BIOGAS

Manual for the Realisation of Biogas Programmes

BORDA

Bremer Arbeitsgemeinschaft für Überseeforschung und Entwicklung
Bremen Overseas Research and Development Association
Association Bremoise de Recherche et de Developpment d'Outre-Mer

Commissioned by: German Agency for Technical Cooperation (GTZ)
and Bremen Senator for Economic Affairs and Foreign Trade

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elaborated by: BORDA (Bremen Overseas Research and Development Association)

on behalf of the State Ministry (Senator) for Economics and Foreign Trade of the Free Hanseatic City of Bremen

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PREFACE

This manual mainly deals with the implementation of biogas programmes in developing countries. Simultaneously a scientific publication and in the framework of the GTZ-gate modules a building instruction for simple biogas plants will be issued. In order to comply with the different parties interested, we have decided for a tripartition.

This book is to serve practical application. Therefore BORDA request all readers to inform us of their experiences with biogas plants and biogas projects. BORDA will make their own and the experiences of others available to everybody and is therefore, upon request, prepared to give advice concerning projects and programmes.

We should like to convey our special thanks to Dr. Rudolf Wagner, Berlin, without whose assistance it would not have been possible to gain access to the multiple experiences of the People's Republic of China for this publication.

Our thanks go to all participants of the International Bremen Biogas Workshop 1979 whose critics and incitations have been of unestimable help.

Mr. Günter Bruns was of valuable assistance to our work.

We should like to convey our thanks to all those who have helped us with this manual.

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INTRODUCTION: Biogas, a contribution to general development

Wide parts of the world are dominated by poverty and starvation. The political and economic reasons for underdevelopment have created a new dimension: The ecological misdevelopment.

Biogas technology can counteract this misdevelopment in the rural areas in the Third World and simultaneously improve the living conditions of the rural population by converting the anyhow existing waste into fertilizer and energy by means of the biogas plant.

This manual has been produced in order to convince its readers that the introduction of the biogas technique offers a good chance to counteract misery in the rural areas and that this technique should therefore be applied whenever possible. The manual supplies all the information necessary concerning the technique itself as well as the presumptions for its application and the consequences thereof. On the other hand it illustrates that renouncing at biogas would mean renouncing at making front against ecological misdevelopment and thus additional economic underdevelopment.

The concept of this manual has been produced by a German-Indian team and has been presented for discussion at the International Bremen Biogas Workshop in May 1979.

Experiences and know-how of more than 60 biogas experts from almost 20 countries — also from the People's Republic of China, the country with the highest number of built biogas plants — have been integrated into the text. The high number of participants in this discussion process give this manual the authority to deliver binding assistance for the decision in favour of the introduction of biogas technology.

The authors and their consultants believe that it is time to point out explicitly one fact above all: Biogas technique as against the industrial large scale-technique can claim to be the better alternative for the development policy of a country. As "appropriate technology" it should therefore at least be given the same rank compared with macro-technique as far as promotion is concerned, since of macro-technology only the people in the large urban concentration centres benefit and even there only to a limited extent. If this change is not effected, the people in the rural areas will remain in poverty and see themselves compelled to go to the cities thus converting these into giant slums.

The decision for this change is overdue — as well on behalf of the developing countries as on behalf of the industrialized nations. This decision must have consequences, that is to say the political intention must become active in establishing programmes which have to be secured by the budgetary plans by providing building subsidies for biogas plants.

Biogas plants are especially needed in areas where poverty is extreme and where the people on their own economic means are unable to improve their situation and therefore are not in the position to build such plants without subsidies.

Subsidies from development aid funds on a national and/or international basis are indispensable as an initial help for a development process which in the future will not require anymore assistance.

There are many different systems of biogas plants. In order to set an end to the experts' discussion concerning the "optimal" biogas plant, the International Bremen Biogas Workshop has formulated clear statements which have been integrated into this manual. It is now time to act.

Having biogas, one has fire and light, better crops and more hygiene. Biogas promises with this perspective a start for a better life. The authors wish this manual to contribute to help this technology find its ways for the benefit of the people in the world.

1. POLITICAL ARGUMENTATION CONCERNING BIOGAS TECHNOLOGY

1.1. The time bomb

In the developing countries a socio-political potential conflict situation is building up which increasingly dominates international discussion. The facts speak for themselves: Poverty of the rural population becomes unbearable in many parts of the world. Millions of people are compelled to leave the villages and make for the cities. With an annual growth rate of more than 4%, in the year 2000 the urban population in the agglomeration centres of the developing countries will have increased from presently 28% to 41% of the population in total (approximately 2000 million people).

Already now more than 800 million people are living in the cities of the developing countries. Efforts to control the exodus from the rural areas have not been successful, despite of the fact that more than 250 million people live under hopeless conditions.

Daily about 200.000 children are born i.e. annually approximately 75 million. This figure has increasing tendency. According to the average analysis of variance of the United Nations, the world population will have increased by 2.286 million people in 20 years. 2/3 of this growth will take place in the cities. In South East Asia alone additional 135 million people will live in the cities at the end of this century.

The high pressure of population into a few agglomeration centres is not compensated by corresponding employment possibilities. Underemployment and poverty lead to occupation of land and the extension of slums which lack even the most primitive facilities. The urban administrations see themselves confronted with giant planning tasks, which they are not in a position to solve.

In September 1978 the World Health Organisation stated that the number of undernourished people in the developing countries has increased to approximately 500 million. 1979 16 million children died of starvation or undernourishment because of the lack of medical assistance. The death rate of the children before reaching the first year of age amounts to 30 - 50% in slum areas.

The natural forest reserves of the world diminish daily by 30.000 ha only by cutting trees for firewood. This has already led to ecological catastrophy not only in the Sahel Zone. As long as the lives of the rural population are threatened by misery, there will be no alternative to the suicidal exhaustion of nature. Firewood and agricultural waste are often the only source of energy. In India and East Africa alone, 400 million t of cattle dung are being burnt annually for cooking and heating purposes and are thus taken out of the natural recycling for the regeneration of the soil.

1.2. Problems of industrial growth

In a study on the rural population published in New Delhi in 1978, it was established that the 30 years lasting planning efforts of the Indian Government to overcome the differences in income and prosperity in the rural areas have remained vain. Against 40% in 1962 presently more than 70% of the rural population are no longer in a position to provide themselves sufficiently with food. These are alarming facts for 500 million Indian village inhabitants i.e. more than the rural population of Africa and Latin America taken together, where the situation is often similar.

The one-sided efforts towards industrial growth actively promoted by export orientated industrialized nations concentrate the national resources and possibilities of numerous developing countries on the agglomeration centres and will be of benefit even there only to a minor part of the middle and upper classes. Energy consumption in these centres amounts to often 90% of the energy available in total in a developing country despite of the fact that 80 - 90% of the population are living in rural areas.

The promoters of central energy supply systems do neither think about the subsequent problems in regional developing nor of the subsequent financial burdens and the newly created technical dependences having developed due to the necessity of gaining technological know-how. The most severe consequence of such a "technologically avant-garde undertaking" is the fact that the major part of the population is left behind. In addition to this the energy supply offered is concentrated mainly on the already overcrowded agglomeration centres, thus promoting the exodus from the rural areas. Energy is not brought to follow the people, but people are brought to follow energy.

Case example

In the framework of an electrification programme in West Samoa, the rural areas will also be connected to the power net work. The total costs of the project are estimated to about 10 million DM. The cost fraction for the supply of the villages amounts to about 6 million DM. Considering that the wired electric conduits can be used also for further extension of the supply net work, the costs per connected household amount to about DM 1.600,--.
In addition there are indirect expenses: Per household supplied with energy, 5 carrying breadfruit trees will have to be cut within the lanes for overhead transmission lines. The expenditures for rice as a substitute for breadfruit amount to about DM 800,-- per household until the fruit of the newly planted trees can be harvested.
The calculable connection cost per family therefore already amount to DM 2.400,--. For the overhead transmission lines approximately 6 million square meters of farmland are lost as far as production is concerned.

In West-Samoa ground is not for sale and therefore without market value. The negative influence on nutrition and health of the population is evident but neglected though in normal cost-profit-analysis. If financial means of similar proportions had been made available for biogas programmes, the energy supply could have been secured in a decentralized way and agricultural yield be increased simultaneously.

1.3. The Alternative or the "different" Approach

The animosity against major industrial development projects is rapidly increasing worldwide. For good reasons. It cannot be denied that this type of development aid missed to meet the basic needs of large groups of the population and has not been in a position to secure same. The very poor in the world do not lack electricity, cars, television sets and machinery, but food, clothing, health, education and housing. Which type of development aid can then meet with these elementary necessities? The different approach has to be adopted. It is based on the use of own efforts of the poor concerned and on material locally available as an enormous development potential. It advocates the use instead of the waste of natural raw materials.

The introduction of biogas plants is one step in this direction.

The catastrophic conditions in the cities are the consequence of the misery in the rural areas. This is were biogas technique is to be initiated. If once hopefully applied in millions of plants, biogas technique is in a position to show results which has merely remained hopeful thinking under the efforts of industrial development aid: improve living conditions of many people, stop migration from the rural areas and give decisive impulses for self-help development processes.

Biogas technology is an appropriate technology. Appropriate technologies assist the seemingly lost human capacity of exploiting the natural resources of the world in a way that environment be preserved and everybody be getting his share.

It is orientated according to the specific characteristics of the country and the needs of its people under consideration of economic resources and technical education.

The manyfold detrimental attitudes of the industrialized countries — as far as natural resources are concerned — urgently require a change of attitude towards new technologies also in this field, adapted to nature and people alike. This finding led to more intense promotion of biogas technology also in the industrialized countries.

The developing countries are still in danger of hoping for an improvement of their situation in general by relying on non-appropriate technologies according to the pattern of the industrialized countries. Contracts on large size power plants still find the interest of the leading classes in the developing countries. They thereby rather secure the export of the industrialized nations than satisfy the needs of their own people.

Still today the nonexistance of large size technical plants is often mistaken for underdevelopment. In conformity with that the attempts to cope with poverty go in the wrong direction. Underdevelopment indicates the misery of the masses and not the technological standard of the upper and middle classes.

1.4. New orientation has already begun

As a reaction to this misdevelopment, new orientation towards appropriate technology has already started in various countries, i.e. also towards introduction of the biogas-system for decentralized energy and fertilizer supply. The most important common result of the International Bremen Biogas Workshop 1979 certainly is: that a state, a region must actively and on all levels engage for the introduction of biogas technology. Expenditures, which the individual farmer cannot afford have to be taken over by the state. The advantages thereby resulting for the country justify these expenses.

1.5. Why the "great break-through" has not yet materialized

Most of the initiative despite of the wealth of inspiration, particularly of the rural self-help groups, of the voluntary agencies and also present at various local and regional decision-making levels has not succeeded in achieving the decisive break-through which could have marked a real alteration process. What are the reasons for this? There is a whole row of them, some of which will be mentioned: Investment costs for biogas plants are much too high for the rural population. This explains the advocates of energy supply decentralization with biogas plants always endeavouring, above all, to cut costs. On the whole, these well-meaning efforts, however, have rather harmed the system. Primitive solutions of utilising old oil-drums and resinous-stained wicker-baskets have given rise to scorn — and not only in the industrialized countries. The gas yield proved unreliable and mostly too small. The comfort of operation with such simple plants no longer satisfied even the more unpretentious demands. Many an unsuccessful attempt has resulted in the biogas system meeting with rejection in a whole area, often for years.

The overall advantages of the biogas technique become effective for the individual only, if the whole region is equipped with these plants where the technique is applied. This is especially valid for the preservation of forests, the improvement of hygiene as well as the promotion of small scale industries, training systems and service-centers.

China	*7.000.000*
India	*70.000*
Korea	*30.000*
Nepal	*350*
Thailand	*300*
Philippines	*200*
Pakistan	*80*
Indonesia	*20*
Fiji Islands	*15*

In many countries test plants are working efficiently.

***Table 1:** Number of built biogas plants (1979).*

The biogas system cannot be successful if a few plants only are erected which, given the present financing system, just the better-off farmers can afford. The gap between them and the poor thereby still aggravates. Despite of impressive progress in India (about 10.000 new plants annually) especially these phenomena can be observed.

Trying to trace the causes why biogas plants have not yet been actively sponsored by financial means in the framework of public development aid of the industrialized states is useless. Despite of the fact that the advantages outweigh the disadvantages and even considering that in none of the other energy systems the part of own labour is a high, the effects of stabilization for the rural areas and the stimulus on the development policy level cannot be overlooked, this natural system known for a long time already, has not been given enough attention until now. This is certainly due to the fact that industrial large scale systems are given preference to as they ensure export chances. Above all, the actual needs of the poorer rural population have not been taken into consideration.

1.6. Mobilize all chances for implementation

What action must be taken to pave the way for extensive expansion of biogas technique? There is a series of starting-points and experiences suitable for the encouragement of world-wide efforts. There is above all the self-conscious realization noticeable in numerous developing countries of the development possibilities in their rural areas.

Compared with the costs of centralized energy supply, decentralized energy supply from biogas plants is cheap. By no means should the impression be won from this that biogas energy supply presents no problem whatsoever. Convincing village communities of the benefits of biogas technique is as much part of its spreading as is the giving of reliable service. Set-backs will occur again and again — this has even happened with the positive experiences in India and China.

To this promotion-strategy belongs also the task of repeatedly posing to the opponents of this energy supply, the question as to which other system offers similar following advantages:

- Increase and improvement of natural fertilizer supplies, thereby reducing dependence upon the supply of artificial fertilizers.
- Generation of cooking and lighting energy for covering domestic needs.
- Technically simple and operationally reliable.
- Improvement in hygiene and thereby better health of the populace.
- Far reaching employment possibilities and encouragement in establishment of artisan businesses with the related training facilities.
- Preservation of forest — and thus of further erosion of the soil.
- Large share of cooperation possibilities for those involved.

The development policy of the industrialized countries could decisively contribute to overcome the obstacles. These states command the necessary financial resourses and are in a position to give the developing countries assistance in introducing the biogas system for direct energy supply in the rural areas. As a result of the International Bremen Biogas Workshop the first projects are now being materialized. In this respect the German-Indian Biogas Team has made the following statements:

- Small farmers are powerless in the face of bureaucracy, administration and the banks (loans, mortgages, securities, etc.). The helplessness grows with the increase of economic distress which is the reason for dependence, lack of education, illiteracy, etc.
- Local self-help groups, cooperatives and community establishments are particularly suitable for cooperating with the voluntary agencies of public development aid — for assisting farmers with the introduction of biogas.

- These self-help groups do not have sufficient trained personnel at their disposal. The promotion of biogas plants could therefore be intensified by giving the self-help groups the possibility to recruit qualified personnel for full time jobs. These experts should work jointly with the village community.

- The local self-help groups often cooperate with the district authorities. But open-minded and responsive mayors and administrators also often lack the appropriate, qualified personnel.

- In order to increase self-consciousness in both, the self-help groups and the communal authorities, it should be considered to make funds from public development aid — of course on certain stipulations and conditions — available for the construction of biogas plants for the realization of which the concerned would be responsible themselves. This would also represent the easiest way of promoting this technique.
- A great number of medium-size and small scale industries, workshops, blacksmith's undertakings etc. are interested in getting orders. The economic interest of these businesses, their organisational capabilities and their contact to the small farmers offer good prospects for a speedy realization of biogas plants to include those who have been excluded to date. At this stage cooperation with the state banks regarding the financial and administrative transactions, including mortgage returns, the institution of revolving-funds, the re-disposal of monies from the revolving-funds etc.

- The promotion of biogas plants from public development aid funds, present the opportunity to mobilize private capital and increase national investments. Development aid funds, in the form of interest grants for free credits can thus increase the number of plants to be realized. The acceptance of guarantees for small farmers is necessary for the facilitation of administratory transactions. The risk is tenable in that the payment intention, as a rule, is excellent if the farmer had the firm conviction that he really wanted the plant.

- Development aid funds should not only be made available on application, but also, especially in this instance, according to the offerings being made available for this special purpose. The propagation of this preparedness should be effected through diplomatic representations abroad, international organisations, religious groups or voluntary agencies of the "development aid".

- There is evidence from various regions of China and India where biogas has been promoted successfully to show that a connection exists between the success of biogas plants and their financial promotion. The most convincing fact, however is the efficiency of the plants. The farmers do not hold back with their satisfaction and therefore there is no need to produce piles of advertising material or organize campaigns of purely persuasive character.

Unfortunately in "development aid" there is a very obvious reserve to start with practical work and a pronounced need, instead, to refrain from actual help for the benefit of always new describing experiments. This manual is to give assistance in the first step towards realisation and to cut down the waiting time of the concerned for better living conditions.

Extract from the Resolution of the Bremen Biogas Workshop 1979
addressed to the Governments of the industrialized countries.

"We are convinced that after the intensive work during the conference, a good basis for further activities has been created. Now it is time to implement the ideas developed by the experts.

Many biogas plants, especially in India and the People's Republic of China are already operating or under construction. However, we are still at a starting initial point. The improvement of living conditions of the population in the countries of the so-called Third World – especially in the rural areas – requires the realization of biogas technique and other appropriate technologies.

Many project proposals have already been developed, but the lack of funds hampers their implementation. The participants of the Workshop will elaborate detailed project proposals in their countries and intend to bring them to the attention of the Governments of the industrialized countries. We should be obliged to the Governments of these States if they supported the efforts of our countries by financing these projects.

The experiences of our countries and the economic potential of the industrialized nations will create a form of cooperation, the results of which will be beneficiary to both sides."

2. WHERE BIOGAS PLANTS ARE NECESSARY AND CONVENIENT

2.1. Advantages of biogas technology

The fermentation of organic material — including animal excrements and urine, human faeces, household garbage and industrial waste results in hygienic, preserving — as far as environmental protection is concerned — and particularly beneficiary sewage treatment.

Biogas plants are of comparatively simple construction and especially appropriate for the rural areas in the developing countries.
The benefits of a biogas plant are multiple: energy, hygiene, manure, environmental protection.
And these are the main advantages:

- Using biogas less trees are cut for firewood. Environmental harmony of nature is preserved.

Fig. 1: The branches of the trees are systematically "harvested". Such a tree can no longer fulfill its important functions of giving shade and controlling the climate. The tree is condemned to die off prematurely.

— Using biodung as fertilizer, the condition of soil and the yield of the fields can be improved. This depends on the fact that manure out of fermented slurry has a higher contents of nitrogen than ordinary dung and that its structure has a favourable effect on the formation of humus.

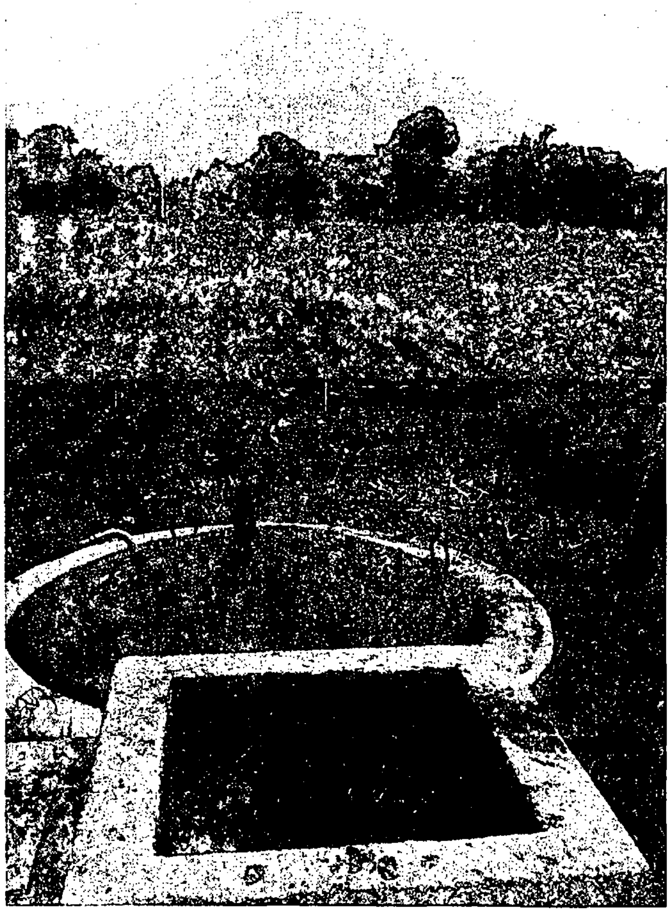


Fig. 2: Healthy, productive fields are of even higher a benefit than the clean, high-quality heating energy of the biogas.

— By the digestion of the faecal matter the major part of various, pathogens are destroyed. The scentless biodung does not attract flies nor any other kind of insects.

The veterinarian in Narodi/India found that mastitis – a disease of the udder with cattle – has been reduced by 80% since the introduction of biogas plants.

It is reported from China that no fly larva were found in the digested slurry. Bilharzia-larva were also completely destroyed. In summer they used to survive 14 days, in autumn 22 days and in winter 37 days. Ancylostoma were destroyed after 30 days up to 90% and after 70 days up to 99%.
Similar values have been established for spirochaeta, which among other diseases cause syphilis or recurrent feaver. Colibacteria at the outlet as compared with the fresh feed material had been reduced to 1/1500.

