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# BIOGAS GENERATION FROM ANIMAL AND AGRICULTURAL WASTES IN AFRICA

BY

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The paper is based on previous work and background in the field of biogas technology, development and promotion, and incorprates as well selected relevant material taken from the published literature.

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# Biogas Generation from Animal and Agricultural Wastes in Africa

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SUMMARY

Biogas, derived from agricultural biomass through anaerobic fermentation, is a promising alternative energy source and a solution to many rural problems relating to land productivity, conserving resources, improving environmental hygiene and decentralised development.

Appropriate village-type biogas technology is known and reliable. Generation methods developed in Asia, particularly the Indian and Chinese schemes, can be adapted and modified to suit local African conditions and skills.

In rural areas of Africa, agricultural residues, weeds and hydrophytes, together with human and animal excreta represent good feedstocks for biogas developments. A preliminary hypothetical estimate of the biogas that could be produced assuming 50% cattle dung collection and 50% of rural human excrement, to which 30% (of weight of cattle dung) agricultural wastes are added indicated about $24 \times 10^9$ $m^3$ annual gas production equivalent to $132 \times 10^{12}$ k cal. In addition, the digested material produced would have a nitrogen content equivalent to about 2.4 million tons of urea. With other intangible benefits such as environmental effects, prospects of biogas are encouraging.

The application of village-type biogas technology (BGT) in some developing countries exhibited various degrees of success. Previous experience has shown that success entails the development of viable conditions to ensure acceptance, adoption and propagation of technology. The technology should be appropriate and compatible with the existing socio-economic conditions. Furthermore, adequate scientific and technical infrastructure should be developed, and a sound national policy and plans on technology promotion must be drawn up.

Successful implementation of biogas programs in Africa would necessitate the development of a strong scientific and technical support. Research and development(R&D) with the highest payoff in Africa appears to be in the adaptive domain. Some specific areas for needed R & D in Africa are outlined, and joint R & D programmes amoung the African countries are recommended. Training-covering different skill levels - should be a basic and integral component in any biogas programme.

Two case histories of biogas programmes - the Tanzanian and Egyptian - were selected for presentation. The applicability and restraints of viewpoints expressed in the paper are illustrated to some extent within the presebation.

Finally, concrete suggestions were outlined for development and utilisation of biogas at national subregional, and regional levels in Africa. The possible role of UN agencies, particularly UNEP, was also touched upon.

## 1- INTRODUCTION : Biogas from Agricultural Biomass as a Promising Alternative Energy Source and a solution to Many Rural Problems.

Among the most important problems of our age, and moreso of future generations, are those pertaining to energy sources, food supply and pollution abatement. In fact, the application of biogas technology in rural areas fits perfectly in this context. On the top of its contribution to improving the rural community conditions, it can help in solving the three mentioned priority problems in a balanced way and in a manner that is harmonious with nature and environment.

First , recycling of animal, human and agricultural wastes through anaerobic digestion provides a clean and renewable source of energy, i.e. the biogas. Second, it furnishes a stabilized effluent that can be used as an excellent organic fertilizer to sustain or even increase land productivity, or can as well be used as animal feed supplement ; and alternatively may be utilised in the so called integrated biogas system to grow algae, aquatic plants and fish and so provide more feed for the animals, more food for the humans and also more biomass for digestion. Third, through wastes digestion, the biogas technology would contribute to combating pollution, waste disposal and sanitary aspects.

By the same token, the problems related to the introduction of biogas to a rural area are more complex than those of any other small-scale source of energy. Apart from providing energy, it is also a technology for waste treatment, nutrient recycling and soil conservation.

In recent years, particularly in the aftermath of the 1973 oil crisis, biogas systems have attracted considerable attention. It is now becoming acknowledged as a promising component of decentralised rural development.

Excellent reviews on the current state of knowledge and technology appeared in the published literature. A selected list is given in the bibliography (1 - 5). Since these reviews provide a fairly complete coverage of the essential features of Biogas Technology (BGT), only a very brief description is given here.

Biogas, basically a misture* of methane and carbon dioxide plus some minor constituents, is produced by anaerobic fermentation of organic matter. By containing the matter in a digester (or biogas plant), the combustible gas can be trapped and used as fuel. The digested slurry that remains can be usually used on land as soil conditioner and fertilizer.

The biochemistry and microbiology of anaerobic fermentation is extremely complex. It is established that in general terms the process proceeds serially through three steps. In the first step; the polymeric compounds

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* The general composition of biogas produced from farm wastes is usually (7). $CH_4$ 54-70%, $CO_2$ 27-45%, $N_2$ 0.5-3%, $H_2$ 1-10% and a trace of $H_2S$. Its energy content (8) is about 5500 K cal/$m^3$.

of carbohydrates, proteins and fats are broken down into soluble monomers by a group of facultative bacteria through enzymatic hydrolysis. In the second step; these monomers are converted through the action of acid-producing bacteria to acetic, propionic, and lactic acids. Carbon dioxide and hydrogen are also formed. In the third step, methanogenic bacteria produce methane from acetic acid and $CO_2$ and $H_2$, but the bulk comes from acetic acid. The methanogenic bacteria are obligate amaerobes and the most delicate with regard to environmental change. Temperature is crucial. There are two sets of methane - forming bacteria : the mesophilic which have an optimum environment temperture of 35 (although they can function down 5 °C but at a very slow rate) and the thermophilic organisms having an optimum temperature of 54 °C. The balance between acids and bases is extremely important, the optimum PH value is around 7.

The optimum operating conditions will depend to some extent on the materials being digested. Almost any organic waste material can serve 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 (C/N ratio), and absence of toxic or inhibitory constituents. If the nutritional requirements of the microorganisms are met by a suitable mix, most organic matter can be used. The carbon to nitrogen ratio should be in the range of 30 for good operation. Possible substrates include : animal manure, human excrement, crop residues, aquatic and terrestrial vegetation, food processing and organic factory wastes, and even kitchen wastes.

The size (i.e. detention time) of a biogas digester will be partly determined by the kinetics and partly by the pathogen kill rate. Operation under mesophilic conditions normally requiresa detention period in the range of 30-50 days. Roughly, a small village-type domestic digester operated on two cattle, an attached toilet and excess household and farm wastes would produce sufficient gas for the family energy needs (cooking and lighting) plus an amount of digested sludge which on further composting with agricultural wastes would provide a good manurial value for a small family landholding.

## 2- Biogas Generation Methods and their Appropriateness to Africa

The Biogas System (9,10) is not just a digester, but rather an integrated sequence of processess involving : biomass feed management, digestion, effluent and gas handling and usage.

The first step entails collection of organic wastes and water, transport, preparation and feeding. The cost is basically a function of the type and amount of materials and the distance between source and the digester. The common biomasses used for biogas generation are various types of organic wastes produced from normal rural household activities (livestock or poultry wastes, night soil, and vegetable-organic wastes). These can be manually collected as a part of daily household activities. Agricultural residues such as spent straw, cotton and maize stalks, and bagasse need to be shredded to facilitate their flow into the digester as well as to increase the efficiency of bacterial action. Materials such as weeds and water hyacinth pose different problems with regard to collection,drying, transportantion, storage and processing. In the case of agricultural residues in particular, storage of materials in a damp and confined space for about 10 days is frequently recommended to reduce the time required for digestion. For better digestion, the feed should be a homogeneous slurry with a total solids concentration of 8-11 percent by weight*. This would normally require dilution with water. Thus, in the situations that do not permit the extra supply of water, like the case of dry zones in Africa, the BGT would not be a suitable choice.

The digester, in which the second step takes place, is the core of the biogas system and requires most of the initial capital investment. It consists of an oxygen-free container with the gas collection device, and in some cases agitation and controlled heat input systems. The process can be batch where the digester is filled and materials left to digest for a certain time before being opened, emptied and the next batch started. Alternatively, the digester design may include input and output ports and the system be set-up for periodic (usually daily) removal of a portion of the slurry and addition of an equal volume of feed. This would lead to uniform gas production, whereas in the batch case several batch digesters which are loaded alternately are needed to achieve more or less uniform production.

The management of digested slurry depends on local situations. It is normally used as fertilizer** and several alternatives exist : direct as a slurry, diluted with irrigation water, after drying, or as an ingredient in compost (absorption on silt and or agricultural and household solid wastes). The last alternative seems to have the best prospects since the technique is already known to villagers, the compost can be stored till needed, and it is easier to handle than liquid slurry.

The management and use of the biogas is the remaining step in the process. This would involve metering and safety, purification (seldom needed), distribution and utilisation. Because of the low biogas working pressure, the user of the gas should be near the generation unit. Like other types of gaseous fuels, biogas can be used for cooking, lightening,heating, or power production (12). Suitable gas-use devices should, however, be designed for efficient and safe use in rural areas. Likely uses of biogas driven engines

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* It is recently reported (Bio-Energy 80-Atlanta, U.S.A.) that higher solids concentrations upto about 20% gave better results. However, this is in conjunction with more advanced type of technology where mechanical mixing and heating is employed and the operation is in the thermophilic range.

** Through recent trend favour its use as an animal feed supplement or through the 'integrated farming concept' (11) for protein production via the growth of algae and fish in oxidation ponds and then as fertilizer in the outlet water stream.

are for pumping irrigation water and for electrical generation.

