in a manner that meets real, perceptible needs at an affordable cost, and to provide an effective organizational infrastructure capable of dealing with planning, implementation maintenance, and follow-up, paying due regard to the available resources and prevailing constraints (15).

The major constraints and ways of lifting them have been classified as follows (22).

Technical constraint	Solution
Lack of optimum designs suitable for a variety of local conditions.	Develop proper R and D and engineering capabilities to study, transfer, adapt and innovate.
Poor local construction and equipment-manufacturing capacities.	Organize training and the formation of specialized integral teams furnished with the required tools and supporting equipment. Encourage the establishment of enterprises manufacturing ready-made parts and ancillary equipment.
Operational problems such as pin-hole leakages, corroded parts, water condensation in gas lines, scum formation, blockages and burner problems.	Organize the proper training of users and the participation of "women-users". Establish extension and maintenance services and regular follow-up, at least initially.
Low gas production during winter.	Apply known technical solutions, including insulation, solar tents, solar-heated feed water and compost around the digester, add urine/water hyacinth, build the digester inside a shed and heat with biogas or heat from an engine exhaust.
Labour-intensive tasks associated with operating the digester and handling effluent.	Apply appropriate, tailor-made designs, modify the animal shed and develop tools to clean the digester.
Excessive water requirements, especially in dry areas.	Employ dry fermentation, recycle water from outlet, use urine and dilute less (to give a higher solid concentration).
Limited supply of animal wastes.	Avoid building a biogas plant, use dry fermentation or utilize other biomass substrates, develop more efficient digesters or community plants.
Lack of adequate space to site the biogas plant.	Construct a fized-dome digester inside a shed, a high-efficiency digester above ground (solar-heated mini-digesters) or community plants.
Problems in using the digested slurry, storing and the use of biogas, together with hygiene aspects.	Employ known technical solutions or develop suitable ones for local conditions (i.e., information and technical capability), educate users.

Economic constraint	Solution
High investment costs that are prohibitive for the majority of the rural population.	Develop less expensive designs and construction techniques and more efficient (planned) implementation schemes, build community plants, or give cash grants and soft loans.
Low economic returns and little, if any, generation of direct cash.	Demonstrate the indirect benefits (e.g. better fertilizer and sanitation), compare with other non-economical investment that meets human needs and increases comfort and modernization (e.g. TVs and cars), enact strict pollution control, in order to mainfest the cash gains to be made from improved sanitation and divert commercial fuels subsudies to biogas, a renewable source of energy.

Socio-cultural constraint	
Culturally deep-seated prejudices working against the use of some wastes, and illiteracy compounded by superstition and resistance to change.	Organize educational programmes, demonstrate by "seeing is believing", persude respected people within the community to use the technology and implement social research.
BGT is biased towards the richer strata of the rural society.	Scale incentives towards the lower-income peasant, develop dry fermenters that use agricultural residues for poor farmers, make digesters cheaper and more reliable or construct community plants.
Lack of or superficial identification of the true needs and priorities of target groups and users, making it difficult to offer a technology package suit their interest.	Implement socio-cultural studies by professionals in order to make biogas seem a necessary requirement (needs are seldom original, they are generally "created" by good marketing) and advertise biogas as a "market" product.
Existence of social differences and lack of co-operation where facilities and community plants are shared.	Establish proper management schemes and make community plants a service that benefits all of those involved.

Organizational/infrastructural constraint	Solution
Lack of nation-wide governmental policies and plans.	Convince leaders of the need for action and develop the interest of decision-makers.
Lack of efficient promotional packages, proper execution schemes, well-planned and monitored field experiments and demonstration, follow-up services and maintenance capabilities, R and D and engineering and centralized information and a co-ordination base, as well as appropriate information and communication flows.	Build full-time specialized organizational mechanisms based on through in-depth studies that are relevant to local conditions.

E. Impact of BGT in rural areas(23)

Although BGT, like any other technology has both a positive and negative impact, its positive benefits far outweigh the negative aspects. It is a multi-faceted technology that through rural applications can have a considerable impact on energy, agriculture, public health and sanitation. The technique can also be adapted to a variety of technical and social conditions (24).

1. General impact

The benefits include the following:

(a) Energy generation leading to the substitution of firewood, dung cakes and fossil fuels (25). This results in the preservation of forests and a decrease in soil erosion, the conservation of soil nutrients and the saving of foreign exchange required to buy fossil fuels (or an increase in income owing to higher exports);

(b) An increase in agricultural yields resulting from the use of digested effluent;

(c) The sanitary disposal of wastes;

(d) Improvements in hygiene and living conditions.

The negative effects include the following:

(i) Deforestration (25) owing to the fact that animal dung is traditionally a free source of fuel. With the introduction of BGT, the dung will be used as a substrate by livestock owners which may force poorer people to switch from dung to firewood;

(ii) The relatively high initial investment required to establish a biogas production plant may ential a "social cost" for the peasant who has to defer or abandon other urgent needs because of the scarcity of financial resources on the part of the majority of rural population;

(iii) In certain instances the loss of time during the construction of the biogas plant (26);

(iv) Shortage of water in places where water is scarce, as water is normally needed to dilute feed materials;

(v) The handling of liquid digested slurries can be an added burden, as well as a distasteful job;

(vi) The increase of social disparities as biogas units are generally owned by well-to-do farmers;

(vii) The creation of social differences where biogas facilities are shared by the community (27).

It is worth noting the following:

a. Many estimates of the eventual nation-wide potential for biogas in energy supply are over-optimistic. Such appraisals assume the production of generous amounts of animal and human wastes, high estimates of their availability (collectable wastes), a good year-round biogas generation rate, and the optimum propagation of the technology. Realistically, the contribution of biogas to national energy budgets is likely to be small (about 1-10 per cent) (12). However, for many developing countries this could constitute a substantial part of rural energy supplies (in the order of 50 per cent).

b. Most of the negative effects, unlike the positive ones, are not of a general nature. In fact, many can be alleviated or substantially reduced by careful planning and by taking the appropriate corrective measures. For instance, the "social-cost" factor relating to the high initial investment can be alleviated through the provision of governmental cash grants or soft loans, as has been the normal practice in India. Shortages of water can be solved technologically, for example by resorting to the "dry fermentation" technique.

c. Optimizing designs, operations and use of the entire output of biogas systems is a key to maximizing the positive benefits of the technology. The true potential of BGT can be realized when its integrated place in the food-feed-fuel-sanitation system is better demonstrated.

2. Individual versus societal impact

The benefits of BGT should be viewed and assessed from two perspectives: the individual (or owner) and societal (or national). To a certain extent, these depend on the area of use of the biogas system, whether it is family, community or commercial (large animal-rearing operations, for example). In general, BGT can easily be integrated into rural life, as it has various uses that are compatible with village conditions.

BGT has made remarkable changes to lifestyles and has brought other tangible benefits to individuals who have access to biogas plants (22, 28 and 29). The positive effects on individuals as well as on society at large are listed below.

(a) Impact on beneficiaries

(i) Offers a clean and efficient energy source that results in cleanliness in the kitchen, is time-saving and does not produce smoke that can cause eye and chest ailments;

(ii) Obviates the need to collect firewood, therefore it is more convenient, saves time and reduces the incidence of snake bites (as snakes often live in piles of firewood) (29);

(iii) Results in a cleaner animal shed, which leads to improved sanitary conditions, and the better and cleaner milking of cows (28);

(iv) Allows more frequent bath-taking (29);

(v) Provides hot meals (29) and tea for the family (28);

(vi) Saves money that is normally spent on fuel and fertilizer;

(vii) Provides for the sanitary disposal of human wastes by connecting latrines to digesters (28);

(viii) Reduce the number of flies, pathogens and parasites.

(b) Societal impact

(i) Provides a locally available renewable energy resource, thus reducing the consumption of commercial energy sources;

(ii) Partially resolves the uncertainty of energy supplies as there is less dependence on outside sources of energy;

(iii) Offers a solution to deforestation problems, as there could be a considerable reduction in the consumption of firewood (depending on the scale and extent of BGT propagation);

(iv) Conserves resources by recycling organic matter to the soil, thus increasing agricultural productivity and reducing dependence on chemical fertilizers;

(v) Increases productivity by improving health and the quality of life of the rural population;

(vi) Has a multiplier effect in view of the ease with which BGT is integrated into rural development, health care schemes, etc., which results in self-reliant and self-sufficient societies.

F. Assessment of the feasiblity of rural biogas systems (30)

The rational and effective diffusion of biogas technology has to be preceded by an objective, well-founded feasibility assessment. This assessment should include such pertinent aspects as: market analyses, technical feasbility studies, investment and production cost analyses, financial appraisals and socio-economic cost-benefit analyses. An attempt has been made to present a preliminary exposition of these facets and to recommend prospective techniques to tackle them (30).

BGT should be treated as a marketable commodity whose demand is developed through a "technology push" market creation-type of process. Market studies must therefore endeavour to cover the various relevant factors pertaining to uses, users and alternative technologies, and end with proposed realistic market strategies, promotional plans, and the required organizational structures.

The technical part of a feasibility study should include an assessment of the technical feasibility of the installation and successful operation of the biogas plant. In addition, it should cover technical details relating to site location and the appropriate digester, system design and size, as well as the factors of construction and production.

Investment costs are relatively easy to estimate, and a standard format is proposed for their computation. On the other hand, production costs pose certain difficulties that are primarily related to the lack of reliable field data and to the pricing of non-tradable inputs. Suggestions based on experience as to how these problems can be avoided are presented.

Similarly, financial analyses are complicated by the problem of how to quantify non-tradable outputs in monetary terms that are based on actual market prices. Although the direct benefits of biogas systems usually include just the gas and effluent, it is possible to include the disposal of the affected waste as an important direct and tangible benefit. The three outputs may then be priced in terms of the alternative they are supplementing or displacing at the point of use. In the case of the use of effluent as a fertilizer, however, the recommendation is that it should be given a value relative to farmyard manure (FYM), which can be estimated from the proportional agronomical yields.

It is more difficult to make socio-economic cost-benefit analyses, but it is worth while to do so, as they can assess feasibility on a macro-level, and reveal the impact of social welfare factors and environmental considerations. In view of the variety of social systems and the insurmountable difficulty of quantifying primary and secondary inputs and outputs in absolute terms, the simplistic "system net change" approach is recommended (31).

In view of the numerous possible sources of inaccuracy it is recommended that the feasibility analyst make the fullest use of sensitivity analyses in order to carry out a specific and reliable appraisal. Accordingly, the analyst should provide a set of relevant appraisals that cover both optimistic and pessimistic scenarios in order to help the evaluators and decision makers to take appropriate decisions.

II. PROSPECTS OF BGT IN DEMOCRATIC YEMEN

A. Overview of the major characteristics of Democratic Yemen

Any analysis of the prospects of BGT in Democratic Yemen should be viewed in the broader context of the general characteristics of the country - those relating to such basic features as its geography, demography, climate, economic structure, agriculture and institutional infrastructure which are discussed below.

1. Geography

Democratic Yemen occupies the south-western corner of Asia and the Arab Peninsula, lying between latitudes 12°40' and 19°00'N and longitudes 30° to 43°. Democratic Yemen looks out over Africa across the strait of Bab al Mandab, south of the Red Sea, and has a total land area of 336,869 square kilometres (km^2).

In 1980, Democratic Yemen was divided adminstratively into six governorates. These are: Aden, Lahej, Abyan, Shabwah, Hadramawt and Mahrah. Each governorate is divided into a number of districts, which are in turn divided into 2-5 centres as is depicted in figure XIV (32).

2. Demography

The total population of Democratic Yemen was estimated to be 2.003 million in 1982 (32). Annual population growth has been about 2.7 per cent over the last few years. According to the 1982 census, population density varied between 1.2-52.6 persons/km^2, with an average of 5.9 persons/km^2, as is shown in table 1.

Table 2 gives the population distribution for the different governorates. The rural governorates (except for Aden) mainly consist of a large number of small population agglomerations of between 100-5,000 persons. Only in Hadramawt Governorate are there 12 comparatively large agglomerations (towns) with a population of 5,001-20,000 (32).

It is generally difficult to differentiate between the urbanized and rural sector. However, since the main concern is the places where animals are found, groups of more than 5,000 persons will arbitrarily be considered as a town belonging to the urbanized sector, since animal holdings in such towns are expected to be small. All other agglomerations containing less than 5,000 persons will be considered as belonging to the rural and nomad sectors. Thus, according to the Statistical Year Book of 1984 (see table 3) (33), the arbitrarily-defined urban and rural population can be estimated as follows:

Total population = 2,109,000 persons;
Population of towns $>$ 5,000 persons = 514,000 persons;
Population of rural and nomad sector = 1,609,000 persons;
Percentage of rural and nomad sector = 76.3 per cent;
Percentage of urban sector = 23.7 per cent.

3. Economic structure

Democratic Yemen declared its independence in November 1967.

Per capita income in Democratic Yemen is among the lowest in Arab countries. According to government estimates, gross national product (GNP) per capita was $US 293 in 1981 (34). However, economic indicators show that income has grown at a relatively fast rate since 1981.

The country has adopted a centralized socialistic regime in its development programmes. The first Five-year Plan 1974/1975-1978/1979, which had a total budget of 92 million Democratic Yemen dinars (YD), paid particular attention to the development of fisheries and the petroleum industry. YD 370 million were allocated to the second Five-year Plan (1979-1983). In 1980, the plan was revised and extended (1981-1985). Emphasis was placed on oil refining, cement and salt industries, fisheries and agriculture (34).[1/]

Exports from Democratic Yemen are quite limited, being mainly confined to refined petroleum products, tobacco, fish and cotton. The main sources of income are foreign aid, expatriate remittances and income from traffic passing through Aden port.

4. Agriculture

The area of cultivable land in Democratic Yemen is in the region of 279,000 acres (see table 4), which constitutes less than 0.4 per cent of the total land area. The actual area of cultivated land is much less, constituting only about 131,000 acres, or around 0.15 per cent of the land area of the country (32).

The area of cultivated land in the different governorates (32) are given in table 4. The most intensively cultivated governorates are Abyan, east of Aden (55,891 acres) and Lahej, north of Aden (27,876 acres). The valleys of Hadramawt are also fertile and contain about 37,515 acres of cultivated land.

Democratic Yemen has a good potential for agricultural development. The financial means to achieve this are, however, a major deterrent. With the aid of a number of Arab and international organizations, the Government is focusing its attention on agricultural development projects. These include the reclamation of new land, development of irrigation, the building of dams and storage facilities for flood control and rainwater utilization and the introduction of new farming methods.

1/ Democratic Yemen, Ministry of Planning, Five-year Plan for Economic and Social Development (1974/1975-1978/1979 (Aden, 1974) (in Arabic); Five-year Plan for Economic and Social Development (1979-1983), 2 vols. (Aden, 1979) (in Arabic); Third General Plan (1983) from the Second Five-year Plan for Economic and Social Development (1981-1985), 2 vols. (Aden, 1982) (in Arabic).

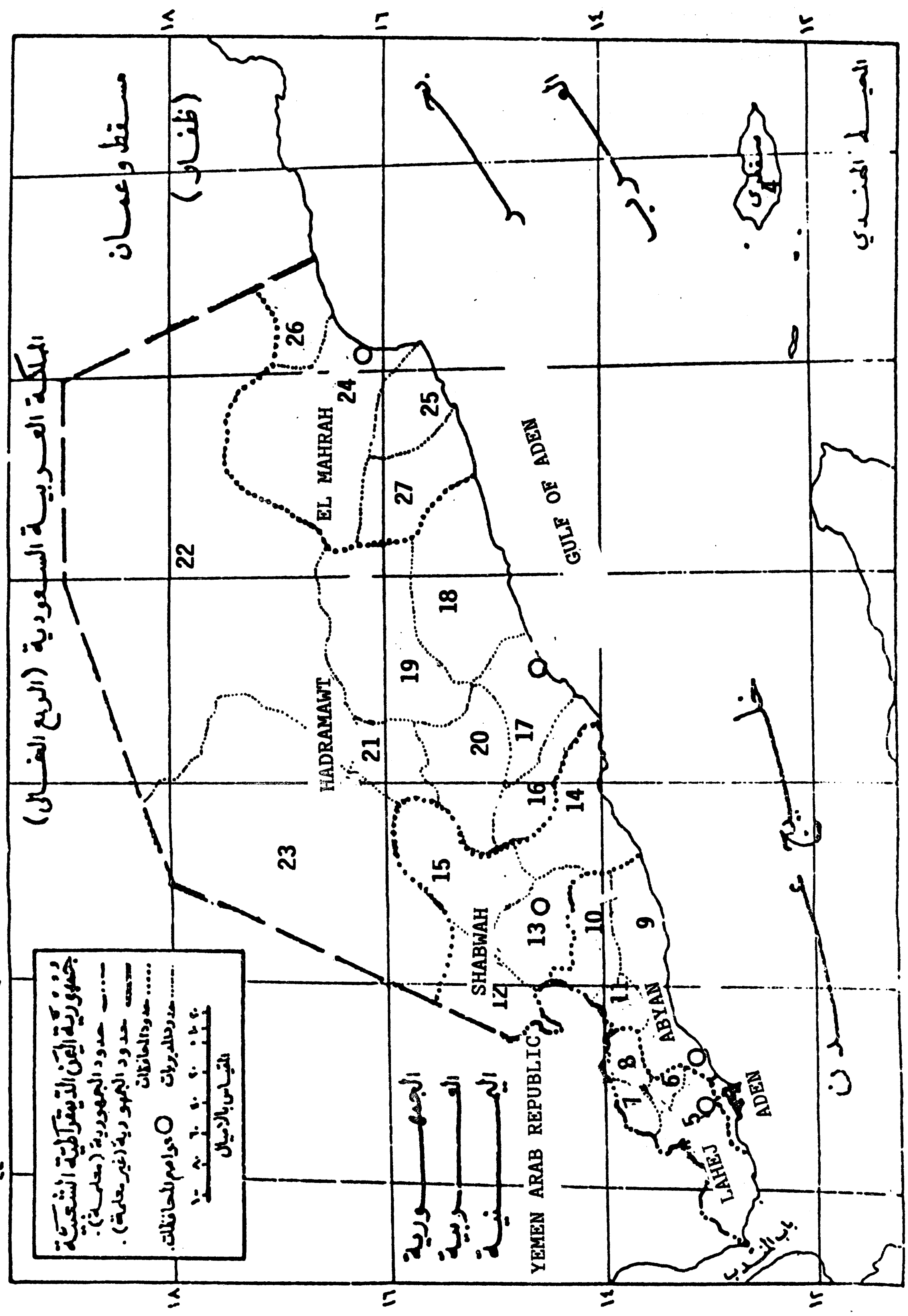


Figure XIV. <u>Map of Democratic Yemen</u>

Legend: Administrative divisions of Democratic Yemen

Governorates	Number	Districts	Centres
Aden	1	Serrah	1. Crater 2. Khormaksar
	2	Madinat Ash Sha'b	1. Shaykh Uthman 2. Little Aden
	3	Al Mina	1. Tawahi/Mayoon 2. Ma'alla
	4	Socotra	1. Hadebo 2. Qalansyah
Lahej	5	Tuban	1. Al Hota 2. Almusaimeer 3. Karish 4. Tor Al Baha 5. Al Madharibah
	6	Radfan	1. Al Habeelain 2. Al Qasha'ah 3. Habeelgabr 4. Habeelraidah
	7	Ad Dali	1. Ad Dali 2. Ash Shuaib 3. Al-Huswain 4. Al Azariq
	8	Yafee	1. Labous 2. Al Had 3. Yahar
Abyan	9	Khanfar	1. Ja'ar 2. Ahwar 3. Rosad/Al-Qarah
	10	Mudiyah	1. Mudiyah 2. Almahfid 3. Gaishan
	11	Lawdar	1. Zarah 2. Al-Wadhi 3. Mukayras
Shabwah	12	As-said	1. As Said 2. Ataq 3. Habban
	13	Nisab	1. Nisab 2. Markhah 3. Hateeb
	14	Mayfa'ah	1. Mayfa'ah 2. Rodhoom 3. Ar-Rodhah
	15	Irmah	1. Irmah 2. Girdan 3. Dahr/At-Talh
	16	Bayhan	1. Al Ulya 2. Usaylan 3. Ain
Hadramawt	17	Al Mukalla	1. Al Mukalla 2. Ghayl Ba Wazir 3. Burum
	18	Ash Shihr	1. Shihr 2. Addis/Al Hami 3. Ar Raydat/Qusayir 4. Ghayl Bin Yamen
	19	Saywun	1. Saywun 2. Tarim 3. Shibam 4. Sah 5. As sawn
	20	Duan	1. Huraydah 2. Wadi al Ain 3. Amd 4. Saif
	21	Al Qatn	1. Al Qatn 2. Sor 3. Hawra 4. Rekhyah
	22	Hajr	1. Al Gool 2. As Sadarah 3. Yeba'ath
	23	Thamoud	1. Thamoud 2. Ramah 3. Al Qof/Hazar
	24	Al-Abr	1. Al Abr 2. Hajr As Sayar 3. Manwakh
Mahrah	25	Al Ghaydah	1. Al Ghaydah 2. Faidami 3. Mana'ar 4. Habroot
	26	Qishn	1. Qishn 2. Haswain
	27	Hauf	1. Cathib 2. Damqawt
	28	Sayhut	2. Sayhut 2. Itab 3. Al Masilah/Qalana

Table 1. Density of population by governorates, 1973 and 1982

Governorate	Area (km^2)	1973 Population	1973 Density ($persons/km^2$)	1982 Population	1982 Density ($persons/km^2$)
Aden	6,980	291,376	41.6	367,134	52.6
Lahej	12,766	273,611	21.4	344,750	27.0
Abyan	21,489	311,142	14.5	392,039	18.2
Shabwah	73,908	161,966	2.2	204,077	2.8
Hadramawt	155,376	491,304	3.2	619,043	4.0
Mahrah	66,350	60,876	0.9	76,704	1.2
Total	336,869	1,590,275	4.7	2,003,747	5.9

Source: Democratic Yemen, Ministry of Planning, Central Statistical Organization, Statistical Year Book, 1983.