— Adding digested slurry to pig fodder or giving it into ponds for creation of algues for duck- and fish-hatchery, would result in additional increase in agricultural production, since growth-promoting vitamine B_{12} is preserved.

2.2. Special advantages of area covering concentration

The advantages of biogas technology can be used to the utmost, if whole villages or regions are equipped with biogas plants. Such an area covering spreading has additional social and technical advantages.

— The economic gap between poor and rich farmers is reduced if even the small farmer benefits of the direct use of a biogas plant and does possibly not have to give his dung to the large scale farmer for the operation of his biogas plant.

— By the creation of new employment for the construction and maintenance of the plants, even the landless benefit of the developing process.

— Service and maintenance of the biogas plants can be improved as with the increasing number the number of service stations will also grow.

— The on the spot training of biogas specialists is possible and therefore assistance can be given by even taking care of specific situations.

— Various individually made experiences with biogas become general knowledge being beneficiary to marginal groups of the population as well.

— Malfunctions in biogas plants are recognized as being exceptional. Confidence into biogas plants is not disturbed thereby.

2.3. Regions in need of biogas

Biogas technology has to be urgently introduced if the situation of a region is to be described as follows:

- Forests or dense wood do not exist.
- There is a lack of easily available, cheap energy.
- The soil is unproductive and damaged by erosion.
- Natural harmony is disturbed by exhaustion, i.e. the number of trees being cut is higher than that obtained by new growth or of forestation.
- Undernourishment and disease are a general problem.
- Unemployment and migration from the rural areas dominate.

If the people of an area suffer from a situation so described, biogas plants become a vital necessity.

Fig. 3: The Sahel Zone: First the trees die, then the cattle and finally the people.

2.4. Conditions necessary

The operation of biogas plants is useful only if two conditions can be permanently met with:

1. 20 kg of feed material, e.g. waste of 1 - 2 cows (corresponding to about 5 kg dried material) are available daily. This is the required quantity for the operation of the smallest plant.

2. Compared with the feed material, twice as much of an appropriate liquid has to be available, i.e. about 30 l of water per cbm of produced gas. If, for instance, the next water supply were at a distance of 2 km from the plant and no sewage water available, disturbances in operation have to be reckoned with as the plant will get choked. The water contained in the slurry can be recovered and be refed into the plant, however, without regular input of new liquid, a biogas plant will not work properly.

Fig. 4: If the water has to be carried from afar to the biogas plant dayin dayout, its operation will be problematic.

Case example

In the Ethiopian Province of Wollo a village of young farmers as well as a textile factory with corresponding housing facilities for the workers are to be established. There will be an availability of 15 stable-bound cows and 10 stable-bound horses as well as small farming animals. The latrines are going to be used by 470 people.

Work for the housing facilities was already in full swing, when Government Authorities expressed the desire that energy supply of the factory be secured by biogas.

An Ethiopian-Indo-German team examined the situation and came to the result that live stock is not sufficient for the supply of the factory with biogas.

The Government Authorities proposed to increase live stock by 100 stable-bound cattle. This proposal is rejected since it does not appear desirable to increase live stock in an area already overgrazed. The fields should not be misused for fodder plantations. Corn, teff and millette are of greater importance for nutrition of the people and cannot be replaced. be replaced.

Only then the "proper question" was being placed: "How can the occurring cattle and horse waste as well as the contents of the latrine pits be made use of in the best manner possible. The consequence: The toilets of the young farmers' settlement were to be centralized in order to connect 4 cbm plants. The gas will be used to heat up the water for the wash-house. The cattle waste available and the kitchen garbage will be fed into a connected plant consisting of two 6 cbm individual plants. The gas is being used in the big community kitchen.

The consequence of this decision was a replanning of both settlements. Since the construction was already well on its way, the best possible solution could not be realized in all the cases. The promoter employed a technician, who, in cooperation with the contractor, effected the construction of the biogas plant. The National energy supply authority showed interest in biogas technology and placed its steel construction workshop and their experts at the disposal of the project. An experienced Indian technician was called in for some weeks for construction and initial phase of operation *(see table page 19).*

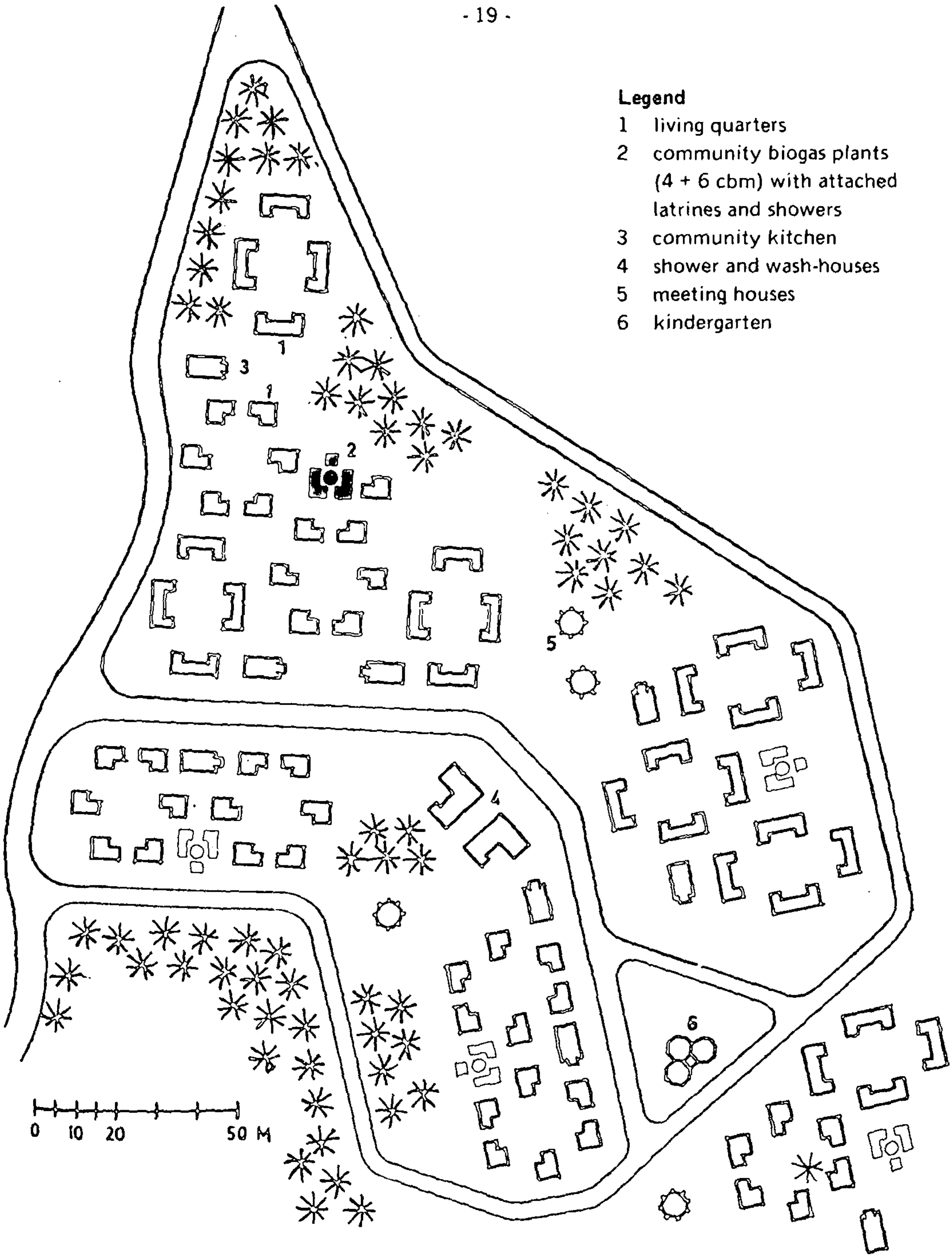


Table 2: Estate layout of the workers's settlement in Kobo/Alamata, Wollo Province, Ethiopia.

2.5. Favouring factors for the operation

A region is to be considered as especially appropriate for the operation of simple biogas plants on the premises that:

- there be an average temperature of about 30° Centigrade throughout the whole year,
- there be always sufficient water for the operation of the plant available, i.e. the same quantity of water as of organic waste,
- live stock can be one cattle unit per capita of the population (1 cattle unit = 500 kg live weight = 1 cow or 5 pigs or 250 laying hens) or that there be an availability of minimum 20 kg of organic waste as feed material daily,
- stabling be common,
- cattle dung being used as fuel or that the waste of the animals be gathered for fertilizing purposes. Handling of "impure products" is not put under taboo.

Fig. 5: 500.000 Indian villages would use dried cattle waste as fuel, which represents an annual loss of 350 million to of manure.

— building material is available locally or at some reasonable distance,

— there is sufficient a number of trained craftsmen for the construction of the plant or there are training possibilities for the population thus enabling them to build the plants themselves,

— the technical training standard of the population is sufficiently high as to guarantee operation of the plant without disturbances,

— there is an efficient already existing or to be created organization for the implementation of the biogas programme and for ensuring its maintenance.

It would however be a mistake to have the materialisation of biogas plants depend on the coincidence of all these favourable factors. Poor regions do particularly need biogas plants, as these favourable conditions do not exist. Therefore, positive decisions in favour of biogas plants should be taken on grounds of those situations where utilisation of biogas is necessary, useful and possible.

2.6. Possible dangers of biogas technology

Every technology, if misused, can cause damage. The benefit endeavoured does then not become effective or has, on the contrary, a negative impact.

Before making a decision in favour of the construction of biogas plants, special warning has to be given as to avoid excessive indebtedness of the economically weaker groups of the population. New dependences and further impoverishment would be the consequences thereof. The cost of construction of the plant would, in such cases, have to be partially taken over by the authorities concerned.

Some advocates of special biological cultivation methods are rather reserved as regards biogas technology. Investigations are being made presently with the purpose of using biogas also in the bio-dynamic field. These investigations have, however, not yet been brought to a close.

Ecologically speaking it would be dangerous, if the construction of biogas plants led to an increase of the otherwise unproductive live stock. Already exhausted regions can by no means recover by an additional number of cattle. The very specific danger for a land-scape due to intensive goat keeping is well known and should be just mentioned in this context without going into further details.

Taking into consideration that the most important ecological danger is involved in deforestation and burning of valuable manure, biogas offers the complex recovery programme with realistic development possibilities.

The dangers brought forth by incorrect operation or technical deficiency of the plants are of minor importance and can be neglected for the time being. They will however, be discussed in more detail in the technical chapters of part 4 and 5 of this manual.

Fig. 6: In an already exhausted region, the decision of a farmer to increase his live stock for the operation of a biogas plant, may represent a serious mistake.

2.7. Profitability of biogas technique

Economic rentability of the individual unit is not the sole decisive criterion but only one factor of cost-profit analysis.
The importance of biogas plants is determined by economic and ecological necessities. The rentability of the plants can therefore not only be seen in respect of the present costs of energy and material. Despite of this, the problems of profitability of the individual unit have also to be taken into consideration.

The calculable economic rentability of the individual unit generally increases with the size of the plant (see table 39). Therefore, community plants as compared with individual units are to be preferred left alone the social reasons or those of technical maintenance. However, already at this phase we should like to draw the attention to the fact that a clearly defined responsibility for the operation and maintenance is the indispensable basic condition for every community plant.

The construction costs for biogas plants vary considerably according to the local situation. In colder regions, for example, the expenditures necessary for insulation or for heating devices for the feed material cause an increase of cost. The decisive factor for the financial outlay, however, are the construction principle, the kind and cost of material and the share of own work.

In 1978 the costs for an Indian gobar-gas plant for instance, for the supply of one family, amounted to DM 1.000,-- - DM 3.000,-- including labour.

These cost data give a first hint as to the financial dimensions, but do not allow a statement concerning the profitability of the plant.

For the calculations of profitability further characteristics have to be taken into consideration which differ in importance according to the type of the plant. These include:
- Size of the digester
- Share of own labour and neighbourhood help
- Effectivity of the gas and fertilizer output
- Comfort of operation and amount of time required for operation
- Frequency and volume of expenses for repairs and maintenance
- Durability of the plant or of individual parts thereof
- Date of the cost data established.

For instance the smallest plant in China constructed in community work required approximately 100,-- DM - 200,-- DM for material only. This, however, does not mean that the costs for a Chinese plant amount to approximately 10% of the Indian gobar-gas plant only. The more complicated operation and smaller gas yield have not been taken into consideration. This price comparison is therefore not of great value. It stresses rather the share of unpaid labour than the actual costs.

In the comparison of costs on a national basis, international monetary correlations play an important part. In this context it is of considerable importance whether steel and cement have to be imported, transported over long distances or be subsidised.

It can be said in general that economic rentability for the individual is not always prevailing due to the high costs of steel and cement. In those cases subsidies to construction costs from public funds should be made available and be understood as infrastructural measures. In this context we would like to refer to chapter 3.4. also.

2.8. Biogas, stimulation to general development

By the introduction of biogas the social and economic development of a region is stimulated and positively influenced in multiple ways. Therefore biogas programmes have to be completed by supporting measures or follow-up programmes with the purpose of introducing biogas. This would include:

- Vocational training programmes for the construction of plants (see chapter 3.5.).
- Agricultural training programmes in order to make utmost use of the manure.
  If the amount of dung is increased by slurry, new possibilities result mainly for vegetable cultivations e.g. in kitchen-gardens, which can be made use of only through extended knowledge in the field of agriculture.
- Irrigation- and water supply programmes.
  Increased dung volume and higher productivity lead to increased water demand. All year round irrigation possibilities could possibly result in additional annual crops.
- Tree planting actions and afforestation programmes.
  In order to overcome the already occurred ecological damage in the shortest possible time, every tree newly planted is of great value. All parts of the population should be made to participate in those actions.

  The farmers of Narodi/India together with the Development Association Maharashtra Arogya Mandal have decided to advise the farmers of the near-by villages as far as they are in contact with them through the local markets and give them practical assistance as to the construction of biogas plants. Simultaneously every owner of a biogas plant is obliged to plant 10 new trees. In October 1978 250 new trees had already been planted and were being looked after by the farmers rather than cut for firewood.

— Training of the housewives in the operation of biogas plants so that they can make better use of the plant and their newly gained free time.
The time-consuming gathering of firewood then becomes superfluous. The fire place is clean, always ready to operate and above all time saving. The saved time can then be used to the benefit of education of children, own further training or a more intense work on the fields and in the garden. Adult training programmes should therefore be made available to the involved.

Fig. 7: Especially the women in the villages benefit of the clean, time saving source of energy.

— Health programmes in the framework of prophylactic medicine.
The influence of biogas technology on health situation is considerable. The slurry does at any rate hardly contain any pathogens. As it is completely odourless, flies and mosquitos are not attracted. The spreading of infections is thereby prevented. In addition, less diseases of the respiratory system and the eyes are being found as there is no smoke in the kitchen. The construction of latrines serves above all the purpose of hygiene. The resulting gas production is an additional asset. The construction of latrines should therefore figure on every development programme.

Finally the improved nutrition, due to higher crop yields leads to increase of productivity and to reduction of costs for medical assistance. Well fed children are less susceptible to diseases. Training courses on dietetics considerably support the efforts of medical services.

For better understanding of the correlations between nutrition and infections, village inhabitants in Guatemala and India were divided into three comparable groups. One of the groups was provided with additional food, the second with intensive medical care and the third was used for controlling purposes. It was thereby found that improved medical care and hygiene did not influence disease frequency but only reduce death rate a little. In the case of the group which was supplied with additional food, the growth of the children improved, they were less frequently ill and their death rate decreased significantly.

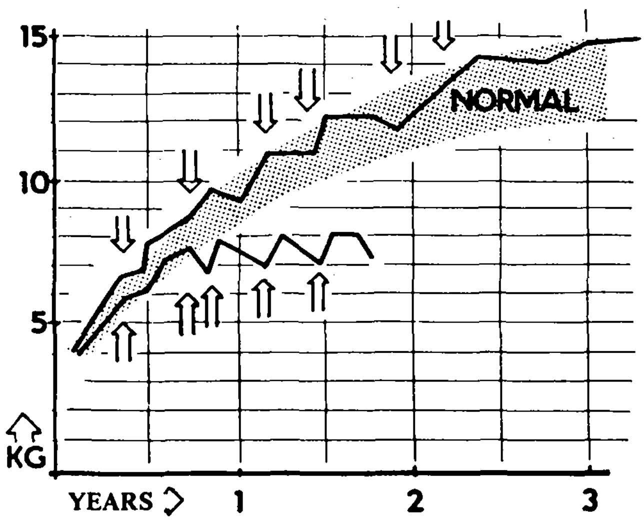


Table 3: Weight diagram of children from different social backgrounds. The jumps in the weight curve mark infections such as measles, hooping cough or diarrhea.

2.9. Individual units or community plants

Biogas plants can be built as individual units or community plants.
Individual plants are suitable for families, community plants for groups, institutions or whole villages.

Fig. 8: Village community plant under construction. In the background the connected latrines.

For reasons of profitability and social justice, community plants should be given preference to individual plants. They can be operated by several families or by groups in rural or urban settlements. The religious, cultural and social situation of a region can favour or impede the operation of community plants. It has therefore to be examined in each case, whether or not, the operation of a community plant is practicable.

This particularly applies to community latrines. Because of the great importance of the toilet facilities in general as regards hygiene, all efforts have to be undertaken in order to materialize such facilities.

Maintenance and cleaning of community facilities are problematic. It is therefore indispensable that responsibility for a community plant be clearly defined and be delegated to persons whose economic well being considerably depends on the efficiency of the plant.

Shall community plants be operated in condominion, the following requirements have to be met with:

- There is already a social community as it is the case, for instance, with neighbourhood plants where mostly only two or three families participate.
- The community is already organized or can be organized in a way as to control the operation and maintenance of the plant. Schools, hospitals, authorities or stations would have to be considered as such communities.

The promotion of community plants is to be especially recommended, if not only one or several individuals or families benefit of the plant, but if the energy generated and the output are advantageous to the public, including the economically weak or underprivileged members of the community.

A community plant is of particular interest if by the energy generated in common, small scale industry can be established, thereby creating additional employment.

In the case of community plants, common utilisation of the gas in direct neighbourhood of the plant, as compared to individual distribution of gas, has economic advantages.

Individual plants should be built in case community plants cannot be constructed or are not desirable for the reasons mentioned above.

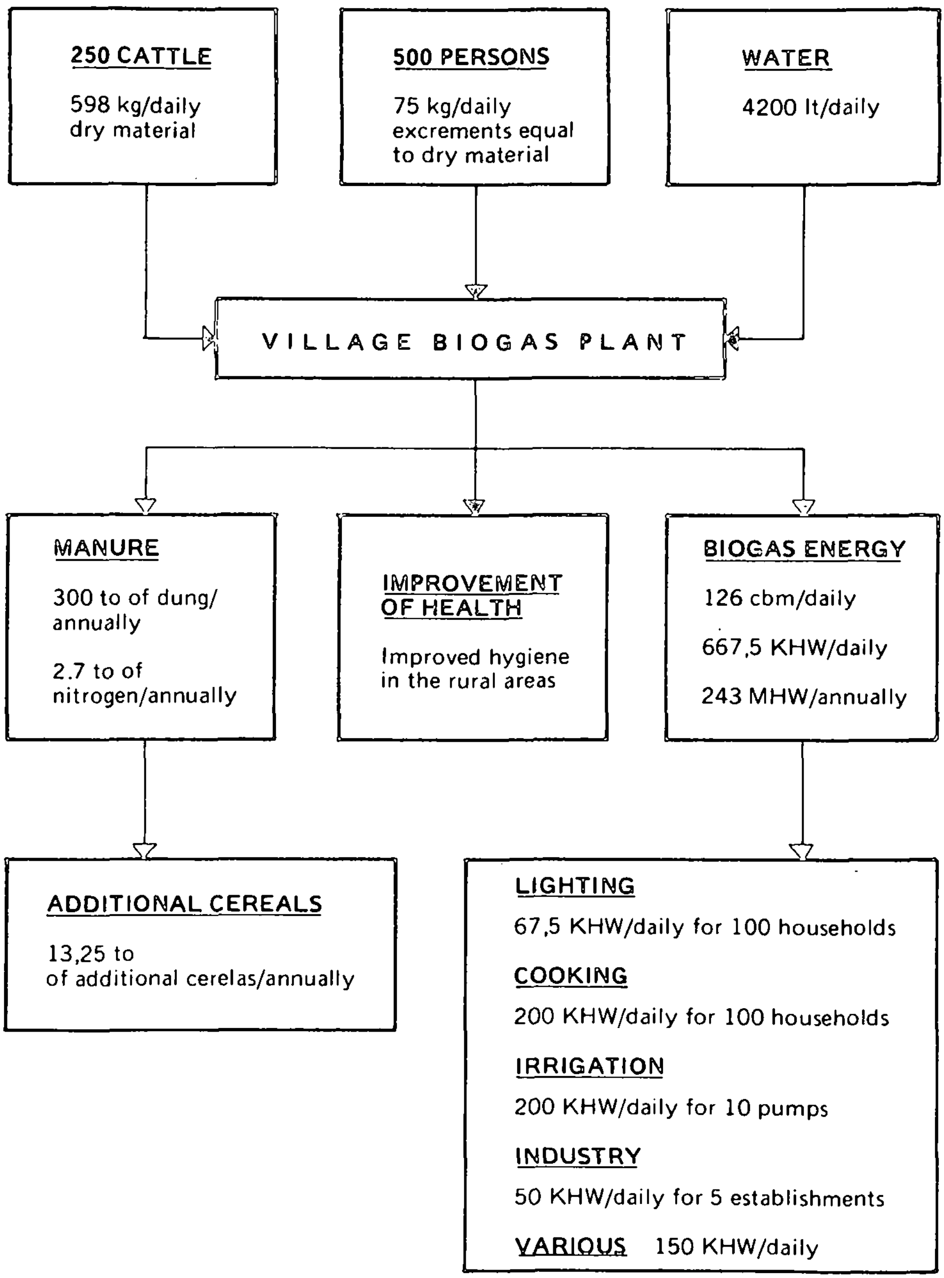


Table 4: Use of a community plant

There is no minimum size prescribed for a community plant. The optimum size depends on the situation prevailing.