The skills required for construction, operation and maintenance of the biogas system depend on the technical sophistication of the system design as well as size. For small-scale units serving individual families, the system is manually managable and skills required are minimal. For large-scale operations, the system gets more complicated and would need a certain degree of mechanisation. Though large-scale units may be more economical, the lack of skills and technological base in rural areas of Africa would be in favour of neither large scale nor sophisticated technologies. Thus, it appears that the village-type biogas technologies developed over the past two decades in Asia, with possible adaptation and modification, would be appropriate for the rural areas of the African continent.

There are five basic biogas system designs in Asia:(13),(14)

1- The Indian Khadi and Village Industries Commission (KVIC) floating gas holder design. (15-17)

2- The fixed dome Chinese design. (18-20)

3- The plastic bag digester (21) (Taiwan).

4- The horizontal vertical (22) digester.

5- The batch digester (23).

The fifth type is different from the other types in that it is batch fed, whereas the others are semi-continuous. Batch-fed digesters are used when raw materials are fibrous like crop residues, or when the supply of raw materials is available at long intervals. The supply of biogas is variable and that of sludge is intermittent*. Batch digesters cost more and require more man-hours to operate. Floating-type batch digesters are preferred in certain parts of Africa, (24-25) particularly in Upper Volta for : easy maintenance and simple equipment, the small amount of water needed and the easy adaptation to fermentation of non-fluid raw material (predominantly vegetable mixture mostly dry grass with only 16-20% cow dung).

Simple sketches of the first four types are shown in Figure 1, and a comparison (26) between the two foremost types: the Indian and Chinese is given in Table 1.

Bag digesters are now available ready-made in the market. They are more costly than expected and some operating and maintenance problems have

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* At Maya farms (Philippines) the batch-fed biogas plants have 24 units in clusters. The retention time is 23 days. Every day one digester is discharged and recharged the same day. Thus, there is uniform supply of gas and sludge. This is possible only for rather large plants.

been encountered. The digester bag is made of 0.55 mm. Hypalon laminated with neoprene and reinforced with nylon, with a PVC inlet and outlet. The digester and gas holder are both combined in one bag. It is mass produced*, easy to transport and easy to install. The disadvantages are : less safe, can be pierced or damaged, for gas pressure regulation additional weights are put and can damage the bag, no stirring can be done and not accessible for cleaning.

The horizontal digester with a floating gas holder was developed by Maya Farms to suit Philippine conditions, particularly where the ground is hard to dig and/or the water table is high and/or flood level is high. It is also recommended for sizes larger than about 20 cu.m The effect of fluctuations in ambient temperature (noted in the vertical type with floating metallic gas holder) is minimised. The construction cost, however, is higher than the vertical digester.

It may be noted that the best design for a digester does not yet exist and certainly never will. For African countries, the ideal biogas plant would be the one that can cope with local conditions (local skills, materials available for construction, climate and materials available for feed). The types presented, perhaps with adaptation and modification, can be appropriate under the varied rural conditions prevailing in Africa . Such a situation (plug-flow and Indian floating combined) will be described later in the case history of the Egyptian Biogas Program.

The size of the digester must be chosen not only according to available feeds or desired gas output, but socioeconomic factors must also be taken into account. A multi-family or community-scale unit might be more efficient under given conditions, but social structures or local customs may make a single family unit more practical.

## 3- Biogas Prospects in Rural Areas of Africa

Wood, animal dung, crop residues, kerosene, human and animal labour provide the barest of energy necessities for the majority of rural population in Africa. Kerosene is now priced out of reach of many people (except when heavily subsidised), and wood-except in heavily forested areas, is in short supply** The search of firewood occupies a large part of the working day and has resulted in widespread deforestation. The consequences of forest destruction are increased soil erosion and siltation problems as well as loss of important hydrological buffer functions. Dried manure when used for fuel deprives the soil of a much needed source of humus and nitrogen. Preparing meals at open fires using wood or dung is very inefficient and health hazardous.

In spite of using chemical fertilizers, the fertility of the African soil

* Available in sizes from 5-100 cu.m. from Fortune Industrial Corporation, Taipei.

** The fuel wood shortage has been called "the other energy crisis".

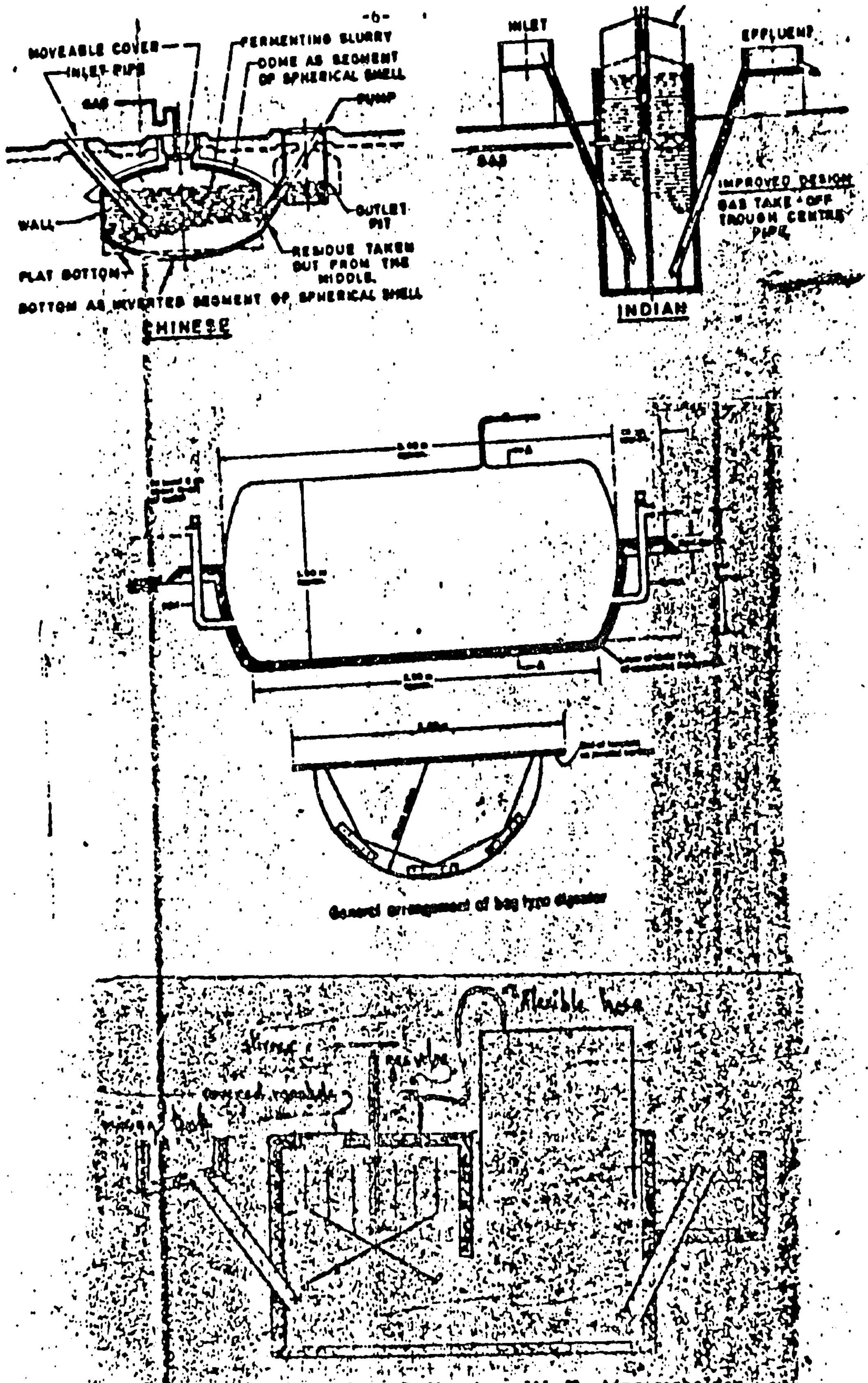


Figure 1. Schematic of four recommended digester types

Table 1 - Comparison between the Indian & Chinese Digesters

| | INDIAN | CHINESE |
|---|---|---|
| Purpose | Primary : gas<br>Secondary: fertilizer | Primary : fertilizer<br>Secondary: gas |
| Construction | simple masonry pit,easy to build but hard to intall where drum cannot be made or easily carried. | closed underground masonry or concrete tank with adjacent effluent chamber. Requires skill to render gastight. Can be built anywhere. |
| Input | virtually only cattle dung slurry may serve as septic tank | mostly mixed organic matter (veg.,dung,feaces) many plants wxclusively night soil |
| Out put | automatic gravity flow | by pump or by bucket |
| Operation | - mostly flow fed<br>- batch loaded(almost never)<br>- virtually no attention beyond mixing and feeding slurry | - batch loaded (generally)<br>- can also work flow fed with dung slurry<br>- labour intensive: for batch loading & emptying and for removing effluent |
| Gas Collection | in floating drum :<br>- height of float shows gas<br>- drum needs regular painting against corrosion | no drum; gas in sealed<br>- gas volume & pressure shown by slurry height in outlet |
| Gas Pressure | - low:70 - 150 mm Water-column<br>- steady,due to floating drum | - high: up to 1000 mm Watercolumn maximum<br>- constantly varying |
| Cost | high because of metal drum fixture | lower cost because no metal |
| Appearance | presentable, neat | neat, clean, unobstrusive |

is falling in many places because of the quick decrease of humic ratio.