Table 2. Distribution of population according to size of settlement

Governorate	100	101-500	501-1,000	1,001-2,500	2,501-5,000	5,001-10,000	10,001-2
	Size of Settlement						
Aden	57	28	11	17	11	8	8
Lahej	37	565	65	15	2	-	1.
Abyan	33	568	52	27	7	1	1
Shabwah	8	271	50	19	3	-	-
Hadramawt	73	314	67	31	10	8	4
Mahrah	2	23	9	9	2	-	-
Total	210	1,769	254	118	35	17	14

Table 3. Estimated population of main towns, by sex (1973-1984)

(Thousands)

Town	1984			1980			1973		
	Total	F	M	Total	F	M	Total	F	M
Tawahi	21.8	9.1	12.7	19.8	8.3	11.5	16.5	6.9	9.6
Khawr - Maksar	19.7	9.1	10.6	17.8	8.3	9.5	14.8	6.9	7.9
Crater	72.0	31.6	40.4	65.0	28.5	36.5	54.3	23.8	30.5
Ma'alla	62.6	27.4	35.2	56.4	24.7	31.7	47.1	20.6	26.5
Dar Saad	34.9	15.0	19.9	31.5	13.5	18.0	26.3	11.3	15.0
Shaykh Uthman	37.7	15.2	22.5	33.8	13.6	20.2	28.3	11.4	16.9
Mansoora	39.5	19.1	20.4	35.7	17.2	18.5	29.8	14.4	15.4
Little Aden	29.9	12.7	17.2	27.1	11.5	15.6	22.6	9.6	13.0
Al Hota (Lahej)	15.5	7.2	8.3	14.0	6.5	7.5	11.7	5.4	6.3
Ad Dali	3.9	1.7	2.2	3.6	1.7	1.9	3.0	1.4	1.6
Al Waht	3.3	1.6	1.7	3.0	1.6	1.4	2.5	1.3	1.2
Zinjibar	7.6	3.1	4.5	6.9	2.8	4.1	5.7	2.3	3.4
Ja'ar	13.9	6.3	7.6	12.4	5.6	6.8	10.4	4.7	5.7
Ahwar	4.0	2.2	1.8	3.6	1.9	1.7	3.1	1.6	1.5
Mudiyah	5.4	2.4	3.0	4.6	2.0	2.6	3.9	1.7	2.2
Lawdar	5.5	2.7	2.8	4.9	2.4	2.5	4.1	2.0	2.1
Mokeras	2.2	1.0	1.2	1.9	0.8	1.1	1.6	0.7	0.9
Ataq	1.8	0.8	1.0	1.7	0.7	1.0	1.4	0.6	0.8
Nisab	3.6	1.8	1.8	3.4	1.7	1.7	2.8	1.4	1.4
Al-Sa'id	1.6	0.8	0.8	1.4	0.7	0.7	1.2	0.6	0.6
Habban	2.3	1.4	0.9	2.1	1.3	0.8	1.8	1.1	0.7
Al Hota (Hadramawt)	3.8	2.3	1.5	3.4	2.0	1.4	2.9	1.7	1.2
Al Olya	6.3	3.2	3.1	5.7	2.9	2.8	4.7	2.4	2.3
Al Nqoob	1.4	0.5	0.9	1.3	0.5	0.8	1.1	0.4	0.7
Mukalla	59.1	29.4	29.7	53.4	26.6	26.8	44.6	22.2	22.4
Ghayl Ba Wazir	11.7	6.3	5.4	10.5	5.6	4.9	8.9	4.7	4.2
Ash Shihr	23.0	12.2	10.8	20.7	11.0	9.7	17.3	9.2	8.1
Saywun	25.4	13.5	11.9	23.0	12.2	10.8	19.2	10.2	9.0
Tarim	22.5	12.7	9.8	20.5	11.5	9.0	17.1	9.6	7.5
Shibam	4.4	2.6	1.8	4.0	2.3	1.7	3.3	1.9	1.4
Al Ghaydah	2.8	1.3	1.5	2.6	1.2	1.4	2.2	1.0	1.2

Key: F = Female; M = Male

Democratic Yemen's agricultural output is dominated by field crops, including cotton, wheat and cereals and animal fodder. Cotton is produced mainly in Lahej and Abyan. As can be seen from table 5, because of the low cash incentives offered to growers (34), the areas allocated to cotton cultivation have declined from 16,600 acres in 1980/1981 to 7,500 acres in 1983/1984. Wheat is mainly grown in Hadramawt and Beihan; in 1983/1984 the total cultivated area was 13,600 acres. Other cereals that are grown include barely, millet and sorgum, which occupied an area of about 60,000 acres in 1983/1984. Animal fodder occupies a relatively large area of 31,000 acres.

To a great extent, Democratic Yemen is self-sufficient in most vegetables, but potatoes, onions and some fruits are imported. Among the vegetables and fruits that are grown there are tomatoes, carrots, salad vegetables, melons, dates and bananas.

Table 4. Area of cultivable and cultivated land in the public sector and co-operatives of Democratic Yemen (1980-1981)

(Acres)

		Cultivated land		
Governorate	Cultivable land	Total	Irrigated by wells	Irrigated by floods
Aden	1,000	550	550	-
Lahej	54,154	27,876	10,287	17,589
Abyan	144,733	55,891	8,211	47,680
Shabwah	21,210	9,027	6,265	2,762
Hadramawt	58,166	37,515	22,635	14,880
Mahrah	-	-	-	-
Total	279,263	130,859	47,948	82,911

Table 5. Estimated production and area under crops (1980/1981-1983/1984) (33)

(Acres and tons)

Crops	1983/1984			1982/1983			1981/1982			1980/1981		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Cotton	7,465	2,184	0.293	11,154	2,942	0.264	13,080	3,850	0.294	16,569	5,193	0.313
Sesame	7,421	1,573	0.212	13,144	1,705	0.180	10,150	1,400	0.138	9,837	1,816	0.184
Coffee	1,533	930	0.607	1,533	930	0.695	1,533	930	0.607	1,533	920	0.600
Tobacco	553	732	1.324	803	671	0.836	820	840	1.024	1,033	811	0.785
Wheat	13,583	11,110	0.818	13,057	7,897	0.605	11,710	7,340	0.627	12,816	7,475	0.583
Other cereals	60,023	19,880	0.331	56,272	18,416	0.327	59,580	21,870	0.367	82,005	27,536	0.335
Tomatoes for canning	658	2,348	3.568	1,015	5,715	5.631	1,090	5,300	4.862	1,262	6,566	5.202
Vegetables	12,294	47,738	3.883	10,052	40,484	4.027	8,833	27,199	3.079	9,612	39,122	4.070
Water and sweet melon	2,971	7,456	2.509	4,910	11,540	2.350	4,379	9,616	2.196	2,743	6,991	2.548
Fruits	2,718	11,408	4.197	2,677	10,889	4.068	2,240	9,750	4.353	2,020	10,919	5.405
Dates	13,549	17,306	1.277	11,886	18,506	1.557	14,060	11,820	0.841	14,047	10,345	0.736
Alhina	-	243	-	-	243	-	-	290	-	-	1,233	-
Qat	-	1,136	-	-	1,106	-	-	1,106	-	-	1,083	-
Fodder	31,411	214,238	6.820	41,641	215,972	5.176	26,240	139,700	5.324	45,894	273,944	5.969

5. Institutional infrastructure

Democratic Yemen is a socialist country with a good institutional pyramidal infrastructure from the governmental level down to the village strata. The various organizations of the system appear to operate harmoniously, an important factor as far as the prospects of institutional BGT diffusion on a national level is concerned. The relevant organizations include the following:

(a) Ministry of Energy and Minerals (MEM);
(b) Ministry of Agriculture and Agrarian Reform (MAAR);
(c) Ministry of Local Government;
(d) General organization for Construction;
(e) General Union of Yemeni Women (GUYW);
(f) Defence Committees;
(g) College of Technology, Aden University.

The last three organizations warrant some explanatory notes.

(i) General Union of Yemeni Women (GUYW)

GUYW is an influential organization in Democratic Yemen. The union is organized on the national scale with the village as the base level. Figure XV illustrates the organizational structure of GUYW. Elected representatives at the governorate and district levels are full-time workers, while those at the centre and village levels work part-time, mainly in the evenings.

The general secretariat of GUYW consists of the following departments:

a. Organizational;
b. External affairs;
c. Culture and information;
d. Social and legal;
e. General activities;
f. Audit and control.

The external affairs department is the only high-level department. The other departments have corresponding sections in the provincial branches of the General Union of Yemeni Women in Aden, Lahej, Abyan, Shabwah, Hadramawt and Mahrah.

During the mission to Democratic Yemen, GUYW representatives at all levels showed that they were capable of contacting and convincing rural and bedouin inhabitants on a family level; if they were properly trained, they could take effective part in the implementation of BGT in Democratic Yemen.

(ii) Defence committees

Defence committees are also active organizations at the different country levels. The village representative of El Hobiel village was contacted during the mission and was quite helpful in obtaining data on the density of animals in the village. The task was done efficiently and quickly indicating the organization's capability of participating in future BGT activities.

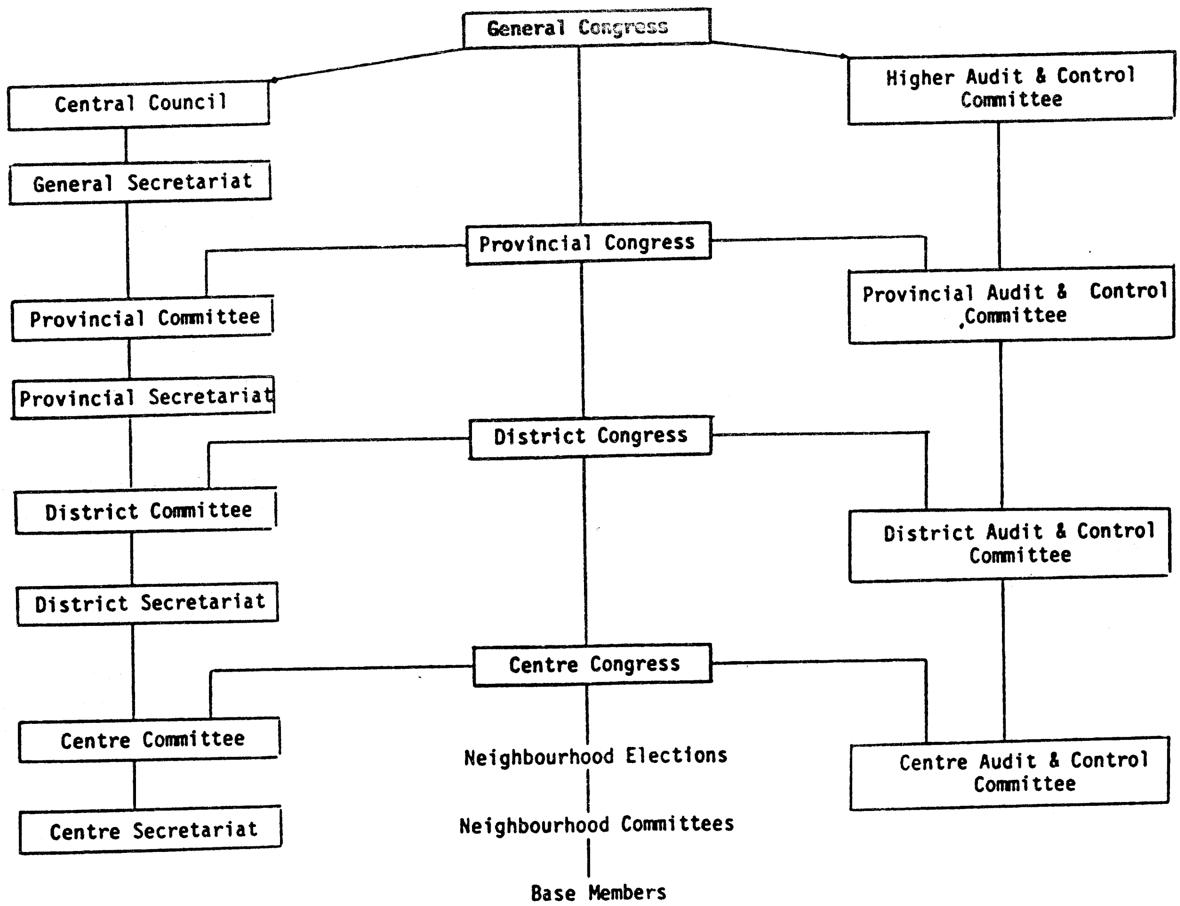


Figure XV. <u>Organizational structure of the General Union of Yemeni Women (GUYW)</u>

(iii) College of Technology, Aden University

The College of Technology has already carried out research work in renewable energy. Research and development could be directed towards the development of BGT. The College is capable of supervising the implementation stage and providing helpful extension services.

6. Climate

The climate of Democratic Yemen varies from one region to another, ranging from humid and hot to mild and cold.

(a) Rains and floods

Democratic Yemen is characterized by its low rainfall. Thus, in most areas rainfall does not exceed 100 millimetres (mm)/year. The exception (36) is the highly elevated areas and mountains, where rainfall can reach 400 mm/year. Occasionally rain falls for hours or even days. The water flows from the elevated areas down to the valleys, causing floods. The last flood occurred in 1982, destroying a large number of houses in rural areas, dams and cultivated fertile land. However, projects have now been undertaken to conserve flood and rainwater for irrigation purposes. Projects such as this would help to solve the acute water shortages, as well as alleviate the danger from floods.

It should be noted here that areas subject to flooding do not constitute favourable locations for BGT as they require special designs that involve elaborate and costly construction techniques.

(b) Temperature

The atmospheric temperature in most populated areas is relatively high throughout the year. As is indicated in tables 6 and 7, temperature variations are quite minor. In Aden Airport during the period 1978-1982 for example, the mean daily temperature varied from a minimum of 25.8°C in January to a maximum of 32.5°C in June, with a yearly average of about 29°C. Similar, though slightly lower values, were recorded in Mukalla Airport (Riyan). Temperatures such as these are favourable to biogas production in the highly populated coastal plains located along the Gulf of Aden. Temperatures in Saywun (Hadramawt Valley) are also favourable, except for the winter season (see table 10) (37).

Less favourable conditions prevail in high-altitude areas where temperatures fall much lower (see table 9) (37). Figure XVI (36) shows that areas with altitudes higher than 900 metres (m) constitute the major part of the land area of Democratic Yemen. However, population density in these areas is very low. No specific data is available on the number of families and livestock so it is not possible to make an estimate of the prospective number of generators needed for these comparatively colder areas.

Table 6. Air temperatures - Khormaksar Airport, Aden (1978-1982)

	Air temperature (°C)						
	Daily mean		Mean of		Absolute		Mean daily Temp.
	Max.	Min.	Highest Max	Lowest Min.	Max.	Min.	
January	28.5	23.3	29.3	20.5	30.0	18.5	25.8
February	28.9	23.4	30.0	19.5	30.4	16.4	26.0
March	30.1	24.8	31.5	21.5	32.0	18.0	27.1
April	31.9	25.6	33.5	22.8	34.5	21.6	28.6
May	34.1	27.5	38.0	23.6	39.3	21.9	30.7
June	36.4	29.0	38.8	27.0	39.9	26.1	32.5
July	36.2	29.0	39.0	27.2	41.0	25.6	32.2
August	36.1	28.1	37.9	25.7	38.6	24.0	31.7
September	34.9	28.3	37.5	25.7	38.0	25.2	31.3
October	32.5	25.3	35.0	21.1	38.0	20.2	28.9
November	30.8	22.9	33.0	19.4	35.9	18.4	27.0
December	29.1	23.4	30.1	19.8	30.5	18.9	26.2

Source: Democratic Yemen, Ministry of Planning, Central Statistical Organization, Statistical Year Book, 1983, 2nd ed. (Aden, 1984).

Note: Yearly average temperature = 29°C

Table 7. Air temperatures - Riyan Airport, Mukalla (1978-1982)

	Air temperature (°C)						
	Daily mean		Mean of		Absolute		Mean daily Temp.
	Max.	Min.	Highest Max	Lowest Min.	Max.	Min.	
January	28.0	20.2	30.2	17.9	31.0	16.5	24.7
February	28.0	20.6	30.1	17.3	32.0	16.0	24.8
March	29.5	22.7	31.5	20.0	32.5	19.2	26.5
April	31.3	24.0	33.3	21.5	34.0	20.5	28.2
May	32.8	26.3	34.7	24.2	36.2	23.0	30.0
June	34.5	27.1	36.2	25.2	37.0	24.0	31.1
July	33.4	26.1	35.5	24.0	35.8	22.4	29.9
August	32.7	25.7	34.6	23.9	35.5	23.0	29.9
September	32.0	25.7	33.9	23.3	35.0	20.9	29.2
October	30.9	23.0	33.1	20.3	34.2	19.2	27.7
November	30.5	21.2	33.5	18.1	34.4	16.8	26.6
December	28.7	20.4	31.2	17.4	32.0	16.0	25.2

Source: Democratic Yemen, Ministry of Planning, Central Statistical Organization, Statistical Year Book, 1983, 2nd ed. (Aden, 1984).

Note: Yearly average temperature = 27.8°C

Table 8. Air temperatures in Saywun (Hadramawt)
(altitude 540 m)

Temperature (°C)				
Mean (max.)	Mean (min.)	Absolute (max.)	Absolute (min.)	Yearly average (calculated)
40	20	51	8	30

Table 9. Air temperatures in high-altitude areas

		Temperature (°C)				
	Altitude (m)	Mean (max.)	Mean (min.)	Absolute (max.)	Absolute (min.)	Yearly average (calculated)
Mukeyras (Abyan)	2,000	27.1	9.1	31	-3	18.1
Ad Dali	1,400	29.1	14.6	37	4	21.9
Bayhan	1,000	33.1	16.5	48	4	24.8

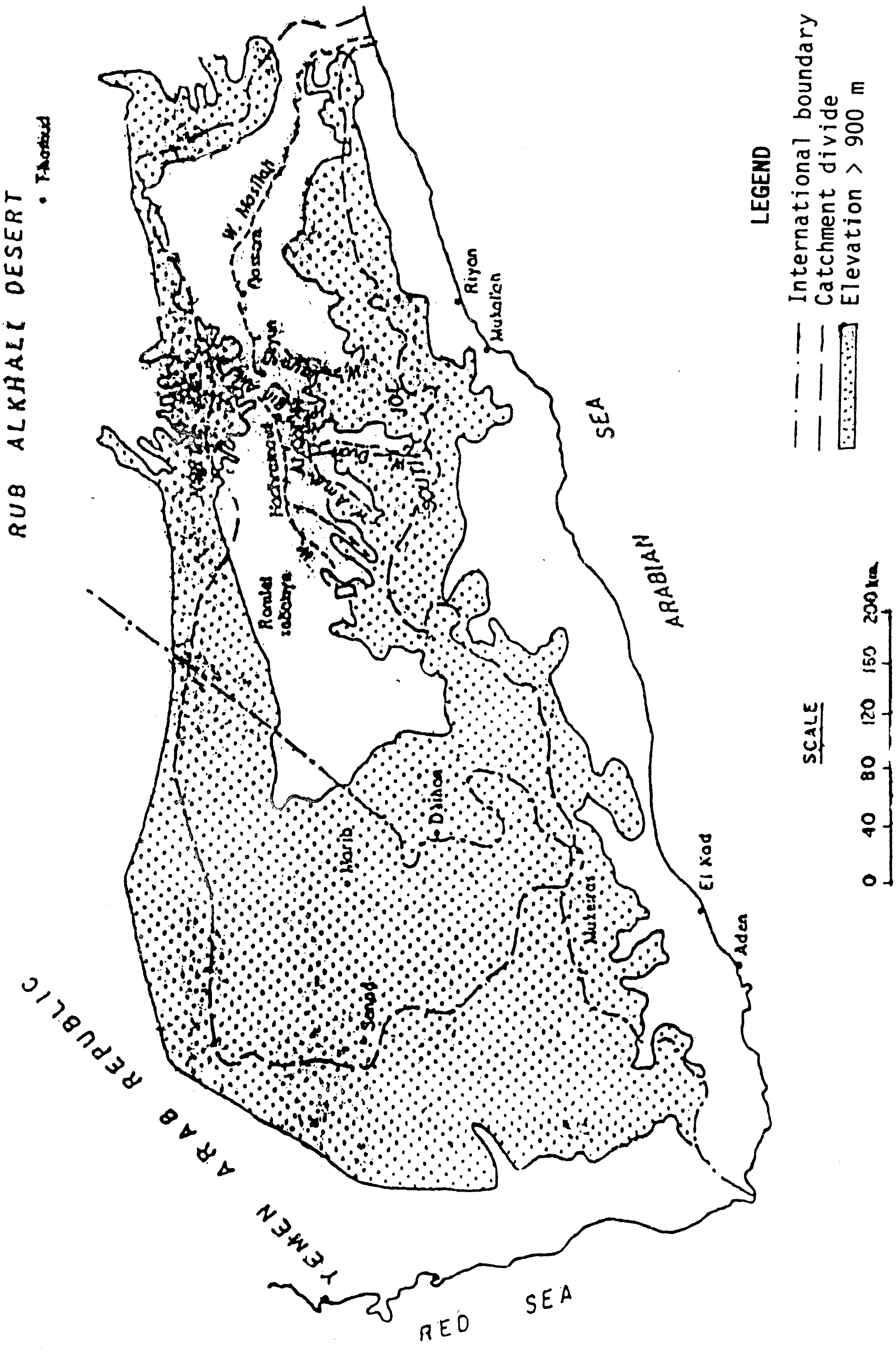


Figure XVI. Elevated areas in Democratic Yemen

B. Energy

At present, most of Democratic Yemen's energy needs are met by imported oil. Non-conventional energy sources such as biogas, wind and solar energy are not yet being utilized, though they have a good potential. Considerable emphasis has been placed on oil exploration, but the results to date have been disappointing (35). Data of the Yemen National Oil Company (YNOC) indicate that from 1975-1977 to 1981 the overall annual average growth rate in total consumption of oil products was 4.9 per cent. Table 10 shows the consumption of petroleum products in the period 1981-1986. Consumption during 1986 was expected to reach 652,900 tons. However, a World Bank report of 1984 expected the growth rate to be 10 per cent per annum (35). Table 11 shows the local price of products.

According to estimates for 1982 (35), 36 per cent of oil was used in power generation and in industry. The state transport sector accounted for 24 per cent and agriculture and fisheries 22 per cent, while private users consumed only 18 per cent.

No statistics on the consumption of different governorates are available. However, Mr. Taher Ben Yahia, Director of the Planning and Statistical Department of the Ministry of Energy and Minerals made available the following approximate figures on the consumption of petroleum products: 60 per cent for Aden Governorate (including central electrical power production), 7 per cent for Lahej Governorate, 7 per cent for Abyan Governorate, 7 per cent for Mukalla and the sea-shore, 9 per cent for Saywun and rural areas and 5 per cent each for Shabwah and Mahara Governorates.

Table 10. Democratic Yemen: consumption of petroleum products (1981-1986)

(Thousands of tons)

Product	1981	1982	1983	1984	1985	1986
Gasoline	74.1	77.9	79.4	89.5	94.0	95.9
Kerosine oil	108.7	114.1	116.4	121.1	127.9	130.5
Diesel oil	166.9	175.2	178.7	185.9	195.9	199.8
Residual oil	156.2	164.0	167.3	174.0	183.4	187.1
Liquid petroleum gases	12.6	13.2	13.5	29.1	30.6	31.2
Others	7.0	7.3	7.5	7.5	7.8	8.4
Total	525.5	551.7	562.8	607.4	640.0	652.9

Source: Compiled from figures supplied by Democratic Yemen, Ministry of Energy and Minerals, Planning Statistics Department.

Investment in electrical power production is considerable. Development plans for the electricity sector are based on the strategy of increasing the proportion of the population that has access to a public electricity supply and achieving a more even spread between regions in rural areas. The target (35) was to give 44 per cent of the population access to public power by 1985, (compared with about 29 per cent at the end of 1982), which represents 83 per cent of the urban population and only 22 per cent of rural areas. However, many residents in rural areas obtain power from small, privately-owned or local authority generators. The anticipated growth of demand is about 12 per cent a year (35).

Table 11. Prices of petroleum products (1986)

(Prices of fuel at Aden Installation)

Wholesale Price:	
Mogas premium 93 octane	985 fils/gallon
Mogas regular 83 octane	935 fils/gallon
Gas oil	385 fils/gallon
Fuel-oil	220 fils/gallon
Price of fuel at filling station:	
Mogas premium 93 octane	1.000 Dinars/gallon
Mogas regular 83 octane	950 fils/gallon
Gas oil	400 fils/gallon
Butane gas (12.5 kg cylinder)	1.750 YD

Source: Democratic Yemen, Ministry of Energy and Minerals, Planning Statistics Department.

Table 12 shows the country's existing and planned power generators. Figure XVII indicates the location of power stations.