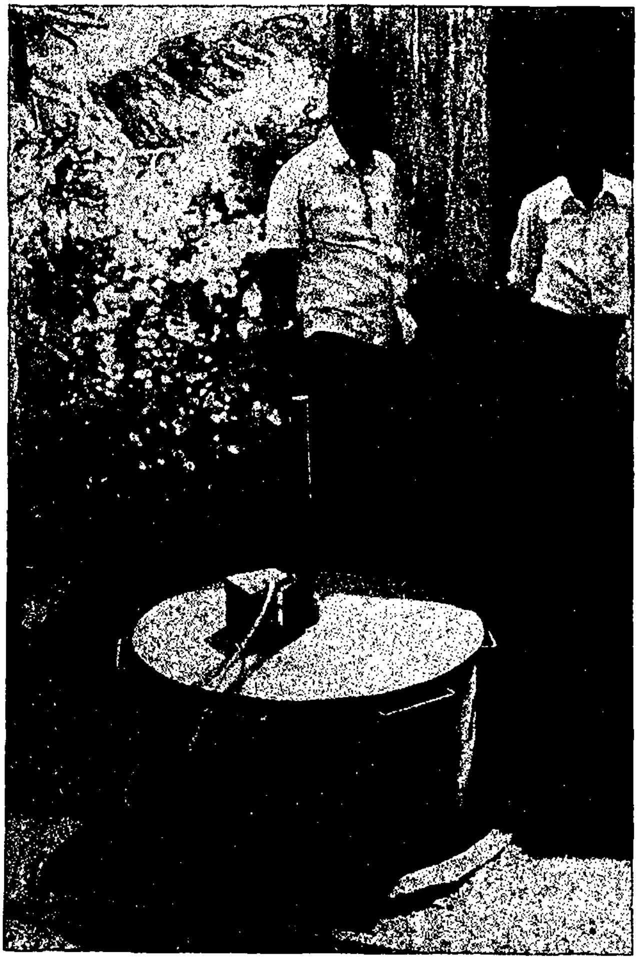


Fig. 9: *'This community plant of a workshop in Poona/India is established onto the sewage pit of the workers's latrines. The gas output is sufficiently high so that the workers can make their tea with.*

3. IMPLEMENTATION OF BIOGAS PROGRAMMES

3.1. Political aspects

Biogas plants do not sell without efforts being made. Therefore its implementation requires specific programmes.

Such biogas programmes will however be successful only, if integrated locally into the traditional structures and if politically supported.

In states with a decentralized political system, cooperation with the regional authorities plays an important part. In any case, governmental circles must be prepared to implement biogas programmes.

Biogas programmes implemented without international financial and technical assistance have to be provided for or planned in the framework of the government budgets in due time and for a period of several years.

If biogas programmes are realized by foreign or international organisations, it is absolutely necessary that they be coordinated with the national development programmes. After expiration of the contracts, follow-up projects and consequential expenses have to be given account of in the budgets early enough.

The supply of a country, a region or a village with biogas plants, is expression of a political intention, orientating itself at a longterm prosperity of the country and its inhabitants and selfconsciously endeavouring at the attainable targets.

Whoever is convinced that the introduction of biogas be necessary should be aware of the fact that discussing about this technology does not yet create implementation programmes.

The political intention shows always and above all in the budgets. This is the point from where realization is made possible.

Introduction of biogas technology in the Province of Kobo Alamata in Ethiopia

This project realized in 1977 is especially encouraging. With the help of funds from the Federal Republic of Germany and the Federal State of Bremen, the transfer of the Indian technology with technical assistance of a German and an Indian specialist and in cooperation with Ethiopian technicians, was made possible within a very short period of time. The necessary supply of material was secured locally. The utilization of the Indian applicances served only the purpose of adaptation in the first phase and thus represents a successful example of the South-South transfer of technology. Since the first biogas plants are obviously working satisfactorily in various Ethiopian villages of the Province of Wollo, the Ethiopian Government is now interested to discuss and prepare the introduction of this technique in the whole country.

3.2. Political-administrative correlations

Whether biogas plants succeed or not, mainly depends upon the political intention. Biogas programmes therefore normally are initiated on national, political and planning level. These must secure the integration of a programme into the entire development programme, provide financial security as well as administrative and organisational integration.

Biogas programmes and their implementation therefore touch the interdisciplinary authorities of all planning levels as well as the various special branches of these.

One of the most important lobbying offices for the introduction of the alternative energy of biogas, is the authority concerned with coordination of development planning of a state. That is either the national energy commission, the ministry for small scale and heavy industry, the ministry of agriculture or the ministry of rural development. Generally, however, it is the ministry of general planning, which closely cooperates with all specialized ministries. This coordinating authority should actively integrate the subsequent authorities on regional and finally those on communal level via the respective specialized authorities on national level into the biogas programme.

Interest in biogas plants is great – but there is a lack of knowledge as to the implementation. It is known to everybody that cement is required – who guarantees, however, that the cement will not be used for building a hotel?

Everybody is of the opinion that government should be contacted – but to whom is it known that the ministry of energy is responsible and to be contacted through the official in charge at room no. X

The following fields have to be considered in connection with introduction and use of biogas:

- agriculture, forestry and water engineering
- economy and in this context mainly the craftsmen
- infrastructure of the primary sector with water supply, sewage and waste recycling system
- energy supply
- settlements and suprastructure in the framework of reconstruction and new developments
- health and social services;

- educational services
- labour market
- research with special inclination towards appropriate technology
- cooperation with self-help organizations.

Always depending upon whether and to what extent regional and communal authorities for general development are already available and responsible, they are to be assigned for the implementation of biogas programmes. An interdisciplinary and specialized introduction of the staff to biogas programmes should preferably take place on national level. It is to be observed that no new administrations be created, if possible, but rather that an integration into the already existing authorities be endeavoured.

An independent biogas authority should be established as an exception only and that only if it commands over appropriate budgetary funds.

An essential factor for the successful introduction and application of the alternative energy of biogas, is the motivation and activation of the people with special regard to the rural population as well as marginal groups in the cities. First of all, people will have to be made conscious of their social and economic situation. Therefore integration of already existing self-help organizations respectively their creation should be given preference. Cooperation with official political and planning authorities is of major importance in this connection. Only thereby rivalry can be prevented. In order to achieve this cooperation, administrative competences and responsibilities on the various planning levels should be made known to the self-help groups. Under consideration of the respective way of life, living conditions and other specific characteristics, it should be the most important aim to interest wide groups of the underprivileged population in the implementation of biogas programmes. Biogas programmes have to be available in order to turn dynamic self-help intentions into self-help activities.

3.3. Social aspects

As already established the lives of the population are being influenced in multiple ways by the introduction of biogas technology. The social structure of a region therefore has an impact on the implementation of biogas programmes.

If certain religions, traditions and social taboos are a strong obstacle to the introduction of biogas or lessen the benefit of a biogas plant, it is above all the task of social workers to establish on the spot the reasons for a possible rejection of biogas and to reduce same by gentle explanation and education.

In this manner common will power of the population in the introduction of biogas technology can be risen.

Characteristics	*Size of plants in cbm*				
	8	*6*	*4*	*3*	*Total*
Number of families	*2*	*10*	*11*	*7*	*30*
Size of families (number of persons)	*22,5*	*17,4*	*11,5*	*10*	*13,7*
Average live stock					
Cows	*4,5*	*2,2*	*1,2*	*1,3*	*1,8*
Buffalos	*2,5*	*1,7*	*1,4*	*1,0*	*1,5*
Oxen	*7,0*	*4,5*	*3,1*	*2,4*	*3,7*
Other animals	*2,5*	*2,0*	*1,4*	*1,3*	*1,6*
Average size of plot (ha)					
Irrigated	*2,8*	*1,8*	*1,8*	*1,3*	*1,7*
Not irrigated	*2,8*	*2,4*	*1,2*	*0,3*	*1,5*
Waste	*2,0*	*0,2*	*0,3*	*--*	*0,3*
Average income/year (in Rupees)	*10.000*	*4.250*	*4.100*	*3.450*	*4.700*

Table 5: *Characteristics of the owners of 30 plants in Narodi and Mahalunga (1977).*

Also property and ownership conditions can be an obstacle to good use of biogas technology. This is particularly the case if the poorer groups of the population are hindered to participate in the development process by the better-off groups. As these differences cannot be eliminated on a general basis, it should be tried to introduce changes at least on partial sectors which hamper biogas programmes as far as their application and spreading is concerned.

If, for instance, the available ground in a village community is owned by a small group, biogas programmes only have the desired result, if the landless population has long term usufructuary rights for the plot on which the biogas plant is planned to be built. Or in cases where families who do not own real estate do not have the possibility of keeping cattle, common structures of organization have to be found in order to supply the majority of the population with manure or other organic feed material for gas generation. This could, for instance, also be effected by an exchange: fresh dung against slurry or dung or waste against man-hours.

Special attention has to be paid to the control that existing injustice in distribution of wealth not be even increased by the introduction of biogas i.e. that the poor and often dependent farmers should not have to give the gathered animal dung to the large scale and therefore socially more powerful farmer against reimbursement or even free of charge for the operation of his biogas plant. The disadvantageous effects on the already poor crop yields of the small farmers would be obvious.

In this connection it is mainly the task of self-help groups to strengthen the socially weaker groups of the population and make them participate, right from the beginning, in the process of raising interest in the introduction of biogas technology.

3.4. Promotion and financing of biogas plants

Essential beneficiary efforts of biogas plants do not show in individual business investment calculations. They only become apparent on the level of national economy and that after the conversion of whole areas to biogas. Individual investment decisions can therefore hardly lead to an increased application of biogas technique as much as it would seem recommendable from the general economic point of view. In order to achieve the target of biogas production and utilisation with positive effect on national economy, public measures for channeling and promotion of biogas technology are indispensible.

Thereby the economic situation of individual groups has to be taken into consideration and where necessary be influenced; particularly in the manner mentioned in the preceeding chapter in order not to increase but rather compensate existing injustice.

These measures, necessary for channeling and promotion of biogas technology, include:

- The establishment of a functioning organization, respectively the support of existing organizations, implementing promotion and financing of biogas programmes.
- Public identification with the aims of this organization.
- The special promotion of further development of a regional biogas technology and its field of application.
- Spreading of the necessary know-how for biogas technology within the population respectively the support of such endeavours.
- Direct subsidising of the plants.
- Public support in obtaining supplies of material, particularly in the case of implementation of far reaching regional programmes.

Subsidies for the construction of plants is of special importance for promotion of biogas technology. They can consist of allowances, low interest or noninterest bearing loans. Loan offerings should be secured on a long term basis by revolving funds. Also the replacement of parts, subject to wear and tear, as well as repurchase of depreciated plants have to be taken into consideration.

Decisive for the attractiveness of subsidies is their type, the amount involved and an unbureaucratic way of granting them. In order to increase incitation to build biogas plants, allowances already made available should be considerably increased or the repayment period be prolongated according to the expected life time of the plant.

The main criterion for every investor is the economic rentability of a measure respectively its economic benefit for the individual. Promotion programmes and subsidies of biogas plants should orientate themselves at these expected profits. This leads to subsidy graduation, taking into consideration rather the type of fuel used by the investors up to the present than their social situation. In practice this leads to differentiation in furtherance, which at the same time, is socially justified.

Neighbourhood interest groups established in order to build a biogas community plant should receive special furtherance. Plants established on this basis show comparatively high rentability and, in addition, promote the process of social equalization.

For area covering spreading of biogas plants, additional financial incitation is required. Special contributions should be granted to all investors, if, for instance, 50% of all village households were supplied with biogas. The discussion process therefore required within the village community, can also result in having favourable influence on more complex development projects. In principle, a high amount of personal effort should be demanded in case of furtherance. Public funds are scarce and personal financial contribution ensures personal interest of the owner in his plant.

Experiences have, however, shown that the owners lose interest in the plants and suspend repayment of loans in case the financial burden does not correspond to the actual benefit.

As source and measure standard for own financial contribution, cost savings for energy and fertilizer due to biogas, as well as to be expected additional yields in agriculture and the amount of income per household have to be consulted.

> *If annual amortization plus annual operation and maintenance costs are lower than the to be expected economies in expenditures for energy and fertilizer plus the value of the additional agricultural yields, then the biogas plant is* ***economically profitable.***
> *I.e., the investment for the construction of a biogas plant is economically advantageous and financially bearable for the individual farmer.*

For the almost 100 family plants established in the Narodi Area in 1977 - 1979, the share of the owners amounted on an annual average to 17 respectively 27% of their monetary household income according to the period of repayment of 5 respectively 8 years.

The average annual household income amounted to DM 1.350,--. The average building costs per plant, in comparison, amounted to DM 2.300,--.

The building costs were financed as follows:
DM 230,-- = 10% by personal contribution (labour, capital),
DM 230,-- = 10% by (lost) contributions and
DM 1.480,-- by noninterest loan repayable within 5 respectively 8 years.

The annual repayment thus amounts DM 370,-- in the case of a 5 years' period of repayment or DM 230,-- if the loan granted is to be repaid in 8 years. In addition there are the current costs of operation and maintenance (approximately DM 20,-- annually, wages not included).

Repayments of this amount are often unbearably high for the farmers. Promotion programmes do not have sufficient funds in order to reduce personal contributions to an economically acceptable dimension. This opens an ideal field for engagement of public development aid of the industrial nations. In the Federal Republic of Germany, for instance, a special budget is available, by means of which biogas programmes can be promoted upon request of the developing countries. Costs of a plant are for example to be taken over to one third by the owner, to one third by the government of the respective country and to one third by foreign development aid.

According to this pattern proposed, a farmer who has no own capital and has to finance his share of the costs for the plant via a bank loan at an interest rate of 12%, sees himself confronted with the following annual charges in the case of a loan maturity of 5 years: DM 92,50 with costs of the plant of DM 1.000,-- and DM 277,50 with costs of the plant of DM 3.000,--. In the case of a cost amount of DM 2.300,--, as mentioned for the Narodi/Mahalunga example, annual charges for the farmer would be approximately DM 130,-- less.

3.5. Educational and training programmes

Prior condition for efficient operation of biogas plants are education and training of the persons in charge of their maintenance. The therewith connected theoretical and practical procurement of knowledge is an indispensable element of every biogas implementation strategy.

The responsible ministries and subsequent authorities must professionally support education and training programmes and integrate them into the fields of agriculture, education and health, for instance, on a national, regional and communal level.

The Indian Khadi and Village Industries State Commission is presently concerned with the concept of a national and international training centre. Education programmes are already being offered in anticipation of this new centre.

Longterm preparatory education should include that biogas be treated as a subject in primary and secondary schools, particularly in physics, chemics and geography. Models of biogas plants should be available in all schools.

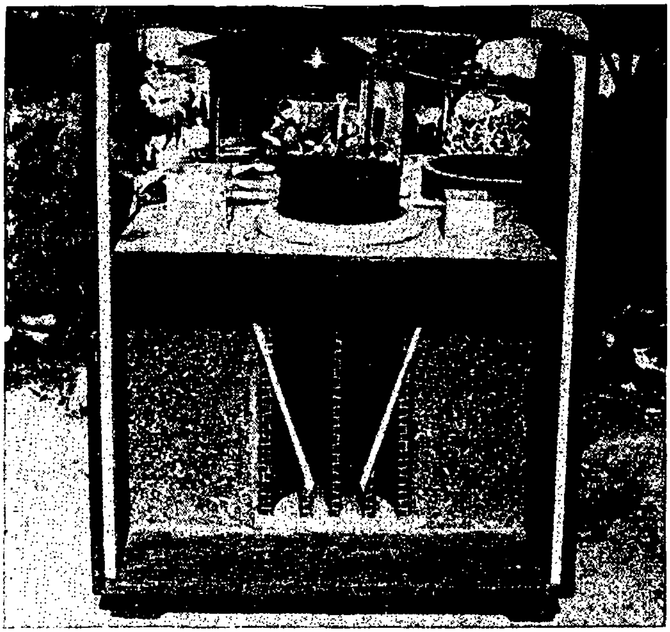


Fig. 10: *Mock-up of a gobar gas plant. Models are very impressive demonstration materials and can even be understood by illiterates.*

Biogas technology should be a firmly integrated part of agricultural training programmes. It would be of great advantage, if the benefit of biogas plants were treated in the medical faculties of the universities, and if practical training in biogas technology were included in the curricula of professional and vocational schools.

It is part of direct and accompanying training programmes that:

- in the framework of adult education, training programmes concerning biogas be available, namely for housewives, farmers, craftsmen as well as further persons interested in the subject,
- each biogas programmes be always connected with consulting and maintenance services,
- local craftsmen and persons trained in different fields be attracted by educational courses and economic advantages,
- production of accessories and spare parts such as burners and lamps be stimulated.

A close network of consulting agencies and repair workshops have to be part of the biogas implementation strategy. Under no circumstances the radius of operation of a services station should exceed 40 km. Location and working methods of service stations and consulting agencies should be coordinated. Also the exchange of experiences must be guaranteed.

Fig. 11: Training programmes are of high importance. These include training courses for local craftsmen, thus creating the necessary basis that technical knowledge be given to the population and passed over from village to village.

BIOGAS – TRAINING PROGRAMMES

Target group	*Method*	*Subjects of instruction*	*Period of courses*	*Instructors*
Housewives	*Training locally at the own biogas plant, the own gasstove, visits to other houses repairs under guidance cooking test with differently regulated burners and different stoves*	*Function of the plant operation and optimum utilization clearing of disturbances performance of smaller repairs best possible regulation of the flame, most appropriate stove, cooking practices and recipes dangers involved*	*permanently, repeatedly*	*servicing staff*
Farmers	*Training locally, at the own biogas plant, on the own fileds, visits to colleagues, laying out of small test fields with different types of fertilizers, laying out of compost pits*	*Function of the plant, operation and optimum utilization, dangers involved fertilizing value of the slurry, decomposition*	*permanently, repeatedly*	*servicing staff agricultural advisers*
Servicing staff	*Seminars and training courses locally (model) tests, visits*	*Function of the plant, various systems, various materials, influence of temperature, filling compound, retention time, consistence clearing of disturbances utilization of gas and fertilizer dangers involved*	*4 weeks annually, 2 weeks brush-up and practical work under guidance*	*senior servicing staff agricultural advisors ingeneers*

***Table 6/1:** Biogas Training Programmes*

Cont. P. 41

BIOGAS TRAINING PROGRAMMES (Cont.)

Target group	Method	Subjects of instruction	Period of courses	Instructors
Craftsmen, producers	Seminars and training locally construction of plants visits	Function of the plant, different systems, specific knowledge of material and construction, production methods execution of repairs	2 weeks and practical execution	engineers senior craftsmen
Organisators	Seminars and visits Visits to various institutions such as banks, authorities, administrations	Correlations concerning general and individual economics cost-profit-analyses, function of the plant, various systems and their advantages and disadvantages, individual and community plants, use of local materials, social correlations, administration: book-keeping, promotion, application, procedures of approval	2 weeks and 1 week's excursion	biogas experts ingeneers agricultural experts sociologists business administrators
All groups mentioned	Workshops, seminars	Individual subjects	permanently repeating, always 3 days	Experts and specialists

Table 6/2: Biogas Training Programmes

3.6. Information and implementation campaigns

The idea of biogas has to be promoted on national, regional and communal level. Basic condition, however, for area covering spreading of biogas plants, is the motivation of the people. Motivation and stimulation are the actual development process. Biogas plants are rather the result of this development.

Therefore implementation campaigns can only be put forward and materialized by the concerned themselves in a decentralized manner. Information campaigns, however, can be planned and controlled in a centralized way and finally be realized without active contribution of the target group.