Rural areas of Africa are also plagued by a lack of adequate sanitation. Improper waste disposal spreads disease, contaminates water sources and provides breeding grounds for disease carrying insects.

Biogas technology seems very promising solution to the above mentioned problems. It appears to be particularly adequate for humid and subhumid areas of Africa as it normally requires substantial amounts of water for dilution of raw materials. In arid regions this may make BGT unfeasible. Anaerobic digestion is quite suitable for the humid tropics. The lush vegetation, abundant water supply, and high ambient temperatures make ideal conditions for digester operation.

The humid tropics are among the areas of greatest biomass production. This vast and renewable biomass resource might be managed to sustain a course of development of rural areas based on self-sufficiency, stability and increased employment opportunity since biomass energy production is both labour intensive and agriculture oriented. End use energy needs in these areas match suitably with the type and quality of biomass energy sources. More than fifty percent of the energy used by rural people in the tropics is for cooking; a much smaller percentage is used for lightening, cultural and eductional needs and about 30% is used for pumping water and powering agricultural or village industries. Many experts believe the BGT is most economical and practical system for producing high quality fuel from biomass(27).

In a report (28-29) examining the subject of village source energy for the villages and farms of Sub-Saharan Africa, certain relevant statements are worthy of quoting. "The BGT is known and reliable, particularly where livestock are abundant. Although there are problems, biogas is one of the more promising of the whole host of small-scale technologies, particularly if applied as a village biogas unit. For Africa, the degree to which biogasification can be accepted and used will depend heavily on both the number of sedentary cattle from which dung can be collected and the willingness to handle it. For most family-size biogas unit's, dung from a minimum of five head of cattle is usually necessary for the process. For village scale use, of course there would have to be a substantial degree of cooperation involved, both in collection of dung and in distribution of gas and fertilizer by-products. Biogasification has some promise for those cultures with domesticated sedentary cattle, particularly if animals are penned or corralled, and provided the people are accustomed to using dung or are otherwise willing to handle dung. It would require some careful investigation of cultural habits for each village or community to ascertain this.

In Table 2, data (30) on livestock and poultry population as well as selected agricultural crops in Africa as a whole, and in seven African countries are compiled. It appears that the animal and agricultural wastes would provide a good source for biogas generation. From the wetlands and waterways there are weed monocultures currently dominant and a nuisance in blocking the waterways (31) to traffic, fishing and efficient flow of irrigation water. Their presence also favour the transmission of disease (such as malaria and belharzia) as well as causes great loss* of water through transpiration. The use of aquatic biomass for generation of biogas seems also propective (32). The current rural African population is probably in the order of 400 million. The use of human wastes in conjunction with biogas production** would have very important sanitation benefits, as well as enhancing gas production. The wastes from one person could be expected to yield about 0.03 $m^3$ of biogas per day.

Potential direct benefits of biogas all-over Africa

If it is assumed that 50% of cattle wastes (excluding other animal and poultry waste sources) had been collected and utilised for biogas production, in addition to 50% of the rural human excrement, to which 30% (of cattle dung weight) agricultural wastes (to keep proper C/N ratio) are added, it is estimated that :

1- total biogas production per year would be around
$24 \times 10^9$ $m^3$ equivalent to $132 \times 10^{12}$ K cal
or $15 \times 10^9$ liter kerosene
or $16 \times 10^6$ liter gasoline
or $11 \times 10^9$ kg butane

compared to fuel wood with energy conversion efficiency in open fire stoves of about 10% (recovered as useful heat) whereas that for biogas with good burners is about 60%, the biogas produeced would be equivalent to 160 million tons of fuel wood. This would provide the household energy needs of about 160 million rural inhabitants.

Alternatively, 24 billion $m^3$ of biogas per year would generate about 40 billion kwh of electricity.

2- Digested effluent that can be utilized as fertilizer :

a) When post-composted with agricultural wastes could produce around 250 million ton per year of good organic fertilizer.

b) As a nitrogen fertilizer source (excluding its organic humus content and phoshporous), it would have a nitrogen content equivalent to about one million ton per year, or to about 2.4 million ton of urea (42% $N_2$).

These direct tangible benefits, in addition to the other environmental benefits should give a clear indication of biogas potential prospects in rural Africa.

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* The present estimate of water loss in Egypt is around 3500 million cubic meter annually.

** Through simple latrines attached to digesters.

4- Development and Utilization of Biogas Technology in Africa: Ways, Means and Problems

The application of village-type biogas technology in various parts of the world exhibited various degrees of success. The Chinese and Indian programs in particular were relatively successful. For instance, more than 7 million biogas village units are now operating in the People's Republic of China. However, such success is no assurance of similar success in other countries, particularly where there are great differences in resources, socio-economic conditions, physical environment and living patterns. Previous experience in other developing countries that have started sizable biogas programs has shown that success entails the development of viable conditions to ensure acceptance, adoption and propagation of the technology. Thus, the technology should be appropriate and compatible with the existing socio-economic conditions. Further, adequate scientific and technical infrastructure should be developed, and a sound national policy and plans on technology promotion must be drawn up.

Key issues pertaining to BGT promotion and implementation have been elucidated and well covered by a number of publications (33-38) drawing principally on the Asian experience.

Although BGT present definite advantages for rural area, a number of problems seem to prevent its widespread adoption. Constraints may be identified as political, technical, social and economic.

On the political level, a major shortcoming in most plans and programmes is the failure to establish clearly defined, quantifiable and possibly attainable goals within the available resources and prevailing constraints. Conflict of policies and lack of cooperation and coordination among the various authorities involved in rural developmental aspects are frequently noted to handicap the desired progress. Limited governmental funds for rural development is also prevelant.

On the technical side, despite the exitence of reliable designs, it appears that poor construction and operating practices resulted in many failures. Many current designs also appear to be more expensive than they need be, putting biogas plants out of the reach of many rural people. Little attention seems to have been paid to the efficiency of gas-use devices, with the result that these components of the biogas system are generally inadequate.

Economic and social constraints to biogas adoption range from lack of resources-capital, animals, land, time, water-to run the plants efficiently, to the spatial arrangements of communities that may not provide suitable space area for digester installation or make carrying the digested slurry to the fields difficult. Large community plants (39) can be a solution, but their operation is confronted with many social and technical problems. In some areas, cultural, social, psychological and religious barriers exist to the extent of resisting or even completely rejecting the technology.

In any attempt to help small farmers, cognizance should be made that we are dealing with restrained systems. System restraints should be identified, and when some are to be relieved, the intricate interrelationships of the whole system must be always taken into account since a modification to one aspect will have an impact on the other parts. This would require a truly interdisciplinary systematic approach.

To start BGT promotion in the right direction, we must first clearly understand all about rural masses modes of life, convictions, religious taboos, traditions, customs and attitudes so that we can envisage what kind of preparation that might be necessary before BGT introduction can hope to be successful.

Second, we should identify the peasants points of view and try to introduce the features of the BGT in a simple and convincing way to these potential users and enable them to sort out their priorities with a knowledge of the full benefits they could eventually achieve. As with anything unfamiliar to their way of life, resistance is bound to occur. An adequate popularisation programme, including rural schools with simple illustrations, posters, movies and simple demonstrative experiments can be quite helpful in this regard.

Farmers are naturally born economists (9). They always make trade-offs whenever they have to make a decision. When a farmer is told a lot of good things about biogas, he would firstly ask about the initial investment. He would make an economic comparison between the biogas system and his other needs, and available alternative sources of energy and fertilizer. Intangible benefits, such as cleanliness and hygienic aspects usually do not weigh heavily in his balance. The net result is that such an investment from his viewpoint as an enterpreneur may not be quite appealing when he considers the opportunity cost. Governmental incentives thus appear necessary*.

Supposing that the farmer has decided in favour of biogas, he would then want to know about his burden in operating the biogas system. He will weigh all the time and efforts required in running the system

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* Benefits on the national level are normally substantial (reduced need for foreign currency for energy imports, reduced destruction of forests and erosion of soils, public health and sanitation, and rural development), thus the investment would be justifiable from the national viewpoint. For this reason, various forms of financial assisstance had been developed, as in the case of other rural services. Assisstance can be in the form of subsidies and "soft" loans.

against those needed in collecting other sources of fuel and fertilizer.

Still if the farmer has finally decided to invest in a biogas system, he would need to know about the construction, operation, safety and maintenance of the system. Though, village-type designs are apparently simple, a certain level of technical skills has to be developed. At this point, governmental technical assisstance, particularly in the form of training, should be available.

Following these basic socio-economic surveys and preparations, a policy has to be chosen, goals defined and the strategy to achieve them must be worked out. At this stage, several questions have to be answered (40) such as:

- Current needs and sources of energy and which needs could be covered by biogas.
- What kinds and amounts of bioconvertible materials are available as digester feed? What sort of pretreatments would they require? How could they best be gathered and at what cost?
- What are the current uses of these materials and how would a new demand on them affect the system?
- What type of biogas plants would best suit the conditions encountered? What local materials, skills and facilities are available or can be developed?
- How many units of what size would be necessary? Would single family, family group or communal plants better suit the conditions and goals?
- Who will operate and maintain the biogas plant? How much training do they need, and how do they get it? How do they get expert advice if necessary?
- How should the gas be distributed to the users? What equipment do they need to use it? Can they afford it, and how do they get it?
- What will be the quality of the sludge? What should it be used for and how will it be handled?
- Which sanitary and safety precautions must be taken?