Mr. Taher Ben Yahia stated that the production of electrical power was 429 x 10^6 kilowatt hours (kWh) in 1985. Consumption in the different sectors was as follows:

	Percentage
Industry	10.96
Petroleum refinery	10.02
Agriculture	13.05
Commercial and Transportation	20.98
Construction	3.03
Household	35.44
Others	6.52

Electrical power is priced according to its consumption rate and use, as follows:

	Price
Household consumption	
Consumption range:	
1-100 kWh per month	16 fils/kWh
101-200 kWh per month	27 fils/kWh
More than 200 kWh per month	50 fils/kWh
Industrial and agricultural utilization	39 fils/kWh
Commercial and other uses	55 fils/kWh

Table 12. General review of existing and planned power generators in Democratic Yemen

Station key name of power plant	No. of generator units	Rating data of generator unit kV[a]	kVA[b]	Installed capacity MW[c]	Available capacity MW	Year commissioned	Fuel
Aden Power System							
Hedjuff D	2	11.0	8,750	1 x 7.0	4.0	1966	GO
	2	11.0	4,250	2 x 3.4	5.4	1982	GO
Khormaksar 1 (F)	5	11.0	6,600	5 x 5.2	18.0	1975	HO
Khormaksar 2 (G)	4	11.0	2,500	4 x 2.2	8.0	1981	GO
Khormaksar 2 (J)	4	11.0	2,500	4 x 2.0	7.0	1981	GO
Al Mansura	8	11.0	10,200	8 x 8.0	60.0	1982	HO
Total existing					102.4		
Hiswa BAS	2	10.5	31,250	2 x 25	48.0	1988	HO
Hiswa EXT	3	10.5	31,250	3 x 25	73.0	1990	HO
Total under construction					121.0		
Ja'ar Diesel Power Station							
Ja'ar EX 1	2	0.4		2 x 0.5	0.9		GO
EX 2	1	6.6		1 x 0.8	0.7		GO
EX 3	3	11.0	1,875	3 x 1.5	4.0	1980	GO
New	2	11.0	1,875	2 x 1.5	2.5	1985	GO
Total existing					8.1		
Lawdar System							
Lawdar 1 UN 1	1	0.42	1,250	1.0	0.8	1980	GO
UN 2	2	0.40	250	2 x 0.2	0.4	1980	GO
Modia UN 1	2	0.42	230	2 x 0.2	0.3	1965	GO
UN 2	2	0.40	376	2 x 0.3	0.6	1978	GO
Total existing					2.2		
Mukayras Isolated							
Mukayras Isolated	14	0.4			1.5	most since 1981	GO

Table 12. (continued)

Station key name of power plant	No. of generator units	Rating data of generator unit kV[a]	kVA[b]	Installed capacity MW[c]	Available capacity MW	Year commissioned	Fuel
Wadi Bayhan							
Bayhan UN 1/UN 2	2	0.4	175	0.140	0.28	1978	GO
Bayhan UN 3/UN 4	2	0.4	291	0.232	0.46	1982	GO
Nisab System							
Ataq Unit 1	1	0.4	625.0	0.5	0.405	1981	GO
Unit 2	1	0.38	438.0	0.35	0.285	1980	GO
Nisab UN 1	3	0.4	312.5	0.25	0.690	1982	GO
UN 2							
UN 3							
Said	1	0.4	185.0	0.15	0.120		GO
	4	0.4	250.0	0.20	0.652	1985	GO
Mukulla System							
Khalf EX 1/2/3	3	11	3,500	3 x 2.8	7.5	1976	GO
Khalf New	1	11	5,800	1 x 4.6	4.0	1985	GO
Mansurah	2	0.4	1,074	2 x 0.86	1.6	1968	
	1	0.4	315	0.25	0.2	1968	
Ash Shihr System							
Ash Shihr 1	1	11	2,750	2.2	2.0	1985/1987	HO
Ash Shihr 2	1	11	2,750	2.2	2.0	1985/1987	HO
Ash Shihr 3	1	11	2,750	2.2	2.0	1985/1987	HO
Ash Shihr 4	1	11	2,000	2.2	2.0	1990	HO
Total under construction					6.0		
Shihr (isolated)		0.4	1,630	1.3	1.3	1966-1971	GO
Ghayl Ba Wazir private		0.4	920		0.7	1963-1978	GO
Deess[d]		0.4	500		0.4	1975-1980	GO
Hami[d]		0.4	240		0.18		GO
Shuhair (private)		0.4	70		0.05		GO

Table 12. (continued)

Station key name of power plant	No. of generator units	Rating data of generator unit kV[a]	kVA[b]	Installed capacity MW[c]	Available capacity MW	Year commissioned	Fuel
Qusayir, Ar Raydat							
Qusayir	1	0.4	250	0.2	0.2		GO
Qusayir (fish storage)	3	0.4	3 x 250	0.6	0.6		GO
Ar Raydat	2	0.4	2 x 165	0.26	0.25	1980	GO
Total existing					1.05		
As Qaraw							
Hadramawt UN 1	1	11	5,250	4.2	3.8	1982	HO[e]
Hadramawt UN 2	1	11	5,250	4.2	3.8	1982	HO[e]
Hadramawt UN 3	1	11	5,250	4.2	3.8	1982	HO[e]
Hadramawt UN 4	1	11	5,250	4.2	3.8	1982	HO[e]
Hadramawt UN 5	1	11	5,250	4.2	3.8	1985/1986	HO
Huraydah	1	0.38	200		0.19	1984	LO
Al Gaydah, Nishtun							
Al Gadan Old 1/2	2	0.4	2 x 175	2 x 0.14	0.280	1980	GO
Old 3	1	0.4	312.5	0.25	0.250	1984	GO
Nishtun	4	11	900	4 x 0.72	2.880	1984	HO
Total existing					3.410		
TWR At Bahah							
Centre	1	0.4	250	0.19	0.130		LO

Source: Fichtner Consulting Engineers (Federal Republic of Germany), Techno-economic study of the Electric Power Sector in the People's Democratic Republic of Yemen (Aden, Public Corporation for Electric Power, 1986).

Key: GO: gas oil; HO: heavy oil; LO: light oil.

a/ Kilovolt = kV.
b/ Kilovolt-ampere = kVA.
c/ Megawatt = MW
d/ Sixty per cent is covered by the Public Corporation for Electric Power.
e/ Presently run on LO as the supply of HO from Mukalla has not materialized due to lack of storage space.

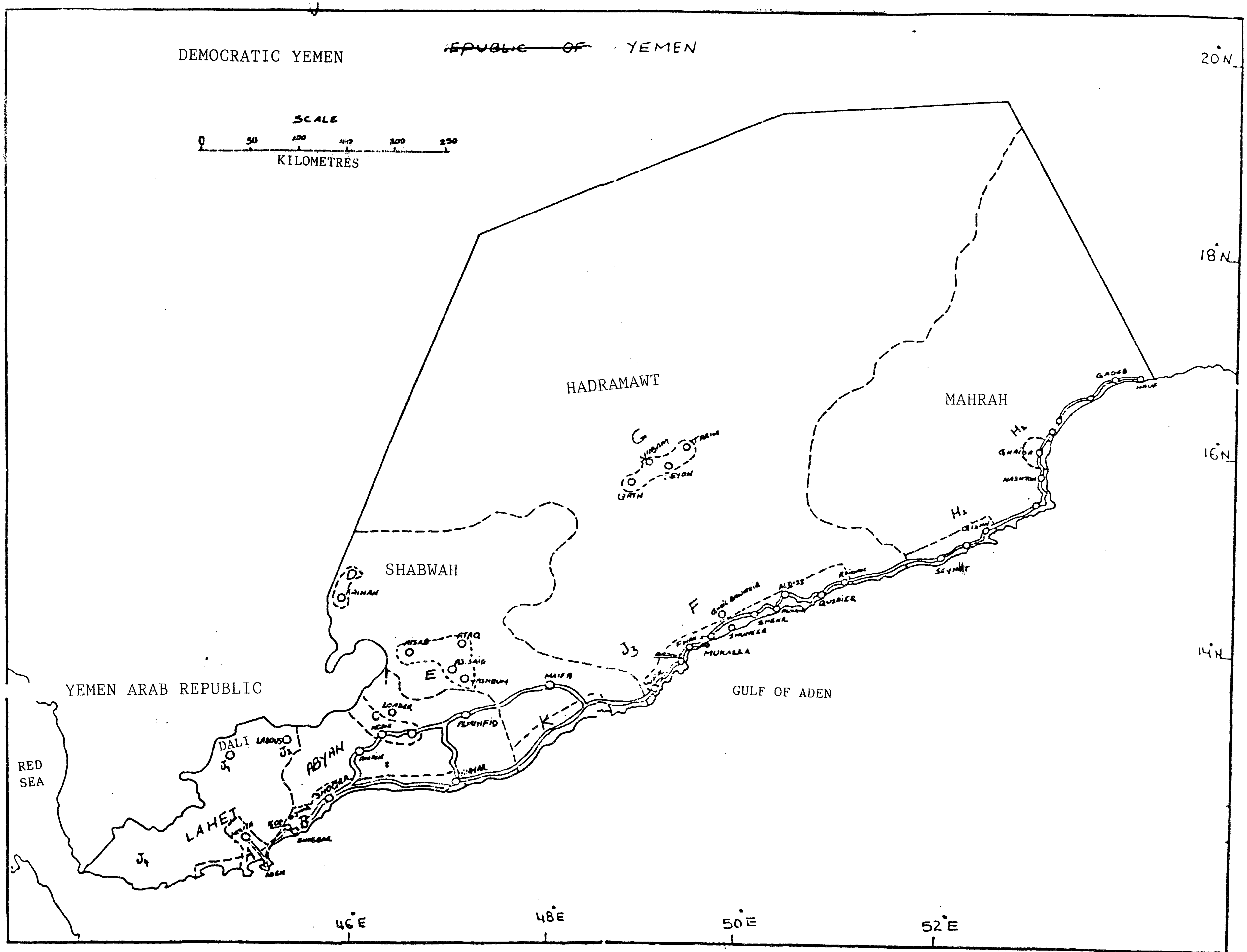


Figure XVII. Location of power stations in Democratic Yemen

1. Energy for household utilization in rural areas

Rural areas of Democratic Yemen depend mainly on biomass to secure their energy requirements which are needed for cooking and baking. Kerosine and butane gas stoves are also utilized, though to a lesser extent.

The main biomass sources in Democratic Yemen are wood, various stalks and straw collected from uncultivated desert land. The volume of agricultural waste is very small and is mainly used for animal feed. Small amounts of cotton stalks, available after grazing, are used as fuel in rural areas. There is a limited use of cow dung for fuel in rural areas.

It has been reported (38) that commercial energy constitutes only 2 per cent of household rural energy, while 98 per cent of energy needs are satisfied by biomass. Forest wood and stalks constitute 88.5 per cent of the biomass used, while crop residues and animal dung constitute only 2.5 per cent and 9 per cent respectively.

The combustion of biomass takes place in primitive rural stoves and ovens.

Figure XVIII shows a typical primitive mud stove similar to the traditional Egyptian "canoon" stove used in rural areas. The stove is open and has no grate or chimney. Combustion in the stove is incomplete, and harmful smoke containing a considerable amount of toxic carbon monoxide is emitted and accumulates in the kitchen. The health of women who prepare food in such a polluted environment is adversely affected, and children are also affected.

An evaluation of the efficiency of similar stoves indicates that it is only in the order of 5-10 per cent, which means that there is a considerable loss of the utilized biomass. This has been demonstrated in Egypt (at the National Research Centre, Cairo), where the efficiency of biomass stoves has been increased to around 30 per cent.

Figure XIX shows one of the baking ovens (bola) commonly used in rural areas of Democratic Yemen. The oven is a vertical mud cylinder, 50 cm in diameter and about 60 cm high. The lower part is closed while the upper part is open. It has a small opening located in the lower part which acts as an inlet for combustion air. Some designs contain an aperture for the removal of ash which is located in the lower part of the oven. The oven is operated by burning the biomass for about 15 minutes, then the bread is baked on the inner hot walls. Heat transfer takes place by both conduction and radiation. The combustion process is also incomplete, and smoke containing carbon monoxide is emitted, so the environment in the baking place is harmful. The process of baking is difficult and dangerous, as women put their hands inside the high temperature zone, which causes a lot of hand burns.

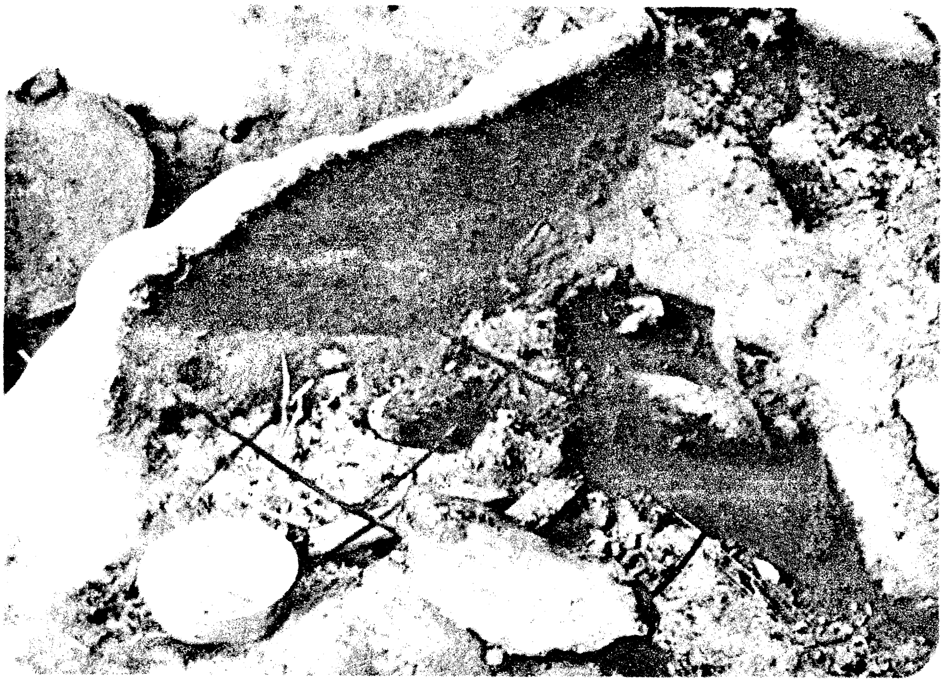


Figure XVIII. Typical primitive mud stove

Figure XIX. Typical oven (bola)

C. Animal Production

1. General

Animal waste constitutes one of the basic prerequisites for biogas production in rural areas as it is the main and most suitable feedstock. Therefore factors relating to animal production are treated separately in this section.

Livestock production has remained fairly static over the last ten years. The number of animals for the period 1976-1982 is shown in table 13. In the absence of more recent data, it is assumed that the present number of animals is the same as in 1982. In 1982 there were 1,250,000 goats, 800,000 sheep, 123,000 cows, 100,000 camels and 140,000 donkeys (39).

Livestock ownership is mostly (99 per cent) private. The governmental sector owns only 1 per cent of animals.

Animals are mainly grazed on natural pasture lands, which total about 9 million hectares (37 and 40).

The majority of cows are of a domastic breed, which is characterized by its small size (about 250 kg). Cow-raising is concentrated in the governorates of Lahej (which has about 60 per cent of the total number of cows in the country) and Abyan (41). New breeds of imported cows have been introduced on five large government farms in these two governorates.

Camels can be found in the desert and coastal plain areas. They are also characterized by their small size (40).

Table 13. Livestock in Democratic Yemen 1976-1982

(In thousands)

	Cows	Goats	Sheep	Camels	Donkeys
1976	90	1,200	750	100	130
1979	100	1,250	800	100	160
1982	123	1,250	800	100	140

Source: Paper entitled "Animal Production in Democratic Yemen" by Mr. Taher Ben Yahia at the Conference of Agricultural Engineers held in Kuwait, 1982.

Sheep are mainly reared in the cultivated areas of agricultural governorates (Shabwah, Hadramawt, Abyan and Lahej). They are also small in size, weighing about 20 kg/animal (41).

Goats are mainly found in the governorates of Hadramawt, Shabwah and El Mahara. There are several different breeds, usually small in size, which weigh between 18-25 kg/animal (41).

During the mission to Democratic Yemen it was not possible to obtain actual figures or a breakdown of the distribution of animals in the different governorates, centres and villages. This information was being prepared in 1987 by the Central Statistical Organization.

2. Large government animal farms

During the period 1972-1977, five large government animal farms were established with imported foreign breeds:

(a) Gaawala dairy farm

The Gaawala dairy farm, which is located in Lahej governorate near Aden, was constructed in 1972-1973. There are no large villages or communities near the farm. Operations were started with imported pregnant Friesian, Boran and Ayrshire cows. About 500 acres of land attached to the farm are available for the production of animal feed. However, only about half of this area is actually cultivated for this purpose; the rest remains uncultivated.

The farm consists of five sheds in which the distribution of animals as at October 1986 was as follows:

Shed number	Type of cow	Number of cows
1	Pregnant	90
2	Dairy	150
3	Dairy	170
4	Calves up to one year old	220
5	Pregnant and ready for delivery	170

As can be seen from figures XX and XXI, the animal sheds are well designed. The floors of the sheds are made of concrete with a slope to allow urine to drain to a central canal; from there it flows to a tank outside the shed. The lateral dimensions of each shed are about 20 m x 60 m. As can be seen from figure XXII, every shed has an open yard about double the size of the shed.

Green feed materials, either whole or shredded constitute the main source of animal fodder. Whole plants are used to feed the animals outdoors in the open yard as is depicted in figure XXIII. This practice would make it difficult to operate a continuously-fed biogas system, since an appreciable amount of stalks would remain mixed with the dung and lead to obstructions in the flow and excessive scum formation.

The farm produces milk with a sales price of 126 fils/litre (l) and the farm obtains a subsidy of 160 fils/litre.

The electrical power consumption of the farm and its agricultural annex runs at about 2,500 Democratic Yemen dinars (YD)/month. Based on a price of 39 fils/kWh, consumption is about 64,000 kWh/month. Consumption is distributed as follows:

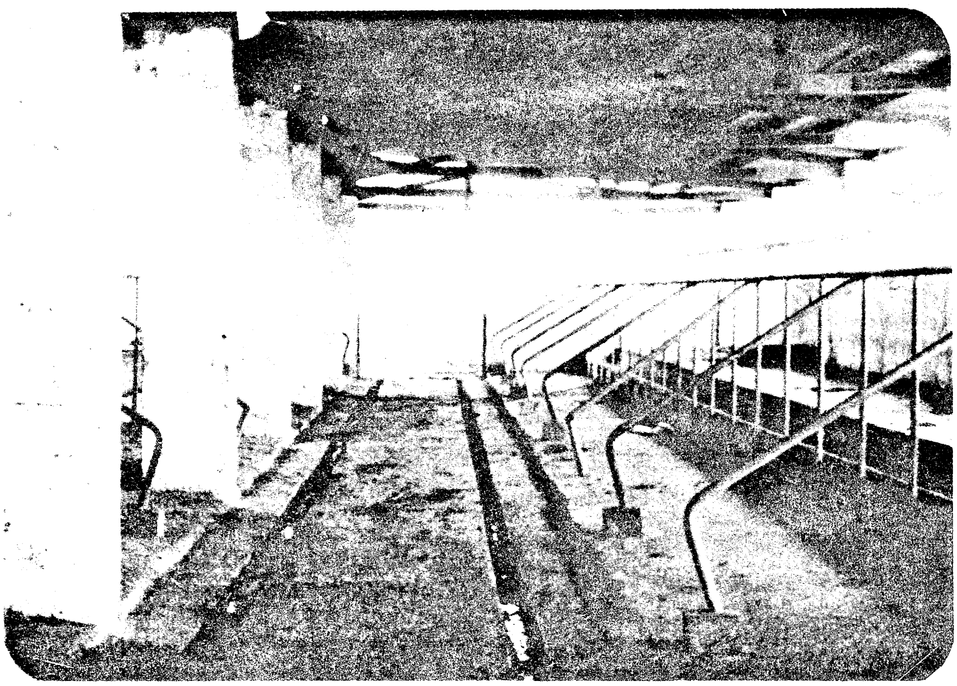


Figure XX. Well-designed animal shed

Figure XXI. <u>Animal shed occupied by cows</u>

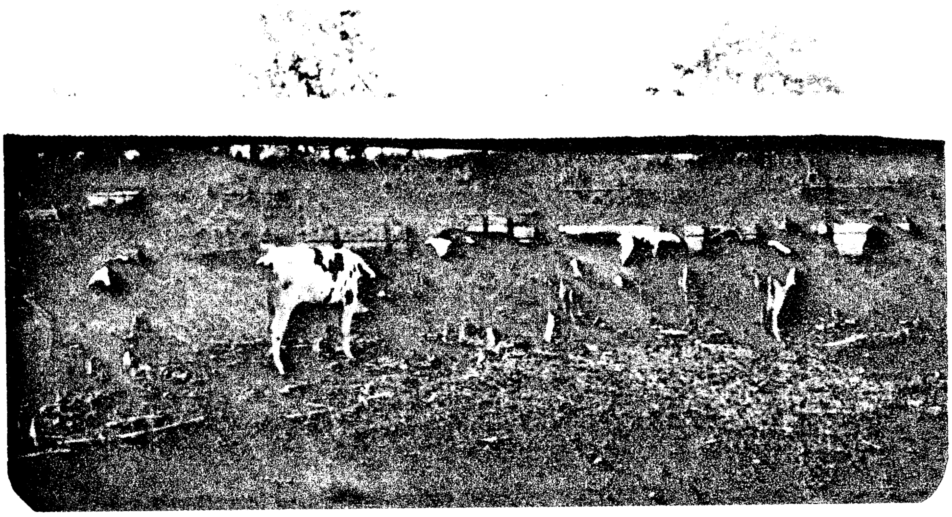


Figure XXII. <u>Feeding animals in an open yard</u>

Figure XXIII. Feed residue mixed with dung

(i) There are nine water wells operated by electrical pumps. The pumps usually operate for about 10 hours a day. At this rate, each pump consumes about 6,000-8,000 kWh/month. Two of these water wells are located within the area of the farm itself;

(ii) The farm itself consumes about 10,000-12,000 kWh/month. A 7 kilowatt (kW) shredder operates for about five hours each day to prepare the animal feed. In addition, small amounts of electrical power are consumed by the milking machines.

The farm also consumes about 125 kg of liquefied petroleum gas (LPG) per month for cooking purposes.

Most of the manure is gathered mechanically in a dry state into large heaps from the shed yards every one to two months. Some is used as a fertilizer in the agricultural part of the farm. The remainder is either sold at a low price or burnt owing to the lack of an accessible market.

As can be seen from figures XXIV and XXV, the escaping liquid portion of the waste causes a visible pollution problem.

(b) El Fayyosh dairy farm

This farm is located in Lahej governorate close to Aden (about 15 km away). There are no villages or large population centres nearby. The farm was biult in 1974/1975, and it began operations using imported Friesian and Boran cows. About 350 acres are allocated to the agricultural sector of the farm for the production of animal feed. However, only 150 acres are cultivated.

Figure XXIV. Manure collected around the sheds

Figure XXV. Liquid waste constituting a pollution hazard

The farm consists of five sheds. The distribution of animals as at October 1986 was as follows:

Shed number	Type of cow	Number of cows
1	Friesian dairy	198
2	Boran dairy	104
3	Non-milking	70
4	Calves up to one year old	200
5	Pregnant and ready for delivery	141

The design of the farm sheds is similar to that of the Gaawala dairy farm.

Electrical power consumption on the farm is less than that on Gaawala farm. There are seven wells, five of which are electrically operated, while the other two are powered by diesel engines. Each of the well pumps has a capacity of 30 kWh. The farm employs 10 horsepower (hp) feed shredder and four 2 hp milking machines. Power consumption is estimated to cost about YD 1,800 per month.