For the promotion of information on biogas, magazines, newspapers, films, leaflets and manuals are suitable. Advertising and information cannot always be clearly distinguished. The best publicity is permanent information

— on the technology as such,

— on the economic effects for the individual,

— on the effects on economy in general.

In this connection wispering campaigns on local agricultural fairs and also on large size posters along side the roads and on market squares are of major importance. The language of information has to be chosen in conformity with the language of the target groups, whereby the readers of this printed information material are mostly not the semi- or totally illiterate final consumers but the "last" multiplicators in the line.

Case example

Contacts have been established between the villages of Narodi and Mahalunga in India. The farms are scattered at an approximate distance of 7 km from each other, so that people can meet directly or on the market.

It hardly lasted 6 months until the Mahalunga farmers convinced themselves of the benefit of the biogas plants of their Narodi colleagues and became active. In the meantime both villages have been to a great extent converted to biogas, the expected improvements in the field of hygiene have taken place and the first increased crop yields have materialized. One should talk to those farmers whose lives underwent decisive changes due to some 100 biogas plants. The best proof for the farmers' satisfaction is the fact *that they declared themselves ready to convince approximately 700 farmers' families in neighbouring villages still in 1979 of the advantages of these plants thereby motivating them to take charge of and improve the often jointly deplored miserable conditions. These efforts included instructions for the production of bricks, digging of pits, selection of the location as well as operational instructions.*

Based on this experience, a programme will be started from 1980 onwards, according to which further villages will be supplied with biogas.

Information campaigns are expensive. Whilst general information can only be spread if public funds are available, private industry advertising for biogas plants and accessories, as far as they contain a minimum of information, could be stimulated by means of tax concessions.

Fig. 12: "Gobar Gas" - Biogas advertising by Khadi and Village Industries Commission (KVIC) in India

Well functioning plants have the best advertising effects. Therefore demonstration plants play an important part in this context. Malfunctioning plants will hamper every programme. The plants do not operate without disturbances, if they are not actually needed and, as a consequence, badly serviced.

Maintenance of biogas plants is easy but indispensable. A disturbance free operation as well as careful maintenance and repair are of great importance for demonstration plants as far as the success of implementation programmes is concerned.

Demonstration plants should only be established where people are willing to keep the plant in good working condition. The responsibility should rest with rather a few individual people than with a whole group. The person responsible should also benefit from the plant. Where maintenance cannot be permanently assured, one should go without demonstration plant. In such cases one should rather decide for the short-life oil-drum plant.

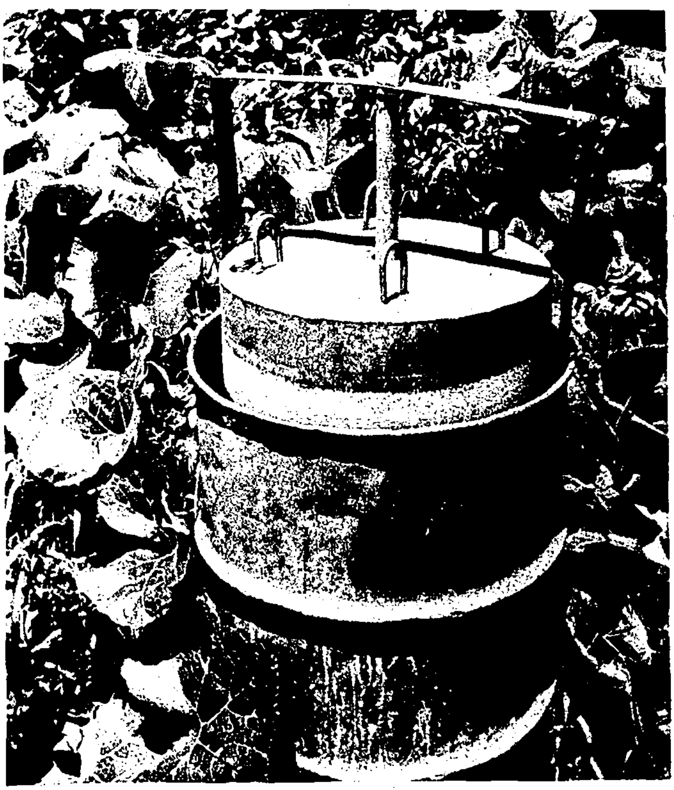


Fig. 13: A biogas demonstration plant made of 2 oil-drums fitted into one another.

4. BIOGAS TECHNOLOGY

4.1. The bio-chemical process

As has become general knowledge in the meantime, organic material is rendered soluble by micro-organisms in the biogas plant. This multiple stage process takes place under exclusion of air and mainly consists of two parts: Of the fermentation of high molecular combinations to low molecular fatty acids and alcohols. Fermentation, in this case, is effected by mixed bacteria cultures. The first, already very complex part of the total process is called "acid phase".

The second part of the digestion process is the "alcalic phase", the "formation of methane", whereby the methane bacteria turn the fatty acids and alcohols mainly into methane and carbon dioxide. Methane is the combustible component of biogas.

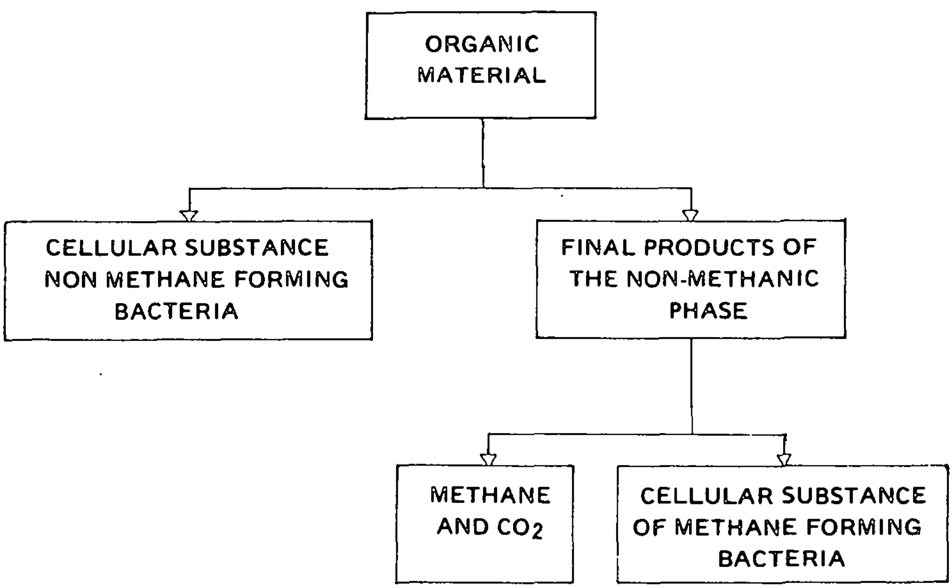


Table 7: Scheme of the fermentation process.

Acid formation

propionic acid

$$4\ CH_3 - CH_2 - COOH + 2\ H_2O$$

$$4\ CH_3 - COOH + CO_2 + 3\ CH_4$$

acetic acid

Formation of methane

$$CH_3 - COOH + 2\ H_2O$$

$$2\ CO_2 + 8\ H$$

$$CH_4 + CO_2 + 2\ H_2O$$

biogas water

Table 8: *The bio-chemical process of biogas formation as shown by decomposition of propionic acid.*

The formulas presented in table 8 describe only one decomposition process. The complexity of the total process is shown in table 9.

The individual transformation processes have to be adapted to one another. This is achieved in practice by leaving the first filling several days in the digester, before feeding the plant anew. Thus the natural process can develop without disturbances.

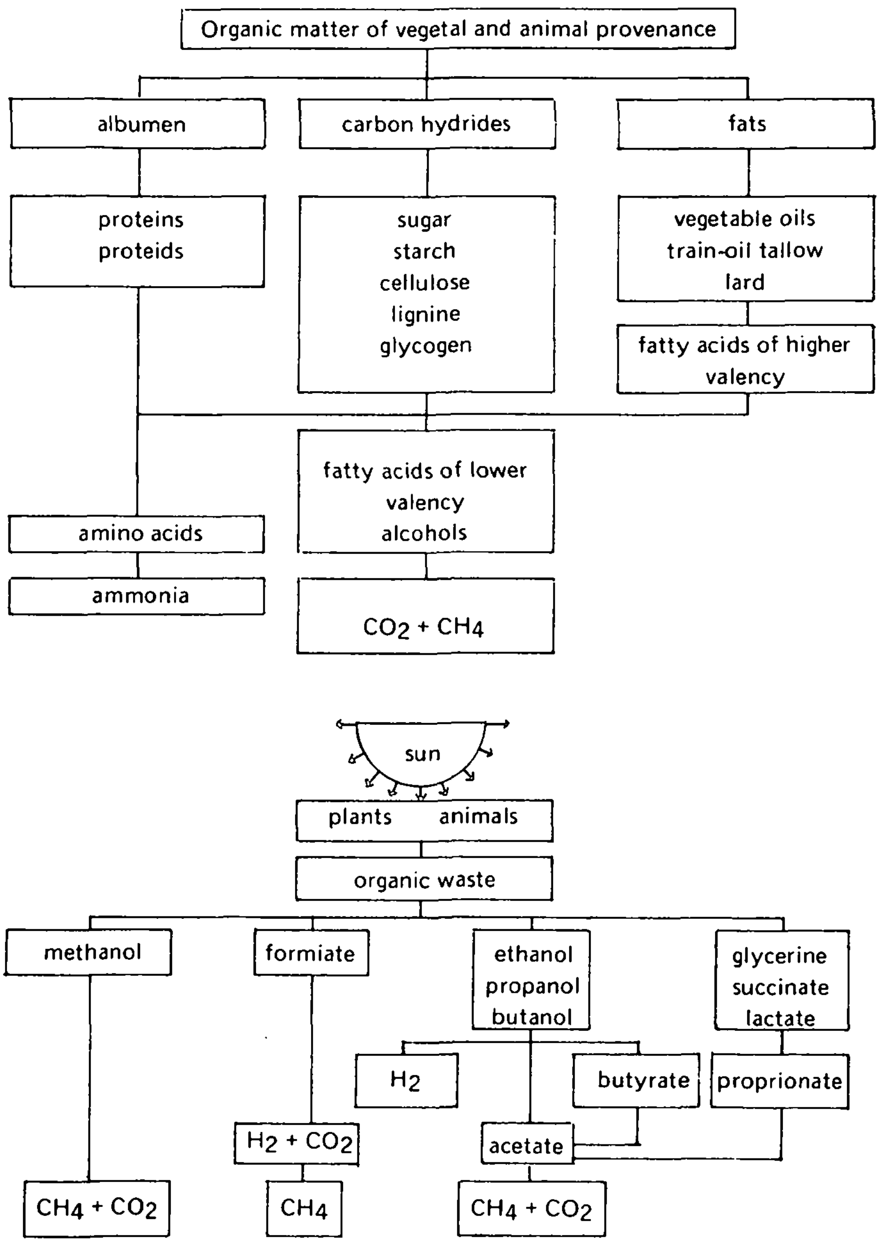


***Table 9:** Formation of methane – a multi-stage process.*

4.2. The influence of temperature

The various strains of bacteria live at different temperatures. There are two main groups of methane bacteria:

1. those in the mesophilic range (20 - 35° C) and
2. those present in the thermophilic range (50 - 60° C).

However, also within these two ranges, thermal fluctuations disturb the methane process, as also in this case various strains can only live under determined thermal conditions.

In practice, temperature is of decisive significance for gas production. Therefore, for instance, the plant should be fed during afternoon hours, i.e. when outside temperature is highest. Otherwise preheated water has to be used. So, the higher the temperature, the higher the gas yield. The following table illustrates these facts.

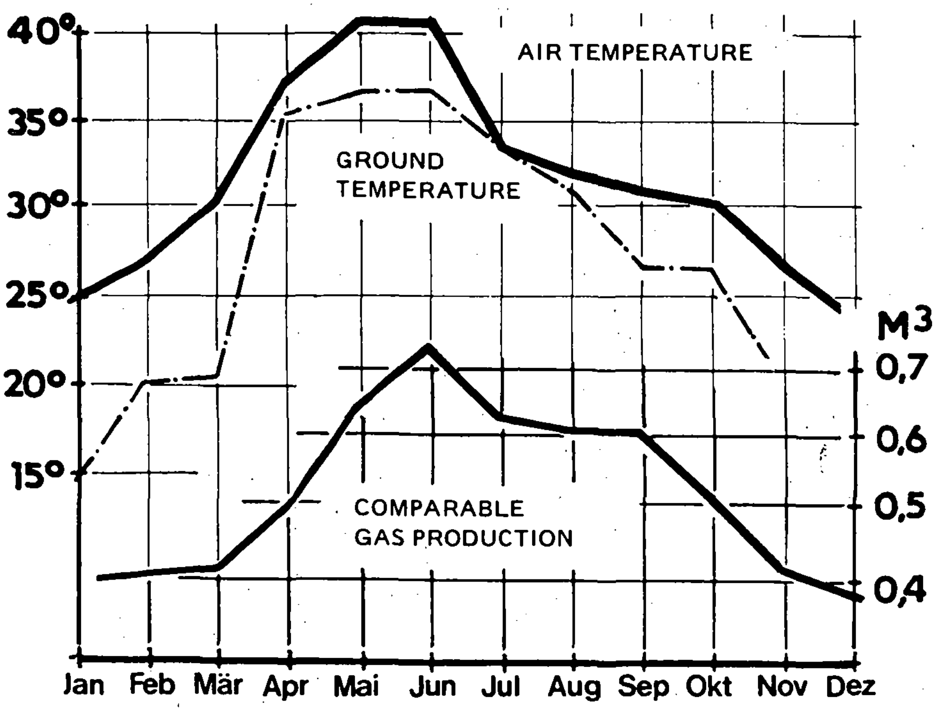


Table 10: Dependence of gas production in a gobar gas plant upon annual temperature. The curve of gas yield follows rather the curve of air temperature than the curve of ground temperature: thus illustrating the high loss of heat through the gas drum.

In regions with tropically hot climate good gas yield can be achieved even without heating or insulation. With simple biogas plants only the mesophilic range is of interest (temperature up to 35° C). In case of 25° C digester temperature digestion or fermentation (retention time) takes 45 days. Under particularly favourable conditiongs — rather constant, high temperature — the time of digestion may even be shorter. In addition to this, the time of fermentation depends upon the material fed to the plants.

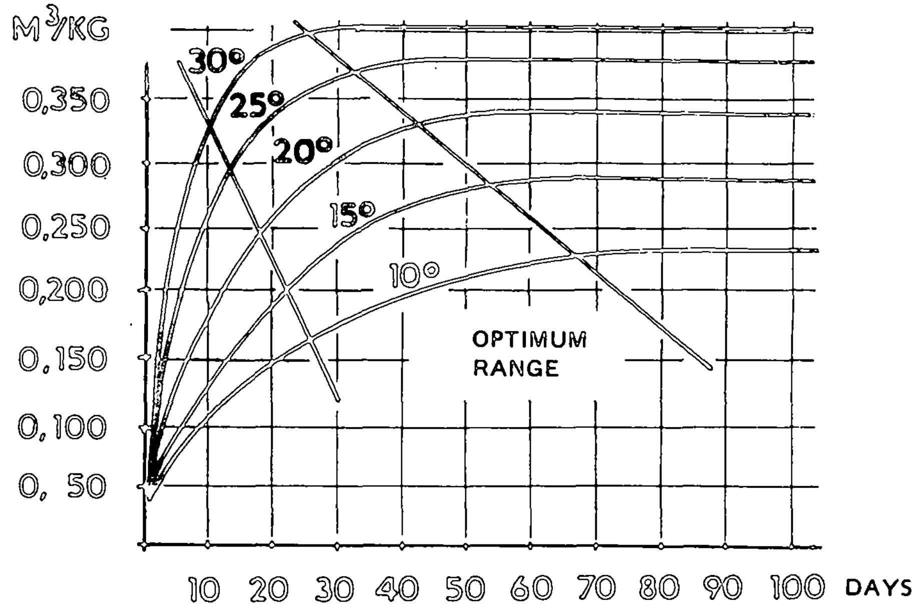


Table 11: *Dependence of gas production upon temperature and fermentation time*

1 buffalo or European cow	*0.50 - 0.74 cbm gas/day*
1 zebu-cow (stable-bound)	*0.25 - 0.40 cbm gas/day*
1 calf (stable-bound)	*0.15 - 0.25 cbm gas/day*
1 pig (stable-bound)	*0.05 - 0.10 cbm gas/day*
10 chicken (stable-bound)	*0.02 - 0.04 cbm gas/day*
1 latrine user	*0.02 - 0.03 cbm gas/day*
As a rule of thumb:	*0.035 cbm biogas per kg excrements (fresh)*
Considering lower gas production in winter, the gas plant should be sized for 0.03 cbm gas per kg fresh dung.	

Table 12: *Average daily gas production.*

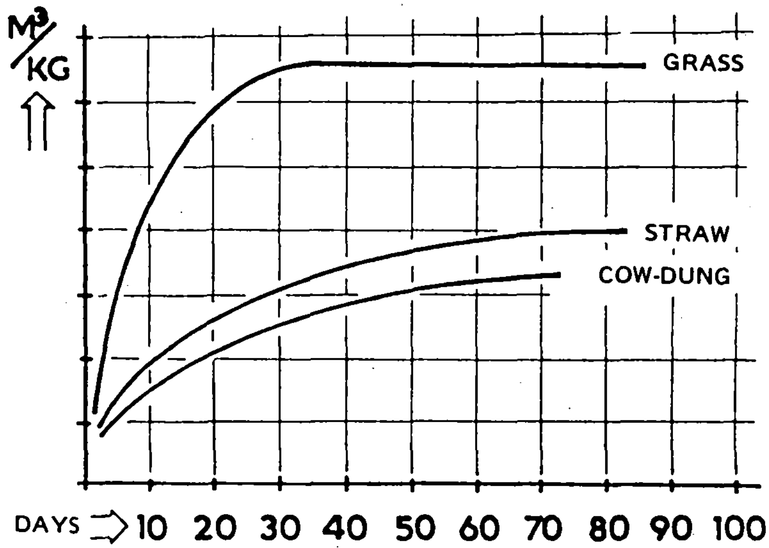


Table 13: Dependence of gas production upon feed material and fermentation time

4.3. The pH-value

For the digestion or fermentation process besides temperature also the pH-value is of considerable significance. The pH-value indicates the concentration of an acid or alcalic state of a liquid. A pH-value of 7 is designated as neutral. The ideal pH-value for methane formation lies between 6.5 - 7.5. The litmus paper sample should just show a slightly blue colour. The colour of the litmus paper is not supposed to change to red.

With fermentation of pure cattle dung (dung, litter and urine) such a pH-value is normally the consequence.

Fresh, green vegetal waste, however, easily enduces the danger of acid fermentation, if used as feed. In that case methane formation does not take place, i.e. no gas is produced. Emission of bad odours from the slurry is the consequence.

4.4. The carbon nitrogen ratio

Feeding the plant with substrates of different nature, necessitates testing the ideal ratio of mixture. Thereupon depends the composition of biogas and thus its caloric value as well as the quantity of the gas produced.

Decisive for gas production is the proportion of carbon/nitrogen of the feed material. It should be: C:N = 20 - 30 : 1.

Raw material	*Carbon content in % raw material*	*Nitrogen content in % raw material*	*C/N ratio*
wheat straw	*46*	*0,53*	*87:1*
rice straw	*42*	*0,63*	*67:1*
corn straw	*40*	*0,75*	*53:1*
leaves	*41*	*1,00*	*41:1*
bean-straw	*41*	*1,30*	*32:1*
weeds/grass	*14*	*0,54*	*27:1*
peanut straw	*11*	*0,59*	*19:1*
fresh sheep dung	*16*	*0,55*	*29:1*
fresh cattle dung	*7,3*	*0,29*	*25:1*
fresh horse dung	*10*	*0,42*	*24:1*
fresh pig dung	*7,8*	*0,60*	*13:1*
fresh human faeces	*2,5*	*0,85*	*3:1*

(These are values of the non-decomposed state of the materials.)

In practice, a mixture of 10 - 12% of dung, 30 - 40% of weeds or straw and 50% of water has proved ideal.

Table 14: *Carbon/Nitrogen contents of different feed materials.*

4.5. Consistence of feed material

A high contents of solid matter (20 - 25%) leads to increase in gas production per digester volume. The slurry can, however, then no longer be stirred and can only be used in batch-plants. Generally a dilution of 1 : 1 to 1 : 2 is recommended as being ideal.

Maramba in laboratory tests with pig dung at the Maya Farms (Philippines) comes to the conclusion that gas yield, dung/water ratio being 1 : 4, is by approximately 30% higher than with a mixture of 1 : 1. Due to the low contents of solid material, gas production decreases per volume of the digester. Therefore a dilution of 1 : 1 to 1 : 2 is considered as ideal. A dilution of 1 : 1.5 in the case of chicken dung leads to maximum gas yield.

Not only the chemical combination of the slurry but particularly a disturbance free operation of the biogas plant is of importance for regular gas production. The operation of a biogas plant is the least complicated, if it is fed with homogeneous material such as cattle or pig dung. Disturbances occur less often.