Based on these answers adequate decisions can be made. Since the objective of any support programme should be to encourage biogas development only in appropriate situations, care is needed to avoid schemes forcing development ahead of the genuine interest of the people concerned, and of their commitment to proper operation and maintenance (33).

In the next stage, demonstration plants may be installed since they could be very effective means of spreading interest and awareness in this type of development, as well as in assessing the socio-techno-economic feasibility. In the demonstration stage, care should be taken to select readily visible locations to the community (for instance, community institutions) or convenient private premises where the owner is prepared to take the operational responsibilities as well as to face the inconvenience inherent in a "demonstration" unit.

Feasibility studies can be made on the basis of the demonstration experience and the accompanying performance tests. Though several feasibility studies are reported in the published literature, their adequacy is questionable. They seem to be somewhat biased for or against the BCT. For instance, the KVIC assessments tend to neglect the value of the feedstock. Other feasibility studies either neglect completely the value of the digested slurry or treat the financial appraisal in the same way as in the case of commercial investments (use high interest rates and neglect the intangible benefits). It is recommended that cost-benefit analyses should include both the farmer and national levels. Good papers are available that provide guidelines in this regard (41-42).

## 5- Research, Training, Exchange of Information and Co-operation Aspects of Biogas Development and Use in Africa

To create and sustain viable conditions for BGT widespread promotion, a strong supporting scientific and technical infrastructure is a must. The transfer of appropriate technologies, their adaptation and modification or eventual innovation cannot proceed without the presence of an adequate research and development base. Similarly, the implementation of biogas programs requires the various technical skills needed in the construction, operation, maintenance and the varied types of extension services. Such technical skills can only be developed through tailored training programmes.

Most of the research and development (R & D) could be entrusted to already existing universities or national laboratories in Africa, until the time is ripe to establish central biogas R & D stations on the national level. However, the R & D should be oriented toward preset objectives and practical applications. R & D endeavours need not start from scratch since there is a wealth of accumulated and accessible information. To avoid duplication, and to guide and co-ordinate the R & D work, some form of a national committee should be set up in respective African countries.

It would appear that the most profitable and needed R & D is in the adaptive domain. Transfer and adaptation of the variety of current appropriate biogas systems developed in various developing countries (particularly Asian) as well as testing their performance under local conditions and optimising or even developing modified versions in which local materials and skills can be beneficially utilized, appear to present a considerable scope for local R & D. Some specific areas for R & D are listed in the following:

i- Due to the limited availability of livestock wastes in certain parts of Africa, digestibility studies using local agricultural wastes would be of great advantage.

ii- Studies for determining and increasing the traditionally acknowledged fertilizer value of the sludge.

iii- Investigations on growing plants hydroponically in sludge-enriched solution rather in soil (this technique is used in China).

iv- Evaluate the possibilities of using sludge as direct feed for cattle and fish.

v- R & D aiming at improving the socio-economic feasibility of BGT. Topics include: reduction of construction cost, development of efficient gas-use devices, and community biogas systems*.

vi- Environmental issues particularly the problem of pathogenic organisms and parasites.

Joint R & D programmes among the African countries, as well as other countries should be strongly encouraged. A notably prospective step in this direction is the Commonwealth Science Council African Energy Program biogas project (Annex 1). The project is entitled "Biogas technologies for rural energy needs in Africa" and is a joint R & D and demonstration program involving Uganda, Kenya, Rwanda, Zambia, Tanzania and Botswana.

In the same way, liaison and information exchange systems should be strengthened within and among countries, so that R & D would be co-operative as far as possible. In the "Report on Working Group on Energy Policy" (Annex 2), the idea of a regional centre for information and experience exchange was proposed (Zambia offered to host), but the proposal was considered premature, though open for the future. Perhaps, one of the UN organs conveniently located in Africa such as UNEP (The United Nations Environment Programme) can serve in the initial stage for this purpose, particularly since UNEP has a centre for demonstration of the technical, economic and social feasibility of harnessing solar, wind and biogas energy in Senegal for the African region. Through its International Referral System (IRS) UNEP is also facilitating information exchange on the subject of biogas. A mechanism is, however, needed to establish this on a more systematic basis.

Training should be an integral part of any biogas programme (34). The entire success of biogas development depends on the technical skills available. And one failure might undo the value of a much larger number of successes. Training programmes should cover different skill levels and can be conducted in institutions involved in biogas activities as well as on-site during field demonstrations. Training on construction and plastering techniques to ensure a liquid and gas leak-proof system is believed to be of top priority.

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* This may be benificially utilised within the somparatively recent African trend for collective-farm agricultural economies.

industry, utilities) and the component households. The energy needs at the household level are: cooking, heating, lighting and water.

Ninety-five percent of cooking is done with wood; charcoal and kerosene account for the remainder. Demand for wood-fuel is estimated (8) at 2.3 cu.m. per capita per year (1630 kg). The evening cooking fire provides heat as well as some light. Additional lighting requirements are estimated around 5 liters of kerosene per household per month. Approximately 8 liters of water per person per day is a reasonable minimum.

## A.3. Biogas Developments

The actual organised biogas development programme started in Tanzania by mid 1975. Before that, there were few units built by scattered individual efforts.

The programme is undertaken by the Tanzanian Small Industries Development Organization (SIDO)* with backup expertise from the Indian Khadi and Village Industries Commission (KVIC). The programme commenced with 6 demonstration plants of standard Indian design on the basis of cow-dung feed in 6 different districts. The units were the family-size type ranging in capacity between 2 and 4 cu.m. The plants were located in village community centres. The biogas produced was used for cooking and lighting purposes.

The few initial demonstrations proved successful and attracted enthusiatic public attention. This good response encouraged SIDO to continue promotional endeavours to spread the biogas technology in all places having good facilities and convincing infrastructure.

Since then, more units have been put up. The total number by the end of 1976 exceeded 29 units**. Table 1, Annex 3 summarises the status of installed units till May 1978. Installed plants covered both domestic and small commercial types with capacities ranging from 2 to 10 cu.m. Except for 3 individual plants, the remainder was located in community centres and institutions (Rural training centres, schools, health centres and a prison). Costing for these gas plants are compiled in Tables 2 & 3, Annex 3 in local Tanzanian currency (Shillings or Shs, 1 US $ = 7.8 shs).

As to gas utilization and gas-use devices, SIDO relied during the first two years of the programme on imported appliances (i.e. lamps,

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* SIDO is the organization responsible of promoting and developing small scale industries in Tanzania.

** In a more recent publication (45), the number is estimated at over fifty units.

mantles, stoves, etc.) thus costing foreign currency. Later on, local manufacturing capabilities were employed. The burners were made out of steel after being produced in one of the local engineering workshops. They were tested for suitability and found good. Lamps were produced in another workshop and efforts were put on the local manufacture of mantels.

Tests were also successfully made to run an Indian made diesel engine on a mixture of biogas and gas oil. Satisfactory results were obtained which averaged 70 % biogas and 30 % gas oil.

## A.4. Evaluation of the Biogas Implementation Programme

On account of the rather short life-span of the Tanzanian Biogas programme, it is definitely premature to make a conclusive assessment. A preliminary sort of appraisal based essentially on published Tanzanian reports as well as the personal view point of the authors will be presented in the following.

From the standpoint of SIDO (44), the high-lights of the programme achievements as well as problems may summarised as follows:

1- The demonstration programme proved successful and quite fascinating to the public.

2- One of the foremost outcomes of the programme is the intense training of personnel. Till 1978, the total number of participants in 6 regions that received technical know-how and assisstance through SIDO was 16.

3- Propagation proceeded at a good rate as manifested by the building of more than 29 plants in less than 3 years.

4- The portion of the programme relating to the development and testing of gas-use devices exhibited acceptable results, though not catching-up with the other portion relating to building of demonstration units.

5- Problems experienced in the course of programme implementation were rather diverse, ranging from environmental conditions to technological digest: a) Owing to Tanzania Topographical condition, the temperature could go as low as 8°C, the state at which gas output would be quite low; b) Since SIDO is almost undertaking the full responsibility in the development stage (installation of plants, training of personnel, day-to-day running of the units and maintenance schedule), expertise problems did arise and obstacles in running the units were observed; c) Construction delays were frequent due to the shortage of cement and the inadequate supply of other construction materials.

In the joint Tanzanian-American workshop on solar energy for the villages of Tanzania which was held in 1977 under the auspices of Tanzania National Scientific Research Council, biogas generation was evaluated in the context of renewable energy resources applications appropriate to the village. It was concluded; principally on the basis of cost-effectiveness, availability of resources and long-range power requirements of villagers; that biogas generation is one of the technologies* recommended. On account of its relevance, the following summary is extracted from the workshop report.