Manure handling and utilization is similar to that on the Gaawala dairy farm.

(c) El Kod farm complex

The farm complex is located in El Kod village in Abyan governorate. It consists of a dairy farm and two poultry fattening farms. The farms are located on one line about 500 m from each other, opposite El Kod village which is about 500 m away on the other side of the asphalt road between Aden and El Kod. The village itself is large, consisting of more than 700 houses and some government organizations such as the Agricultural Research Institute, together with a number of industries.

(i) El Kod dairy farm

This farm is similar in design to the previously-mentioned dairy farms. It has a number of different breeds including Friesian, Boran and mixed. The number of animals is well below the farm's capacity. The distribution of animals in the five sheds is as follows:

Shed number	Type of cow	Number of cows
1	Dairy	117
2	-	-
3	Non-milking	90
4	Calves	120
5	Pregnant	140

Manure handling and utilization is almost the same as that on the other farms. Dung collected in the yard is also mixed with large amounts of nabiergrass stalks and other feeds, which produces a mixture that is unsuitable for continuous biogas systems unless the method of animal feeding is changed.

There are five water wells operated by 30 kWh electrical pumps, eight diesel pumps in the agricultural sector, and one electrical pump on the animal farm, all with the same capacity. The animal farm is equipped with a 10 hp shredder and two 3 hp milking machines, all of which operate for about four hours daily.

Electrical power consumption is estimated at about 40,000 kWh/month, while the consumption of diesel oil is in the region of nine tons/month.

(ii) Poultry fattening farm

There are two poultry fattening farms at El Kod located at a distance of about 500 m from each other. The two farms are identical. Each farm consists of 14 sheds. The dimensions of each shed are 90 m x 9 m. The sheds which are 24 m apart, form two rows 50 m from each other. The farm has a mechanized watering and feeding system. Manure is removed manually once every rearing period (50-60 days). A 5 cm layer of fine saw dust is used as a bedding material.

The production capacity of the farm is large, as it can operate five cycles per year and each shed holds 7,000 chicks. Since each farm has 14 sheds, annual production is around 490,000 chicks per farm. However, owing to temporary difficulties, production decreased appreciably during 1986.

The maximum power requirement for each shed is 3.8 kW. This is mainly used for lighting the sheds for about 12 hours daily. The mechanical feeding system also operates electrically. The estimated maximum energy consumption for full-capacity operation is about 1,000 kWh daily for each farm, which amounts to about YD 1,200 every month.

Droppings mixed with fine saw dust are collected manually after each cycle. The collected manure is either used as a fertilizer or disposed of elsewhere.

(d) Lenin dairy farm

The farm, which is located at Khanfar in the governorate of Abyan, was constructed in 1976-1977. A small village with 50 houses (El- Karadif village) is located at about 800 m from the farm. The farm design is the same as those mentioned previously. There are also five animal sheds for Friesian and Boran cows. The distribution of animals in October 1986 was as follows:

Shed number	Type of cow	Number of cows
1	Dairy	130
2	Dairy	121
3	Ready for delivery	63
4	Calves under 8 months old	107
	Calves 8-12 months old	31
5	Pregnant or ready to conceive	178

The total area of the agricultural sector of the farm is 800 acres, of which only 280 acres are cultivated.

The dairy farm is equipped with two 3 hp milking machines, a 10 hp shredder for the preparation of feed, and a 30 hp diesel-fuled electrical generator. The generator is operated in case of emergency to light the farm and operate the milking machines. The kitchen and other utilities consume about 75 kg of LPG per day.

The agricultural farm has eight water wells, seven are electrically operated and the eighth is operated by a diesel engine to irrigate 15 acres of cultivated land.

Electrical power consumption costs about YD 27,000 per year, which is equivalent to about 1,900 kWh daily.

(e) El Garad fattening farm

El Garad farm undertakes the fattening operations of the calves produced from the above mentioned four dairy farms. No precise data is available on the capacity of the farm.

3. Poultry farms

The production of broilers was estimated to be about one million during 1986; the target capacity is about four million broilers/year. Egg production was about 50 million during 1986. The target capacity is 65 million eggs/year. There is a large number of poultry farms in the country. Two of these were mentioned previously as they form part of the El Kod farm complex. The others are:

(a) El Rabat (Dar Saad) Layer complex

The farm is located outside Aden.

It has two divisions: rearing and layer farms.

(i) Rearing farms

The rearing farms are used to rear replacement chicks from one day old to 20 weeks old. The rearing division consists of two farms. Each farm has eight sheds measuring 90 m x 9.5 m. The total capacity of these rearing sheds is 300,000 chicks per year. The sheds are provided with mechanized feeding systems, watering and lighting.

(ii) Layer farms

The layer farms have a fully mechanized system for feeding, watering, egg collection and manure removal. There are two with 30 sheds each. The dimensions of each shed are 9.5 m x 90 m with a capacity of 10,320 layers. Total capacity is therefore about 600,000 layers.

(iii) Energy requirements

The maximum power load of each rearing shed is 3.8 kWh. Lighting needs are about 3.6 kW for 10-12 hours. The total electrical consumption of the rearing sheds is about 1,000 kWh daily.

The peak load of each layer shed is 13.7 kW. Lighting requires about 3.6 kW for six hours daily. Total consumption is estimated at about 2,500 kWh per day.

(iv) Manure handling and utilization

Manure is removed mechanically once or twice a day and deposited near to the sheds. The collected manure is transported by vehicle to other places for use as a fertilizer. The area around the farms is not cultivated, though it would appear to be cultivable. The transportation of manure costs the farm about YD 3,000 annually.

(b) Other poultry-rearing farms

These include the following:

(i) Three farms in the governorate of Abyan. They each have six sheds similar to those at El Kod. They have an area of 700 m^2 and a capacity of 7,000 chicks/shed;

(ii) Three farms in the governorate of Aden. They each have five houses with a capacity of 7,000 chicks/shed, and can operate five cycles a year. Power requirements and manure handling and utilization are similar to those of the El Kod farm.

Table 14. Distribution of livestock among different sectors

(Thousands)

	Goats	Sheep	Cattle	Camels	Donkeys	Equivalent animal units[a/]	Percentage of animal units
Public sector	3	3	3	-	-	5.0	1.0
Rural sector	747	477	120	30	100	322.4	64.6
Bedouin sector	500	320	-	70	40	172.0	34.4
Total	1,250	800	123	100	140	499.4	100.0

Source: Adapted from report of FAO programming mission, Vol. 1, DD: People's Democratic Republic of Yemen, TCP/PDY/3598, September, 1985.

a/ Equivalent animal unit = 1 local cow = 10 goats = 10 sheep = 2 donkeys = 1 Camel = 0.66 Friesian cows.

4. Animal ownership

In Democratic Yemen animals are distributed between the public (governmental), rural and bedouin sectors. As can be seen from table 14, the public sector only owns about 1 per cent of animal wealth. The rural sector and bedouin nomads hold 64.6 per cent and 34.4 per cent respectively (42). It can also be seen that the level of animal ownership is generally low in Democratic Yemen.

The density of animal ownership is of central importance when assessing the prospects of BGT, particularly in the case of household units, which require the presence of sufficient animals within the family unit to feed and sustain the operation of a biogas system. Unfortunately, information such as this was not available on a country level. Accordingly, during the mission to Democratic Yemen, an estimate was made for a sample village in Lahej governorate.

The El Hota Centre in El Hobiel village, which belongs to the district of Tuban, was selected for this purpose. Table 15 is a compilation of the data collected with the help of the village Defence committee. The village consists of scattered communities with a small number of inhabitants. Houses are distributed in such a way that there is sufficient space to erect biogas-producing units all around. Open animal sheds, located close to houses (see figure XXVI), are the dominant feature of rural areas in Democratic Yemen.

Table 16 indicates that only 5.2 per cent of families in the village own three or more animal units, which is usually sufficient for a household biogas unit. The total number of animal units belonging to this group is quite large, representing about 28.7 per cent of total animal holdings in the village. Owners of two animal units constitute 11.2 per cent of the total number of families and possess about 25 per cent of the total animal stock in the village. Thus, some 50 per cent of livestock belongs to about 16 per cent of the population, while over 50 per cent of families own only a few goats and sheep (about 0.25 equivalent animal units).

Table 15. Density of animal ownership in a sample village

No.	Number of animals owned: Cows	Camels	Sheep and Goats	Equivalent animal units	Number of owners	Percentage of animal units
1	8	-	9	9.0	1	0.37
2	4	-	20-22	6.0	2	0.74
3	4	-	10	5.0	1	0.37
4	3	-	57	8.0	1	0.37
5	3	-	31	6.0	1	0.37
6	2	2	10	5.0	1	0.37
7	2	1	6-8	4.0	2	0.74
8	2	-	15-20	4.0	2	0.74
9	2	-	1-8	2.0	11	4.10
10	1	1	7	3.0	3	1.11
11	1	-	12-16	2.0	4	1.48
12	1	-	7-10	2.0	11	4.10
13	1	-	5-6	1.5	18	6.66
14	1	-	0-4	1.0	20	7.41
15	0	1	-	1.0	1	0.37
16	-	-	25	2.0	1	0.37
17	-	-	16-20	2.0	3	1.11
18	-	-	11-5	1.0	4	1.48
19	-	-	6-10	0.75	31	11.48
20	-	-	1-5	0.25	152	56.20
Total	125	8	1,387	243.25	270	100.00

Note:

Village:	El Hobiel, Lahej governorate
Number of families:	270
Population:	1,469 persons
Land ownership:	mostly around 3 acres
Landless people:	57 families
Cultivated land:	564 acres

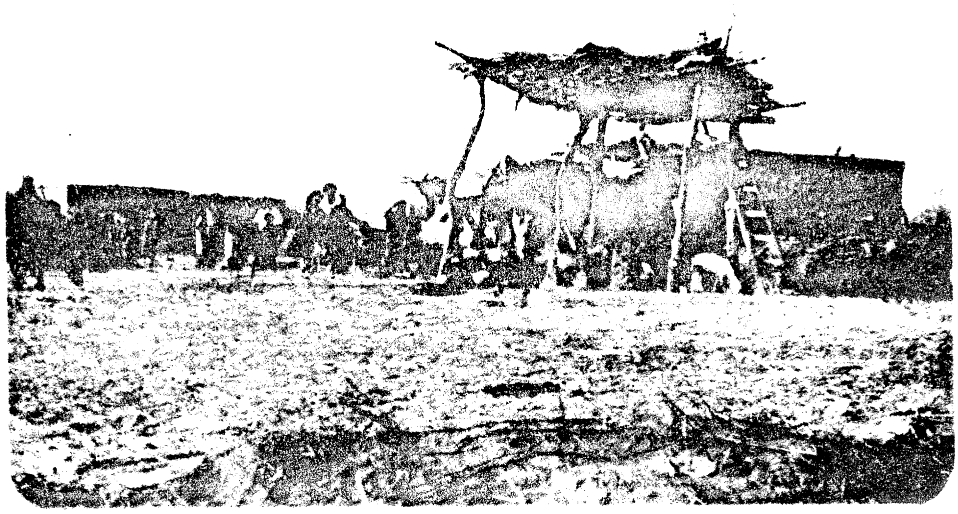


Figure XXVI. Rural houses with nearby animal shed

Table 16. Distribution of animal ownership in the sample village (El Hobeil)

	Distribution							Total
Number of animal units owned by family	8-9	5-6	3-4	2.0	1-1.5	0.75	0.25	243.25
Percentage of owners	0.74	1.85	2.6	11.2	15.9	11.50	56.2	100.00
Percentage of total animal units	7	11.50	10.3	24.6	21.4	9.60	15.6	100.00

Animal ownership in the sample village seems fairly representative of the rural sector of Democratic Yemen as a whole, as is shown in table 17. Animal holding in the village is about 0.20 animal units/person, compared to 0.23 animal units/person for the rural sector as a whole.

The nomad community would not generally have access to biogas production because of the continuous movement of its members. However, as the Government is working on the settlement of the nomad population in order to improve their quality of life, it is reasonable to assume that about 50 per cent of the bedouin population and their animals could be settled within the next 10 years, therefore they can be included in the future prospective biogas plan.

Based on the above assumptions, the estimated future distribution of animals in the rural sector is shown in table 18. A correction factor was included in order to make up for the higher density of animals in the rural sector compared with that in the sample village. The projections are based on a rural population of 1.5 million persons following the partial settlement of bedouins. The total number of animal units has therefore increased from 322,400 to 408,400.

Table 17. Comparison of the animal-holding ratios of the sample village and rural areas

Location		Cows	Camels	Sheep	Goats	Donkeys	Animal units	Population (persons)
El Hobiel village	Total number of animals	125	8	823	564	(104)[a]	293.3	1,470
	Mean ownership units/person	0.085	0.005	0.56	0.380	0.071	0.20	
Rural areas	Total number of animals (thousands of units)	120	30	477	747	100	322.4	1,400,000
	Mean ownership units/person	0.085	0.021	0.341	0.534	0.071	0.23	

a/ Estimate.

Table 18. Estimate of the projected distribution of animals in rural areas of Democratic Yemen

Mean number of animals units owned by family	14	10	6	3	2	1	0.5	Total
Percentage of Owners	0.74	1.85	2.6	11.2	15.9	11.5	56.2	100
Number of owners (thousands of families)	2.035	5.090	7.150	30.800	43.725	31.625	154.550	275 a/
Total number of animal units (thousands of units)	28.49	50.90	43.90	92.40	87.45	31.63	73.63	408.4
Percentage of total no. of animal units	7.0	12.5	10.8	22.6	21.4	7.7	18.0	100.0

a/ Estimate based on a population of 1.5 million and a mean of 5.5 persons per family.

D. Potential and prospects of BGT in Democratic Yemen

BGT should be treated as a marketable commodity whose potential demand must be assessed in the early stages of any feasibility appraisal. Market potential normally is estimated on a national or macro-level, as well as on the micro-level of a specific location such as a village where the actual implementation will take place. Overall estimates, theoretical in nature, are usually needed in the early stages of any promotional activity in order to ascertain the maximum potential of the technology on a national scale under the most favourable conditions. These optimistic estimates of technology prospects are designed to attract the attention of the policy makers and planners. In order to identify specific cases that have the right conditions and socio-economic environment, micro-level estimates of realistic and specific prospects are essential prior to or during the propagation and implementation stages.

Subject to certain constraints and restrictions, the potential of BGT depends on the fundamental requisite of the availability of the basic raw materials needed to feed the biogas system. Apart from socio-economic factors, the limiting technical parameters include climatic conditions, site availability, the existence of appropriate designs and the availability of construction facilities, materials and manpower.

1. Availability of basic feed materials

The two basic materials required to feed the digester are biomass (mainly organic residues and waste) and water. In the case of dry fermentation, water may not be needed, or at most it is of secondary importance.

(a) Biomass

The main biomass sources in Democratic Yemen are: animal dung, poultry droppings, household kitchen waste, human excreta (faeces and urine), agricultural residues, municipal solid wastes, sewage sludge and industrial organic wastes (from food processing, slaughterhouses etc.).

(i) Animal dung

Animal dung is the most important feedstock material for biogas production in rural communities. The composition of animal excrement is generally highly suitable for anaerobic fermentation as it contains balanced ratios of carbon (C), nitrogen (N) and phosphorus.

The total estimated volume of animal dung produced in Democratic Yemen is given in table 19. The results indicate an annual production of about 363,570 tons of dry manure annually.

Table 19. Total animal dung production in Democratic Yemen

Serial No.	Type of animal	Total number (thousands)	Assumed average live weight (kg)	Assumed Fresh manure production/ head (kg/day)	Assumed moisture content of fresh manure (%)	Dry manure produced/ head (kg/day)	Average dry manure produced/ head[a] (kg/year)	Total dry manure production (thousands of tons/year)
1	Friesian and other imported cows	3	350	20.00	80	4.00	1,440	4.32
2	Local cows	120	220	12.00	80	2.40	691.2	82.94
3	Camels	100	300	12.00	75	3.00	864.0	86.40
4	Goats	1,250	20	0.75	68	0.24	69.1	86.25
5	Sheep	800	20	0.75	68	0.24	69.1	55.28
6	Donkeys	140	120	6.00	80	1.20	345.6	48.38
	Total							363.57

a/ Taking a factor of 0.8 in order to include the effect of small animals in the stock mix.

Table 20. Total poultry droppings produced on large government farms

Type	Total number (thousands)	Assumed average weight (kg)	Fresh droppings produced (gm/day)	Assumed moisture content of fresh droppings (%)	Dry droppings produced per head (gm/day)	Dry droppings produced per head (kg/year)[a]	Total dry droppings production (thousands of tons/year)
Broilers	420	>1.5	30	60	12	2.16	0.920
Replacement layers	150	>2.0	50	60	20	5.60	0.840
Layers	600	2.0	90	60	36	12.96	7.740
Total							9.500

a/ Taking duration to be equivalent to 180 days for broilers (three cycles of 60 days each), 280 days for replacement layers (two cycles of 140 days each) and 360 days for layers.

(ii) Poultry droppings

Poultry droppings also constitute a good organic feed material. However, their comparatively high N content, which reaches more than 6 per cent, makes the digestion process more sensitive and liable to ammonia toxicty unless proper operational precautions, particularly in the feeding system, are taken. The mixing of poultry droppings with another biomass source with a lower N content is recommended. Nevertheless, if necessary they can be used as feed material without mixing.

The amount of poultry droppings produced on government poultry farms (some 9,500 tons/year) is presented in table 20. Droppings produced in rural houses are estimated to come from about 10 chicks/family. As is shown in table 21, this amounts to about 22,000 tons/year. Thus, total poultry droppings are estimated to be about 31,500 tons/year.

(iii) Kitchen waste

Organic kitchen waste is also known to be a good feeding material for digesters. Kitchen waste in the rural sector of Democratic Yemen is estimated to be about 11,000 tons/year (see table 21).

(iv) Human faeces and urine

Human faeces and urine are also good feeding materials although their high nitrogen (N) content will increase the sensitivity of the anaerobic fermentation process. The mixing of human excreta with other feed materials that have a lower N content is therefore recommended.

Estimates of the amounts of human excreta for both rural and nomad sectors are given in table 22.

(v) Other biomass sources

Other biomass sources that can be used for biogas production include: sewage sludge, municipal solid wastes and industrial organic wastes from food processing, slaughter houses etc.). However, these sources are not included in this study as they are not normally available in rural areas. Furthermore, there is no significant agricultural residue available for biogas production in rural areas of Democratic Yemen.

(b) Water

Water is an essential raw material as it is used for dilution. However, the amounts required for biogas production can be minimized in several ways, including:

(i) Operation of digesters with higher solid concentrations;

(ii) Modification of animal sheds by changing to a sloping concrete floor so as to allow the utilization of animal urine instead of water;

Table 21. Poultry droppings and household kitchen waste in rural areas

Type of waste	Assumed mean fresh waste production/ family (kg/year)	Assumed moisture content of fresh waste (%)	Assumed mean dry production/ family (kg/year)	Number of families (thousands)	Total production (thousands of tons/year)	
					Fresh	Dry
Kitchen	100	60	40	275	27.5	11
Poultry	200	60	80	275	55.0	22
Total					82.5	33

Table 22. Estimates of amount of human faeces and urine produced in rural and bedouin areas of Democratic Yemen

Sector	Population (millions)	Type of waste	Assumed mean fresh waste production/ person (kg/year)	Assumed moisture content of fresh waste (%)	Assumed mean dry production/ person (kg/year)	Nitrogen content dry matter (%)	Total production (thousands of tons/year)	
							Fresh	Dry
Rural areas	1.40	Faeces	75	75	18	5-7	105	52.2
		Urine	300	95	15	15-19	420	21.0
Bedouin communities	0.20	Faeces	75	75	18	5-7	15	3.6
		Urine	300	95	15	15-19	60	3.6
Total							600	52.0

(iii) Connection of latrine to the biogas unit so as to allow the utilization of human urine and cleansing water;

(iv) Partial circulation of effluent;

(v) Collection of waste water and its utilization in manure dilution.

The adoption of one or more of the above-mentioned techniques can remove the constraints caused by difficulties in obtaining water.

2. Estimate of theoretical biogas production in rural and bedouin areas of Democratic Yemen

Based on the availability of biomass in the rural and bedouin sectors of Democratic Yemen, estimates of theoretical biogas production can be made. Table 23 shows that annual biogas production is estimated at about 97 million m^3. About 78 per cent of this amount is estimated to be generated from animal manure. Total biogas production is therefore equivalent to about 61 million litres (l) of kerosine annually, which represents about 9.3 per cent of the country's total consumption of oil and about 61 per cent of oil consumption in rural areas (based on assumed annual consumption of 100,000 tons of oil for rural areas).

3. Main constraints on biogas production in Democratic Yemen

As has been mentioned, these estimates for the theoretical production of biogas cannot be achieved because of the constraints that prevail in rural areas of Democratic Yemen. The most important constraints are as follows:

(a) The low density of animal ownership, as more than 40 per cent of the animal stock is scattered in small agglomerations where families own two animals or less. Concentrations such as these would not normally provide sufficient feedstock to sustain the operations of household biogas-producing units. Though the adoption of community and mini-type solar heated digesters could partially cope with this constraint, the net effect is such that it will inevitably decrease the overall potential of biogas production.

(b) An appreciable part of the animal stock (34.4 per cent) belongs to the Bedouin sector (41), a society which is characterized by the continuous movement of an appreciable portion of its members to different areas in search of animal feed and water. Conditions in this sector also hinder the utilization of animal waste in biogas production, which leads to a further decrease in the propective potential of biogas production in Democratic Yemen. A partial solution could be reached by settling bedouins in new cultivated areas whenever possible. Also the use of portable digesters could provide another opportunity to utilize manure for biogas production in the bedouin community.

Table 23. Estimates of theoretical biogas production in rural and bedouin areas of Democratic Yemen

Feed material	C/N	Characteristics of feed materials[a] Percentage of volatile matter (VM)	Percentage of volatile matter destroyed	Biogas production (m^3/kg of VM destroyed)	Total amount of available feed material (thousands of tons/year)	Total volatile matter (thousands of tons/year)	Total biogas production (10^6 m^3/year)	Percentage share
Animal dung	16-25	65	40	0.8	363.57	236.32	75.62	78.0
Poultry droppings	9.3	85	60	0.6	31.50	26.77	9.64	9.9
Human excreta	9	90	60	0.6	28.80	25.92	9.33	9.6
Kitchen wastes	20	90	30	0.8	11.00	9.90	2.38	2.5
Total							96.97	100.0

a/ Adapted from references (10, 44 and 45).

(c) The lack of water in some areas can also constitute a major deterrent. Water is one of the raw materials used to dilute the biomass fed to digesters. The modification of animal sheds by covering the floor with a concrete layer allows urine to be collected and used to minimize the need for water, which would partially help to solve the problem. The employment of special biogas systems that operate with high solid concentrations can also help to remove this constraint, and the collection of other waste water produced in the house could provide another source of water. The connection of a latrine to the digester would provide an excellent combination of supplemental feed, water and sanitation.

(d) The lack of a suitable site with sufficient space is another limiting factor. Family-size digesters are generally connected to both an animal shed and a latrine. There must therefore be sufficient space in the vicinity of the farmer's house to permit the erection of a biogas system. During visits to a large number of villages in Democratic Yemen, it was noted that, from this point of view, the villages are suitable for the introduction of BGT since sufficient space is normally available in the vicinity of houses. Hence, this would probably not have any appreciable negative effects on the prospects of BGT.