Long fibrous materials are difficult to process. They choke the plant and form a heavy scum which impedes or completely prevents the process of gas production.

Manure from ruminants (cattle, camels, lamas, etc.) is most appropriate for biogas plants due to its homogeneity and its inoculation with methane bacteria in the intestines. Gas yield as compared with other materials is, however, lower. This is due to the fact that decomposition of the substrate has already taken place during digestion. In case ruminant dung is blended with pig dung, for instance, experiences show that gas production increases almost to the value of pure pig dung on account of the favourable mixture.

If the slurry contains urine, not only gas yield increases but also the contents of nitrogen and potassium and thus the fertilizing effect of the bio-dung.

Human faeces (night soil) can be digested solely. Blending with other material, however, increases the gas yield. The first filling of the plant has, under all circumstances, to contain, besides human faeces animal dung or has to be inoculated with already active slurry.

There are various possibilities of inoculating the slurry by adding "starters" to the first filling. This might be slurry from an already operating plant, mud from the ground of a puddle or joghurt.

A well balanced and undisturbed process is basic condition for maximum gas production. It is therefore of importance also that no chemicals, detergents etc. be led into the plant. Bacteria are living organisms and can be poisoned.

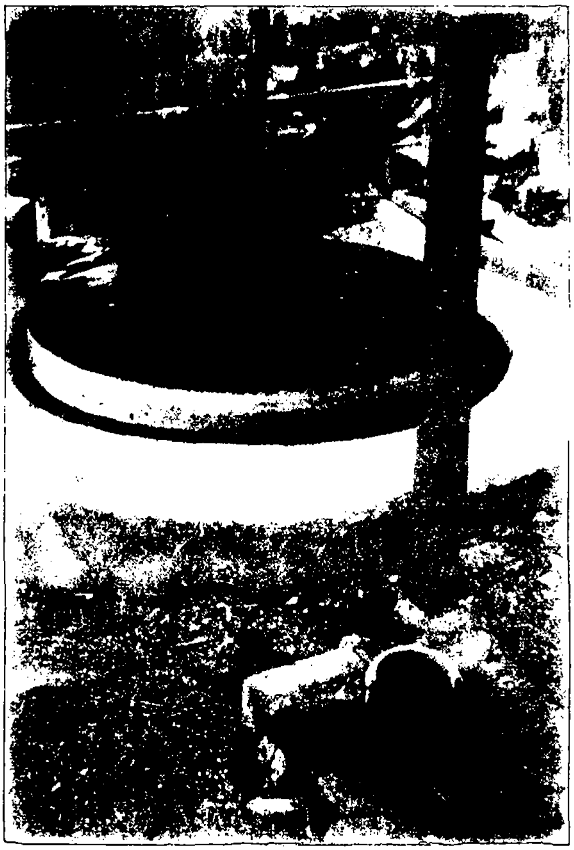


Fig. 14: *Biogas plant of the Ghandi Institute in Poona. The plant has been in operation for 12 years without any disturbances and is exclusively fed with night soil.*

4.6. Different fermentation or digestion processes

Principally there are two different processes:

1) fermentation in the continous plant.
   The plant is fed regularly, mostly once a day, whereby always the same quantity leaves the plant via the overflow or has to be cleared manually.

and 2) fermentation in the batch-plant.
   This plant is fed in longer intervals and cleared when the process of digestion is finished.

The continuous plant supplies constant gas production. In the case of the batch-plant, gas production is interrupted for each clearing. Therefore it is useful to establish several chambers which can be fed by alternation.
The continuous plant requires smaller digesters than the batch-plant, since the time the slurry is retained in the plant, is principally shorter. This is due to the fact that with the batch-plant during the fermentation process the ratio bacteria/substrate is ideal only within a determined period of time. In the beginning the percentage of organic substrate and too high a percentage of bacteria. In the case of the continuous plant, substrate and too high a percentage of bacteries. In the case of the continuous plant, this ratio can be optimized and thus a minimum digestion time be achieved. Therefore the digester may be smaller. For batch-plants the size of the digester has to be calculated for approximately 90 - 100 days, whilst for the continuous plant calculation for 30 - 60 days is sufficient.

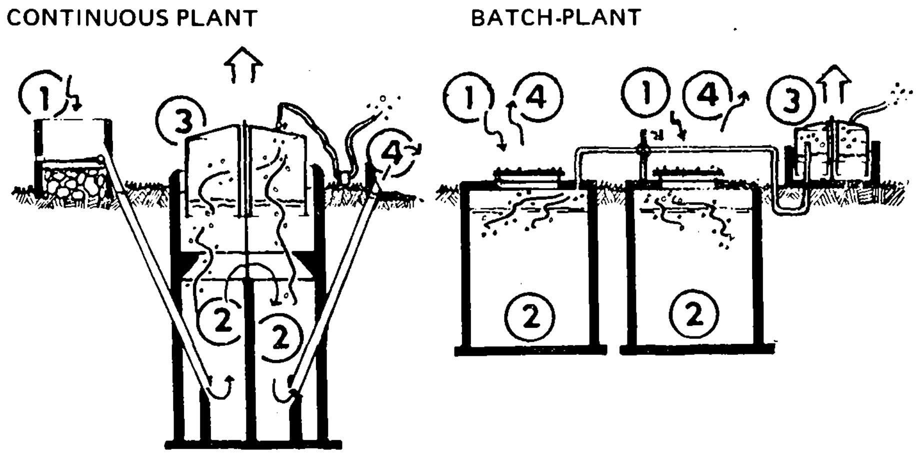


Table 15: Comparison of the processes.
1. Inlet. 2. Digester. 3. Gasholder. 4. Outlet.

Batch-plants should be used, when long fibrous, strawy, consistent, not flowing or not stirring material is to be digested (semi-wet process). The batch-plant is not continuously fed with new material. Thus the formation of scum does not play the leading role as in the case of the continuous plant. Scum formation does occur. The scum is, however, removed upon discharge and is therefore not in a position to grow indefinitely.

Batch-plants are to be preferred in those cases where hygienically precarious waste (from hospitals, for instance) is used due to the precise control of the retention time. On the other hand, human faeces should be fermented, if possible, in continuous overflow plants in order to exclude handling of the faecal matter right from the beginning. Continuous bi-chamber plants do take hygiene into consideration adequately.

Batch-plants should always be inoculated with fermented slurry. This is of special importance when green vegetal material is being used in order to prevent an immediate and total change-over to the acid phase right at the beginning of the process. Methane formation would in that case not even take place. If the feed material has to be stored before being fed to the plant, gas yield is lower, since the material has already undergone a process of decomposition.

This disadvantage can be compensated partly, since the heat generated during decomposition has a favourable effect upon the fermentation process and the liquid resulting is also fed to the plant. The quantity of water is to be reduced accordingly.

Many of these problems are solved by the continuous plant. The operation of a continuous plant is therefore simpler and involves less work, provided the feed is suitable.

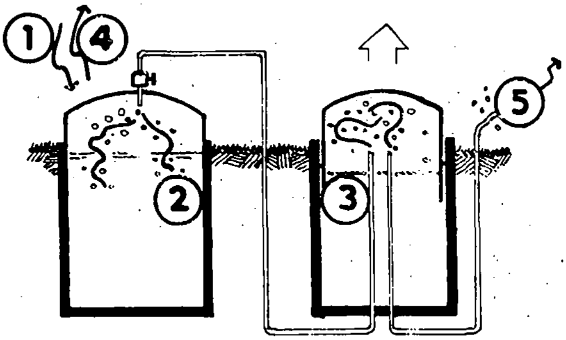
The digesters of the biogas plants may be of various shapes: cylindrical, cubical, rectangular, oval or spherical and can be arranged horizontally or vertically, above or underneath the ground. Each shape has advantages or disadvantages and that always according to the prevailing conditions.

With high groundwater level or rocky ground, flatly arranged plants, just slightly let into the ground or above ground plants, for instance, have proved most advantageous.

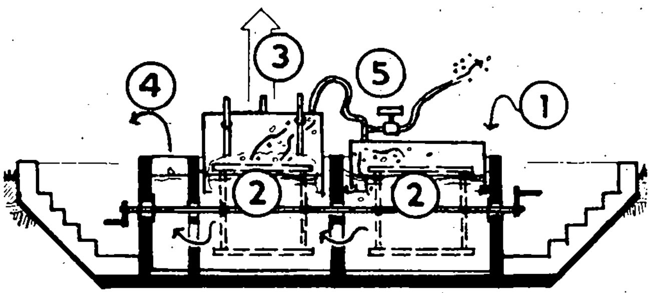
In the case temperatures fluctuate considerably in the course of the day, plants deeply let into the ground are to be preferred. Should this type of arrangement be impossible due to high groundwater level, the digester has to be placed above ground and be insulated jacketing it with earth or straw.

4.7. Technical variations

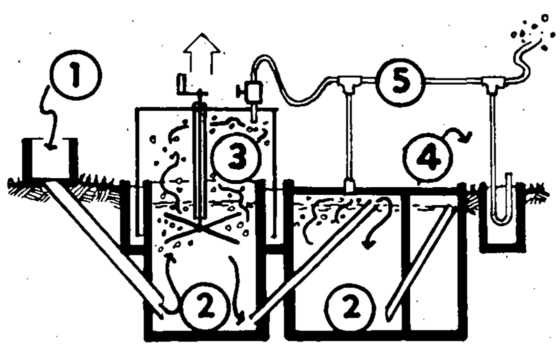
The possibilities of technical variation are practically unlimited as far as material, construction, degree of mechanisation and efficiency are concerned. The following examples are to prove this statement:



Biogas plant with separate gasholder
- improvement of digester insulation possible
- higher costs
- suitable for larger size plants



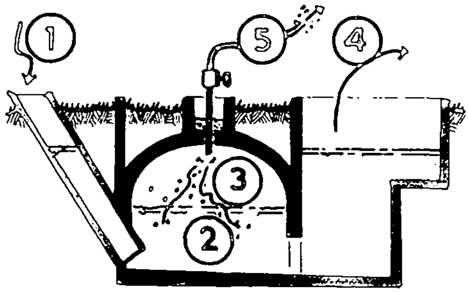
Multichamber plant with horizontal stirring device
- sophisticated construction
- favourable maintenance possibilities
- advantageous gas yield



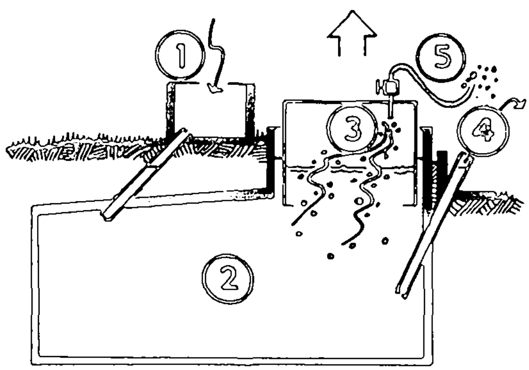
Double stage plant with integrated gas holder
- hygienically secure digestion
- higher gas yield
- higher costs

Table 16 - 18: Technical variations

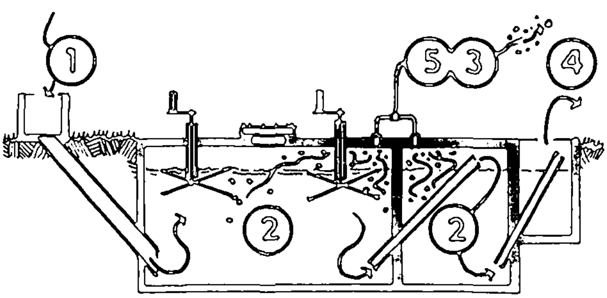
1. Inlet; 2. Digester; 3. Gas holder; 4. Outlet; 5. Gas pipe



Dome biogas plant (Chinese plant)
- simple construction
- gastightness is problematic
- low costs

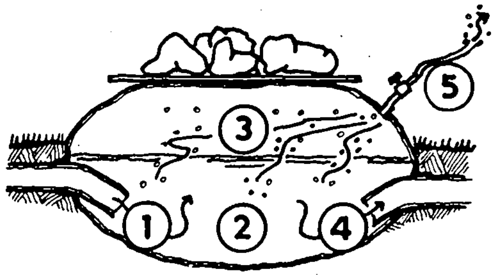


Horizontal biogas plant with movable gasholder
- suitable for high ground-water level or rocky ground
- simple construction
- gastightness of digester cover is problematic

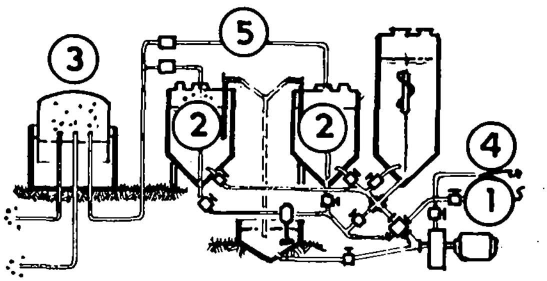


Multi-chamber plant with stirring equipment, without gasholder
- gas storage tanks necessary
- good protection against corrosion
- gastightness problematic

Table 19 - 21: *Technical variations*
1. Inlet; 2. Digester; 3. Gasholder; 4. Outlet; 5. Gas pipe



Plastic bag plant
— construction without trained craftsmen not possible
— inefficient heat insulation
— short time of construction, however, high percentage of foreign currency for developing countries.



Fully mechanized plant
Schmidt-Eggersglüss-system
— high costs
— high gas yield
— suitable for plants with a digester of more than 100 cbm volume.

***Table 21 - 22:** Technical variations*
1. Inlet; 2. Digester; 3. Gasholder; 4. Outlet; 5. Gas pipe

For large size plants with a digester of more than 20 cbm volume (= daily feed exceeding 500 kg), there is a choice of several construction variants, whereby mechanisation of the feeding and discharge systems as well as of the mixing and stirring devices have to be particularly taken into consideration.

Use of the gas in engines for small scale industry purposes, irrigation and power generation plays an important part in the case of larger size plants. In this connection only heating the sludge by energy-heat coupling should be mentioned. Please refer to specific literature.

4.8. Biogas plants for developing countries

For the rural areas of the developing countries, biogas plants have to fulfill certain, well determined conditions. Local production must above all be possible. Only thereby effective spreading of biogas technology can be realized.

These particular conditions are:
- utilisation of mainly locally available materials (bricks, lime, cement, etc.)
- utilisation of local crafts — in case of masonry, for instance, — and workshop equipment for processing of steel and plastic materials.
- minimum technicality of the plants. No controlling devices, mechanical stirring equipment, pumps and heating.
- stable, solid and lasting finish with limited demand for servicing, if necessary at the expense of maximum gas yield.
- efficiency also in the case of small plants covering the demand of only one family and with a filling capacity of 10 - 200 kg daily.
- economically within the reach of the major part of the population.

Fig. 15: China: The dome, built of self-burnt bricks demands high craftsmanship which can be achieved, however, without formal training.

Fig. 16: India: Brick production for biogas plants creates employment.

Doubtless, two types of plants have proved efficient concerning these conditions and are being explicitly recommended:

- The Indian gobar gas plant
- The Chinese dome biogas plant

Both types of plants operate without additional devices and can be built locally with relatively simple means. For many years thousands of plants have proved successful in India respectively in China.

4.9. Comparison of the dome biogas plant and the gobar gas plant

Dome biogas plant	Gobar gas plant
Systeme	
Regular filling, irregular discharge	Regular filling, regular discharge via overflow
Material	
Concrete blocks, bricks, quarry-stones, sand, lime, cement, steel	
Main cost factors	
Cement, bricks	Steel and cement, bricks
Construction	
Can be built in self-help. High demands as far as masonry technique is concerned.	Construction in self-help possible, gas holder has to be produced in workshop
Heat insulation	
Underground construction, thereby heat insulation and constant temperature; effect of heat insulation can be even increased by building the plant underneath the stables	Loss of heat through steel gas holder, insulation of the gas holder problematic, therefore less suited for detached plants in colder regions
Gas-tightness	
The gas storage dome has to be given special treatment for gastightness (precise craftsmanship required) and protection by paints	Not problematic
Feed material	
Agricultural waste, various, even fibrous material, animal and human excrements	Animal and human excrements, chopped agricultural waste in addition only
Productivity	
Time of digestion 50 - 60 days, gas yield 0.15 - 0.35 cbm per cbm digester volume. The plant being absolutely gastight, the values go up to 0.4 - 0.6 cbm daily	30 - 60 days, gas yield 0.3 - 0.6 cbm per cbm digester volume daily

Maintenance

If fibrous material is added, the plant has to be cleared 1 - 2 annually	Gas holder has to be painted annually and to be replaced after 10 years

Costs

In the case of high share of own efforts comparatively low	Expensive due to high steel prices

Possible improvements

Tightness of the dome, stirring equipment, heating installation	Rust proof gas holder, overhead structuring for insulation purposes

4.10. The gobar gas plant

The gobar gas plant is a continous-fed plant. Normally it is let into the ground like a well. Its visible and most obvious part is the steel gas holder floating on the slurry.

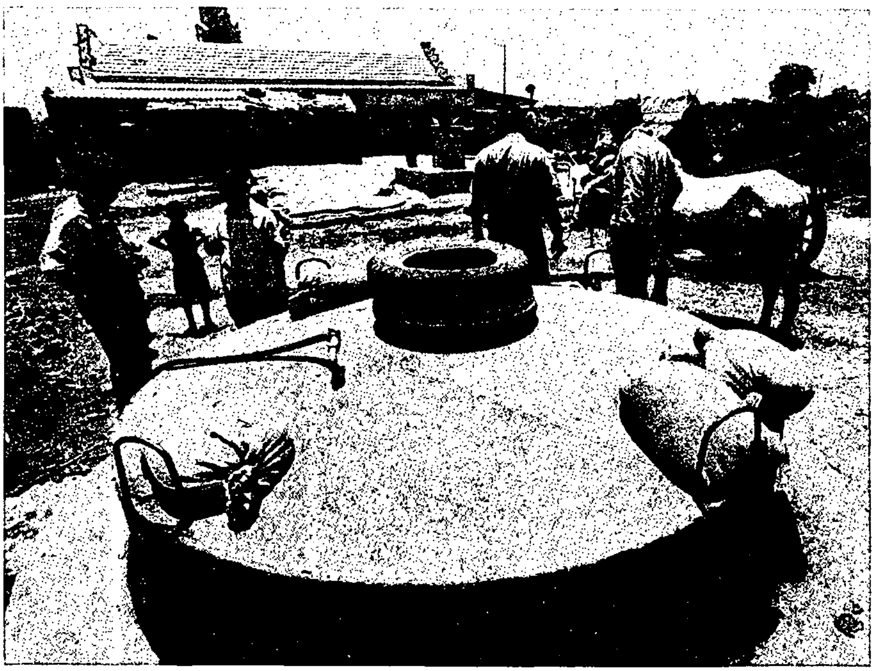


Fig. 17: Gobar gas plant at an Indian farm. The gas has pushed up the gas holder considerably. Ballast sacks increase gas pressure.

The technical principle is so simple that given good maintenance the plant remains permanently operational. There are examples where gobar gas plants have been in operation for more than 15 years without interruption.

This requires the following conditions:

— homogeneous, non-fibrous, sufficiently diluted feed material

— protection of the steel parts against corrosion

— regular maintenance and servicing.

In case of highly fibrous material danger of scum formation is given. By turning the gas holder manually and by the rising and lowering of same due to changing gas contents, the scum is destroyed. Only thereby it is possible to operate the plant without stirring device.

Gathering sand can produce sedimentation at the bottom of the digester and lead to operational disturbances in the course of years. Clearing the plant then becomes necessary.

There are two different versions of the gobar gas plant: without partition wall for plants up to 3 cbm, with partition wall for larger plants.

Partitioning avoids that material newly fed into the plant leaves it prematurely via the overflow. The longer the substrate is retained in the plant before reaching the overflow, the higher is the gas yield. Furthermore the partitioning prevents pathogens with a higher specific weight from reaching the overflow and thus the fields in still infectious conditions.

The gobar gas plant can be built with technically simple means. This especially applies to the digester, which is simply masoned and covered with water proof plaster. The production of the gas holder is more complicated, however. It has to be welded in a workshop by qualified craftsmen. To a limited extent this applies also to the guide frame.

For the following reasons the gas holder is the crucial point of the gobar gas plant:

— Loss of heat through the freely floating drum reduces gas yield particularly in colder regions.