"Several biogas plants are already operating in Tanzania and a body of experience in their construction and operation is being accumulated. The results show that the use of biogas should be considered not only for village lighting and cooking, but also for the generation of electricity or mechanical power. The use of cattle dung is assumed. The following Table gives the costs of lighting by a gas-mantle lantern and with generated electricity when biogas is used (Table 2)

Analysis of the data shows that gas requirements for cooking three times a day are approximately 1.4 $m^3$/day per family, which could be supplied by dung from three to four cows. On the other hand, to supply the electric lighting needs of a family (1 kWh/day) by using biogas to operate an engine-generator set (at peak load) would require 4-5 kWh/day of heat energy, which could easily be supplied by two cows. This method of lighting, therefore, is almost four times as efficient, in energy use, as a gas-mantle lantern, eventhough it requires a much greater capital investment. Finally, this same amount of gas - the gas supplied by dung from one cow - would provide mechanical power alone at 1 kWh/day. Of course, the variations in methane composition that may occur in actual practice may reduce the efficiency of the internal combustion engine by an unknown amount from the figures used in our calculations.

Another potential use for biogas, as a replacement for wood and charcoal, is in firing clay pottery, used for water and cooking vessels. For small-scale production, 8 $m^3$ of methane, over a period of about 5 hours are required to fire earthenware to 1,000°C in a kiln having a volume of 6 $ft^3$ (0.2 $m^3$). This is the equivalent of about 13 $m^3$ of biogas, which could be supplied by a 4-day accumulation of biogas from the dung of 5 cows. Larger production capacities - for instance, a village industry - could be scaled up accordingly, and would represent another potential use for community digesters.

To summarize:

Heat energy, even from a single-family biogas plant, can be supplied at well below (less than one-ninth) the equivalent energy cost of electricity.

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* Other technologies recommended were: photovoltaic electricity generation, small-scale hydroelectric generation, and solar refrigeration and drying for food and/or crop preservation.

Table 2. Cost of Supplying Cooking Fuel, Lighting, Mechanical Power, and Electricity by Biogas.

| | | |
|---|---|---|
| Base Data | Cattle dung: | 10 kg/cow/day |
| | Biogas production: @ 0.06 $m^3$/kg dung = | 0.6 $m^3$/cow/day |
| | Energy content of biogas @ 60 % methane: (This means that about 4 kWh of biogas energy is available daily from each cow). | 6.4 kWh/$m^3$ |
| | System lifetime: | 20 years |
| | Conversion efficiencies | |
| | Internal-combustion engine: (c) | 25 % |
| | Electrical generator: | 90 % |
| Plant Cost | Single-family plant (3 $m^3$) | Sh 6,000 |
| Financing Costs (a) | Single-family plant Sh. 6,000 @ 10 % for 20 years: | Sh 705/yr |
| | Engine/generator to provide 1 kWh/day Sh 5,400 (d) @ 10 % (5 hr/day) | Sh 5,940/yr |
| | Engine to provide 1 kWh/day mechanical energy Sh 3,200 (d) @ 10 % (4 hr/day) | Sh 3,520/yr |
| Energy Costs (b) | Cooking and lighting directly by gas (20 kWh/day) | Sh 0.10/kWh |
| | Cooking and generation of electricity @ 1 kWh/day | Sh 18.2/kWh |
| | Cooking and generation of mechanical power @ 1 kWh/day | Sh 11.6/kWh |

(a) Based on amortization of loan in equal yearly installments.
(b) Cost of energy production only - does not include cost of appliances, or cost of collecting dung.
(c) Efficiency at peak loading. At lower loading rates, engine efficiency would drop off rapidly, with consequent higher gas requirements.
(d) [illegible], Dar es Salaam, August 1977.

Ujamaa villages lend themselves readily to communal systems. Because of the economies of scale in biogas plant construction, such communal systems (e.g., schools, community latrines, community cattle-dung digesters in Masai settlements) should be seriously considered."

In the authors opinion, though the initial phases of the Tanzanian programme were fairly successful, yet there are several critical points that may endanger future progress.

1- The ambitious and rather hurried implementation scheme may not permit the proper build-up of the necessary supporting scientific and technical infrastructure. In fact, it seems that decision makers, once convinced with a project of this nature, tend to push for rapid implementation without allowing sufficient time for preparation stages. (This trend was strongly resisted by the Management of the Egyptian Project, which is going to be our second illustrative case).
2- The Tanzanian programme relied heavily on Indian expertise and know-how. Thus, the transfer of technology was basically limited to one source, and little attention seemed to have been given to appropriate adaptation and modification to local conditions.
3- The heavy involvement of SIDO in undertaking the programme implementation, from installation of plants to their daily operation and maintenance, may not lead to sufficient commitment of the villagers in the programme and the kind of attachment that would ensure the required level of adoption and continuity.

## B. Case 2: Egypt (46)

### B.1. General

Egypt covers an area of about one million square kilometers. The Nile Valley covers only 4 % of the land area. The present population is around 42 million. Thus, the population density in the Delta and Nile Valley is quite high, amounting on the average to about 1000 persons per square kilometer.

The agricultural population (55 % of the total), is engaged in practising a system of agriculture which has largely remained unchanged for five thousand years. Recent increases in labour wages, have induced a gradual trend toward shifting to mechanisation. Presently, the total land under cultivation amounts only to about 30,000 sq. km.

Egypt has around 4000 villages. The average village population is 5000 persons, and the average family size is about 5. Each large village has a number of surrounding small villages. The total number of these sub-villages is estimated at 30000. The government is undertaking a major rural electrification program. About 3000 large villages (out of the 4000) are supposed to be connected at present to the national grid. The small size sub-villages are not included. And even in electrified villages, the percent of rural household electrified is only around 20 %. Thus, kerosene lighting represent the major percent.

Huge efforts are being devoted to extending and improving the irrigated area in Egypt, and to production of new irrigated lands from desert areas. In such settlements, new-planned villages (which are quite different from the traditional-type villages) are established.

In recent years, Egypt has become a net staple food importing country, particularly wheat. Plow cultivation cropping includes: cotton, wheat, rice, maize and vegetables. Approximately, one-third of the total land area is devoted to fodder crops to feed the livestock, much of which is used for draught and transport purposes.

The total number of animals in Egypt is about 10 million: 2.2 million cows, 2.3 million water buffaloes, 3.4 million sheep and goats, 1.5 million donkeys and the remainder includes camel and horses. An acute fodder problem is prevailing in Egypt.

## B.2. Energy Sources and Needs in Rural Egypt

The major sources of energy available to most Egyptian villages are the non-commercial sources (dung cakes and agricultural wastes), which are estimated to have provided over one-third of the total energy consumed in Egypt in 1975. The present use of biomass in Egypt often involves open fire stoves which are in-convenient to use and pose a health hazard due to heavy concentrations of smoke in the building. Consequently, rural people are tending to switch to kerosene or butane stoves as soon as finances permit. In fact, there is significant demand on commercial energy sources in rural areas, and consumption of petroleum products is increasing very rapidly, almost doubling every 8 years. It is worthy to note that these petroleum products are very heavily subsidised by the Government.

A preliminary rough estimate was made of the biogas that could be produced by utilization of crop residues already used as energy sources as well as animal and human wastes available in Egyptian villages. This indicated that the biogas could provide the major portion of the residential rural energy requirements, i.e., substituting for all the non-commercial sources as well as kerosene and butagas. Furthermore, as additional amount of organic fertilizer equivalent to more than 12 million tons of farm yard manure would be produced, which would otherwise be lost through the direct burning of crop residues and dung cakes. This is also very important since it is estimated that the present deficit in farm yard manure in Egypt is more than 80 million tons per year.

## B.3. Biogas Developments

Since the early seventies, research on bioconversion and biogas production from agricultural and animal wastes was conducted at Egyptian universities and research institutes. Very few, mostly unsuccessful attempts were made to build and operate pilot digesters.

A national R & D and demonstration programme started by the end of 1978 for the development and application of village-scale BGT. The programme is managed by the Egyptian National Research Centre under the auspices of the Academy of Scientific Research and Technology, and is financially supported by the USAID.

The overall objective of the 5-year project, is to demonstrate that the application of BGT is technically, socially and economically feasible in rural areas of Egypt; and to lay the foundation for subsequent wide-spread implementation on the national scale. The project is executed by an interdisciplinary team of scientists, engineers and sociologists.

The project started with a short fact-finding phase in which the BGT state-of-art was assessed, an Asian study tour was conducted in China, India and Thailand, socio-economic surveys of typical Egyptian villages were undertaken, and two villages representing traditional as well as new-planned types have been selected for field demonstration.

The second phase, which is almost complete, encompassed extensive R & D endeavours. Considerable digestibility research work was done to determine optimum conditions conducive to greater efficiency, highest pathogens destruction rates and diminishing the effect of toxic and inhibitory materials. Various substrates including cow dung, sewage and agricultural wastes (weeds, water hyacinth, maize and cotton stalks) were investigated at different mixing ratios, organic loading and temperature. Certain pretreatments including pre-composting were also examined. Laboratory research was as well conducted on two relevant problems: the selective inhibition of hydrogen sulphide, and destruction of ova and embryos of Ascaris.

A sizable portion of work was done on the evaluation of digested products as fertilizer and soil conditioner; as well as on their handling, storage and application.

The engineering and development work was directed towards design, construction, operation and testing of three family-size prototype units at the demonstration site of the National Research Centre; as well as development of local appropriate gas-use devices. The first prototype unit is a fixed roof 10 $m^3$ rectangular digester of Chinese design. The second is 6 $m^3$ cylindrical wide, shallow type dome-roofed Chinese digester. It is anticipated, after the experience gained with construction of the second prototype and its successful operation for almost one year, that this type has good prospects as a family-size unit in rural areas of Egypt. It presently costs around US $ 300 using locally available materials and skills. The third prototype unit, which has been recently constructed, is a new adapted design combining the features of both plug flow and the Indian movable cap types (Fig. 2). Its effective size is about 7 $m^3$ and costed around $ 500. Provisions for solar heating of feed water, composting of the digester effluent on the top of the plug flow part, and attachment to both a latrine and an animal shed were incorprated in the unit. This type seems readily expandable to the community size. The National Research Centre demonstration site, with all the biogas systems present, is also utilised for training as well as for publicising the BGT.