As land in cultivated areas is mainly composed of mud transported from higher zones, it is generally assumed that the construction of digesters 2 m below ground level would not be difficult. However, in special circumstances digesters can be erected above ground.

(e) Cold weather is also an impediment. Generally, however, climatic conditions in Democratic Yemen favour biogas production owing to the prevalence of relatively high temperatures in most areas of the country. The mean temperature in most populated areas is around 30°C. However, elevated areas are comparatively colder, with mean temperatures that vary from 20 to 25°C or even lower.

(f) Another factor that may limit the prospects of BGT is the lack of construction materials and gas-use devices. The main materials required for the construction of biogas systems are: cement, sand, aggregate, lime, steel and bricks. All of these materials are available in Democratic Yemen. Although cement and steel are imported, a cement factory is being constructed. Gas-use devices are generally imported, but the available devices that are used for LPG can be converted to operate on biogas.

(g) The availability of adequate manpower is a major factor. BGT is an intermediate technology, so Yemeni labourers can easily be trained to construct, operate and maintain biogas systems. Various specialists at Aden university would also be valuable in this regard.

4. Prospective designs and systems

The presence of variable conditions within the rural sector of Democratic Yemen necessitates the selection of appropriate designs and biogas production systems in order to optimize their potential. Tailored schemes such as these must not only meet the criterion of suitability, they must also remove prevailing constraints as far as is possible.

As was noted previously, Democratic Yemen has a relatively warm climate as a result of its location within the solar belt. Under these conditions, the maximum temperature that could be expected during the fermentation process is in the order of 30°C, which is generally considered to be satisfactory. However, anticipated gas production at 30°C would only be about half of that produced at an optimum mesophilic fermentation temperature of 37°C. In many cases passive or active solar heating can be used to increase the fermentation temperature, thereby bringing it closer to the optimum temperature, though there is, of course, an additional cost. Moreover, under cold conditions, a heating system is mandatory.

In rocky places, special designs are also needed. Bedouin communities would also need special systems to suit their occasional movement from one location to another. A portable-type digester would seem to be a plausible alternative for this particular case.

Apart from the family-size digesters, for which there seems to be a good potential in Democratic Yemen, community and large-scale digesters also have promising prospects. The recommended designs and systems to cover the different varieties and situations are presented in the following:

(a) Relevant designs

The prospective designs have already been described in the introductory section. the relevant types will be listed here under three groups: family, community and large digesters.

(i) Family-size digesters

The following types are suitable for existing conditions:

a. Modified Indian and BORDA-type digesters;
b. Egyptian-Chinese water-pressure digester;
c. Solar-heated mini-digester;
d. Flexible bag digester;
e. Dry batch fermentors.

(ii) Community-type digesters

Communal-type digesters to serve several families or a small community) are essential for Democratic Yemen for various reasons, the most important of which are as follows:

a. The preponderance of the ownership of small animals amongst rural families means that there are insufficient feed materials to sustain digester operations to meet family energy requirements. The construction of family-size digesters under these circumstances is economically unfeasible. This drawback could be offset by building a community biogas producing facility;

b. The absence of latrines in the majority of rural houses. The construction of communal latrines connected to an appropriately-sized digester combines the benefits of sanitary disposal and energy production;

c. Taking advantage of economies of scale. Even when a number of neighbouring families have good working relations and a sufficient number of animals to sustain individual digesters, a larger shared digester facility would prove more economical.

Suitable designs for community-size digesters are the same as those listed for family-size systems, but excluding the mini-type digester.

Digester volumes range from 8-50 m^3. Passive solar heating is recommended for all applications in order to enhance the productivity of the system.

(iii) Large-scale digesters

They would be used primarily on government animal and poultry farms. The gas produced could either be distributed to nearby communities for household or other communal uses (in the case of El Kod farm), or converted into mechanical and electrical energy for use on the farm or its agricultural annex. The latter would appear to be more common in Democratic Yemen.

Designs that are suitable for large-scale digesters include those that were indicated for community-type digesters, in addition to tunnel-type digesters with either fixed or flexible roofs.

Digester volumes would probably be in the range of 50-250 m^3. Heating and mechanical mixing would be necessary, particularly for digesters with a volume greater than 100 m^3.

(b) Prospective systems

Based on the conditions that were identified during the field visits to rural areas of Democratic Yemen, as well as an analysis of the data on animal stocks and distribution and other relevant parameters, the following conceptual models would probably realize the optimum potential of BGT in Democratic Yemen:

(i) Family-size units

For families who own three or more equivalent animal units, the construction of household units connected to a domestic latrine is proposed. This would supply not only the energy needs of the household, but also provide a sanitary disposal system.

For families who own the equivalent of two animal units, a solar-heated mini-digester is proposed. Most of the energy requirements of the family can be met by the higher biomass conversion rate of this system.

(ii) Community-type units

These would be based on a combined feedstock of human and animal wastes. These systems would incorporate public or collective latrines as an integral part of their working scheme. The biogas and fertilizer that is produced would be shared on a pro rata basis among the families who provide the animal dung. In essence, the system is basically a means of providing sanitation, with energy and fertilizer as by-products. A system such as this can be subdivided into two major types depending on whether human waste or animal dung is the principal feedstock. The first type is based primarily on public latrines, with supplementary animal dung being contributed from a small number (2-4) of nearby families who own one or two equivalent animal units. The second type is based on collective contributions of animal and human wastes from 12-30 families owing one or two cows.

(iii) Large-scale system

As was mentioned previously government poultry and animal farms offer the ideal conditions for the 100 per cent utilization of organic wastes to produce biogas and stabilized fertilizer. The presence of large amounts of manure on different farms means that large mechanized digesters capable of producing substantial amounts of gas at a reasonable cost can be constructed. The gas can be used either on the farm or in a nearby community. It can be used directly or indirectly to generate mechanical or electrical energy. Digested wastes can be pumped directly to the agricultural farms or dried and used as a fertilizer.

5. Estimate of the required number of digesters

(a) Number of family-size digesters

Based on the estimated distribution of animals (see table 18), the number of family-type digesters that is required has been estimated in table 24.

The calculations are based on the following assumptions:

(i) Only about 50 per cent of animal manure is available for digestion, the remainder being lost in the fields since animals are generally released from the sheds during the daytime;

(ii) Latrines are connected to the digester; an amount of 1.5 kg of faeces/family is assumed to be available for fermentation;

(iii) An amount of 0.25 kg of organic kitchen wastes/family are assumed to be available for fermentation;

(iv) Waste collected from about 10 chickens per family (about 0.5 kg) are assumed to be available daily;

(v) Digester retention times are set according to the mean temperature of the location. Thus, in warm areas with a mean temperature in the order of 29°C, the retention time is taken to be equal to 40 days. For areas with a mean temperature of 25°C, the retention time is taken to be equal to 50 days. In colder areas with a mean temperature of 20°C, a retention time of 60 days is assumed and passive solar heating (greenhouse) is incorporated in order to increase the operating temperature;

(vi) Digesters with volumes of less than one m^3 are heated by a solar heater.

As can be seen from table 24, the individual digester volumes vary between 0.5 and 10 m^3; the total required volume is 139,000 m^3. The total number of family-type digesters required is estimated to be 55,075.

(b) Number of community-type digesters

Community-type digesters would be used to serve rural inhabitants who own two or under equivalent animal units. The human wastes collected in the proposed public latrines would provide a supplementary feed material. Two main groups are proposed:

(i) Group 1: Owners of one or two equivalent animal units

These families would join together to form a collective of 12-30 families with a total of 24-50 equivalent animal units. A communal digester would be constructed, and a public latrine would be connected to the biogas unit to serve these families and other inhabitants of the village. The gas produced would be distributed to the same families (12-30) that collect the animal manure to feed the digester. The effluent would be used as a fertilizer and distributed among the families that provide animal manure, in proportion to the number of animals owned. The amount of gas will depend on the number of individuals who use the public latrine. The retention time would be longer (60 days) in order to kill the harmful pathogens and parasites that are found in human faeces and to achieve a higher conversion to biogas. The volume of digesters in this group varies from 25-50 m^3, while the total volume is estimated at 44,500 m^3 (see table 25).

(ii) Group 2: Families owning an insufficient number of animals

As about 50 per cent of the population own less than 0.5 equivalent animal units, and there are virtually no latrines in houses, a public latrine would be constructed and connected to the digester to treat the waste and produce energy. The available manure would be added as a supplementary feed. The gas that is produced would either be used for general public requirements (water pumping) or distributed to a small number of families (2-4). The effluent would be used as a fertilizer.

Table 24. Estimate of the number of family-type digesters required for rural areas of Democratic Yemen

No. of families	Estimated mean no. of equivalent animal units/family	Manure produced/day/family (kg)	Biomass available for fermentation/day/family: Manure (50%) (kg)	Human Excreta (kg)	Kitchen wastes (100%) (kg)	Poultry wastes (100%) (kg)	Total dry weight (kg)	Average daily feed (litres)	Conditions of operation: Mean atmospheric temperature (°C)	Temp. (°C)	Retention time (days)	Size of digester (m^3)	Total volume (m^3)	Type of digester a/
1,200									29	29	40	7.1	8,520	2/3/4
500	14	168	84	1.5	0.25	0.5	17.7	177	25	25	50	8.9	4,450	2/3/4
335									20	22	60 b/	10.6	3,551	2/3/4
3,000									29	29	40	5.2	15,600	2/3/4
1,250	10	120	60	1.5	0.25	0.5	12.9	129	25	25	50	6.5	8,125	2/3/4
840									20	22	60 b/	7.7	6,468	2/3/4
4,100									29	29	40	3.2	13,120	2/4
2,000	6	72	36	1.5	0.25	0.5	8.1	81	25	25	50	4.0	8,000	2/4
1,050									20	22	60 b/	4.9	5,145	2/3/4
5,000			18	-	0.25	0.5	3.9	39	29	37	20 b/	0.8	4,000	1
10,000	3	36	18	1.5	0.25	0.5	4.5	45	29	29	40	1.8	18,000	2/4
8,000			18	1.5	0.25	0.5	4.5	45	25	25	50	2.3	18,000	2/4
7,800			18	1.5	0.25	0.5	4.5	45	20	22	60 b/	2.7	21,060	2/4
10,000	2	24	12	-	0.25	0.5	2.7	27	29	37	20 b/	0.5	5,000	1
55,075													139,000	

a/ 1. Mini-digester; 2. Egyptian-Chinese; 3. BORDA; 4. Flexible bag.

b/ Externally heated type digesters.

Table 25. Estimate of the number of community-type digesters required for rural areas of Democratic Yemen

No. of digesters	System	No. of families served by gas	Total no. of equivalent animal units	Manure produced/ day (kg)	Human excreta (kg/day)	Daily biomass		Daily Feed		Conditions of operation					
						Fresh (kg)	Dry (kg)	Concen- tration (%)	Volume (litres)	Mean atmospheric temperature (°C)	Temp. (°C)	Retention time (days)	Size of digester (m^3)	Total volume (Thousands of m^3)	Type of digester[a/]
1,000	Public latrine	12	24	288	40	184	38.4	9	426	29	29	60	25	25.00	1/2/3
500	"	12	24	288	40	184	38.4	9	426	25	27	60	25	12.50	1/2/3
100	"	30	50	600	40	340	70.0	9	777	29	29	60	47	4.70	1/2/3
50	"	30	50	600	40	340	70.0	9	777	25	27	60	47	2.35	1/2/3
200	"	4	3	36	80	100	25.0	7	357	25-29	27-31	60	21	4.20	1/2
2,000	"	2	1	12	40	47	11.4	7	163	25-29	27-31	60	10	20.00	1/2
50	School latrine	-	-	-	40	-	10.0	7	143	25-29	27-31	60	9	0.45	1/2
3,900		27,300	46,500											69.20	

a/ 1. Egyptian-Chinese; 2. Flexible bag; 3. BORDA.

Table 26. Estimate of the number of large digesters required for government animal farms in Democratic Yemen

Farm	Shed no.	No. of animals	Manure produced/ day (tons)	Biomass available for digestion: Fresh (tons)	Biomass available for digestion: Dry (tons)	Daily Feed: Concentration (%)	Daily Feed: Volume (m^3)	Conditions of operation: Mean atmospheric temperature (°C)	Conditions of operation: Temp. (°C)	Conditions of operation: Retention time (days)	Conditions of operation: Size of digester (m^3)	Type of digester a/
Gaawala	1	100	1.80	1.80	0.360	10	3.60	29	29	30	108	1/2
	2	150	2.70	2.70	0.540	10	5.40	29	29/37 b/	30/25	162/135	1/2
	3	170	3.06	3.06	0.612	10	6.12	29	29/37 b/	30/25	184/153	1/2
	4	(220) c/	1.10	1.10	0.220	10	2.20	29	29	30	66	1/2
	5	170	2.70	2.70	0.540	10	5.40	29	29/37 b/	30/25	162/135	1/2
Subtotal		810									682	1/2
El Fayyosh	1	200	3.60	3.60	0.710	10	7.10	29	29/37 b/	30/25	213/178	1/2
	2	100	1.80	1.80	0.360	10	3.60	29	29	30	108	1/2
	3	70	1.26	1.26	0.252	10	2.52	29	29	30	77	1/2
	4	(200) c/	1.00	1.00	0.200	10	2.00	29	29	30	60	1/2
	5	140	2.52	2.52	0.504	10	5.04	29	29/37	30/25	151/126	1/2
Subtotal		510									609	
El Kod	1	120	2.16	2.16	0.432	10	4.32	29	29/37 b/	30/25	130/108	1/2
	3	90	1.62	1.62	0.324	10	3.24	29	29	30	97	1/2
	4	(120) c/	0.60	0.60	0.120	10	1.20	29	29	30	36	3
	5	140	2.52	2.52	0.504	10	5.04	29	29/37 b/	30/25	151/126	1/2
Subtotal		470									414	
Lenin	1	130	2.34	2.34	0.468	10	4.68	29	29/37 b/	30/25	140/117	1/2
	2	120	2.16	2.16	0.432	10	4.32	29	29/37 b/	30/25	130/108	1/2
	3	60	1.08	1.08	0.216	10	2.16	29	29	30	64	1/2
	4	(140) c/	0.90	0.90	0.180	10	1.80	29	29	30	54	1/2
	5	180	3.24	3.24	0.648	10	6.48	29	29/37 b/	30/25	194/162	1/2
Subtotal		630									580	1/2
El Garad d/		500	5.00	5.00	1.000	10	10.00	29	29	30	3x100	1/2
Subtotal		500									300	
Total		2,920									2,585	

a/ 1. Tunnel with fixed roof; 2. Tunnel with flexible roof; 3. BORDA, Egyptian-Chinese or bag.
b/ Externally heated digester;
c/ Calves less than one year old;
d/ Estimated number of animals.

The volumes of digesters in this group would be comparatively small and vary from 8-21 m^3. The total volume of required digesters is estimated at 24,700 m^3. The total volume of community digesters is therefore in the region of 69,200 m^3 (see table 25).

(c) Number of large digesters for public farms

(i) Animal farms

The number and volume of digesters required for the different types of animal farm are given in table 26. The estimates are based on the following assumptions:

a. One hundred per cent of the manure produced is available for biogas production;

b. The concentration of daily feed is 10 per cent total solids;

c. The mean temperature of the slurry is very close to the mean ambient temperature of 29°C;

d. The retention time is taken to be 30 days in the case of unheated digesters and 25 days for heated digesters;

e. It is recommended that digesters with volumes greater than 100 m^3 have external heating systems, as the economics of operation would permit this additional expenditure. Accordingly, the slurry temperature and digester volumes are included for both heated and unheated digesters. However the total digester volume is based on an unheated system;

f. The digester is heated by solar heating (solar panels).

i. Gaawala farm

The results are given in table 26. Five large digesters with volumes between 108-184 m^3 could be constructed. The total volume of the digesters would be equal to about 682 m^3. Three of the digesters would be heated by solar panels in order to maintain an optimum temperature.

ii. El Fayyosh farm

Five large digesters with volumes between 60-213 m^3 could be constructed. The total volume of the digesters would be equal to about 609 m^3. Two digesters would be heated.

iii. El Kod farm

Four digesters with volumes ranging from 36-151m^3 could be constructed. The total volume of the digesters would be 414 m^3. Two of the digesters would be heated.

iv. Lenin farm

Five large digesters with volumes ranging from 54-194 m^3 could be constructed. The total volume of the digesters would be 580 m^3. Three of the digesters would be heated.

v. El Garad farm

Based on the estimated number of animals, digesters with a total volume of 300m^3 are deemed sufficient. The number of digesters depends on the exact distribution of the animals. However, for the purposes of this study it is estimated that the digesters would be distributed between three locations, therefore three digesters are recommended.

The total volume of the digesters suggested for use on government animal farms is estimated to be about 2,585 m^3.

(ii) Poultry farms

Two methods are used for the collection of poultry droppings on government farms: daily by mechanical means or manually at the end of a cycle. By the first method droppings are moist, while by the second they are almost dry. For this reason, one digester is recommended for each shed on layer farms where operations are totally mechanized. For dry droppings, on broiler farms, suitable digester sizes have been based on the total production of wastes, not on the number of sheds.

This evaluation has been based on the following assumptions:

a. That 100 per cent of the manure produced is available for digestion;

b. The concentration of daily feed is 8 per cent total solids;

c. The mean temperature inside the digesters is equal to a mean ambient temperature of 29°C;

d. The retention time is 30 days for non-heated digesters and 20 days for heated digesters. The other assumptions are the same as those mentioned in the case of animal farms.

Table 27 shows the total volume of the required digesters for polutry farms to be 10,020 m^3. More than 90 per cent of the total volume would be required for the El Rabat layer farm. The estimated number of total digesters required is 72.

Table 27. Estimate of the number of large digesters required for government poultry farms in Democratic Yemen

Farm	no. of sheds	No. of chickens (thousands)	Type	Amount of droppings produced (ton/day)	Biomass available for fermentation		Average daily feed		Conditions of operation					
					Fresh (tons/ day)	Dry (tons/ day)	(%) concen- tration	Volume (m^3))	Mean atmospheric temperature (°C)	Temp. (°C)	Retention time (days)	Size of digester (m^3)	Total volume of digesters (m^3)	Type of digester[a/]
El Rabat														
Replacement 1	8	75	Replacement	2.91	2.91	1.16	8	14.5	29	29/37	30/20	2x240/2x145	480	1/2
Replacement 2	8	75	Replacement	2.91	2.91	1.16	8	14.5	29	29/37	30/20	2x240/2x145	480	1/2
Layer 1	30	300	Layer	27.00	27.00	10.80	8	135.0	29	29/37	30/20	30x35/30x90	4,050	1/2
Layer 2	30	300	Layer	27.00	27.00	10.80	8	135.0	29	29/37	30/20	30x35/30x90	4,050	1/2
El Kod														
Broiler 1	14	98	Broiler	1.47	1.47	0.59	8	7.4	29	29/37	30/20	220/150	220	1/2
Broiler 2	14	98	Broiler	1.47	1.47	0.59	8	7.4	29	29/37	30/20	220/150	220	1/2
Abyan														
Broiler 1	6	42	Broiler	0.63	0.63	0.25	8	3.13	29	29	30	94	94	1/2
Broiler 2	6	42	Broiler	0.63	0.63	0.25	8	3.13	29	29	30	94	94	1/2
Broiler 3	6	42	Broiler	0.63	0.63	0.25	8	3.13	29	29	30	94	94	1/2
Aden														
Broiler 1	5	35	Broiler	0.52	0.52	0.21	8	2.63	29	29	30	79	79	1/2
Broiler 2	5	35	Broiler	0.52	0.52	0.21	8	2.63	29	29	30	79	79	1/2
Broiler 3	5	35	Broiler	0.52	0.52	0.21	8	2.63	29	29	30	79	79	1/2
Total													10,020	

a/ 1. Tunnel with fixed roof; 2. Tunnel with flexible roof.

Table 28. Summary of the potential number of digesters required for rural areas of Democratic Yemen

Type	Design	Volume of digester (m^3)	Possible number	Operating conditions: Temp. (^oC)	Operating conditions: Concentration (%)	Operating conditions: Retention time (days)	Expected gas production rate m^3/day (43-45 days)	Gas production per digester (m^3/day)	Expected volume of gas (10^3 m^3/ year)	Share (%)
Family size	Ready-made mini-digester	0.5	10,000	37	10	20	1.00	0.50	1,800.0	
		0.8	5,000	37	10	20	1.00	0.80	1,440.0	
	Egyptian-Chinese and bag	2.0	10,000	29	10	40	0.40	0.80	2,880.0	
		3.0	19,900	22-29	10	46-60	0.25	0.75	5,373.0	
		4.0	2,000	25	10	50	0.25	1.00	720.0	
	Egyptian-Chinese, bag and BORDA	5.0	1,050	22	10	60	0.15	0.75	283.5	
		5.0	3,000	29	10	40	0.45	1.25	1,350.0	
		7.0	2,450	22-29	10	40-50	0.35	2.45	2,160.9	
		8.0	840	22	10	60	0.15	1.20	362.9	
		9.0	500	25	10	50	0.25	2.25	405.0	
		10.0	335	22	10	60	0.15	1.50	180.9	
			55,075							64
Community size	Egyptian-Chinese and bag	10.0	2,050	27-31	7	60	0.20	2.00	1,476.0	
		20.0	200	27-31	7	60	0.20	4.00	288.0	
	Egyptian-Chinese, bag and BORDA	25.0	1,500	27-29	9	60	0.25	6.25	3,375.0	
		50.0	150	27-29	9	60	0.25	12.50	675.0	
			3,900							22
Large size	Egyptian-Chinese, bag and BORDA	50.0	2	29	10	30	0.55	27.50	19.8	
	Bag and tunnel	60.0	3	29	10	30	0.55	33.00	35.6	
	Tunnel	80.0	4	29	8-10	30	0.55	44.00	63.4	
		100.0	9	29	8-10	30	0.55	55.00	178.2	
		90.0	60	37	8	20	1.20	108.00	2,332.8	
		110.0	2	37	10	25	1.00	110.00	79.2	
		130.0	5	37	10	25	1.00	325.00	585.0	
		150.0	5	37	8-10	20-25	1.20	180.00	324.0	
		170.0	2	37	10	25	1.00	170.00	122.4	
			92							14
	Total		59,067						26,510	

6. Overall situation

Based on the above-mentioned estimates, the total number, type and characteristics of the biogas-producing digesters required for rural areas of Democratic Yemen are summarized in table 28. Annual gas production is estimated to be about 26.5 million m^3 of biogas. This is equivalent to about 16,700 tons of kerosine, which means that biogas could save about 17 per cent of the oil used in rural areas. The share of family-type digesters would be 64 per cent while community types would represent 22 per cent. The large digesters suggested for government farms could produce about 14 per cent of total gas.

About 12,000 families (4.4 per cent) could become self-sufficient using biogas energy. About 60,000 families (22 per cent) could benefit directly or indirectly from biogas energy. The effect on sanitation would be much greater as more than 180,000 families (65 per cent) could have access to latrines connected either to family or community biogas units.

The utilization of digested effluent as an organic fertilizer in place of imported chemical fertilizers would also be of considerable benefit.

In some locations and under certain conditions, it might be feasible to utilize the effluent as a feed material for animals through drying or the use of hydroponic systems to produce green animal fodder. This would be of greater economic value than the alternative of using the digested effluent as a fertilizer.