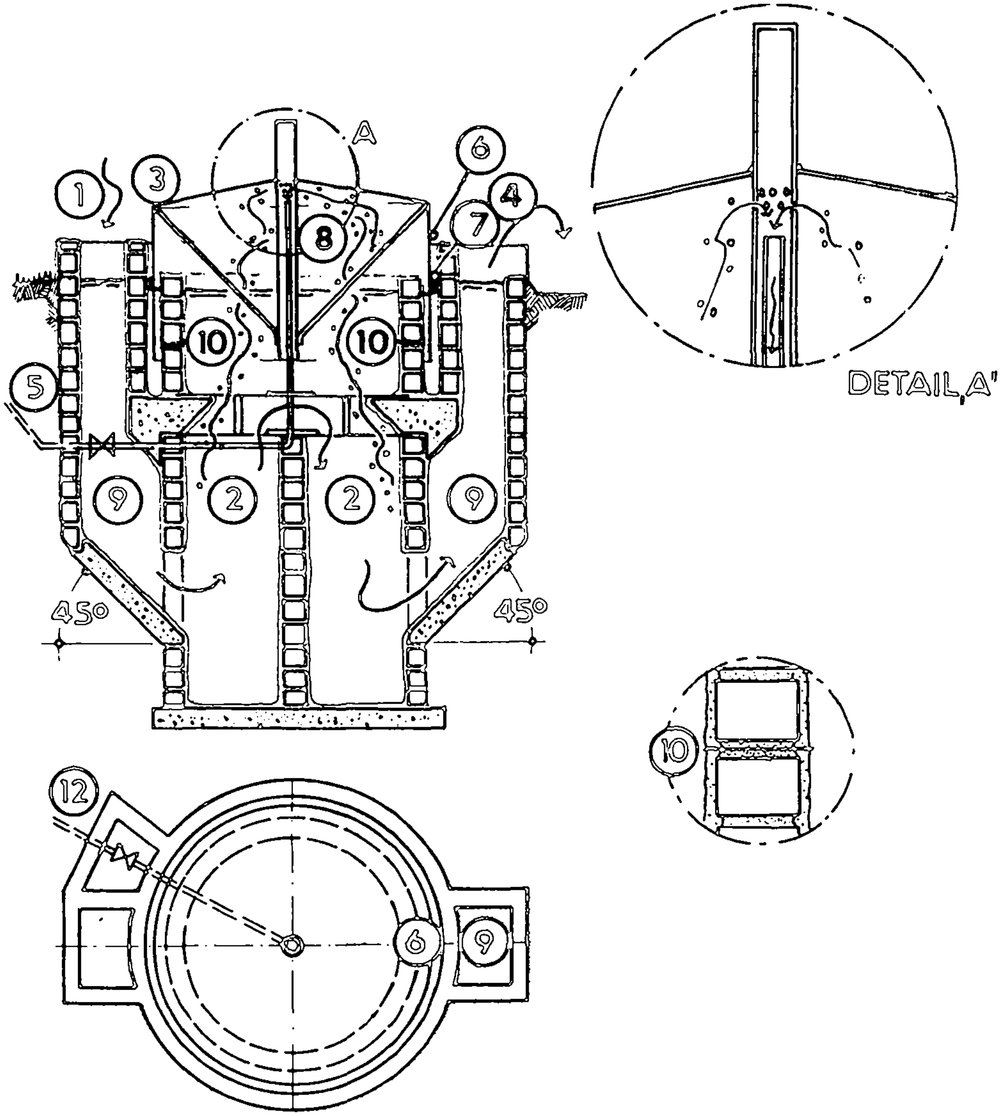
— The normal commercial steel is susceptible to corrosion, especially with a low contents of copper and too high a carbon contents. Even with regular cleaning and annual painting, durability of the steel gas holder is limited. With digestion of chicken waste, even the steel parts not in touch with air, are susceptible to rust.

Therefore research has to pay special attention to the development of lasting gas holders and cheap corrosives. Stainless steel, galvanized steel or plastics (particularly polyethylene) have proved technically efficient. Under normal circumstances, however, these cannot be taken into consideration because they are too expensive and hardly locally produceable. Plastic foiling might represent a compromise.

In India, gas holders made of ferro-cement with a thickness of 2 - 3 cbm have been successfully tested. They are produced in concrete works. The implementation of this method depends upon to which extent the wire netting baskets can be produced without welding and the production technique of the cement gas holder be so simplified that they can be made locally. Up to the present, the procedures were dependent upon highly qualified experts.

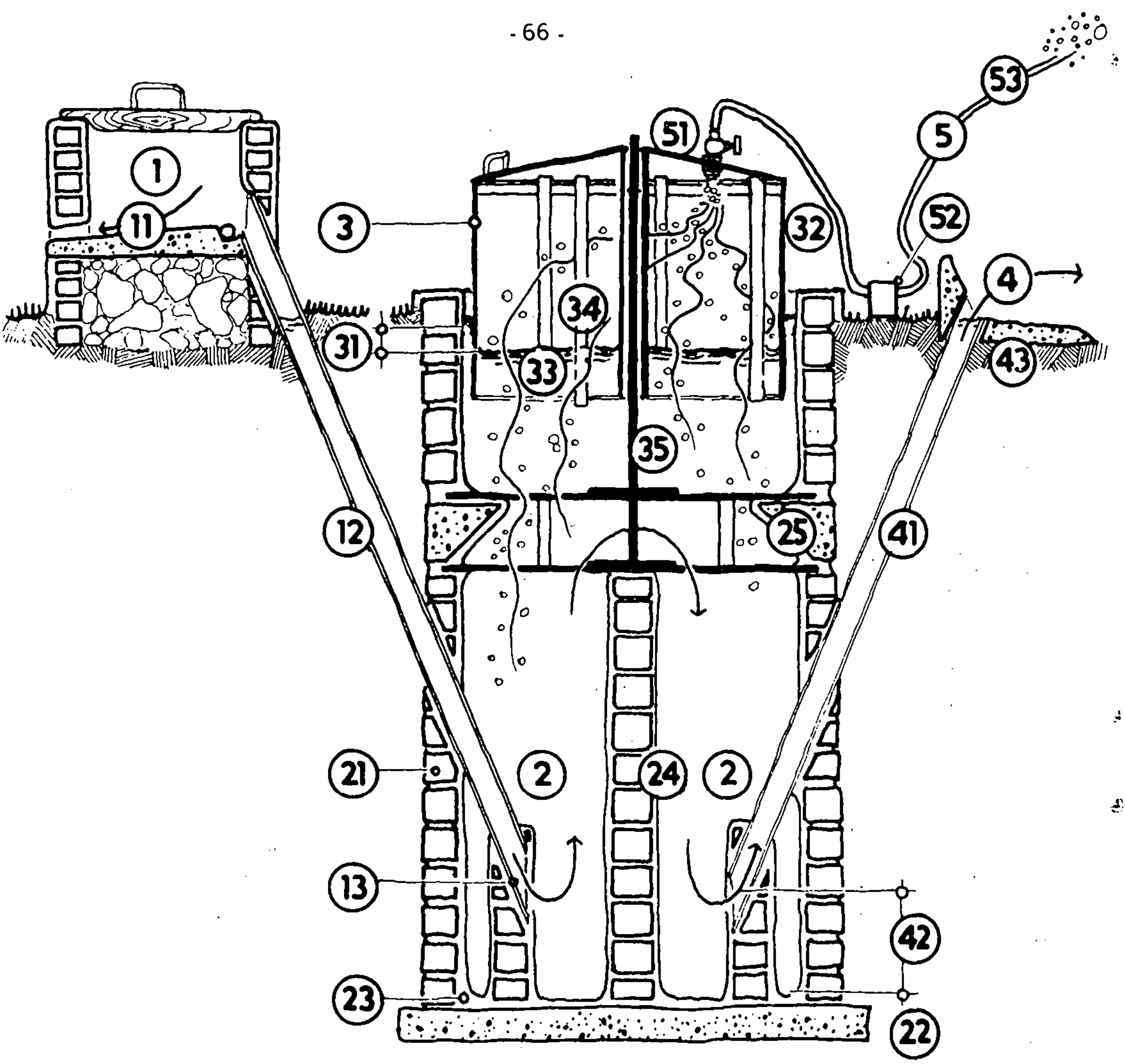
The protection against corrosion of the gas holder can be improved by floating the drum in a separate water bath encircling the digester. A film of waste oil or bitumen on the water greases the rust susceptible outside of the dome and avoids too fast an evaporation of the water. In addition to this such a plant looks cleaner. The interior bracing of the gas holder has to be slightly changed. Diagonal braces destroy the scum by the up-and down movement of the drum (table 24).

The connection of the gas pipe has to be flexible due to the movability of the gas holder. In Kathmandu/Nepal a special arrangement of the piping inside the gas holder has been developed (centre gas pipe system). This plain construction offers protection against corrosion, avoids possible breaking away of the movable gas hose pipe and protects the delicate gas pipe from being destroyed by children. Longer durability justifies higher costs involved (table 24).



1) Inlet. 2) Digester. 3) Gas holder. 4) Outlet. 5) Gas pipe. 6) Separate water bath. 7) Floating oil film. 8) Diagonal braces. 9) Instead of inlet- and outlet pipes in this case shafts have been masoned alternatively. The bottom of those shafts has to be beveled under 45%. 10) Tar board or plastic foil for gastightness.

Table 24: *Water jacket plant with centre gas pipe*



(1) Mixing- and inlet tank, feed: water 1:1 up to 1:3. (11) Counterslope so that sand can deposit. (12) Feeding pipe with minimum ø of 100 mm. (13) End of the pipe has to be cut vertically in order to keep gas losses low.
(2) Digester, 30 - 60 times larger than daily feed volume. (21) Masoned walls of the digester. (22) Ground plate in concrete work or masoned. (23) Watertight cement plaster. All corners and edges smoothed off. (24) Partition wall prevents the newly fed in slurry from leaving the plant on the shortest way. (25) Console avoids gas losses.
(3) Steel gas holder (painted rustproof). (31) Difference of water levels is equal to gas pressure in mm water column. (32) The lateral parts of the gas holder are particularly susceptible to rust. The crown of the wall should not exceed the outlet by more than 10 cm in height. (33) This is where the scum is formed. (34) Diagonal trussing. The scum is destroyed by rotation of the gas holder. (35) A guide frame prevents the gas holder from tilting. It is solidly fixed in the masonry.
(4) Overflow-outlet. The height of the shaft determines the standard level in the digester. (41) Discharge pipe with minimum ø of 100 mm. (42) Sludge container.
(5) Flexible gas pipe out of rubber or plastic material. The gas holder has to be freely movable. (51) Gas outlet with main cock. (52) Condensation drainage at lowest point of gas pipe. (53) Gas pipe to consumer with slope towards drainage.

Table 25: Gobar gas plant, constructional description

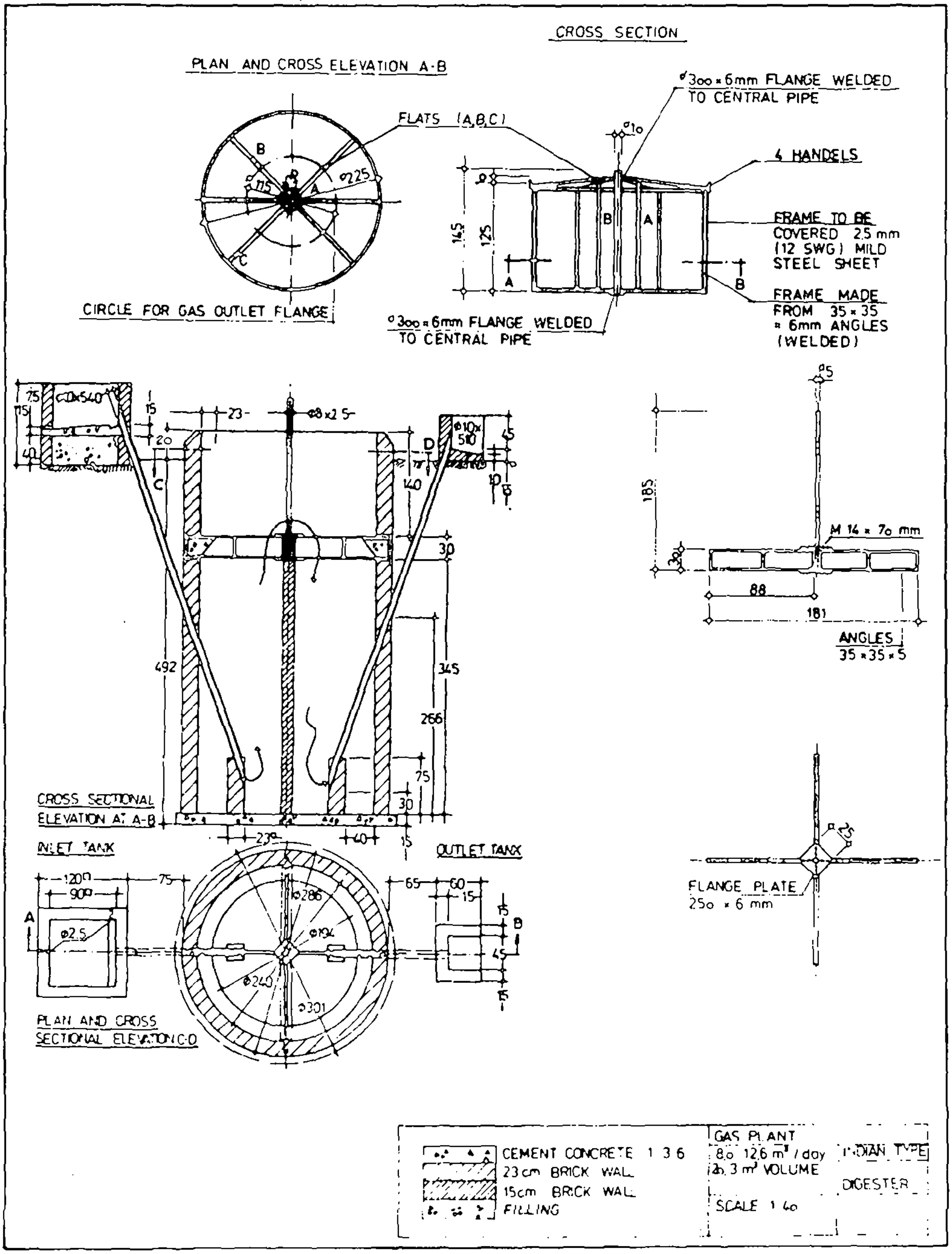


Table 26: Gobar gas plant. Constructional drawing

4.11. The dome biogas plant

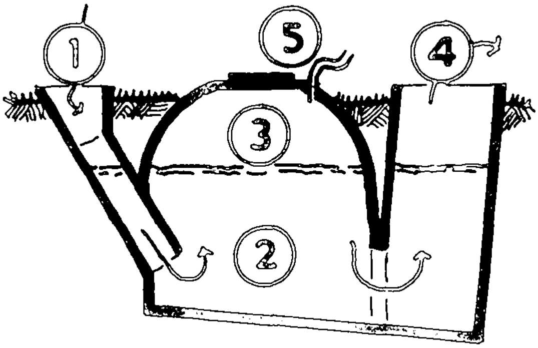
The dome biogas plant is a continous plant which has to be fed regularly. The gas collector, the dome and the digester form one unit. The gas is practically stored in the upper part of the digester.

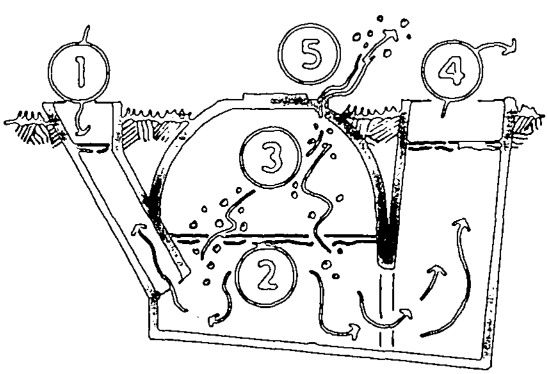
Fig. 18: Dome biogas plant. The inlet, the dome cover opening and the discharge shaft are clearly visible. Once the plant has been finished, only the shaft cover remains visible.

The construction comprises hardly any or no metal parts, thus excluding the problem of corrosion.

The gas produced presses the slurry into the inlet and outlet chamber which works as compensatory basin. The gas pressure changes according to the gas volume. A measuring instrument indicates gas pressure and volume of gas stored.

The outlet chamber has to be sized as to hold the gas volume to be stored (approximately 10% of the digester volume). Despite of the plant being fed daily, the slurry is cleared weekly.





1) Inlet. 2) Digester. 3) Gas holder. 4) Outlet. 5) Gas pipe

Table 27: *above: The plant has just been filled*
below: Gas production has started, gas pressure drives the digested slurry upwards into the outlet chamber.

Due to the geometrical shape of the dome, gas pressure with this displacement system varies considerably between 0 and 150 cm water column — always according to the type of construction.
Burner and lamps have to be easily adjustable so that they can be adapted to the varying gas pressure. For better control, simple tubular manometers can be found next to the fire-places in Chinese kitchens (Fig. 24).
The gas volume stored in the gas holder can be judged by the gas pressure. The manometer scale has to be adjusted according to the respective shape of the gas dome.

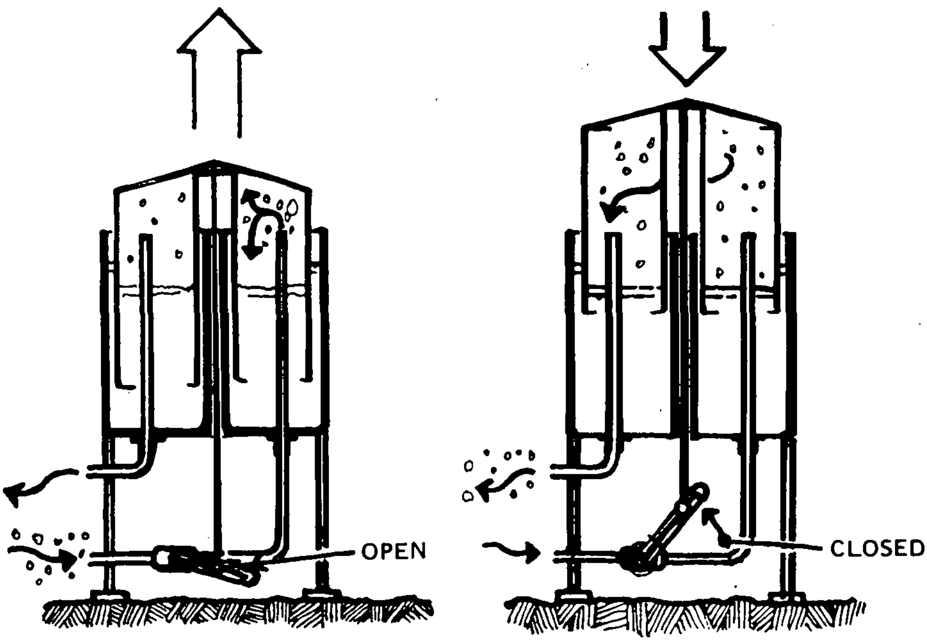
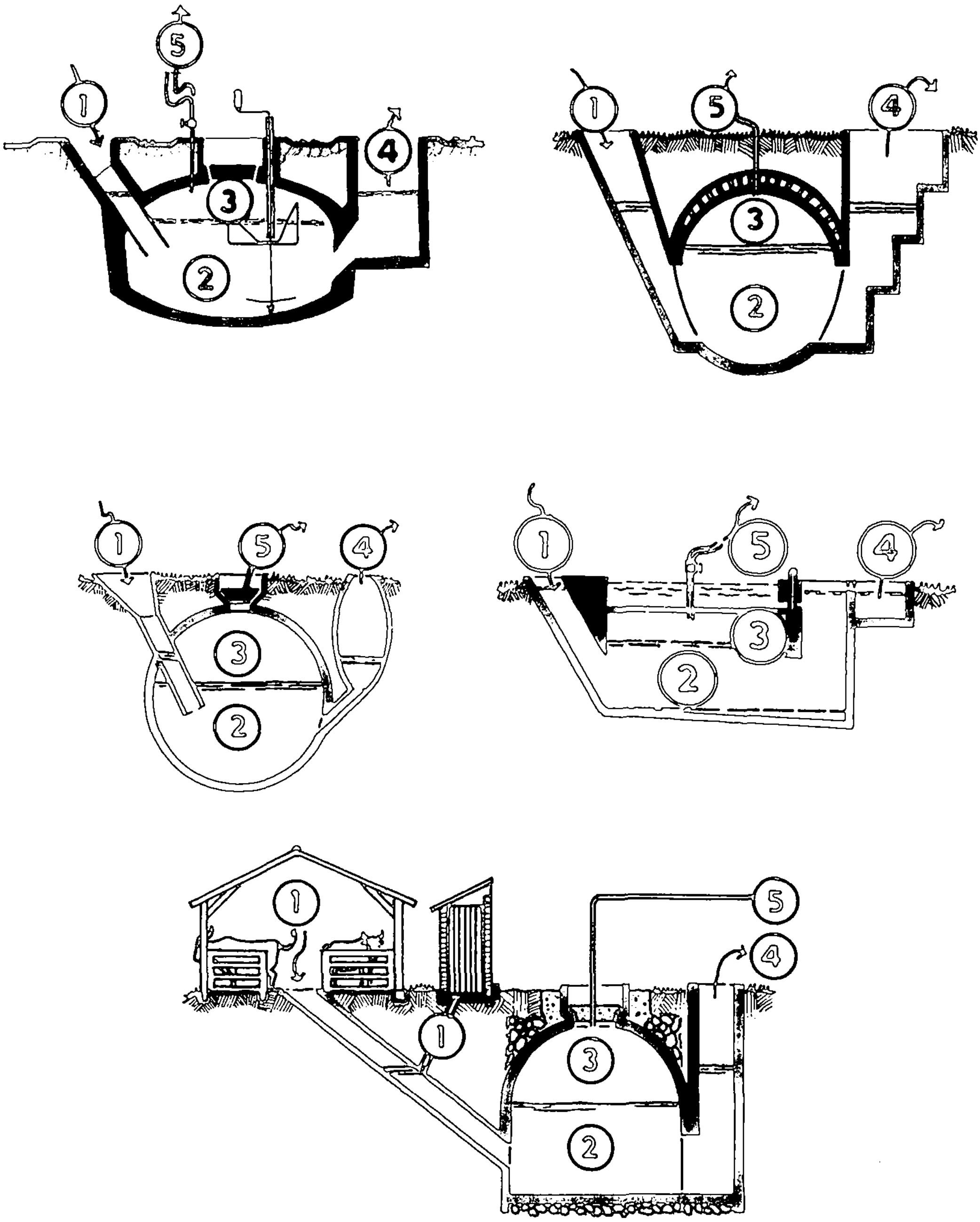


Table 28: *Gas pressure controlling aggregate developed in Nepal. When the gas flows in, the drum (Ø 20 cm) is driven upwards under high pressure, the inlet tap is closed by a tow line. If gas pressure decreases, new gas will flow in.*



1) Inlet. 2) Digester. 3) Gas holder. 4) Outlet. 5) Gas pipe.