Field demonstrations will shortly start in a traditional village where a complete socio-economic survey was made, active linking ties were developed and preparatory orientation* started. It is planned to construct five demonstration units: four family size and one community type. Demonstrations in the second new-planned village will follow. Close follow-up and assessment of various factors and impacts will continue to enable a thorough socio-techno-economic appraisal of BGT feasibility in rural areas of Egypt.

At this point, a final comment on both cases is perhaps in order. It appears that neither the enthusiatic Tanzanian approach, nor the conservative and cautions attitude of the Egyptian programme are recommendable courses of action. Probably, a compromise would be the best. In fact, recent developments in the Tanzanian programme seem to give attention to the R & D support, and indeed the attitude of the Egyptian project management has undergone modification toward enhanced implementation by pushing up the schedule of the village demonstrations.

## 7- Suggestions for Development and Utilization of Biogas at National Subregional and Regional Level in Africa

Large-scale implementation of a biogas programme is a lengthy and complex affair. A methodological, well-supported plan of action is needed to break down the economic, cultural and institutional barriers in tradition-dominated rural communities geared as they often are to subsistence or semi-subsistence living.

To hasten the adoption and propagation of BGT, measures taken on the individual country national level are of utmost importance. Collaborative

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* Simple posters, slides and movie presentation, in addition to simple demonstration with a mobile exhibition unit (Fig. 3) were fruitful.

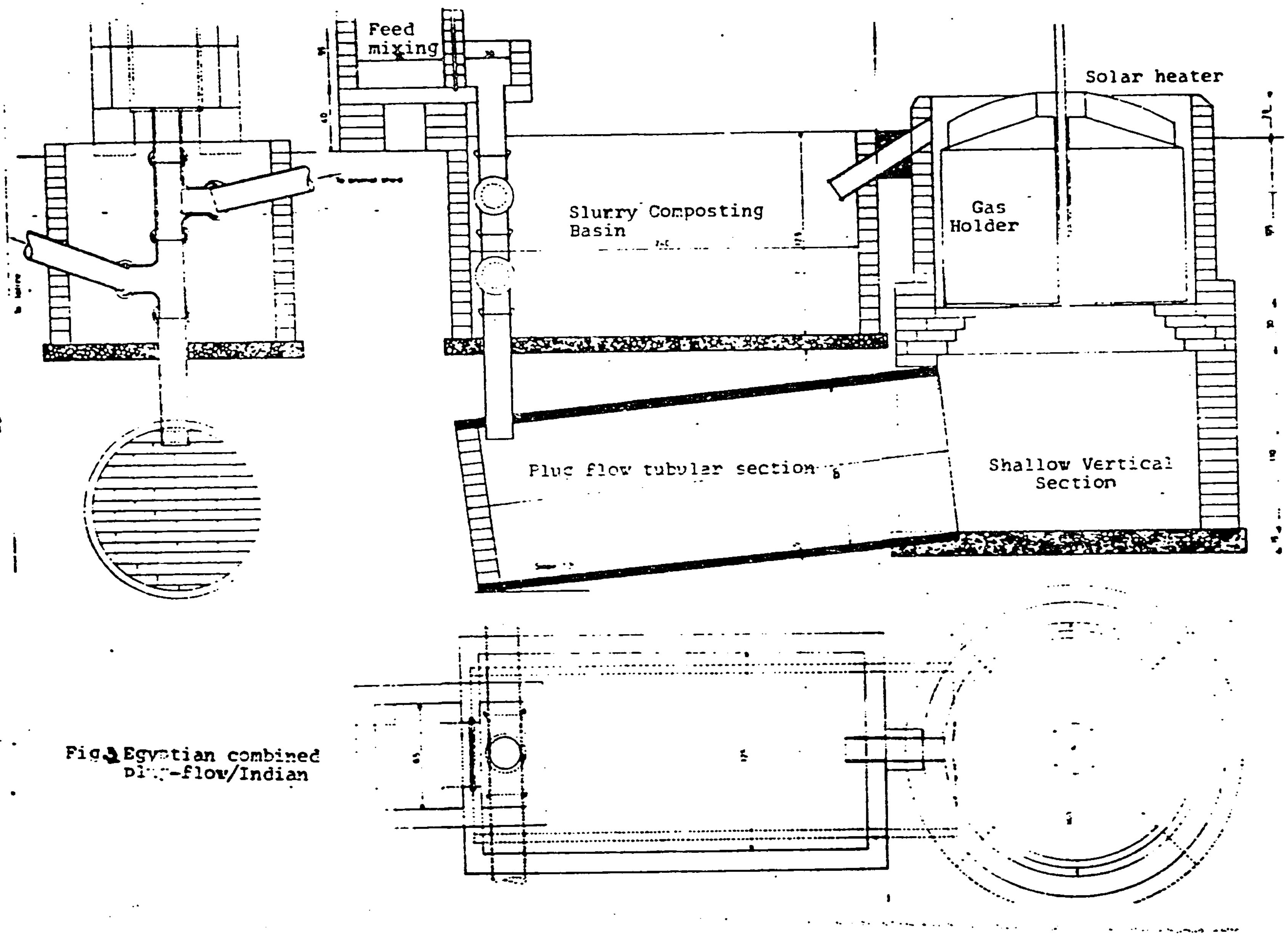


Fig.3 Egyptian combined
Plug-flow/Indian

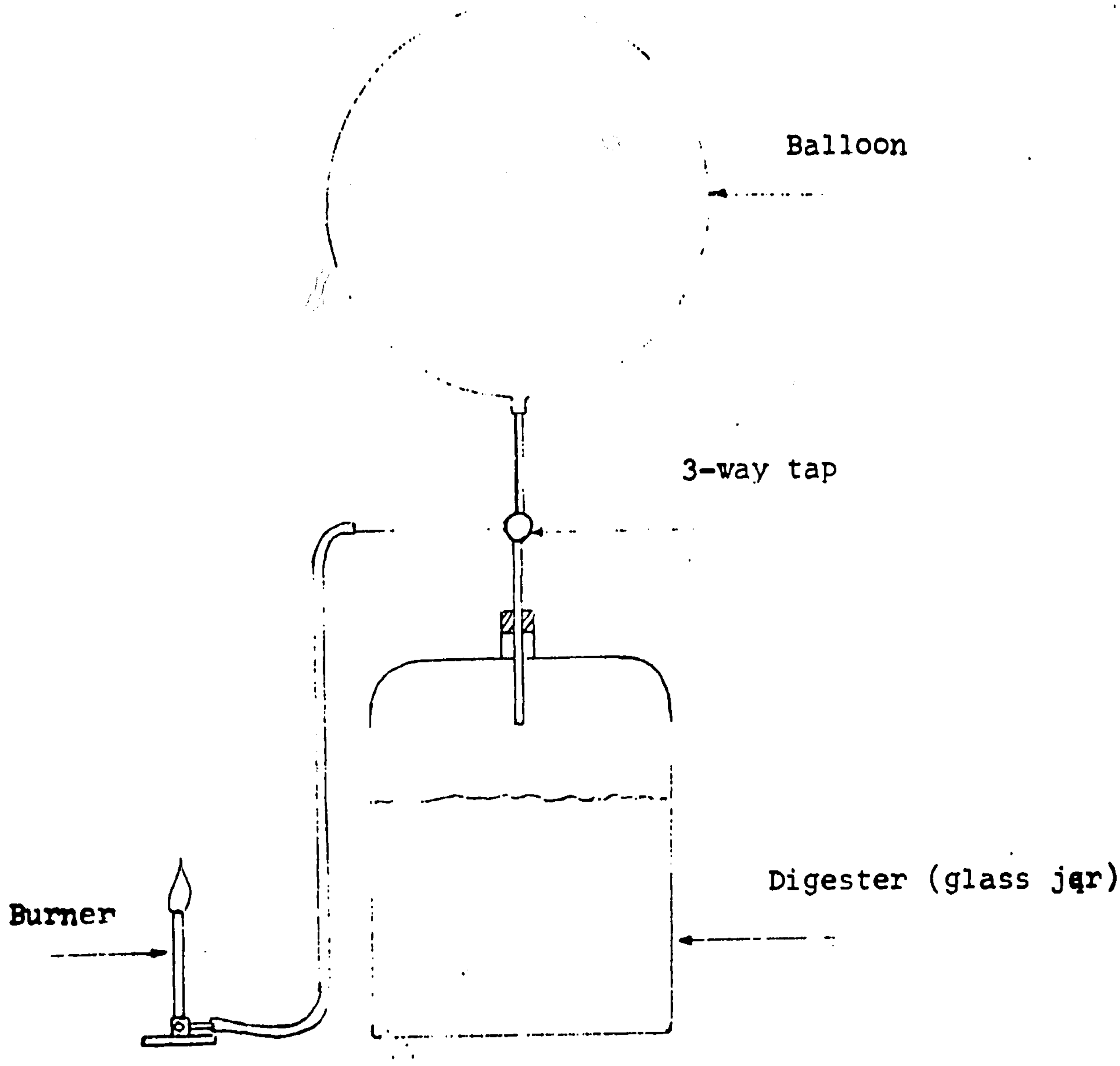


Figure 3. Simple mobile exhibition unit
used in publicising BGT in Egypt

subregional and regional level endeavours would be catalytic and serve as auxiliary support of the country programmes.