E. Preliminary appraisal of the economics of some prospective biogas systems

In this section an attempt will be made to make a preliminary techno-economic evaluation of some of the prospective systems proposed in the previous section. These include examples of family-size, community-type and large-scale digesters. Although social cost-benefit analyses would have provided more information and would probably have revealed the societal benefits and impact of BGT, it was not possible to produce them at such an early stage in the absence of relevant base-line data. Only simple financial analyses have therefore been made, and even these involve a number of assumptions. They should be regarded, then, as nothing more than early general indicators of the prospective viability of biogas systems in Democratic Yemen. In view of the limited amount of data available, and as BGT is highly site-specific, reliable estimates can only be made on the basis of actual field demonstrations at certain locations; these constitute the vital follow-up stage of this project.

Design and performance data are mainly based on actual experience at the biogas units of the National Research Centre of Egypt. The cost of construction materials and labour are based on prevailing costs in Democratic Yemen which were obtained during the visit.

1. Family-size unit: 5 m^3 Egyptian-Chinese type

The evaluation is based on the following:

(a) Both the latrine and animal shed are connected to the digester. The animal shed would be modified for this purpose by covering the floor with concrete with a suitable slope to allow the urine to be fed into the unit by gravity;

(b) The addition of a low-cost system for the collection of household waste water needed to dilute the manure before the unit is fed;

(c) The gas produced will be utilized by the family. To a large extent the amount will depend on temperature. In the first instance an average temperature of 29°C is assumed, but lower temperatures of 25°C and 20°C have also been evaluated. The financial analysis has been made on the basis of substituting biogas for either kerosine or LPG. One cubic metre of biogas is taken to be equivalent to 0.63 litres of kerosine or 0.5 kg of LPG. The local prices of kerosine and LPG are taken to be YD 0.088/l and YD 0.14/kg respectively. No additional cost for transportation is included;

(d) Feedstocks (animal and human wastes) are taken at zero value. Their concentration at the digester feed point is assumed to be 10 per cent solids;

(e) The digested effluent is assumed to contain 1.5 per cent nitrogen, which is valued at the equivalent local price of urea fertilizer. Phosphorous, potassium, humus and trace elements are valued together at half the value of nitrogen. This is a conservative estimate.

The undigested manure is given a zero fertilizer value as it is not used as a fertilizer in most of the rural areas of Democratic Yemen in view of the presence of wild seeds from grazing land that are harmful to plants. Anaerobic digestion can eliminate this adverse effect and therefore help to recover the value of the manure as a fertilizer.

The concentration of effluent solids is estimated at 8 per cent. It is assumed that it will be absorbed on silt for easy handling and to keep nitrogen volatilization losses to the minimum.

The results of preliminary economic appraisal for the basic operation at an average temperature of 29°C are given in table 29. Tables 30 and 31 indicate the results of operating at the lower temperatures of 25°C and 22°C respectively. As can be seen, the simple rate of return on investment varies with temperature and whether biogas is used as a substitute for kerosine or LPG. Its order of magnitude is from about 4 to 27 per cent, which indicates the prospective financial feasibility of the system. It should be noted again here, that accrued societal and sanitation benefits have not been included, and whose impact should considerably improve the system viability.

Table 29. Preliminary economic appraisal of a 5 m^3 Egyptian-Chinese Design family-size unit operating at 29°C

Investment costs:		YD
Digester buildings		120
Animal shed modifications and latrine		50
Connections and gas-use devices		30
Total, A		200
Annual production costs:		
Raw materials		-
Depreciation:		
Civil construction (20 years)		8.5
Connections, metallic parts and gas-use devices (10 years)		3.0
Repairs and maintenance		5.0
Total, B		16.5
Annual income:		
	Kerosine equivalent in YD	LPG equivalent in YD
Biogas	39.9	50.4
Fertilizer	19.8	19.8
Total annual income, C	59.7	70.2
Annual profit (C-B)	43.2	53.7
Return on invested capital	21.6%	26.9%

Table 30. Preliminary economic appraisal of a 5 m^3 Egyptian-Chinese Design family-size unit operating at 25°C

Investment costs:		YD
Digester buildings		120
Animal shed modifications and latrine		50
Connections and gas-use devices		30
Total, A		200
Annual production costs:		
Raw materials		-
Depreciation:		
Civil construction (20 years)		8.5
Connections, metallic parts and gas-use devices (10 years)		3.0
Repairs and maintenance		5.0
Total, B		16.5
Annual income:		
	Kerosine equivalent in YD	LPG equivalent in YD
Biogas	25.0	31.0
Fertilizer	17.6	17.6
Total annual income, C	42.6	48.6
Annual profit (C-B)	26.1	32.1
Return on invested capital	13.0%	16.0%

Table 31. Preliminary economic appraisal of a 5 m^3 Egyptian-Chinese Design family-size unit operating at 22°C

(Ambient temperature 20°C)

Investment costs:		YD
Digester buildings		120
Animal shed modifications and latrine		50
Greenhouse (solar heating)		20
Connections and gas-use devices		30
Total, A		220
Annual production costs:		
Raw materials		-
Depreciation:		
Civil construction (20 years)		8.5
Connections, metallic parts and gas-use devices (10 years)		4.5
Plastic film for green house (2 years)		2.5
Repairs and maintenance		5.0
Total, B		20.5
Annual income:		
	Kerosine equivalent in YD	LPG equivalent in YD
Biogas	15.0	18.9
Fertilizer	14.7	14.7
Total annual income, C	29.7	33.6
Annual profit (C-B)	9.2	13.1
Return on invested capital	4.2%	6.0%

2. 25 m³ BORDA-type community plant

The following is a preliminary techno-economic evaluation of one of the prospective core systems. The system is based on a combination of public latrines and a community-type digester. The following basic data and assumptions form the basis of the study:

(a) The public latrines serve about 150 persons daily. The daily collection is not less than 40 kg of fresh or 10 kg of dry human faeces daily, while the volume of urine and cleansing water amounts to about 150-200 l/day;

(b) Dung is collected from at least 24 equivalent animal units owned by 12 families; it forms the main daily feed. The expected amount of fresh dung is 144 kg with a solid content of 20 per cent;

(c) The latrine water is sufficient to achieve a slurry concentration in the range of 8.9 per cent;

(d) Latrine wastes are fed directly into the digester, while the animal dung is mixed in the mixing chamber after being diluted with the recycled effluent. No additional water is required;

(e) The collection of manure and the feeding of the unit are about equivalent to the previous operation of cleaning the animal shed. The additional work constitutes an improvement of the conditions in the house and animal shed. Therefore no labour costs are included with this item;

(f) The gas produced is distributed to the families who contribute the dung (10-12 families);

(g) The cost the gas network and gas-use devices are estimated to be equivalent to YD 33.3 per family. The houses should be located close to the unit.

Other conditions are similar to those mentioned for the family-type digester, particularly with regard to the value of the effluent as a fertilizer.

The results of the preliminary economic appraisals for the community-type digester operating at temperatures of 29 and 25°C are respectively given in tables 32 and 33. The return on invested capital varies between 7.4 and 15.6 per cent reflecting the potential feasibility of the system.

Table 32. Preliminary economic appraisal of a 25 m^3 BORDA-type community digester operating at 29°C

Investment costs:		YD
Digester buildings		290
Gasholder		125
Connections and gas-use devices		400
Public latrine		150
Total, A		965
Annual production costs:		
Raw materials		–
Depreciation:		
Civil construction (20 years)		22.0
Gasholder (10 years)		12.5
Connections, and gas-use devices (10 years)		40.0
Repairs and maintenance		20.0
Total, B		94.5
Annual income:		
	Kerosine equivalent in YD	LPG equivalent in YD
Biogas	150	189
Fertilizer	56	56
Total annual income, C	206	245
Annual profit (C-B)	111.5	150.5
Return on invested capital	11.6%	15.6%

Table 33. Preliminary economic appraisal of a 25 m^3 BORDA-type community digester operating at 25°C

Investment costs:		YD
Digester buildings		290
Gasholder		125
Connections and gas-use devices		400
Public latrine		150
Total, A		965
Annual production costs:		
Raw materials		-
Depreciation:		
Civil construction (20 years)		22.0
Gasholder (10 years)		12.5
Connections, and gas-use devices (10 years)		40.0
Repairs and maintenance		20.0
Total, B		94.5
Annual income:		
	Kerosine equivalent in YD	LPG equivalent in YD
Biogas	110	139
Fertilizer	56	56
Total annual income, C	166	195
Annual profit (C-B)	71.5	100.5
Return on invested capital	7.4%	10.4%

3. Large tunnel-type digester

The following preliminary techno-economic evaluation is based on a tunnel-type digester operating on droppings collected from one of the layer houses in Rabat farm. The evaluation covers unheated as well as solar-heated systems.

(a) Solar-heated system

The evaluation is based on the following assumptions:

(i) The volume of the digester is 90 m^3, the mean ambient temperature is 29°C while the operating temperature is 37°C. The system has a retention time of 20 days. The total solid concentration is 8 per cent and the rate of gas production is 1.2 m^3/day;

(ii) The droppings, which are collected twice daily at 12 noon and 5 p.m., are mixed with solar-heated water and fed to the digester;

(iii) The temperature inside the digester is maintained around 37°C using a closed solar heated system;

(iv) It is assumed that the value of droppings as a fertilizer will not change during fermentation;

(v) Labour for the operation is estimated at one half man-day;

(vi) The gas produced is mainly used for the generation of electrical power. Accordingly it will be a substitute for gas oil;

(vii) Gas will not be stored for more than eight hours;

(viii) The utilization of the effluent is not included in the evaluation.

However, it can be used as a fertilizer or animal feed. The use of effluent as an animal feed would be of great advantage to Democratic Yemen, and it can be used on large poultry and animal farms. It can be used either directly by drying and mixing with other ingredients, or indirectly in hydroponic systems to produce green fodder.

As can be seen from table 34, the return on invested capital is about 26.7 per cent, based on the utilization of biogas as a substitute for gas oil.

(b) Unheated system

The evaluation is based on the following assumptions:

(i) The volume of the digester is 110 m^3, the mean ambient temperature is 29°C and the mean operation temperature is 29°C. The retention time is 25 days. The total solid content is 8 per cent and the rate of gas production is 0.55 m^3/day;

(ii) The droppings, which are collected twice daily at 12 noon and 5 p.m., are mixed with water and fed to the digester;

(iii) Other parameters are similar to those given for a solar-heated system.

As can be seen from the evaluation given in table 35, while total investment costs are slightly lower than those for the solar-heated system, there is an appreciable difference in the return on capital investment, which is only 11.9 per cent. It should be noted however, that this system is much easier to operate.

Table 34. Preliminary economic appraisal of a 90 m^3 solar-heated tunnel-type digester

Investment costs:	YD
Civil construction	2,500
Gasholder	1,000
Mixing systems	400
Solar heaters and heating system	1,000
Total, A	4,900
Annual production costs:	
Labour	360
Depreciation:	
Civil construction (20 years)	125
Gasholder (10 years)	100
Mixing systems (10 years)	40
Solar heating system (10 years)	100
Repairs and maintenance	120
Total, B	845
Annual income:	
Biogas	2,155
Total annual income, C	2,155
Annual profit (C-B)	1,310
Return on invested capital	26.7%

Table 35. Preliminary economic appraisal of a 110 m^3 unheated tunnel-type digester

Investment costs:	YD
Civil construction	3,000
Gasholder	700
Mixing systems	400
Total, A	4,100
Annual production costs:	
Labour	360
Depreciation:	
Civil construction (20 years)	150
Gasholder (10 years)	70
Mixing systems (10 years)	40
Repairs and maintenance	100
Total, B	720
Annual income:	
Biogas (gas oil equivalent)	1,207
Total annual income, C	1,207
Annual profit (C-B)	487
Return on invested capital	11.9%

F. Proposed demonstration phase

The demonstration of BGT under actual field conditions forms an important part of the efforts to promote the widespread propagation of this technology. The demonstration phase is basic for introducing the technology, examining its feasibility, assessing its impact in concrete terms pinpointing the major constraints and problems and working out the required solutions. Above all, the demonstration phase is needed to encourage social acceptability, which is a major factor in the adoption of the technology by virtue of the fact that "seeing is believing".

It is recommended that the demonstration phase be divided into two major stages:

(a) Demonstration of family and small community-type units;
(b) Demonstration of large-scale farm plants and community units.

1. First demonstration stage

This stage entails the construction of 3-4 digesters in a village in the governorates of Abyan or Lahej. El Hobiel village in El Hota in the governorate of Lahej is one of the recommended sites. The main reason for its selection is the availability of biomass feed materials and its location near Aden, which will facilitate visits by different categories of prospective users and decision makers.

The proposed demonstration designs are as follows:

(a) Egyptian-Chinese family-size digester

The volume of the unit would be about 5 m^3. The digester would be connected to both a household latrine and animal shed. The manure from 8-10 equivalent animal units would be collected and mixed with waste water to provide the daily feed of the unit. The gas produced would be used to provide household energy. An LPG stove-oven combination would be adjusted to operate on biogas. The effluent slurry would be dried close to the unit and used as a fertilizer.

(b) BORDA-type family-size digester

The recommended volume of the unit is 5-6 m^3. The unit would also be connected to the latrine and animal shed of a family in the village.

(c) Flexible bag family-type digester

A 10 m^3 unit would be connected to the latrine and animal shed of a family in the same village.

(d) Small community-type digester

A small community-type digester of 10-15 m^3 would be constructed. One of the three above-mentioned digester designs would be chosen. The digester would operate with public latrine wastes and manure collected from the animals of two families. The two families would care jointly for the digestor. The gas produced would be delivered to the houses of the two families. Similarly, the effluent would be dried and divided between the two families.

The construction of these four different types of digesters in one area will make it easier to operate, maintain, evaluate and compare the different designs and systems.

2. Second demonstration stage

This stage involves the demonstration of large community and farm digesters. A large community digester would be constructed in a suitable large village. The large farm digester could be constructed at the El Rabat poultry layer farm. A community-type digester could also be constructed near this area. The recommended units are as follows:

(a) Large tunnel-type farm digester

A 100 m^3 tunnel-type digester could be constructed near one of the layer houses. The system would be mechanized. Solar heating would be used to heat the feed water and maintain the temperature inside the digester at an optimum 37°C. Slurry would be mixed inside digester by gas circulation. Droppings would be collected twice daily and mixed with water before being fed to the unit. The effluent would be dried and used as a fertilizer. The gas produced would be used mainly to generate electrical power. About 160 kWh per day would be produced and used to illuminate and operate the poultry houses. If there is sufficient finance, a generator with a waste-heat recycler could be installed to produce electrical power and heat. The heat produced would help to raise the temperature of fermentation in the digester.

(b) Large community digester

A 40 m^3 community digester would be constructed. A BORDA, Egyptian-Chinese or flexible bag design could be used. The unit would be connected to public latrines. Manure from the animals of a large number of families would be collected and used to feed the unit. The gas produced would either be distributed to the families or used to operate a number of engines used by the community. The fertilizer that is produced would be distributed among the families, preferably on a pro rata basis according to manure contributions.

G. Suitability of the technology for the rural women Democratic Yemen

The majority of the population in Democratic Yemen lives in rural and mountainous areas. Most energy needs are met by non-commercial fuels such as fuel wood and agricultural wastes. The collection and transport of these materials over quite long distances is a burdensome and time-consuming job undertaken by women. During an ESCWA mission[1/] it was estimated that at least six hours per day of the Democratic Yemen rural women's time was spent collecting and carrying fuel and fetching water.

The same mission also reported that these fuels were burned directly to produce heat for cooking, baking and other domestic uses, and that the responsibility for this fell upon women. The direct, primitive-type employment of these fuels for burning causes health hazards from air pollution and the handling of raw animal manure. Women are therefore more vulnerable to eye, chest and intestinal tract diseases.

The rural type of BGT is highly appropriate for women. Women could play a supporting role in the implementation phase, including construction (after training of course), and would have full responsibility for the operational stage. They would also gain the most benefit from the technology. The benefits to be gained include sanitation, cleanliness and the creation of a healthy atmosphere around the house, as well as considerable time-saving (in fuel collection and cooking).

The demonstration phase would provide an ideal opportunity to develop women's awareness of the technology and its benefits, as well as to train a core group of women. These women could then train others and could quickly diffuse the knowledge gained.

1/ The United Nations Development Fund for Women (UNIFEM) project paper is entitled "Appropriate technology for women in rural and mountainous areas of the Democratic Yemen".

III. MAJOR CONCLUSIONS AND RECOMMENDATIONS

1. Biogas technology would seem to be feasible, greatly needed and recommended for rural areas of Democratic Yemen for the co-production of energy and fertilizer. Meanwhile, the technology could also be adapted to function as a sanitary disposal system, thereby providing an extra merit of considerable importance.

2. The rural version of this technology is highly appropriate and beneficial for women in the rural and mountainous areas of Democratic Yemen. Women could play a valuable supporting role in the propagation and construction stages, and a major role in operating working systems. Cleanliness, health and time-saving factors are the principal benefits that would be gained from the use of BGT.

3. The full exploitation of BGT under the conditions prevailing in the rural areas of Democratic Yemen will only satisfy the energy requirements of about 17 per cent of the rural population. In order to increase this potential and enhance the role of BGT in Democratic Yemen, the biomass resource base should be extended through a long-term strategy.

4. In order to meet the energy needs of rural areas, other technologies have to be applied in unison with BGT. For example, efficient biomass-burning stoves and ovens need to be used. These stoves are up to 300 per cent more efficient than traditional primitive stoves and ovens, and cause much less pollution (as has already been demonstrated at NRC, Egypt).

Part Two

SOCIAL ASPECTS OF BGT AND ITS IMPACT ON WOMEN

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* Prepared by H. Badran, Helwan University, Cairo. The views expressed in this paper are those of the author and do not necessarily reflect those of the United Nations.

IV. REVIEW OF THE LITERATURE

Now that it has been agreed that development priorities should satisfy the basic needs of all the population, ensure national self-reliance and guarantee people's participation, the application of appropriate technologies plays a major role in achieving these objectives. It includes the knowledge and skills used to satisfy people's needs, to ensure their control over their environment and to enable them to participate in development. In effect, this technology determines what can be done with the society and how it can be done. In view of this, the introduction of BGT as a renewable energy technology should be studied and dealt with not just as a manifestation of the hardware involved, but as a tool that modifies the productive, organizational, social and comsumption modes of the society. Therefore, BGT should not be introduced in isolation, it should be integrated into the socio-economic and cultural framework in order to give it the required coherence. Technology introduced in this way is not imposed on people; it is voluntarily and selectively incorporated into their lives. Cultural characteristics can then be used to support the new technology, instead of acting as obstacles.

In spite of this, there is relatively little literature on the social aspects of BGT. The report of the International Conference on Biogas Technology, Transfer and Diffusion: State of the Art, held in Cairo in November 1984, for example, included a short section on the socio-cultural aspects of BGT which only constituted 4.5 per cent of the total report.[1/] The following is an outline of the basic characteristics of the available literature.

(a) The presentation and analysis of information on socio-cultural aspects is mainly done by people outside the field of social sciences. As a result, the analysis of social variables that contribute to a particular phenomenon are oversimplified or misinterpreted, and occasionally based on faulty assumptions. It has been assumed, for example, that both Indian and Egyptian farmers are essentially individualistic and that it is almost impossible for them to co-operate in a community-type biogas system. This, in fact, is an incorrect assumption, as theory and experience have demonstrated that co-operation and individualism are situational rather than absolute attitudes. It is also difficult for non-social scientists to deal with the methodology of incorporating BGT into an existing culture and identifying the social activities needed to facilitate this. As a result, data on the social procedure for introducing the technology is limited and superficial. One of the reasons why this situation prevails is the existing perception of the role of social scientists who are included in the teams that deal with BGT. Their role is usually confined to making a preliminary analysis of the community and family systems in preparation for the introduction of the technology. Their role does not proceed beyond this stage, and they do not participate during the implementation, follow-up and evaluation of projects.

1/ Biogas Technology, Transfer and Diffusion, M. M. El Halwagi, ed., Proceedings of the International Conference, held at the National Research Centre, Cairo, 17-24 November 1984, (New York, Elsevier, 1986).

(b) Although women constitute that part of the population most affected by BGT and they are the principal managers of its basic input and output, the "material" aspects of BGT projects are usualy dealt with by males. There is no doubt that the relevance of the technology to the needs of housewives would be increased if women participated in the design of the material aspects of the technology. The inclusion of a female social scientist playing the role explained above is not sufficient to bridge this gap. The availability of suitably qualified women scientists means that they can assist in the design of the material aspects of the technology.

In view of the above, the following is a review of the available literature on the social, i.e. non-physical aspects of biogas technology. This section will review the three main issues related to these, namely:

(i) Evaluation of the social impact of BGT;

(ii) Evaluation of the impact of BGT on the quality of life of women;

(iii) The relevance of BGT to the lower socio-economic classes.

The review includes theoretical discussions and frameworks based on experience gained from BGT projects in Asian countries and Egypt.

1. Evaluation of the social impact of BGT

The problem of assessing the impact of BGT has been dealt with in literature as being the problem of making a choice between the different production techniques that are appropriate to rural areas in third world countries. Attempts have been made to assess its viability on the macro- and micro-level. As a macro-problem, it is set in the wider context of fuel and rural development policies. As a micro-problem, it is discussed in a certain location and under a specific set of micro-conditions. Obviously, the two levels only interact where micro-analysis provides the basic information necessary for choices and decisions to be made on the macro-level. Accordingly, the problem of evaluating BGT is initially dealt with as a micro-problem.

The most widely accepted approach for the evaluation of BGT on a micro-level is to make a social cost-benefit analysis. An attempt is made to determine the relationship between the input and output associated with the technology by giving socio-economic values to those events. The concept of opportunity cost is central to the social cost-benefit analysis. Accordingly, the analysis involves the comparison of a set of alternative techniques that can perform the same function as BGT. The opportunity cost of the input and output associated with investment in biogas is calculated in the analysis.

There are two basic models for carrying out a social cost-benefit analysis. The first model1/ consists of three major steps: (a) an examination of alternatives to BGT; (b) the identification of the input and output and the relationship between them; and (c) the valuation of the various inputs and outputs.

1/ A. Barnett, "Biogas technology: a social and economic assessment", Biogas Technology in the Third World: a Multidisciplinary Review, A. Barnett and L. Pyle, eds. (New York, 1978).

(a) The first step involves considering the possible functions of biogas and the identification of other techniques that could perform each of these functions. The procedure is as follows:

(i) As a fuel source, biogas can be evaluated in terms of its ability to satisfy the energy needs of villages as compared with other energy sources. Comparison could be made with the following sources:

a. Firewood, which may be scarce and take some time to collect;

b. Electricity, which could be subsidized or not;

c. New stove designs that run more economically on existing fuels;

(ii) As a provider of fertilizer, BGT could be compared with aerobic compositing processes or chemcial fertilizers;

(iii) As a substitute for harmful and wasteful activities such as burning dung and wood, BGT could be compared with composting or the growing of trees and other plants for fuel;

(iv) As a safe way of disposing of human and animal wastes, BGT could be compared with composting or other conventional processes for waste disposal;

(v) As a method of utilizing waste resources, BGT could be compared with other possible methods.

It is important to be precise about the alternatives to possible methods that are included and those that are being excluded before moving on to the next step of identifying and estimating the physical quantities of inputs and outputs involved in the project and putting values on them.

(b) The specification of inputs and outputs and establishment of relationships between them is usually the engineers' responsibility. The specification is usually carried out on a technical/economic dimension only. The direct physical quantitative input and output of BGT is estimated and subjected to economic analysis. The Barnett model suggests two other dimensions that should be considered when specifying the output of BGT during the social cost-benefit analysis. These are the social and environmental dimensions. The indicators related to these two dimensions can be classified as follows.