Table 29: *Various dome biogas plants, all of them working according to the same basic principle*

Since the dome biogas plant is to be cleared manually, even long fibrous material can be digested. Therefore, however, the inlets and outlets have to be of a larger size than those of the gobar gas plant. If mainly fibrous material is being used, stirring equipment or devices are necessary. In order to bring only the absolute minimum of still pathogenic germs on to the fields with the slurry, the stirring device should always be operated after discharge.

If also kitchen garbage, straw, leaves or similar are being used, it is necessary that the plant be cleared of sediments once or twice annually and the scum be taken off. The cleaning necessary for this purpose is hard and dirty work. One should therefore find out before the construction of such a plant, whether or not, the users are prepared to carry out this work. This holds especially true, if human faeces are fed to the plant. For these cleaning operations, it has to be made sure that the pit is well aired before being entered by the cleaning staff, as there would be otherwise the risk of suffocation.

The plants are completely let into the ground. They are thereby and because of the masoned gas dome well protected against the cold and thus particularly suited for regions with low winter temperatures. The daily solar radiation however, can therefore not fully be made use of. By using heated up mixing water, this disadvantage can be compensated.

The main problem with these plants is that their domes must be gas-tight. Concrete and masonry are principally not gas-tight. The surface treatment of the masoned gas dome is therefore of major importance. Bitumen and plastic paints (diffusion sealing paints) are especially appropriate. It has been tried in China to rub brine, alum water, urine, silicate of sodium or pig blood into the still moist plaster instead. In order to protect the cement against the agressive hydrogen sulphine in biogas, a double coat of bitumen is indispensable.

Absolutely precise treatment and careful finish of the surface (compression of the plaster by strong grinding) are of extreme importance. Every defect leads to gas leakage. A repair is only possible after complete cleaning of the biogas plant. Therefore before initial operation tightness should be tested with water.

Dome biogas plants can be established almost completely by self-help. Bricks, concrete, stones and concrete blocks can be used for the walls. The quantity of mortar required is considerably high.

Because of the high prices for cement, special procedures have been developed in China in order to replace cement by lime or similar bonding agents. Experiments in this direction should be encouraged in other regions too.

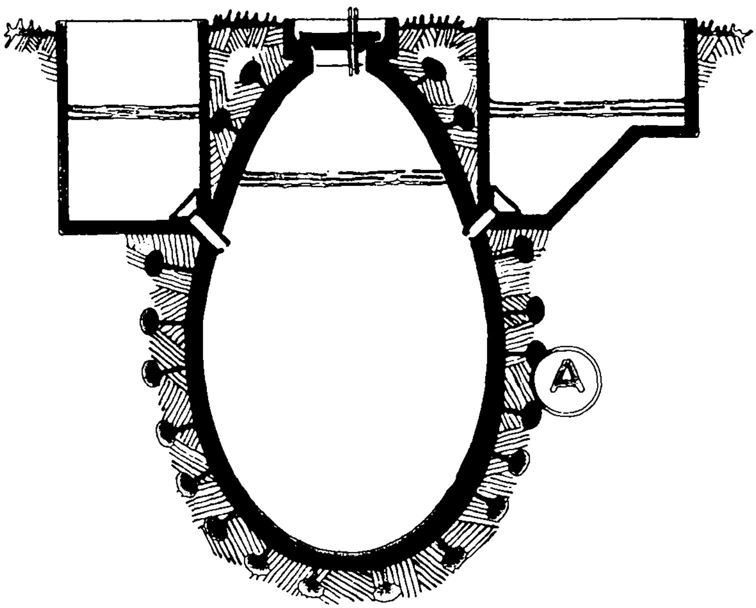
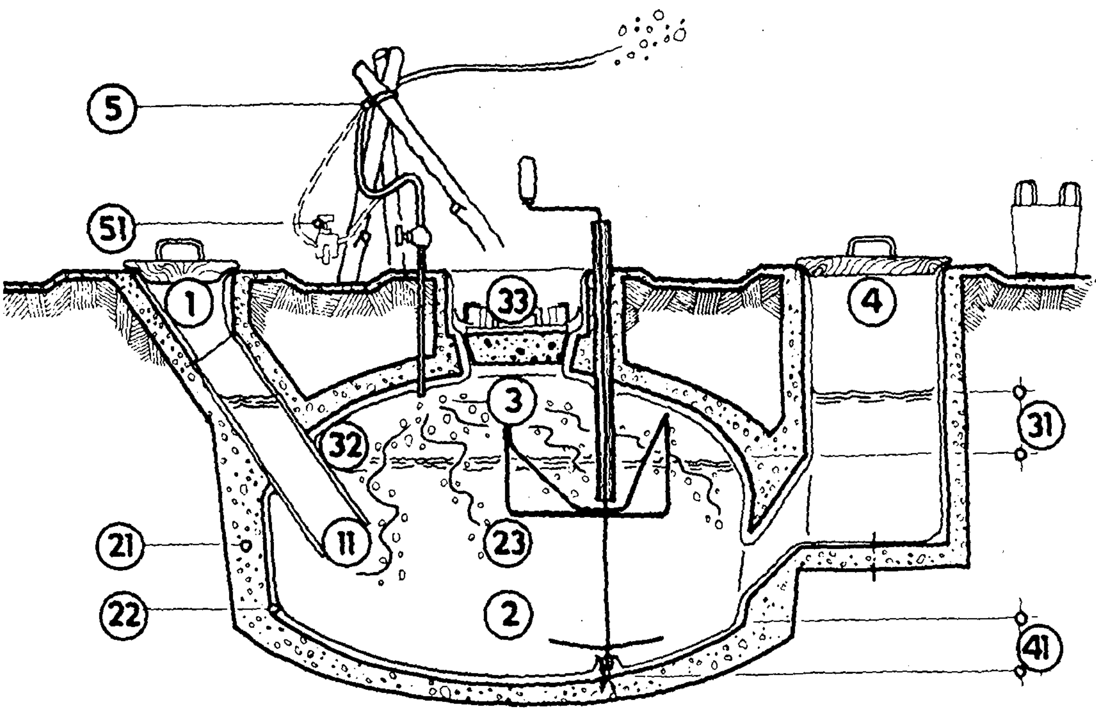


Table 30: In case the condition of the soil is suitable, cement can be saved by applying it on just a thin wire netting onto the ground. The fastenings by holes which are drilled into the ground and subsequently filled with cement (A), can be clearly recognized.

DOME BIOGAS PLANT



(1) Feeding shaft ⌀ 250 - 400 mm. Feed material : water 1:1 up to 1:3. To be fed daily or every second day. (11) The pipe has to end up in the slurry and not in the gas chamber even if the gas storage tank is full.
(2) Digester 50 - 60 times larger than daily feed volume. (12) Walls and ground of the digester are masoned. (22) Waterproof cement plaster. (23) Stirring device recommended.
(3) Gas dome. If the gas volume increases, the slurry is driven into the compensatory basin. (31) Difference of the water levels is equal to gas pressure in mm water column. (32) The surface of the gas dome has to be painted with bitumen or plastic paints. The plaster has to be trowled carefully. (33) Removable cover which has to be secured and painted gastight.
(4) Discharge- and compensatory basin. To be cleared weekly, total clearing 1 - 2 annually. Observe safety instructions before entering: gas poisoning!
(5) Gas pipe and main cock. (51) Gas pipe to consumer with slope towards the plant or towards discharge cock at the lowest point of the gas pipe.

Table 31: Dome biogas plant, constructional description

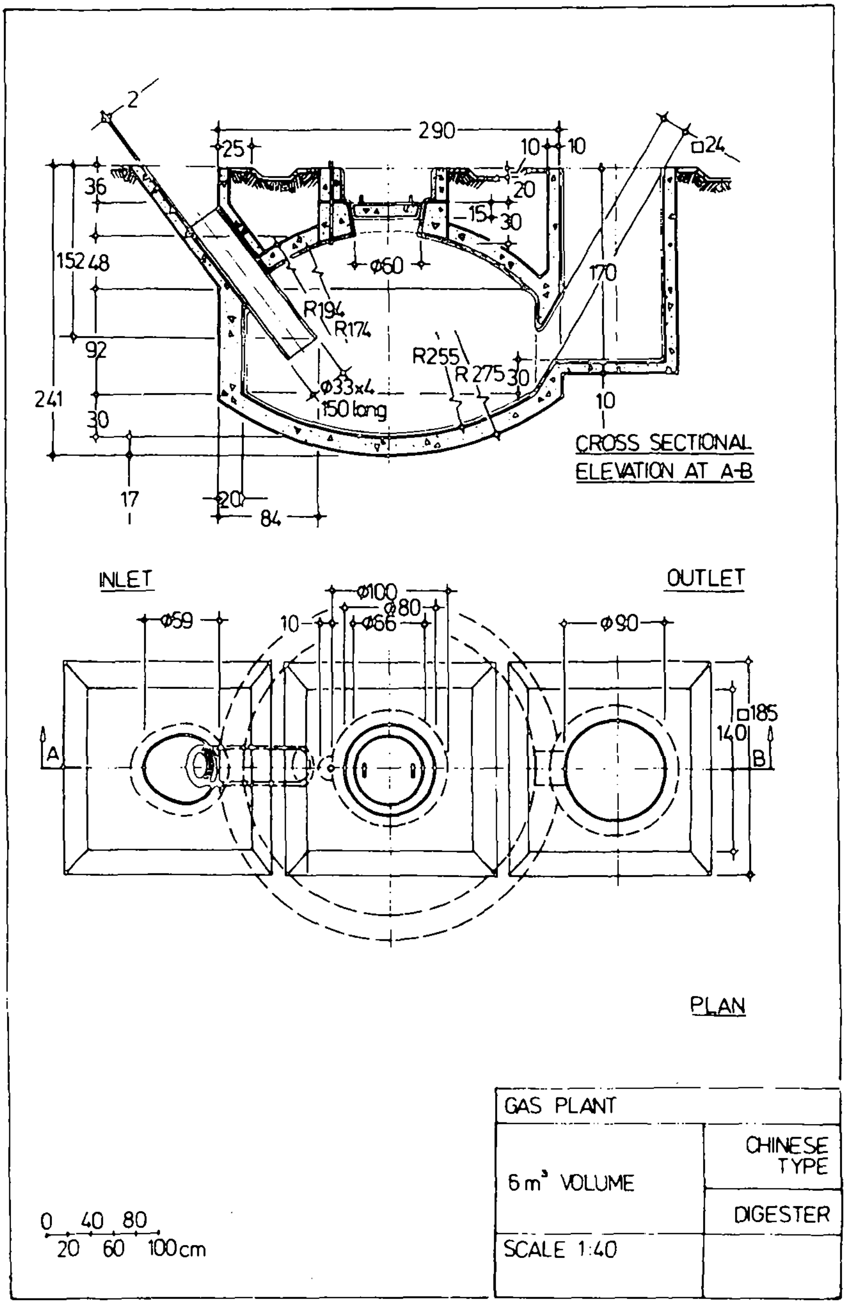


Table 32: Dome biogas plant, constructional drawing

4.12. Technical aspects in general

Insulation and heating

If the plants are established in tropically warm climates, special measures to obtain a sufficiently high digestion temperature are not necessary.

In colder climates additional steps have to be undertaken.

It is important that heating and insulation form one unit. Heating is useless, if insulation is insufficient and vice-versa. Insulation does not create heat but rather maintains the initial temperature.

Insulation stopping the cold, also keeps the heat out. Therefore it is of importance that the insulation does not impede heat supply.

Every heating requires technical efforts and thereby expenses. Heating systems in general can therefore not be used in simple biogas plants. In order to increase the temperature in the digester, there remains the alternative of heating up either the mixing water or the slurry.

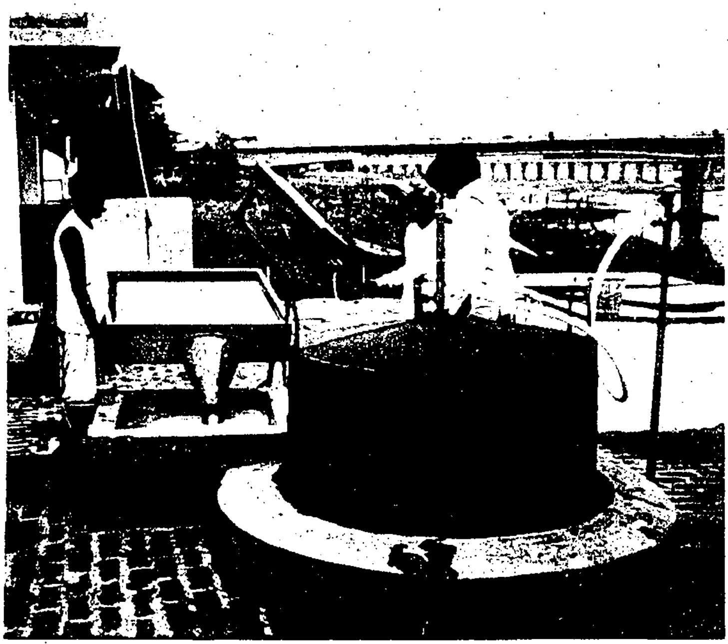


Fig. 19: Solar collector heating system for the slurry in Amedhabad/India.

Solar collector heating is only advisable for large size plants.
For small plants it is worthwile, to place a black painted water tank in a sunny and wind protected location, in order to preheat the mixing water. It has already been mentioned before that the plants should be fed, if possible, during the midday heat.
A further possibility of heating is predecompositioning. Either predecomposition of the feed material and/or combination with a decomposition plant. At any rate, part of the organic matter is lost for digestion during the decomposition process.

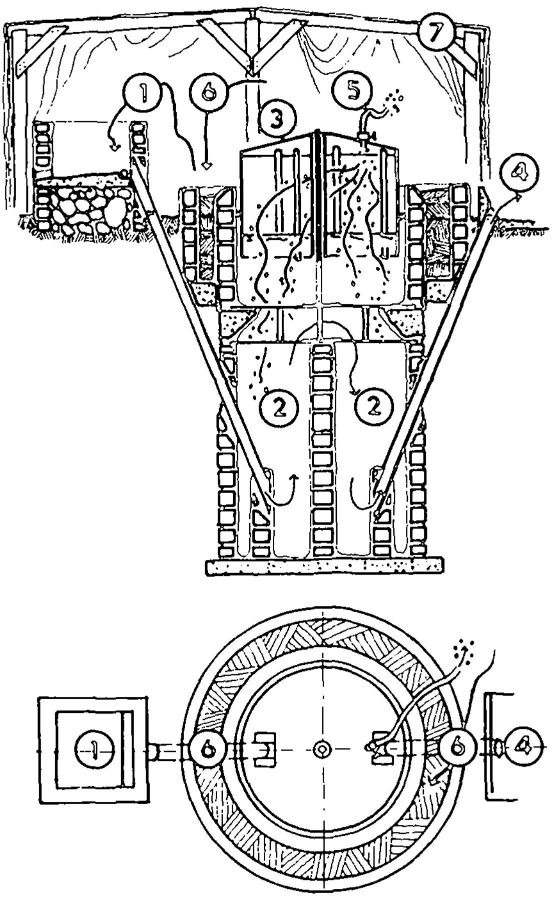


Table 33: *The digester is surrounded by an annular shaped decomposition pit. For heat insulation the plant has a sort of "greenhouse" overhead structure.*
1 Inlet 2 Digester 3 Gas holder 4 Outlet 5 Gas pipe 6 Compost tank 7 Overhead structure

High quality insulation materials out of plastic foam or mineral wool are hardly available and therefore expensive. As substitutes, straw, litter, leaves, coconut fibres or similar may be used. Air layers as, for instance, between double walls, are of high insulation value. The in-between spaces, however, can also be filled with the above-mentioned insulation materials. In the case of the gobar gas plant, insulation of the gas holder by which approximately 80% of the heat escapes, is difficult.

S t i r r i n g

Firmly incorporated stirring devices are necessary and useful only with the dome biogas plant. They are supposed to break the scum as well as to impede sedimentation at the bottom of the digester.

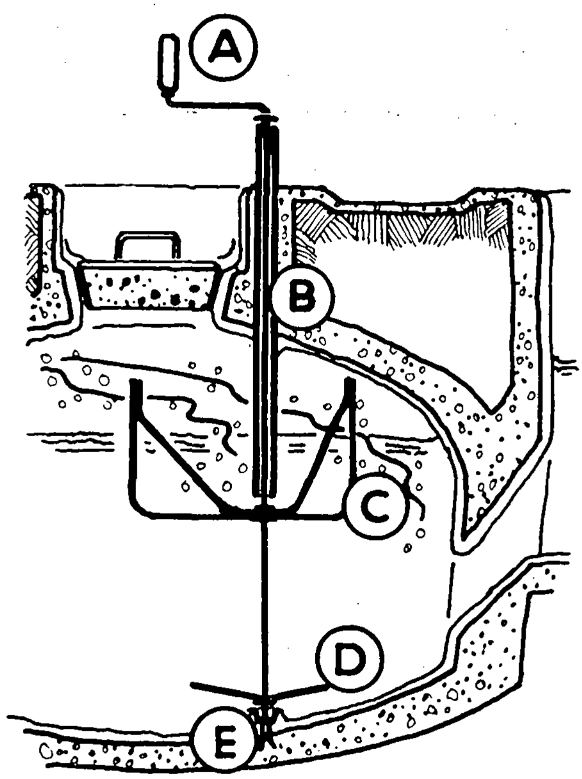


***Table 34**: Stirring equipment for dome biogas plant*
A) Handle. B) Shaft. C) Scum stirring device. D) Bottom stirring device
E) Lower bearing

Tightening of movable parts is difficult. Therefore stirring devices should never lead from the gas holder direct to the outside but rather be introduced into the digester inside of a fixed shaft. With the gobar gas plant, the rotating gas holder serves as stirring device.

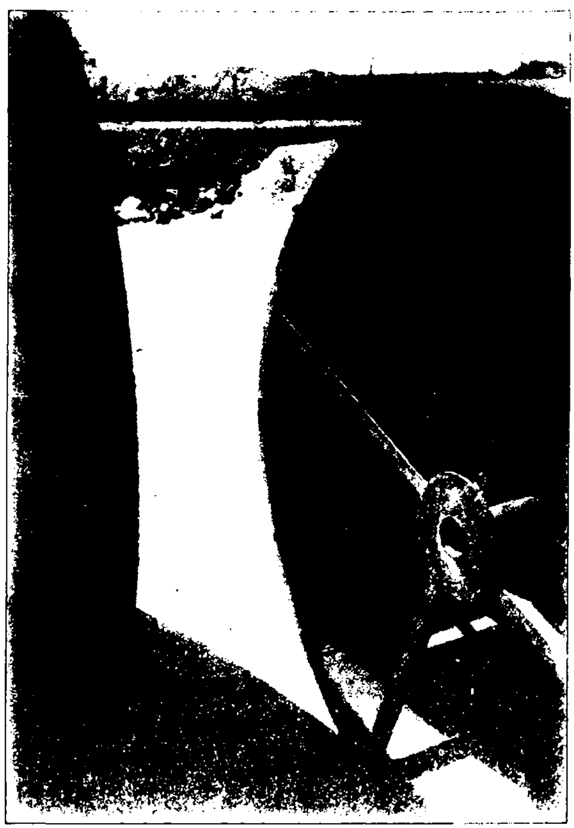


Fig. 20: The welded braces break the scum by rotation of the gas holder

4.13. Maintenance and repair

Maintenance of biogas plants is uncomplicated but absolutely necessary and not to be substituted by any expensive construction.