The respective countries will have to devise individual approaches as conditions in each country are different. Nevertheless, some general guidelines on the national level can be recommended on the basis of the experience already gained through the implementation of biogas programmes in some countries.

1- Identification of the need for and prospects of BGT within the framework of local conditions, national goals and priorities.
2- Setting of programme goals and strategy as an essential guide to R & D, demonstration and implementation on the national scale.
3- Making a country inventory of the institutions and individuals having particular interest in and/or related to the biogas system.
4- Establishment of an efficient administrative mechanism to act as a national focal point for biogas development. Such a focal point could provide a single channel for information*, provide a mechanism for liaison in R & D** and training, undertake administrative and executive responsibilities; as well as exchange of information and liaison with other countries and international organizations.
5- Prior to taking a final decision on BGT adoption and widespread implementation, a "biogas for villages pilot (or demonstration) project" should be established to explore the BGT practical prospects and assess the socio-economic feasibility.

On the subregional and regional levels, perhaps coordination and cooperation within the wider scope of renewable energy resources would be more appropriate, at least in the initial stages. Emphasis should be on aspects of group or general interest, such as joint manufacture of gas-use devices, integrated biogas systems and community scale plants.

Possible areas of collaboration, particularly on the subregional level (refer to Annex 2) could encompass: information and expertise exchange, joint R & D projects, as well as educational and training programmes.

On the regional level, two types of activities (47) are worthy of consideration:

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* Data storage and dissemination, central biogas library, preparation of bulletins and pamphlets, etc.

** Every effort should be made to utilize the existing academic and research institutions to reduce overhead expenditure.

1- Organization of specialised workshops, and
2- Establishment of a regional institute for research and development.

Inter-regional workshops including African, Asian and Latin American representation together with representatives from international agencies would be very effective media for discussing central issues and exchanging experience in the field of BGT.

A regional research and development centre, staffed basically with multidisciplinary African personnel, could serve a leading rule in generating an information base, carrying R & D to meet regional needs, provide adequate training facilities, and maintaining close contact with scientific and engineering developments and BGT applications in other centres of the world.

UN organs, such as UNEP can take the lead in initiating such a centre. As previously mentioned, UNEP has a renewable energy demonstration centre in Senegal for the African region. UNEP has also participated in organising several international workshops. The biogas seminar held in China (48) in 1979 under the joint sponsorship of UNEP and the Environment Protection Office of China's State Council, is worthy of mention as it was extremely beneficial in extending the Chinese biogas experience to other parts of the Third World.

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Annex 1.

# COMMONWEALTH SCIENCE COUNCIL
## AFRICAN ENERGY PROGRAMME

1 **Project Number :** 6 BIO-GAS

2 **Specific title:** Bio-gas technologies for rural energy needs in Africa.

3 **Objectives:** To develop and promote bio-gas technologies for use in rural areas of Africa through investigations into, among others, user needs, feedstock for bio-gas plants, quality and utilisation of slurry from the bio-gas plants, storage, distribution and practical application of the gas.

4 **Brief outline:**

**Phase I : (2 years)**

1. Identification of user needs and target costs per unit.

2. Investigations of :

   (a) the availability and relevant properties of different feedstocks including both animal and vegetable wastes.

   (b) design and development of digesters suitable for ... needs and available feedstocks.

   (c) the quality and utilisation of the slurry from the bio-g... as opposed to the use of the feedstock for fertilizer pu...

   (d) storage and distribution of the bio-gas.

   (e) investigation and development of prototypes for practical applications of bio-gas such as cooking, lighting, refrigeration, soldering, and conversion into mechanical power for water pumping, crop processing and electricity generation.

3. Technical and evaluation at the end of phase I.

**Phase II ( 1 year )**

1. (a) Field demonstrations of the viability of bio-gas plants.

   (b) Training of extension personnel and users.

   (c) Provision of mobile display facilities including audio-visio aids.

33

5 Name and address of Regional Coordinator

Principal Secretary
Ministry of Water, Energy and Minerals
P O Box 9153
Dar es Salaam
Tanzania

6. Names and addresses of National Coordinator with which Collaboration is sought

**Kenya** - National Council for Scierce and Technology
(Attention: Mr G Muchiri
Nairobi - Kenya

**Uganda** - National Council for Scientific Research
Kampala - Uganda

**Rwanda** - Centre d'Etudes et d'applications
de l' Energie Rwanda
(Attention: Unimana Enge'ne
Rwanda

**Zambia** - The Secretary General
National Council for Scientific Research
Boc CH 158
Chelston
Lusaka - Zambia

**Tanzania** - The Director-General
Small Scale Industries Development Organisation
Dar es Salaam - Tanzania.

**Botswana** - Mr Derek Medford
Botswana Technical College
P O Box 43[illegible]
Gaborone
Botswana

**Seychelles** - Mr M Fayon
Principal Secretary (W)
Ministry of Planning and Development
Department of Works
P O Box 53
Unity House
Seychelles

**Sierra Leone** -

7 Component of project to be undertaken by each country.

Kenya - Labour, Laboratory facilities.

## TABLE I SHOWING COUNTRIES SEEKING COLLABORATION IN VARIOUS RESEARCH ACTIVITIES AS INDICATED IN PARAGRAPH 4 (BRIEF OUTLINE)

Nation is referred to paragraph 4 (Brief outline)

| | Phase I | | | | | | | | Phase II | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 1 | 2a | 2b | 2c | 2d | 2e1 | 2e2 | 3 | Ia | Ib | Ic |
| Uganda | x | x | x | x | | x | | x | x | x | x |
| Kenya | x | x | x | x | | | | x | x | x | x |
| Rwanda | x | x | x | x | | | | x | x | x | x |
| Zambia | x | x | x | x | | | | x | x | x | x |
| Tanzania | x | x | x | x | x | | x | x | x | x | x |
| Botswana | | | | | | | x | | | | |

$2e_1$ - refer to adoption of available equipment for direct use of bio-gas (such as cookers, tilley lamps, refrigerators, soldering etc.

$2e_2$ - refers to indirect use of bio-gas after conversion into mechanical power, e g water pumping, crop processing and electricity generation.

8 Project cost

Notation under item is referred to paragraph 4 (Brief outline) and Table 1

Phase I

| Item | | External US$ | Local US$ | Multiply by the number of countries seeking to pursue R & D as per previous US$ | |
|---|---|---|---|---|---|
| 1 | Travelling | | 3,000 | 15,000 | (5) |
| 2a | Baby digesters and anxilliaries | upto 20,000 | | 100,000 | (5) |
| 2b | $3M^3$ digester and auxilliaries | | 2,000 | 10,000 | (5) |
| | 10 $M^3$ digester and auxilliaries | | 6,000 | 6,000 | (1) |
| 2c | Laboratory facilities | | 500 | 2,500 | (5) |
| 2d | Storage and distribution facilities (compressor, tank etc) | 3,000 | | 3,000 | (1) |
| 2e1 | Direct application | 1,000 | | 1,000 | |
| 2e2 | Bio-gas for mechanical power | 3,000 | | 3,000 | (1) |
| | Overseas travel (once) | 35,000 | | 35,000 | (1) |
| | Small workshop/seminar for researchers | 10,000 (each year) | | 30,000 | (3) |
| | Consultancy | 25,000 | | 25,000 | (1) |
| | Total: | 97,000 | 11,500 | 197,000 | External |
| | | | | 33,500 | Local |

Phase II

| Item | | External US$ | Local US$ | Multiply by the number of countries US$ | |
|---|---|---|---|---|---|
| 1a | Field demonstration (3 x 3m 3 digesters) | | 2,000 | 6,000 | (3) |
| | (2 x 10m3 digesters) | | 6,000 | 12,000 | (2) |
| 1b | Training of extension personnel | | 20,000 | 20,000 | (1) |
| 1c | Land rover and audi-visio equipment | 60,000 | | 60,000 | (1) |
| | Total: | 60,000 | 28,000 | 60,000 | External |
| | | | | 38,000 | Internal |

9 Time plan of project

Phase I - 2 years Phase II - 1 year

Annex 2

# REPORT OF WORKING GROUP ON ENERGY POLICY

The working Group on Energy Policy was composed as follows:

| | | |
|---|---|---|
| Dr L J Saliba | Malta | - Chairman |
| Mr R G Miti | Zambia | - Rapporteur |
| Mr V T Gondwe | Tanzania | |
| Prof J O Ilukor | Uganda | |
| Mr F Rutazihana | Rwanda | |
| Mr K F Mokola | Botswana | |
| Dr M J Mwandosya | Tanzania | |
| Mr P M Nyoike | Kenya | |
| Mr A S O Taal | Gambia | |
| Mr T S Kimaro | Tanzania | |
| Mr S J Asman | Tanzania | |
| Mr A De Terra | International Energy Agency | |
| Mr D P Turner | Overseas Development Administration | |
| Mr D J Kavishe | Tanzania | |
| Dr G Mariki | Tanzania | |
| Mr I M Michaelides | Cyprus | |

Mr R G Miti (Zambia) presented his paper on Energy Policy in Zambia, with particular reference to those sections dealing with elements to be incorporated in National energy policies.