(i) Social dimension

a. Structural developments

i. Promotion of self-reliance at all levels;

ii. Promotion of citizen participation;

iii. Reduction of inequalities among individuals and social groups;

b. Cultural compatibility

Harmony with indigenous societal traditions.

(ii) Environmental dimension

a. Quality of human life

i. Satisfaction of social and emotional/psychological needs;

ii. Replacement of unpleasant activities with better ones;

b. Ecological balances

i. Conservation of non-renewable natural resources;

ii. Reduction of pollution.1/

Some of these indicators, such as the cost of pollution are included in the technical/economic analysis, but it is useful to separate them under the social/environmental category in order to emphasize the interests of those who will be affected by the project. Two important issues concerning the specification of indicators should be mentioned here. First, social effects cannot be measured quantitatively. They have to be analysed qualitatively in order to stress their importance. Secondly, attention should be paid to those parts of the system not immediately connected to the project, i.e. the secondary or linkage effects.

(c) The third step in the Barnett model after the specification of the social/environmental impact is to put a value on the different inputs and outputs. The evaluation has to be made in terms of a set of objectives that must take the interests of four groups into consideration:

(i) The Government;

(ii) The owners of the project, i.e. the farmers;

(iii) The village as a whole;

(iv) The different groups in the village.

1/ A. Barnett, "Biogas technology: a social and economic assessment", Biogas Technology in the Third World: Multidisciplinary Review, A. Barnett and L. Pyle, eds. (New York, 1978), pp. 70-71.

2/ Ibid, p. 72.

Barnett identifies the different systems that are used to value the impact and indicates the shortages in each before suggesting his own system, which has at its core the concept of opportunity cost. This system involves deciding what real alternatives there are to the use of particular inputs and outputs and their categories. To illustrate, five broad inputs and outputs associated with BGT were analysed: cellulosic organic material such as dung inputs and slurry outputs, methane gas, labour, capital and other outputs such as improvements in public health.

Five possible opportunity costs can used to give a value to cellulosic organic material as an input: valuation according to market prices, which indicates the return that could be achieved from the alternative uses of dung, valuation in terms of the use of dung as a fertilizer used directly on the field, valuation in terms of its use as a fuel, valuation in terms of being a free commodity and in terms of its nuisance value, in which case it becomes a negative cost, i.e., in effect it constitutes a benefit.

Methane gas is valued in relation to the real cost of alternative energy sources such as electricity or wood, with subsidies, transportation, etc., being taken into consideration.

The valuation of the labour used to carry and spread the slurry depends on the labour situation in the village and on the previous way fertilizer and dung were handled. It should be noted that labour is not a homogeneous category. Some of the tasks associated with BGT can be carried out by unskilled labour, while others require skilled labour. Each type has a different opportunity cost, which also varies according to the sex of the performer of the task.

Capital is valued in terms of its opportunity cost and the problems associated with discounting costs and benefits that occur over differing time profiles, as compared with its present value. Access to capital plays a major role in determining the rate of adoption of BGT plants and hence in the pattern of their ownership. Where loans are involved, it is important to consider the cash returns to a project. A Government may have to subsidize the loan in order to maximize social as opposed to financial returns.

The model treats social outputs as "other" outputs and does not go into great detail on this matter. It refers to the social outputs mentioned above and to the difficulty of quantifying and putting a value on them.

The reduction in the transmission of human pathogens that occurs as a result of processing human waste in a BGT plant is a special case in point. When human waste can be classified as an input, its value will increase, and this will encourage the safe disposal of excreta. The reduction in the incidence of illness that results from this process is difficult to estimate because other factors may intervene. It is also difficult to place a value on any such reduction. Accordingly, social benefits can be introduced in the valuation as qualitative objectives. Improvements in the domestic environment following the reduction in weed and dung smoke is another social output that should be valued in the same way, as is the reduction in cooking time when BGT substitutes dung or weed. Surplus labour should then be valued according to the opportunity costs of that particular type of labour.

Based on the previous social cost-benefit analysis, it can be assumed that BGT is viable in situations where inputs have a low opportunity cost, where the efficiency of the plant is adequate and where alternative outputs have a high opportunity cost.

The required inputs have a low opportunity cost where:

(i) The nature of agriculture is such that there is an adequate amount of material from which methane gas can be produced and that the opportunity cost is no higher than when it is used as fertilizer or fuel;

(ii) There are industries that produce large amounts of material from which methane can be produced;

(iii) There are no social restrictions on the use of human waste;

(iv) Cow dung is usually collected;

(v) Water is available and can easily be fed into the digester;

(vi) Capital with a sufficiently low opportunity cost is available;

(vii) Labour is available and willing to undertake the work of operating the methane generator.

Alternatives to the outputs of BGT plants have a high opprtunity cost where:

a. There is a physical limit to the amount of fuel and fertilizer available from alternative sources;

b. There is a scarcity of wood;

c. Dung is burned as a fuel;

d. There is insufficient water to make the use of chemical fertilizers possible;

e. There is not enough cash to buy other fuels and fertilizers;

f. The gas is used near the generator;

g. The cost of handling slurry is not enough to reduce the net value of the slurry to unacceptable levels.

Some of these criteria can be modified by government policy and expenditure. The availability of inputs in the areas that have been identified are determined more by the social groups concerned than by geographical characteristics. Ten groups can be considered: (i) those with intensive animal or crop production; (ii) co-operatives formed to produce biogas; (iii) large existing social groups that are able to co-operate (large families); (iv) communal cooking groups; (v) co-operatives formed for other purposes; (vi) large farmers; (vii) small farmers; (viii) landless labourers; (ix) traditional collectors of cow dung; and (x) women.

Unless the output of BGT can be sold, investment in BGT will only be viable for those who have access to the various inputs and who have a use for the output. Therefore, only the first four social groups can invest in biogas, which means that only the relatively well-off can afford the cost of investing in biogas. Dung and other wastes may be denied to those who traditionally collect them.

If income distribution forms part of the Government's objectives, then the strategy of introducing biogas plants only for the rich may be unacceptable. The solution would be to encourage the use of community plants.

Beside the social cost benefit analysis approach, a number of positive effects have been identified as indirect benefits of biogas technology. A report on experiences in Sri Lanka advocates viewing BGT as a means of national rural development. From a macro point of view, the social effects of BGT are reported to include an improvement in health and sanitation, the generation of employment opportunities, reduction in subsidies and the promotion of self-reliance in fertilizers and fuel development.[1/]

The report states that hygienic toilet facilities are almost non-existent in the rural areas of third world countries. The resulting pollution, particularly that of waterways, frequently causes bowel diseases. In Sri Lanka, for example, some 60 per cent of hospital patients suffer from bowel diseases caused by drinking polluted water. The use of integrated BGT systems where toilets are connected to a digester generally has a positive effect in reducing the incidence of bowel disease. Furthermore, benefits accrue as a result of the decrease of pressure on medical institutions and medical staff. The health budget and the need for medical supplies and equipment is also reduced. Improvements in the health of the population will have a positive effect on the volume and quality of productivity. Improvements in animal and plant health that result from a decrease in pollution and the destruction of pathogens is another benefit. The Sri Lankan report also mentions that the introduction of BGT can help to solve the problem of rural employment. The manufacture of bricks, collection of sand and production of gas-utilizing equipment provide alternative avenues of employment. BGT also encourages animal husbandry, and offers other diversified employment opportunities. The report also states that Sri Lanka, together with a number of other countries in the third world, provides subsidies food, fertilizers and fuel. These subsides sometimes result in an increase in the burden on the national budget. This situation can be effectively exploited by diverting some of these financial resources to integrated systems that provide a degree of self-reliance in fertilizer and fuel development in rural areas, which can also increase local production.

1/ M. Amaratunga, "Towards obtaining optimum benefits from biogas technology", Biogas Technology, Transfer and Diffusion, M. M. El Halwagi, ed., Proceedings of the International Conference held at the National Research Centre, Cairo, 17-24 November 1984, (New York, Elsevier, 1986), pp. 98-102.

Another social cost-benefit analysis model was proposed by El Halwagi and was illustrated by applying it to an actual Egyptian case. It attempts to assess the costs and benefits that result from installing a BGT system in terms of the net variations caused by its impact as an agent of change.1/

The model gives a list of positive and negative effects that are associated with the introduction of BGT. It differentiates between the effect on individuals and on society as a whole. The positive effects on an individual/beneficiary level include the following:

(i) It provides a clean and efficient source of energy that results in the cleanliness of the kitchen, the saving of time, and the elimination of smoke that would otherwise cause eye and chest ailments;

(ii) There is no need to collect firewood, which is more convenient, saves time and reduces the threat of snake bites (that often live in piles of firewood);

(iii) It results in cleaner animal sheds which leads to improved sanitary conditions and the improved, cleaner milking of cows;

(iv) It allows more baths to be taken more frequently;

(v) Hot food and hot tea are availale daily;

(vi) It permits savings to be made on fuel and fertilizers;

(vii) It provides for the sanitary disposal of human wastes with the connection of a latrine to the digester;

(viii) It results in fewer flies, pathogens and parasites;

(ix) It provides a locally available renewable energy resource, thereby reducing the consumption of commercial energy;

(x) It partially resolves the uncertainty of energy supplies as there is less dependence on outside sources of energy;

(xi) It offers a solution to the problem of deforestation as it often results in a considerable reduction in the consumption firewood (depending on the scale and extent of BGT propagation);

1/ M. M. El Halwagi, "Impact of biogas technology in rural areas", paper presented at the Scientific Meeting on Technology Assessment for a Self-reliant Development: Research and Development Strategies in Using Local Resources for Rural Development, held at Bucharest, 4-6 November 1985.

(xii) It aids resource conservation by recycling organic matter back to the soil, thereby increasing agricultural productivity and reducing dependence on chemical fertilizers;

(xiii) It contributes to increased productivity through improvements to health and the quality of life of the rural population;

(xiv) It has a multiplier effect because of the ease with which BGT can be integrated into rural development, health-care schemes, etc. These help to produce self-reliant and self-sufficient societies.

The first step in the model is to identify the basic components of the rural organic waste-generating system, i.e. the BGT plant. The model uses a generalized framework for the three types of prospective systems, the single household, multi-household and large livestock-rearing operation. The basic components according to the generalized framework are classified into three groups: social components, productive components and service or support components. The social component consists of people, including the owner, family members and employees.

The next step in the analysis is to compare the status of each component before and after the introduction of BGT. A physical, social, economical and environmental comparison is then made. Any net changes after calculating the costs and benefits are then valued in monetary terms on the basis of alternative opportunity cost.

The model was illustrated by applying it to the analysis of an Egyptian case. Social changes included the effect on hygiene, manure handling and benefits to women. The positive environmental effects were reflected in a decrease in the medical bill and improvements in the quality of life and efficiency of work.

These effects were valued at 30 Egyptian pounds (LE) per annum. The savings in man-donkey time made through the introduction of a combination of concrete shed floor and digester were valued at LE 600 per annum. A further saving of LE 60 per annum was estimated to result from the new way of handling manure which made it unnecessary to hire outside labour. Benefits to women were valued at LE 200 annually, which represents the opportunity cost of one half day of work saved.

other components were analysed and valued in the same way. The model assumed that the individual owner in the case in question made a net benefit of about LE 1,280, whereas net costs only amounted to about LE 330. From a macro point of view, the benefits would actually have been higher if the real (unsubsidized) price of fuel, food and fertilizer had been used in the calculations. The estimated total benefit would also increase if the decrease in the incidence of contagious diseases resulting from improved sanitation was also taken into consideration.

Eight proposals to highlight the social, ecological and cultural considerations associated with BGT systems have also been made. The proposals are derived from five years of research and demonstration activities in Egyptian rural village.1/

The propositions are as follows:

(i) BGT and development activities will be more successful if they are compatible and operate within the level of requirements of the system;

(ii) The raw materials for BGT are yet to be exploited to meet the staggering world-wide need for a sustainable source of energy;

(iii) The successful design and implementation of BGT systems will be influenced by the cultural patterns of the people;

(iv) Patterns of bureaucracy and the social structure impose powerful constraints on the diffusion of biogas technology;

(v) The different types of initiation and sponsorship of biogas technology will result in a number of outcomes;

(vi) Management requirements and responsibilities for operation and maintenance will differ markedly in the different types of BGT systems;

(vii) Biogas technology makes a positive contribution to improving health, sanitation and aesthetics;

(viii) It is easier to assess the technological soundness of BGT than its social and economic feasibility.

Other studies have commented on the socio-economic effects of biogas technology but they only address the major issues covered above.

2. Impact of BGT on women

The role of rural women is central to the process of generating energy and fertilizers. Traditionally, the management of animals is their responsibility. They are responsible for collecting the fuel, making dung cakes and using the fuel, mainly for cooking. A study on Pakistan has indicated that a rural woman spends about 35 per cent of her day on caring for

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1/ H. R. Capener and M. M. El Halwagi, "Social, ecological and cultural realities of biogas development", Biogas Technology, Transfer and Diffusion, M. M. El Halwagi, ed., Proceedings of the International Conference held at the National Research Centre, Cairo, 17-24 November 1984 (New York, Elsevier, 1986), p. 71.

and feeding livestock, 11 per cent on cooking, 7 per cent on milking and churning and 5 per cent on cleaning and making dung cakes.[1/] Egyptian women in rural areas spend their time in a similar way.[2/]

Rural women play a central role in the operation of a small farm household biogas system. A system such as this is usually organized on a family kinship model, which allows for some exchange of management functions between the sexes and which utilizes all family members as unpaid labour. The role of women in this system incudes caring for animals, handling wastes, feeding the digester and utilizing the gas.

It should be noted, however, that in spite of the central role played by rural women in the different systems of energy generation, and the fact that any change in the system entails several behavioural changes for them, they are rarely consulted before a BGT system is introduced. The wives of owners of BGT plants in a rural village in Egypt indicated that they were only informed rather than consulted by those responsible for introducing the systems.

Most of the evidence suggests that the introduction of BGT affects the role of rural women and leads to improvements in the quality of their lives. Essentially these improvements are reflected in better standards of health and cleanliness and in the saving of time and effort put into labour tasks.

(a) Health and cleanliness

As was mentioned before, BGT systems help to improve the health of the whole family, including women. BGT systems break down the life cycle of parasitic and pathogenic materials in human and animal wastes and help to combat the transmission of disease. The introduction of a solid floor in animal sheds makes it easier to keep them clean and improves the level of cleanliness throughout the house. This will reflect on the personal cleanliness of the members of the family, but the impact on women will be even greater because of the central role they play in the generation of energy and fertilizers and their use of the products.

As rural women are responsible for household activities such as cooking, washing and baking, they are also the most vulnerable to health hazards resulting from air pollution caused by the direct burning of organic fuels and from handling animal manure manually. The by-products of the burning process include carbon particles that are inhaled by women as they perform their daily household duties. The handling of dung and human excreta leaves residues that are difficult to wash off completely from women's hands and clothes. The prevalence of enteric diseases among villagers, especially infants and children, is directly related to unsanitary conditions such as these.

1/ Slide presentation on the role of rural women in Egypt, organized by the Food and Agriculture Organization of the United Nations in Damascus in August 1974.

2/ Based on information gathered during interviews with four families in the village of Manawat, Egypt, who had installed biogas digesters.

The implementation of biogas systems will free rural women from having to handle animal manure and from being exposed to the by-products of the direct burning of organic materials. A recent study of India has indicated that about 93 per cent of the owners of BGT have installed cooking units. "The smoky flame from the traditional fuel (cattle dung) blackens the kitchen and utensils and affects the eyes."[1/] In one Indian state where 56 BGT plants have been installed, a recent survey has indicated that the use of biogas has reduced the incidence of eye infections in housewives, increased the life of the utensils, and improved the cleanliness of the house and clothes of women.[2/]

(b) Women's labour

The time and effort that rural women put into the daily activity of generating energy and preparing fertilizers varies according to which social group they belong to and the size of the family. It also varies according to the available alternatives to the BGT system. In areas where energy needs are met by firewood, the collection of wood is primarily the responsibility of women. It is either undertaken by the wife or other female members of the family, or by hired female workers. The collection of firewood is an increasingly time-consuming activity because of its growing scarcity. In rural India, between 50 to 200 or more days of work per family are now required to ensure adequate fuel supplies.[3/] Where dung cakes are used for cooking and baking, women have to collect the excreta, mix it with staw and shape it into cakes. No precise calculation has been made of the time and effort spent in this process, but it is a hard, dirty, repetitive and degrading task. When a BGT system is installed, the dung is easily fed into the digester, and gas is ready for use at the turn of a knob. Biogas does not need as much time to produce flames as wood and dung.

The bedding process, which is a common pre-biogas production operation that keeps the shed relatively dry, together with the other processes involved in preparing and transporting the fertilizer to the field, is heavy work which women also share with men.

It is estimated that installation of BGT plants will lead to a net saving of at least one half day of work for women. This calculation also takes into consideration the faster milking of the cows due to the solid clean ground of the shed. Less time will also be spent on washing utensils, as there is less dirt from smoke when biogas is used.

1/ S. K. Subarmahian, "Biogas systems in Asia", Biogas Technology in the Third World: A Multidisciplinary Review, A. Barnett and L. Pyle, eds. (New York, 1978), p. 115.

2/ *Ibid*., p. 115.

3/ *Ibid*., p. 71.

Women are also aware that the installation of biogas plants will ease the burden of working with animals. It has also led to the use of new multiple burner units in the kitchen and the introduction of other equipment which has helped to ease women's work.1/

But how was the time saved used by the women and what impact did it have on them and on the quality of life of their families? The reports fail to answer this important question. The absence of information on the social aspects of biogas technology supports a point raised at the beginning of this report. The limited role of social scientists in the implementation of BGT projects and the discontinuation of that role once the plant has been installed leaves a gap in the follow-up process and evaluation schemes. The absence of supportive social components, such as health education, self-awareness, life skills education, etc., in the implementation process leaves the women with free time which they are unable to exploit to the advantage of their own families and communities. Because women are not involved in the pre-installation process and do not participate in any of the related decisions, they do not look after the new stove they have acquired as part of the BGT project. During visits to the houses of owners in one of the sites in Egypt, it was noticed that the stove was dirty and that all of the control knobs were missing.

(c) BGT and the poor

One of the important issues mentioned in most of the literature is the need for a minimum level of waste input before a biogas system can be installed and poor families generally lack this. In the Indian experience, only the middle and upper middle casses were able to benefit from biogas plants. The situation is similar in other Asian countries, where essentially it is only the rich who could afford to install biogas plants.2/ In Egypt, rich families were selected to experiment with the technical aspects of BGT. A diffusion theory was used to rationalize their selection. It was observed that the social structure is such that those who most need the service are the hardest to reach. Therefore, as the introduction of family BGT systems has only a limited impact on the rural poor, community plants or multi-house digesters are a possible solution.3/

1/ M. M. El Halwagi, "Impact of biogas technology in rural areas", paper presented at the Scientific Meeting on Technology Assessment for a Self-reliant Development: Research and Development Strategies in Using Local Resources for Rural Development, held at Bucharest, 4-6 November 1985, p. 10.

2/ S. K. Subarmanian, "Biogas systems in Asia", Biogas Technology in the Third World: A Multidiscplinary Review, A Barnett and L. Pyle, eds., (New York, 1978), pp. 114-115.

3/ H. R. Capener and M. M. El Halwagi, "Social, ecological and cultural realities of biogas development", M. M. El Halwagi, ed., Proceedings of the International Conference held at the National Research Centre, Cairo, 17-24 November 1984 (New York, Elsevier, 1986), pp. 75-78.

The available literature on the subject indicates that experiments with community plants have not proved successful. In Asia it was claimed that the factor of leadership was crucial, and that the change of the community worker in a certain project led to its collapse. The unco-operative, individualistic disposition of the Indian and Egyptian farmer was said to be another factor working against community plants. This claim was supported by evidence from a special case that was used in an experiment in rural Egypt.1/

The social problems associated with multi-house or community plants cannot be simplified. They have to be tackled scientifically in order to extend the benefits of biogas to all groups in the community, and to the disadvantaged in particular. A qualified community worker needs to be involved in a project during the planning and subsequent stages. The role of this worker, with the participation of the families, would be to establish a formula for co-operation between them, which would allow them to perceive the direct benefits that each would gain from the system. The role would also include training participant families to perform their proper roles in the system.

1/ M. M. El Halwagi and others, "A pilot experiment for co-operative community biogas facilities in rural Egypt indicated social failure", paper presented at the International Biogas Workshop on Community Plants, held at Bremen, May 1984.

V. SOCIAL FEASIBILITY OF THE INTRODUCTION OF BIOGAS TECHNOLOGY IN DEMOCRATIC YEMEN

The aim of this section is to assess the social feasibility of introducing BGT systems in Democratic Yemen. In particular, an attempt will to made to assess the possible effects on women of introducing BGT, and to identify the social requisites needed to improve the relevance of BGT systems to the community.

The assessment is based on information gathered in Democratic Yemen and on the theoretical discussion presented in the first part of the report. The information gathered in Democratic Yemen was obtained from several reports and field studies relevant to the subject, from discussions with officials and citizens and from field observations.

In order to put the assessment into a wider context, information on the national policy relevant to the subject will be presented. The present situation of women in general, and their situation in Lahej and Abyan, in particular, will be discussed. These two governorates were proposed as sites for the introduction and study of BGT. A number of villages and farms in these governorates were visited during the mission to Democratic Yemen. The report concludes with an assessment of the possible impact of biogas on women in Democratic Yemen, and presents a number of recommendations on how to introduce this technology.

1. The national policy of Democratic Yemen

Since 1969, socialist principles have been applied in the country. The basic features of the Government's objectives are to:

(a) Transfer a significant proportion of production and distribution mechanisms to the public sector;

(b) Reorient the economy away from services and into the producing sectors;

(c) Assure an equitable income distribution;

(d) Meet the basic human needs, including educational and cultural services, of the entire population at a subsidized price.

In order to achieve these objectives, the Government has extended its ownership and control over a significant number of economic activities, redistributed assets and instituted social reforms. In 1979, the public sector accounted for 56 per cent of industrial production, while the co-operative sector accounted for 1.8 per cent and the private sector made up the remainder. In the agricultural sector, 12 per cent of cultivated land is state owned, 80 per cent is owned by co-operatives and 8 per cent is owned privately.

The Government attaches high priority to the development of the agricultural sector. Because rainfall is scarce throughout the country and is not sufficient for the purposes of cultivation, agriculture depends almost entirely on irrigation. Women play an important role in the agricultural sector. It has been estimated that the sector employs 51 per cent of economically active women and 40 per cent of men. As a result of male migration to oil-rich countries, certain areas rely heavily on female agricultural labour.

By the end of 1985, Democratic Yemen had completed three development plans. They assigned a leading role to the public and co-operative sectors, which duly expanded owing to various government measures, particularly the nationalization of private property, agricultural reform and state supervision of the utilization of national resources. A great effort has been made to achieve overall equality in the standard of living, but there are still differences between the rural and urban population. The Government is aware of these differences and is trying hard to improve living conditions in rural areas in terms of food, health and sanitation, education, energy, etc.

The Third Five-year Plan (1985-1990) continues to give priority to the evaluation and expansion of the productive base and expansion of the principal framework in an effort to ensure a higher standard of living for the entire population. It is planned that per capita income for 1990 will reach around YD 124.2 compared with YD 118.4 in 1985, i.e. an average annual increase of 1 per cent.[1/]

One of the aims of the plan is to increase the value of agricultural products and production by 42 per cent by the end of 1990. Investment in the agricultural sector will be directed towards improving agricultural co-operatives, developing animal wealth and emphasizing the role of women in irrigated farming.

In an attempt to ensure the prevalence of equal opportunities in rural and urban areas, the Second Five-year Plan (1981-1985) included a number of industrial projects in the various governorates, including a cement factory in Abyan. In the energy sector, the plan includes the construction of a power station to generate electricity for five towns east of Mukalla in the governorate of Hadramawt, a joint electrical project to link Abyan governorate with the Ad Dali Electricity Station and the Lahej electric project in order to increase the generation of electrical energy in Hadramawt and Mukalla. The plan also includes several other smaller electricity projects in different areas of the country.[2/]

1/ Democratic Yemen, Ministry of Agriculture and Agrarian Reform, "The role of rural women in development with special emphasis on irrigated farming", (1985), pp. 6-7 (in Arabic).

2/ Ibid., p. 7.

Research on renewable energy is being carried out at Aden University, while the Petroleum and Mineral Board (PMB) and Public Corporation of Electric Power (PCEP) are involved in limited activites in this field. It is hoped that rural and remote areas can then be provided with an appreciable portion of their energy needs. A special report on the subject recommended the establishment of a new department for renewable energy that would expedite the widespread adoption of renewable energy technology in Democratic Yemen, including biogas.1/

The health sector in Democratic Yemen is also interested in using biogas technology to provide a solution to environmental health in rural areas. The health sector in Democratic Yemen is strongly committed to primary health care (PHC), and places special emphasis on the development of rural areas. It is also concerned to develop the egalitarian distribution of services and community involvement through mass organizations. A Cabinet Decree of 1980 established multisectoral responsibility for PHC and the Party Congress also stated its commitment to PHC. The health sector has identified a number of priority health problems and areas. Plans have been made to expand and strengthen the coverage of basic health services in rural areas, where they are still rudimentary. The system is supported at the community level by volunteer health guides. Around 340 health guides have been trained, and it is planned that around 2,050 will be functioning by the year 2000. The guides are selected and supervised in the first instance by the community, while technical training is organized by the Ministry of Health (MOH) using supervisory training teams based at the district level.

MOH has conducted an intensive planning exercise to develop the health sector component in the Third Five-year Plan (1986-1990). The aim is to continue the expansion of PHC to cover 90 per cent of the population by 1990, and to consolidate and improve the quality of services. Mothers and children are to be given priority. Environmental protection and sanitation are mentioned separately. Financial support will be given to the National Council for Environmental Protection, which will have a broad mandate to monitor and control the environmental factors that affect health.2/ The Chairman of the Council is the Minister of Public Health. MOH will provide the secretariat which will ensure the co-ordination of other important environmental protection issues with other ministries and agencies.3/ The Ministry will support the Council and provide agencies with expertise in certain fields. Emphasis will be placed on developing appropriate non-polluting sources of energy and the promotion of environmental awareness among the public.

1/ M. A. Saleh, Mission Report to People's Democratic Republic of Yemen, (E/ESCWA/NR/86/2) (Baghdad, Economic and Social Commission for Western Asia, 1986).

2/ United Nations Childrens Fund, The State of the World's Children 1985, (Oxford, 1984), pp. 1-6.

3/ P. G. Clark, Water and Sanitation Sector in Democratic Yemen, World Health Organization Regional Office (1985), p. 4.

The collection and disposal of solid and liquid wastes in Democratic Yemen is the responsibility of the Local People's Councils, whose activities come under the jurisdiction of the Ministry of Local Government. The present legal framework for sewage disposal and other sanitation services, with the exception of that in Aden, is not well developed. The law which established local government structures provides only a broad framework of powers and duties in relation to those services. The sewage disposal component of the Third Five-year Plan (1986-1990) is also unclear. Most of the projects currently being constructed, together with a number of other new projects will continue. However, all of these projects are designed to serve big towns rather than deprived villages.[1/]

As part of a village development package, a study on environmental health and appropriate technology was undertaken at the request of the Ministries of Local Government and Public Health.

The study listed a number of appropriate technology measures to improve environmental health in Democratic Yemen, particularly in small communities, which would fit in with the plans of the Ministries of Local Government and Public Health. An important measure was the introduction of biogas systems.[2/]

An assessment of the sanitation sector was then undertaken and a number of recommendations which emphasized certain issues were made, including the following:[3/]

(i) The intersectoral nature of the sanitation problem;

(ii) Appropriate technology such as BGT should be introduced in order to improve the unsatisfactory facilities.

The Ministries of Local Government and Public Health requested the co-operation of the World Health Organization (WHO) to experiment with different biogas digesters in the governorates of Lahej, Abyan and Hadramawt. WHO installed a semi-industrial digester in a slaughter house and two digesters in cow farms in Lahej.

A number of sectors in Democratic Yemen already recognize that BGT can help to meet the energy and health needs of the rural population. However, more co-ordination is needed between the services sectors and energy institutions.

1/ P. G. Clark, Water and Sanitation Sector in Democratic Yemen, WHO Regional Office (1985), p. 4.

2/ B. S. Ghongassion, Assessment of Environmental Health Situation in Democratic Yemen and Recommendations for Appropriate Approaches, (August 1984), p. 27.

3/ P. G. Clark, op. cit., p. 18.

2. The situation of women

According to the last census, there are slightly more females than males in the total population of Democratic Yemen. The sex ratio, however, varies considerably across the age groups. While there are more males than females up to the age of 15, the picture is reversed for those over 15, which reflects the emigration of Yemeni males and the consequences of the war in the 1960s.1/ Fifty seven per cent of the population live in rural areas; 80 per cent of the rural population is distributed in roughly equal proportions, in the three governorates of Lahej, Abyan and Hadramawt.2/

The Government of Democratic Yemen has taken a number of measures to improve the situation of women since the country's independence. The Family Law and other legal measures have made Democratic Yemen one of the most advanced countries in this respect. However, conservative attitudes and behaviour, especially outside Aden, are still strong. This can be seen the seclusion of women and the low participation rates of girls in schools and in non-agricultural employment. The General Union of Yemeni Women (GUYW), which was founded in 1968, has responsibility for advancing women's interests and encouraging their participation in the country's development efforts. GUYW is an extension of the Yemeni Socialist Party and implements government policies that affect women.

GUYW has a 35-member general secretariat and each of the members heads a committee that has specific responsibilities. This structure is replicated at the local level throughout the country. The union has about 9,000 members, many of whom are housewives under 35 years of age.

Agriculture is the largest employer of women. As table 36 shows, about 51 per cent of the economically active women worked in agriculture, and constituted about 35 per cent of the total work-force in this sector.

Agriculture and animal husbandry together provide employment for 43.3 per cent of the population of working age, contributing 8 per cent of gross domestic product (GDP).3/ Animal husbandry is an important source of income for rural families. Women participate in these activities as unpaid family workers and wage workers. As is the case in many other third world countries, men tend to monopolize the use of modern technology, while women use primitive tools. Women and children are responsible for most of the work involved in raising livestock, feeding, cleaning barns, herding and milking the animals.

1/ United Nations Fund for Population Activities, Needs assessment for Population Assistance, Report No. 76, p. 15.

2/ Ibid., p. 16.

3/ United Nations Development Programme, Inter-organizational Assessment of Women's Participation in Development, Evaluation study No. 13, (1985), p. 99.

Table 36. Sectoral distribution of the active population, 1987
(16-59 years of age)

Sector	Number of men	Percentage of total	Number of women	percentage of total	Number of women as a percentage of total sectoral work-force
Agriculture, hunting and fisheries	130,700	40.2	71,150	50.6	35.2
Mining and quarrying	4,740	1.5	1,740	1.2	26.9
Manufacturing	22,640	7.0	9,470	6.7	29.5
Electricity, gas and water	5,410	1.7	1,740	1.2	24.3
Building and construction	26,360	8.1	6,970	5.0	20.9
Trade, hotels and restaurants	28,710	8.8	12,210	8.7	29.8
Storage, transport and communications	19,240	5.9	6,270	4.5	24.6
Finance, insurance, estates and business services	330	0.1	150	0.1	31.2
Community, social and personal services	87,170	26.7	31,000	22.0	26.2
Total	325,300	100.0	140,700	100.0	30.2

Source: Compiled from estimates provided by the Ministry of Labour and Civil Services.

Women are responsible for herding, fetching water and collecting firewood, in addition to their other regular household activities. It is estimated that they spend about one third of their day in these three activities. Women leave their homes early in the morning to collect wood weighing as much as 10-15 kilograms, which they carry over an average distance of three or more kilometres.[1/]

There are three types of farms in Democratic Yemen: state, co-operative and private. There is no sex discrimination in employment on state farms nor in the ownership of co-operative farms. Only a few women, however, are represented at the decision-making level owing to their lack of skills and illiteracy. Only a limited number of women have direct representation in co-operatives, as co-operative membership is limited to heads of households, who are usually men.

The Government is attempting to make modern agriculture and animal husbandry technology more accessible to rural women through the increase of female extension workers, but various constraints affect the situation; these need to be studied and handled in a comprehensive manner.

3. Labour of rural women

The following discussion applies to all rural women, but it deals in particular with the two governorates of Lahej and Abyan, which contain about 37 per cent of the population of Democratic Yemen. Most of the land in the two governorates, both on co-operatives and state farms, is dependent on flood irrigation and well water.

Women who are engaged in agricultural activities fall into three main categories, as follows:

(a) Women farmers who work almost daily during the agricultural season on their own or family farms in the co-operatives. These are generally older women in the household who own land in the co-operative;

(b) State farm labourers who are permanently employed as agricultural labourers on state farms;

(c) Temporary labourers who work on other farms (state farms and co-operatives) for short or long periods, and who are paid on a daily basis or for a specific job. The payment they receive is sometimes is partly in kind (fodder or grain).

The first group of women always share work on the land with other family members who live in the same house or close by, or they work with hired labourers. It is important to note that there is a co-operative attitude between family members outside the household, and in certain activities sometimes even between neighbours.[2/]

1/ United Nations Development Programme, Interorganizational Assessment of Women's Participation in Development, Report of Study No. 13 (1985), p. 100.

2/ A. Ali and others, Women in Irrigated Farming in the Wadi Tuban Delta, Lahej Governorate, PDRY, (November 1985), pp. 18-19 (in Arabic).

Women are involved and participate in the tasks and work related to all the crops. There is a stricter division of tasks on the basis of sex on state farms than in co-operatives. Land preparation and irrigation are carried out by men, while other manual work in the fields is done mostly by women. Owing to stricter division of labour in large areas covered by one crop and to certain other factors, women employed on state farms work harder and for longer periods than those in co-operatives. However, most of the women who work in the agricultural sector consider that their work on the land is heavy work. They complain about the long distances they have to walk to reach the land, the uninteresting activities they have to undertake and the pain caused by picking spiny okra.[1/]

One of the basic responsibilities of rural women is to care for animals. Most families own between two and six sheep. Shepherds own around 40-50 sheep and goats. Camels and oxen are usually owned by men, while women own other animals such as sheep, goats, cows and donkeys. Sheep and goats are kept for meat, while goats also give milk. Donkeys and camels are used for transport, mainly by men. Oxen are also used by men for ploughing, and cows are kept for milk. Poultry is raised by women to provide meat and eggs.

Taking care of animals means that women clean the pens, collect fodder, take the animals to the fields to graze, and milk them. Pens have to be cleaned once or twice a day; they are cleaned once if the animals remain in the fields during the day, and twice if they stay in the pens. Cows are milked twice a day, usually by women or their daughters. Women and children take animals to the fields to graze. They have to walk long distances with the animals in order to find a place for them to graze or to collect heavy loads of fodder which they carry on their heads.

Dried animal dung is burned directly to produce energy for domestic purposes. It is also mixed with straw and used to finish walls and floors. Huge piles of refuse containing animal dung and dried grass particles are accumulated in villages and towns next to dwellings, waiting for the seasonal floods to sweep them away.

Fetching water is also the responsibility of women, as only a few households have a water tap inside the house. Women have to go several times a day to a well or public water taps to get water, which they carry home on their heads in tins.

Other tasks performed by women include caring for children, preparing meals and baking bread, washing dishes, cleaning the house, washing clothes, shopping, sewing and mending clothes, house maintenance and collecting firewood.

1/ A. Ali and others, Women in Irrigated Farming in the Wadi Tuban Delta, Lahej Governorate, PDRY, (November 1985), pp. 18-19 (in Arabic).

Bread, which is eaten at breakfast and supper, is baked fresh for each meal. The dough is made in the early morning or at night. Women dislike the baking process as they run the risk of burning their hands. In veiw of the way ovens operate it is necessary to almost touch the flames when placing the dough inside. It is a difficult task to master. The smoke produced during baking may get rid of mosquitoes, but it doubtless affects the eyes and respiratory system of the whole family, particularly women.

Further problems are caused by the serious shortage of firewood needed by women for their ovens and for other cooking purposes. Natural forests in Democratic Yemen cover an area of some 2.5 million hectares. Forests provide approximately 85 per cent of the fuel needs of the rural population. The average annual consumption of firewood per person is 0.1-0.9 cubic metres.[1/]

However, a government official has stated that the monthly consumption of a family amounts to 1.5 cubic metres. Law No. 1 of 1975 prohibits the cutting of wood but it is not strictly observed. The excessive cutting of trees has caused many varieties to disappear, including the high-energy Acacia species.

Women could not give any exact indication of the time or distances involved in obtaining their daily fuel needs. They were also unable to estimate the total cost of their energy needs.

Reports, however, estimate that high-energy wood costs approximately $240 per cubic metre. It is also estimated that women spend at least six hours per day collecting fuel and fetching water.[2/]

Over-grazing and excessive fuel and fuel wood gathering have caused serious erosion problems. The introduction of kerosene and gas cylinders for cooking purposes has helped to ease the situation somewhat, but women still prefer cooking with fuel wood.

4. Health and cleanliness of women

As was indicated in section 1, the use of firewood and dung to produce energy for cooking, baking and other domestic purposes has a negative effect on women's health. It particularly affects the eyes and respiratory system. Women are also prone to burning themselves in the daily baking process.

1/ United Nations Development Programme, Inter-organizational Assessment of Women's Participation in Development, Report of study No. 13, (1985), pp. 105-106.

2/ M. Saleh, Mission Report to People's Democratic Republic of Yemen, (E/ESCWA/NR/86/2) (Baghdad, Economic and Social Commission for Western Asia, 1986), p. 36.

During the mission it was noted that a significant number of family members suffered from eye diseases. Many families had at least one member who had partly or completely lost their sight, particularly elderly women living with their married sons or daughters. Of the five houses visited in the villages of Markaz El Houghta, Lahej, two had an elderly blind woman. Although no exact figures about blindness are available, it is interesting to note that women are aware that there is a relationship between inflammation of the eyes and the smoke produced by burning dung and firewood when cooking and baking.

The staff of one mother-child health centre in Tuban Valley indicated that eye disease was one of the most common complaints among women using the centre's facilities. Continuous exposure to smoke makes it impossible for the staff to take remedial action. The staff also indicated that intestinal and respiratory diseases are most common among children. Such diseases are probably related to the pollution resulting from mothers handling raw animal manure, and from inhaling the by-products of burning dung and wood. About half of the women interviewed during the mission complained of respiratory ailments ranging from coughing to continuous chest pains.

No statistics are available to show the incidence of the different kinds of disease, particularly among women. The Annual Statistical Book of the Ministry of Health gives data on those who seek medical treatment as hospital out-patients or in-patients. Needless to say, this data represents only a small percentage of those affected by disease. Nevertheless the Annual Statistical Book for 1985 shows that women out-patients seeking medical treatment for intestinal diseases constituted about 8 per cent of the female population of Lahej and about 12 per cent of that of Abyan. Statistics also show that 12 per cent of the total female population in Lahej and 31 per cent of that in Abyan sought medical treatment for respiratory diseases as out-patients. Two per cent of total females in Lahej and 4 per cent of those in Abyan sought eye treatment as out-patiants. The percentages for eye diseases appear to be rather low, but this is understandable in view of the tendency of people to deal with eye inflammation themselves before it becomes serious. The overall national percentages for the incidence of these diseases for both sexes in 1985 are much lower: 40 per thousand for intestinal diseases, 34 per thousand for respiratory diseases and 24 per thousand for eye diseases.

The personal cleanliness of women in Lahej and Ayan varied according to social class. The standard of cleanliness of women themselves, their children and houses corresponded to their social class.

VI. SUMMARY AND CONCLUSIONS

At this stage it would be unwise to make any attempt to undertake a precise socio-cost-benefit analysis to determine the feasibility of introducing biogas technology in Democratic Yemen, as there is insufficient time and data. However, it is possible to assess the advantages and disadvantages of experimenting with this technology.

On the positive side, the Government recognizes the need to use biogas technology to help to solve the energy and environmental sanitation problems in rural areas. Three ministries, Public Health, Local Government and Energy and Minerals, have already indicated to different United Nations Agencies that they are interested in introducing BGT and, as was mentioned previously, steps have already been taken to experiment with it.

The introduction of BGT will assist government policies that aim to equalize opportunities in the different areas of Democratic Yemen. Only Aden and large towns are currently supplied with electricity and other commercial forms of energy. The limited material resources of the country do not permit the extension of these facilities to all rural areas in the near future. BGT is therefore one measure that will help to provide the rural population with a better source of energy that will narrow the gap between rural and urban areas in terms of this basic facility. The other benefits that would accrue to the Government through the use of biogas have been mentioned in other reports, so they will not be repeated here.[1/]

On a local rural community level, biogas will help to improve the cleanliness and sanitation of the environment. The piles of dung left on roads to be washed away by rain will disappear. The placing of waste materials in the digester will get rid of the flies and other insects that were seen to gather around this matter during the mission. Dung and other waste materials that are normally only partly utilized will be fully used by BGT, so community resources will no longer be wasted. BGT will also promote the self-reliance of a community, as its people will have control over both the inputs and outputs of this technology. At present, fuel wood is becoming more scarce and kerosene is sometimes not available.

The quality of life of the family and of women in particular can be improved by BGT. Women will save around six hours daily of the time they currently spend fetching and collecting fuel wood and agricultural residues which are burned for cooking, baking and other purposes. They will also be spared the time and effort of collecting animal waste and piling it outside their homes, have to spend less time cleaning their houses, and will improve their personal cleanliness by handling the waste matter in a different way. BGT will also help to reduce inflammation and eye infections that are prevalent among rural families in Democratic Yemen as a consequence of the

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1/ M. Saleh, Mission Report to People's Democratic Republic of Yemen, (E/ESCWA/NR/86/2) (Baghdad, Economic and Social Commission for Western Asia, 1986).

smoke associated with the current mode of cooking and baking. Air pollution will be reduced, which will decrease the incidence of respiratory diseases, particularly among women. It is also expected that intestinal diseases will be less prevalent, particularly among children, with the improvement of environmental sanitation. The time and energy saved by women could be used to increase child care and for other useful activities.

In discussions with the rural women of Lahej and Abyan, the possibility of introducing BGT was met with great enthusiasm, especially by members of GUYW. Members of GUYW in the two governorates also showed great interest in the project and indicated their readiness to participate in the preparation and implementation stages. They stated, however, that the final decision about accepting BGT or its details lay with the men of the families. A great effort will have to be made through GUYW to get women involved in the necessary activities.

It should be noted that the introduction of the individual household-type digester will not allow the rural poor to participate in the project. They do not possess the inputs that will allow them to benefit from the new technology. The demand created by BGT for dung and other waste materials may increase the cost and effort required by the poor to obtain them. Therefore, in order to meet the needs of the rural community, it is proposed that a multi-household or community digester be installed.

Generally speaking, biogas inputs have a low opportunity cost in Democratic Yemen, and the alternatives to BGT outputs have a high opportunity cost. To conclude, the introduction of biogas technology in rural areas of Democratic Yemen will have a positive impact on the life style of rural families, and particularly on women. The individual house system will not meet the requirements of government policy, which emphasizes equal opportunities. It is suggested, therefore, that Democratic Yemen experiment with other systems, particularly the community or the multi-house models. The rural communities of Democratic Yemen are renowned for their willingness to take community action, where not only the members of a village co-operate in projects, but neighbouring villages also provide help that will be reciprocated in similar future projects. Other systems could be introduced on state farms or co-operatives to meet the needs of these institutions, but the following points apply to the community or the multi-house types of digester where the direct beneficiaries would be rural families. Democratic Yemen could initially experiment with two multi-house projects in Lahej and Abyan. The following points should be taken into consideration for the experiment.

1. Institutional responsibility

It is suggested that the Ministry of Local Government take overall responsibility for the introduction of biogas technology in the rural areas of Democratic Yemen. The intersectoral nature of the Ministry's responsibilities and its ability to use its institutions to teach local communities and mobilize rural people to participate in different activities and projects puts it in a position to be able to assume the overall co-ordination of the project. The Ministry has already started to perform this role.[1/] GUYW, which can mobilize women and which already has experience in working with local government, should attempt to involve rural women in the project from the start. A co-ordinating committee that represents all of the bodies interested in the subject could be formed.

The expenses involved in the experiment could be shared by United Nations agencies, the Government and beneficiaries. The latter should be aware that the project can be useful to them and that it offers a better way of producing energy than the one used at present. This would involve the organization of individual and group discussions with members of the households selected for the experiment. In addition to GUYW, three organizations could organize meetings and discussion in order to encourage the acceptance and confidence of the people in he project: the Federation of Democratic Yemeni Peasants, the Federation of Yemeni Socialist Youth and the Organization of the People's Defence Committees. And, of course, a training programme should be organized for the participants.

The exact share of the costs of the experiment has to be discussed between the United Nations, the Government and the beneficiaries in order to determine their resources. The cost of the equipment installed inside the house, such as the stove, pipes, etc., should be borne by the beneficiaries in order to encourage an awareness through ownership of how to use and maintain it properly.

2. Participating households

During the mission it was noted that relatives and kin often live next to each other in separate houses with separate sheds. In some instances parents are surrounded by two or more married sons and daughters who live separately. Exchange marriages between two families is also common, with sons and daughters living separately but close by. It is suggested that groups of relatives living in close proximity should be chosen for the experiment with the multi-house digester. A group of relatives such as this already co-operates in certain activities such as collecting fuel and baking bread. The project can take advantage of the present attitude of co-operation.

Another alternative to choosing family relatives would be to select a number of nearby houses whose owners are members of the same co-operative farm. An existing work relationship could help to start a group project.

It should be pointed out here that it will be difficult to involve the poorest members of the community who cannot provide the minimum inputs required. They will have to be served by a community project managed by the Government. The multi-house system, however, will consolidate the few resources possessed by the poor and enable them to participate in the project.

3. Organization and management

A committee should be formed to manage the project on a local level. The committee should include representatives from the houses participating in the project, the GUYW and the Local People's Defence Committees. The committee will establish the rules and procedures governing the inputs required from each house, the schedule for the distribution of the gas, the share each house will take in the output, the maintenance system, etc. A committee leader will be elected on a rotation basis.

1/ Based on discussions with Mr. M. E. Eaissa, Director of Local Departments, Ministry of Local Government, Democratic Yemen.

4. Training for operation and maintenace

Two training programmes should be organized. In line with the culture, women will have to be trained to use the equipment inside the house, while men will be trained to operate the apparatus outside. Both types of training should provide information and instruction on the maintenance of the system and the performance of minor repairs. Major repairs will be undertaken by a technical unit located in the governorate.

Finally, in order to maximize the impact of BGT on family living standards, and particularly on women, GUYW should co-operate with the agricultural extension service to organize group discussions and home visits to women to provide education on health and nutrition. Child care information and training on life skills will be provided through different audio-visual aids. Subsequently, income-generating activities that take advantage of the time saved by BGT could be introduced.

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