The working group agreed to tackle the matter of guidelines in the formulation of national energy policies on the basis of the recommendations contained in Mr Miti's paper, and following that, to explore possible areas of collaboration at regional level in this field.

The working group agreed that every country requires a national energy policy which may be based on the following guidelines:

1. Inventory of all energy resources, including deficiencies
2. Consumption patterns together with indication of foreign content in each and how, where possible, substitution by a local resource may be achieved smoothly.
3. Data collection and forecasting

4. Merit ordering on basis of -

- economics
- reliability of supply or availability,
- diversity,
- indigenousness,
- type is renewable or non-renewable,
- environmental implications.

5. An indication of the role that technology is expected to play in achieving policy objectives as an essential guide to energy research, development, demonstration and commercialization activities, and presentation to energy policy makers of the options offered by technology.

6. Implications on the existing mode of life in order to identify need for training in production methods, use and acceptability i e how to cope with the problems of technology and market penetration.

7. Undertaking studies so as to arrive at an optimal energy resources mix.

8. Conservation efforts which may include one or more of the following:

- deliberately restricted consumption by changes in hours of service.
- speed limits
- limited importation of certain types of vehicles
- fuel rationing
- changes in consumption patterns
- use of price mechanism
- architectural changes in design of buildings, insulation of buildings, etc.
- educational and training programmes in conservation
- quality of maintenance of machinery and equipment (e g boilers, motor vehicles, etc).
- quality of use, e g driving of motor vehicles, housed equipment
- Reafforestation and anti-desertification programmes
- promotion of efficient public transport
- development and utilization of energy-efficient technologies, e g wood, charcoal, etc.
- efficient utilization of animal power.

9. Appropriate institutional analysis and set-ups so as to ensure that the national energy policy takes effect and benefits society as much as possible.

Areas of collaboration:

The group discussed potential areas for collaborative effort and tentatively drew up the list below for possible attention:

- information exchange on national energy policies
- data collection, analysis and methodology
- development of shared energy resources
- possible pooling of energy resources
- possible joint use of transportation systems
- joint measures for the conservation of eco-systems affecting energy supplies
- exchange of field experience and expertise
- shared use of relevant facilities.

It was proposed to establish a regional centre for information exchange on energy policy which Zambia offered to host. The group discussed the proposal but considered it premature, though open for the future.

Assistance from CSC:

It was noted that most countries will probably require assistance in the formulation of their national energy policies in which the Commonwealth Science Council could provide the necessary support in the form of expertise or finance. Similarly CSC could assist by encouraging the exchange of field experience and expertise through the provision of funds to cover the costs involved (travelling, subsistence allowances, etc), and data collection and dissemination.

Annex 3 - Tanzanian Case
Supplementary Tables.

Source : Reference (44)

**TABLE 1** : [illegible] OF GAS PLANTS INSTALLED UNTIL MAY 1976

| No. | Plant Location | Establishment | Capacity (cu. m.) | Utility | Source of Technical know-how | Remarks |
|---|---|---|---|---|---|---|
| 1. | Misungwi Rural Training Centre (Mwanza District) | June 1975 | 3 | Cooking and lighting | [illegible] | Running in good condition |
| 2. | Ngudu Health Centre (Kwimba District) | June 1975 | 4 | ditto | ditto | ditto |
| 3. | Murutunguru (CCM) Ideological College (Ukerewe District) | August 1975 | 5 (2 Nos) | ditto | ditto | ditto |
| 4. | Magu District Health Centre (Magu District) | August 1975 | 2 | ditto | ditto | ditto |
| 5. | Sengerema Rural Medical Aid (Sengerema District) | October 1975 | 2 | ditto | ditto | Latest information not received |
| 6. | Butiama Ujamaa Village (Mara) | September '75 | 8 | ditto | ditto | Running in good condition |
| 7. | Malya Prison (Shinyanga) | October '75 | 3 (3 Nos) | ditto | ditto | ditto |
| 8. | Arusha Prison | 1975 | 2 | ditto | ditto | ditto |
| 9. | Monduli Juu Primary School (Monduli District) | 1976 | 4 | ditto | ditto | ditto |
| 10. | Monduli Rural Training Centre | 1976 | 6 | ditto | ditto | Starts operating this year |
| 11. | Hanang - Arusha (Hanang District) | 1976 | 3 | ditto | ditto | ditto |

Table 1 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 12. | Kiteto - Arusha (Kiteto District) | 1976 | 3 | ditto | ditto | ditto |
| 13. | Mbulu (Mbulu District) | 1975/1976 | 4 | ditto | ditto | Start operating this year |
| 14. | Kindai Holding Ground (Singida District) | March 1976 | 3 | ditto | ditto | In good condition |
| 15. | Urambo - Tabora | February 1976 | 4 | ditto | ditto | Be ready by June 78 |
| 16. | Chamwino - Dodoma | 1977/1978 | 3 | ditto | ditto | Be ready by the end of September 1978 |
| 17. | SIDO Pavilion - Azimio Ground -(Arusha) | February 1977 | 4 | Cooking and lighting | SIDO | Used during celebrations and demonstrations |
| 18. | [illegible] (Mwanza) | [illegible] | [illegible] | ditto | ditto | In good condition |
| 19. | Magu District Health Centre (Mwanza) | 1974/1975 | 6 | ditto | ditto | ditto |
| 20. | Nyashimo Health Centre (Magu - Mwanza) | 1977/1978 | 10 | ditto | ditto | Recent information not received |
| 21. | Kalala Health Centre (Geita District - Mwanza) | 1977/1978 | 10 | ditto | ditto | Latest report not received |
| 22. | Katila Health Centre (Magu district - Mwanza) | 1977/1978 | 10 | ditto | ditto | ditto |
| 23. | Kagunga health Centre (Sengerema District) | 1975/1976 | 3 | Cooking and lighting | [illegible] | In good condition |
| 24. | Nzera Health Centre (Geita District - Mwanza) | 1977/1978 | 10 | ditto | ditto | Latest report not received |

42

Table 1 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| . | Katunguru Health Centre (Sengerema) | 1977/1978 | 10 | ditto | ditto | ditto |
| [illegible]. | [illegible]ridi - Shinyanga ([illegible]ridi Mission) | 1976/1977 | 10 | ditto | ditto | In good condition |
| | INDIVIDUAL PLANTS | | | | | |
| [illegible]. | [illegible] ([illegible]) ([illegible] District - [illegible]) | 1977/1978 | 3 | Home compound cooking, lighting | ditto | In good condition |
| 28. | Dr. Maeda - Ubungo Dar es Salaam | 1977/1978 | 4 | ditto | ditto | Under construction |
| 29. | Water Resources Division - Ubungo (Dar es Salaam) | 1977/1978 | 6 | Demonstration and testing purposes | ditto | Construction just completed |

Table 2 : **COSTINGS FOR FAMILY GAS PLANTS**

| S.No. | Capacity (cu.m) | LABOUR | | MATERIALS FOR CONSTRUCTIONS AND FABRICATION OF GAS HOLDER | | | | PIPE FITTING | TOTAL ESTIMATE |
|---|---|---|---|---|---|---|---|---|---|
| | | Excavation (shs) | Masonary work (shs) | Bricks | Cement | Sand | Gas Holder, frame & Stoves | | |
| 1. | 2 | 200 | 300 | 600 | 500 | 200 | 3,000 | 600 | 5,400 |
| 2. | 3 | 300 | 400 | 1,000 | 600 | 300 | 3,400 | 700 | 6,700 |
| 3. | 4 | 400 | 700 | 1,400 | 740 | 400 | 4,000 | 800 | 8,440 |
| 4. | 6 | 500 | 800 | 1,700 | 800 | 500 | 5,600 | 1,000 | 10,900 |
| 5. | 8 | 800 | 1,000 | 2,000 | 800 | 650 | 7,800 | 1,200 | 14,250 |

TABLE 3

**COSTINGS FOR COMMERCIAL PLANTS (INDUSTRIAL)**

| S. NO. | CAPACITY (CU.M) | LABOUR CHARGES | | BRICKS | CEMENT | SAND | GAS HOLDER | STOVE & LAMPS | FITTING | TOTAL COSTS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | EXCAVATION. | MASONARY WORK | | | | | | | |
| 1. | 10 | 1,000 | 1,200 | 2,500 | 1,000 | 800 | 9,000 | 1,100 | 1,500 | 17,900 |
| . | 15 | 1,600 | 1,950 | 3,000 | 1,800 | 1,200 | 13,000 | 1,400 | 1,550 | 25,500 |
| . | 20 | 2,200 | 2,700 | 3,500 | 2,600 | 1,600 | 17,000 | 1,700 | 1,800 | 33,100 |
| . | 25 | 2,800 | 3,450 | 4,000 | 3,400 | 2,000 | 21,000 | 2,000 | 2,050 | 40,700 |
| . | 35 | 3,600 | 4,050 | 4.600 | 4,000 | 2,600 | 27,000 | 2.600 | 2,650 | 51,100 |
| 6. | 45 | 4,200 | 4,650 | 5,200 | 4,600 | 3,200 | 33,000 | 3,200 | 3,250 | 61,300 |