Continuous plants have to be fed and cleaned regularly, i.e. twice to 7 times a week. Only by these measures good functioning and maximum life time of the plants can be achieved.

Should there be disturbances in operation, trained servicing staff have to be available. In the course of time all users of biogas plants attain sufficient know-how. This means: The longer biogas technology has been introduced and the more complex this introduction is, the more does special know-how become general knowledge and thus specifically trained servicing personnel are normally no longer required.

Nevertheless a close network of advisory and repair workshops is indispensable especially as far as implementation strategy is concerned. As already mentioned in the chapter "Education and training programmes", one service station should at no rate have to cover an area exceeding 40 km in radius.

Basic condition for the creation and existence of regional respectively local repair or service stations is a concentration of a minimum of plants — hardly less than 100 within the range of a service station.

With the gobar gas plant daily maintenance consists of feeding the plant. Thereby special attention has to be paid as to well mixing the feed material and adding the adequate quantity of water. Contamination by sand, stones or wooden material has to be excluded. Turning the gas holder after each filling, in order to break the scum, should not be forgotten.

The lateral parts of the gas holder should be washed with clear water (without detergents) and the water level of the syphon be checked once weekly (see chapter 5.1.). Approximately once annually the steel parts need a new coat of paint.

As regards the filling of the dome biogas plants, the same holds true for the gobar gas plant. However, there is no gas holder to be turned, instead the stirring device should be used daily or the slurry be stirred via the inlet.

Digested bioslurry has to be removed at least weekly, preferably daily, so that gas pressure remains somewhat constant. The upper dome opening is to be checked as to its gas tightness.

During the period when the fields are being manured, the plants have to be cleaned once or twice annually. At the same time necessary repairs for gas tightness should be carried out and possibly a new coat of paint be applied. Attention has to be paid when entering the pit. Should the plant not be sufficiently aired, there is the danger of suffocation.

5. THE BENEFIT OF BIOGAS TECHNOLOGY

5.1. The utilisation of biogas

Biogas is a valuable energy carrier, consisting of 50 - 70% methane and 30 - 50% of carbon dioxyde as well as of low quantities of various gases, amongst them hydrogen sulfide. It is almost 20% lighter than air and has an ignition temperature of 650 - 750°.

Characteristics	Components				Mixture
	CH_4	CO_2	H_2	H_2S	(60% CH_4/ 40% CO_2)
Volume share %	55 - 70	27 - 44	1	3	100
Calorific value MJ/m^3	35,8	—	10,8	22,8	21,5
Limit of inflammability Vol. % in air	5 - 15	—	4 - 80	4 - 45	6 - 12
Ignition temperature °C	650 - 750	—	585	—	650 - 750
Density normal g/l	0,72	1,98	0,09	1,54	1,2
Relation of density to air	0,55	2,5	0,07	1,2	0,83

Table 35: Biogas, technical data

Biogas can be used for different purposes. It is mainly used for cooking. It may also be used to drive engines, water pumps, in small scale industry, for instance, and for cooling or drying fruit. If it is to be used for lighting several lamps, it is generally more economic to operate one generator for power supply than burn the biogas direct in the lamps. It should always be checked whether the waste gas heat can be used to intensify the fermentation process.
The use of biogas for heating purposes is insignificant for most of the developing countries for climatical reasons.

Gas cooker *representing approximately*	*0.23 m^3 gas/h* *0.3 m^3/individual person/day* *0.15 m^3/member of family/day*
Gas diesel engine *representing approximately*	*0.42 m^3/HP/h* *10.5 m^3 for 5 PS for 5 h*
Gas lamp (equivalent of 40W)	*0.04 m3 gas/h*
Gas refrigerator (220 l)	*2.4 m^3 gas/day*

***Table 36:** Gas consumption of various devices*

The working pressure of the gas depends upon the type of the plant and amounts to 8 - 80 cm water column. Also the pipe diameter required is dependent on the gas pressure and therefore varies accordingly.

With a pressure of approximately 8 cm water column, 1 m^3 biogas can be transported in an 1/2" G.I.-pipe over about 20 m, in a 3/4" pipe over about 150 m and in a 1" pipe over approximately 500 m, always in one hour. In order to transport 2m^3/hour, the distances are 5 m with a 1/2" pipe, 40 m with a 3/4" pipe and 50 m with a 1" pipe.

The air gas mixture ratio for best possible combustion is approximately 4.5 : 1, for urban gas, however, it is 1 : 1. Therefore, gas devices originally made for natural or urban gas, have to be especially equipped for biogas.

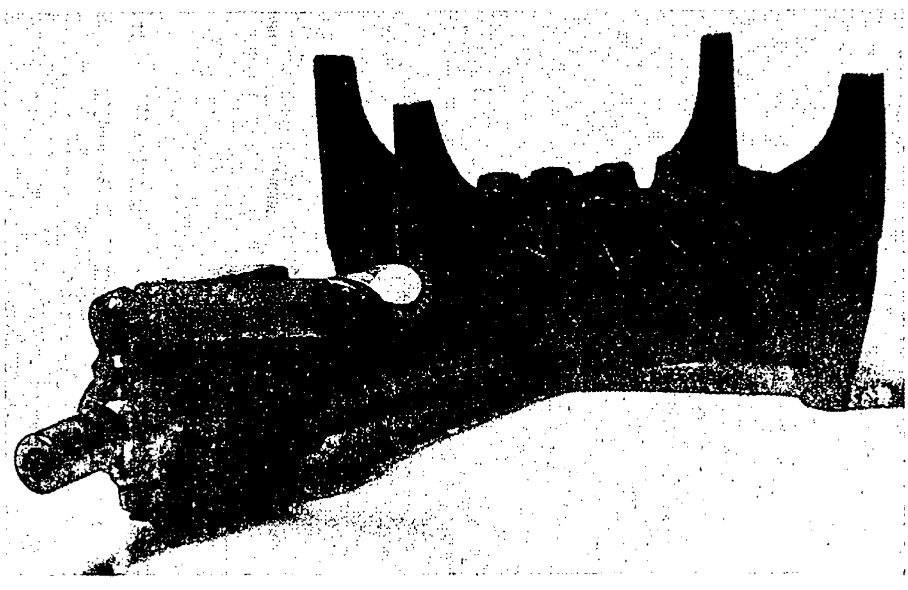


Fig. 21: Cast iron burner from India

Fig. 22: Biogas lamp from India

Valuable development work has been done in Nepal for lamps, burners and other biogas accessories. Constructional drawings and latest results are regularly published in the Biogas News Letters and are thus made accessible to the public.

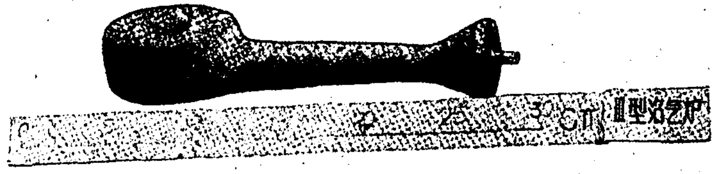


Fig. 23: Simple clay burner from China

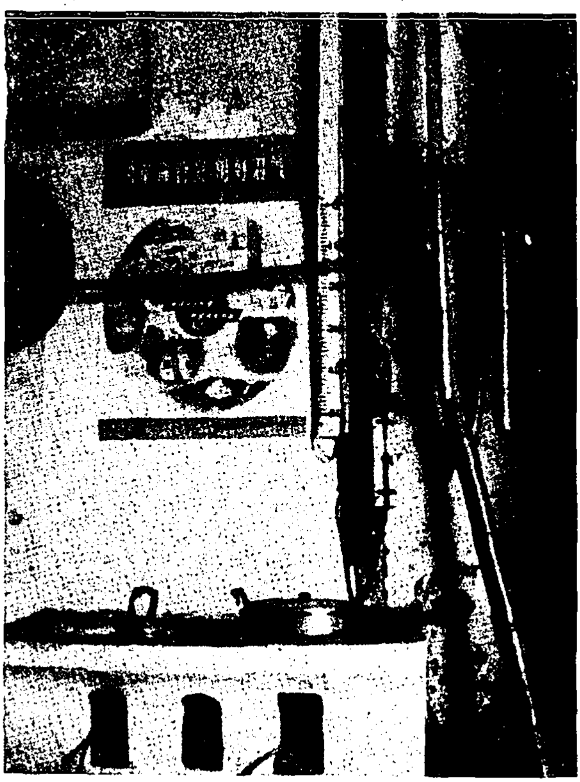


Fig. 24: Cooking stove in a Chinese kitchen. The burner is deeply inserted into a brick stove in order to make optimum use of the heating energy

The use of engines becomes interesting with plants exceeding 20 m^3 gas production per day, for instance, for generation of electricity by village community plants or for production procedures where waste heat can be fully made use of (e.g. for drying fruit). By the combination of heat-energy, a 90% exploitation of biogas energy can be achieved as against 30% with generation of electricity only.

Fig. 25: Slurry is pumped directly onto the fields of a village commune in China by means of a gas operated pump

The subsequent change of diesel or gasoline operated engines to biogas can be effected without great technical efforts. Practically only the carburettor has to be adjusted to the operation with biogas. Biogas operated engines have longer life time. This is particularly the case, if the sulphuric component of the gas is eliminated by means of iron filings. The iron filings can be regenerated by open-air storage. With Otto engines the carbon dioxide contents of the gas may lead to difficulties in ignition. Therefore the composition of the feed material has possibly to be changed under consideration of this fact.

The calorific value of biogas depends upon its methane contents. This varies between 4700 and 5500 kcal/cbm gas volume. The useful calorific value depends upon the efficiency of the burners, respectively on the type of combustion.

Relative calorific value	Relative monetary value
1.0 cbm Biogas	1.0
3.6 kg fire wood	--
1.5 kg charcoal	0.68
13.0 kg cow dung	--
0.5 kg butane	2.30
0.6 lt kerosene	1.61
5.0 kwh electric power	2.12
0.4 lt fuel oil	2.39

***Table 37:** Comparison of the calorific value of biogas as against other fuels*

Gas production of a gobar gas plant:

1 calf 5 kg dung/day 1 cow (zebu) 10 kg dung/day 1 buffalo 15 kg dung/day 1 European cow 20 - 25 kg dung/day	10 kg dung = 0.35 m^3 biogas	
1 pig 2.5 kg dung/day (quantities valid for stable-bound animals)	10 kg dung = 0.35 m^3 biogas	
Latrine 1 kg/person	10 kg excrements =	0.25 m^3 biogas
straw (dried)	10 kg =	2.5 m3 biogas
water hyacinth (dried)	10 kg =	3.5 m^3 biogas
rice husks (dried)	10 kg =	1.0 m^3 biogas

The actually available quantities of dung and waste have to be measured precisely. Production values in a dome biogas plant are up to 50% lower.

Size of gas tank for daily gas supply:
10 kg dung/day = 0.35 m^3 x 1/2 equals a volume of approximately 0.2 m^3 gas tank digester
10 kg dung or excrements/day = 1.5 - 1.8 m^3 digester
1 kg straw or dried waste/day = 0.4 - 0.7 m^3 digester
With daily gas consumption this results to a volume proportion of the gas tank to the digester of approximately 1 : 6 to 1 : 9 for the gobar gas plant and approximately 1 : 10 to 1 : 12 for the dome biogas plant.

***Table 38:** Approximate values of gas production*

Gathering fire wood, cooking with this material and the cleaning involved afterwards require a lot of time — especially for the housewife. When biogas can be used for cooking, daily working time is reduced by approximately 2 1/2 hours.

Women in Narodi:
"Now we finally have time to play with our children and take care of their home-work."
"We can sleep one hour longer, as there is no need to leave the house before it gets hot, in order to gather fire wood."

Fig. 26: Hours of unproductive walking in order to meet the firewood demand, make the already hard life of the women in the rural areas even more difficult

Biogas considerably improves living and housing conditions. Therefore an ever increasing number of people learn to appreciate the value of this technology. In some of the Indian and Chinese villages biogas plants have already become symbols of prestige.

With demographic growth also the demand for energy increases without corresponding expansion of the present energy sources being possible. In the whole world energy will have to be used and saved in future in a rational way. Utilisation of biogas is a step in this direction.

The demand for fire wood can be reduced by 70 - 100%. Deforestion with all its negative consequences such as erosion of the soil and change of climate can be prevented. A 2.8 cbm volume plant can preserve a forest of 1200 qm (ICAR-Study).

5.2. Utilisation of manure

The fertilizer created in biogas plants is of particularly high value to the farmers and this for the following reasons:

— That part of the dung which up to the present had been dried and burnt for cooking, is now used for fertilizing the fields. Thus the farmer has a considerably larger quantity of dung at his disposal.
The quantity of dung available is also increased by processing of agricultural wastes in the biogas plant as well as by adding latrine contents.

— The slurry has a higher fertilizing effect than decomposed dung since it contains more nitrogen, soluble in water, which is important for the plants. In addition to this, 30 - 50% of the nitrogen escapes into the air in case the dung is air-dried. Nitrogen escaping from digested slurry after more than 10 days of storage amounts to approximately 10 - 15% only. Hereby twice or three times as much nitrogen is available. If urine is led into the biogas plant as well, the quality of the fertilizer is improved by the increase in nitrogen and potassium contents. In total here is an increased availability of nutritive substances of approximately 25% for fertilization of the plants.

— By adding slurry to pig fattening forage, up to 10% of the feed stuffs can be saved.

— By processing the dung in a biogas plant, weed seeds and insects are almost completely destroyed, so that less money for weed killers and insecticides is needed. If the slurry is decomposed together with agricultural wastes, this effect is at least partially lost.

— Fertilization with slurry as against direct fertilizing is more hygienic. This has particularly positive effects on vegetable cultivation and cattle breeding. The pasture grounds fertilized with slurry improve health of the animals, since parasites are destroyed up to a great extent. By this odourless fertilizing appetite of the animals is hardly cut.

Fig. 27: Slurry is a good protection against insects. The lower part was manured with decomposed dung, the upper part with slurry. The blanks in cultivation shown in the lower part of the picture are caused by root eating wurms, the eggs of which are destroyed in the slurry.

The increase of quality and of the quantity of dung available leads to higher yield and saving of expenses for artificial fertilizer or to both.

Increases in yield by fertilization with slurry, as against the use of decomposed dung depend upon many factors such as nature of the ground, climate and type of fruit. Decisive is also the time of fertilization as well as the fact that fresh slurry as against dry dung possesses higher fertilizing value. Attention has to be paid to the fact, however, that vegetables should not be fertilized shortly before being harvested.

In China the following average growth rates have been experienced:
Wheat + 13.6% corn + 16.9% rice + 9.4% rape + 9.1% cotton + 20.2%
sweet potatoes + 18.8% vegetables + 25%.

On the average increases of approximately 10 - 20% have materialized. Further increase can be achieved by adding unorganic fertilizer in order to adjust the supply of nutritive substances to the demands of the plants. Mixing with ashes can also lead to increase in yield. 30% of artificial fertilizer could be saved in India, if the overflow liquid of the biogas plants were used for growing of algues in the rice fields.

A large proportion of the farmers is not in a position to purchase fertilizer. In these cases a biogas plant would thus not lead to actual financial advantages. The financial profit is to be found in sales profits of increased yield in agriculture.

If in the framework of a programme for the implementation of biogas plants, the fertilizing effect is given preference, a programme to improve productivity of the soil should be offered at the same time. Recognizing the elements of environmental harmony is absolutely indispensable in this connection.

In order to maintain productivity of the soil, the combination of multiple inner compensation processes is of importance. In the case of double use of the fields the trees create a mild micro-climate with increased atmospheric humidity and reduced thermal fluctuations. Due to their deep roots the trees unfold the nutritive substances of the ground and transfer them onto the fields by falling leaves. Strata of organic substances (mulch) such as straw grass and weeds diminuish erosion of the soil and loss of water, form ample humus and encourage development of a crumbling structure of the soil. Ions retention power, absorption of the water and water retention are closely connected therewith. The high contents of organic substances leads to rich insect life of the soil enabling binding of nitrogen from the atmosphere. Root and leaf secretion of the weeds often have nematozoidal and bactericidal effects and avoid exhaustion of the soil and thereby decreases in yield.

The below mentioned ecological farming methods which are to be adjusted to the respective conditions of a region, must also include consideration of the socio-economic situation of the population.

Key words in this connection are:

integration of tree-, field-, fodder-, and special cultivations as well as animal breeding; productive, guided multiplicity of the system and variety of the products; self-containing metabolica and energy circulation; productivity through use of slurry in high quantities; limited, mechanical processing; biologic erosion controls; partitioning by hedges; resistent types offering average yields; mixed cultivations; weed tolerance.

Together with demographic growth there is an increased need of food and hereby a progressively increasing demand for fertilizers. Thereby the necessity of making intensive use of the available natural dung potential as achieved by biogas plants, gains more and more importance.

5.3. Costs and economics

In order to keep the costs low and to increase positive effects on the situation in general, local or regional enterprises, labour and material should be taken into consideration as far as possible for construction and maintenance of the plants.

Production costs of a plant depend upon its size. The larger the plant, the lower are the costs per unit of gas produced. Normally the size of a plant should not be planned according to the demand for energy but rather in conformity with the feed material availabe (number of cattle units, number of latrine users or quantity of organic waste). nic waste).

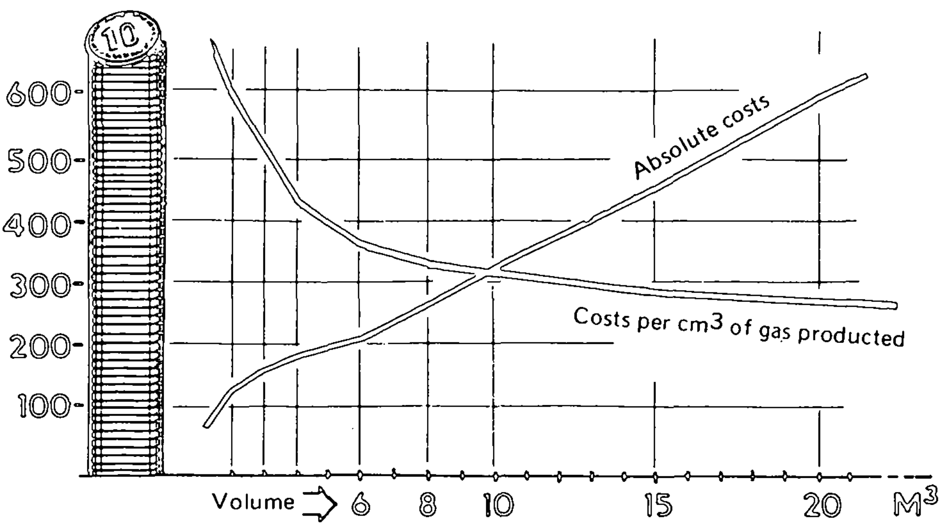


Table 39: Dependence of costs per cbm of gas produced on the size of the plant. A gobar gas plant of 8 cbm shows already a favourable cost-production proportion

In addition to this, costs and thereby profitability of a biogas plant depend upon the serviceable life. A biogas plant can be used up to 15 - 20 years. The main parts have different serviceable lives: 40 and more years of service life can be reckoned with for the digester, approximately ten years for the gas tank of the Indian plant, approximately 20 years for pipes and accessories.

In this connection the pro-rata distribution of costs to the individual parts is of importance. With the gobar gas plant about 45% of the costs are required for the digester as against 77% for the gas tank and 18% for additional equipment. With the dome biogas plant, this cost proportion decisively depends upon the share of own labour. In the case that the digester and the gas dome are carried out by hired workers, 80% of the costs have to be invested for the plant and 20% for additional equipment.

Self-help in construction of Indian biogas plants mainly consist in excavation works. They cover only about 5% of the production costs. In China labour contribution which is not to be remunerated, since performed by members of the commune, amounts to 90% of the production costs. Also main parts of equipment are produced by the people themselves.

Going in detail of business cost calculation would require a real situation as a basis. The results could, however, hardly be generalized. The Bombay KVJC-study is to serve as a reference for cost-profit analysis.

Scheme of a cost-profit-analysis

Annual costs
Interests and repayment of credits
Depreciation (10 years) for steel parts
Depreciation (20 years) for accessories
Depreciation (40 years) for digester masonry
Paint of the steel parts
Other costs of maintenance
Value of the feed material as fertilizer
\- - - - - - - - - - - - - - - - -
Costs of operation
==============================

Annual benefit
Value of the slurry as fertilizer (resp. increased yield)
Value of the gas as fuel
Savings made timewise or in transport
\- - - - - - - - - - - - - - - - -
Annual profit
==============================

In order to realize a real comparison of costs between the gobar gas plant and the dome biogas plant, exact figures are needed which, however, only reflect a specific situation and can therefore again not serve as comparative figures.

The following graphs are to show the chief costs and trends. These graphs are based on a political-economic situation to be found, for instance, in India and in many African countries. The system of commune work in the People's Republic of China does make any cost comparison with other countries an unsoluble problem. The planning costs shown are also to be understood as administrative costs of self-financing biogas programmes.

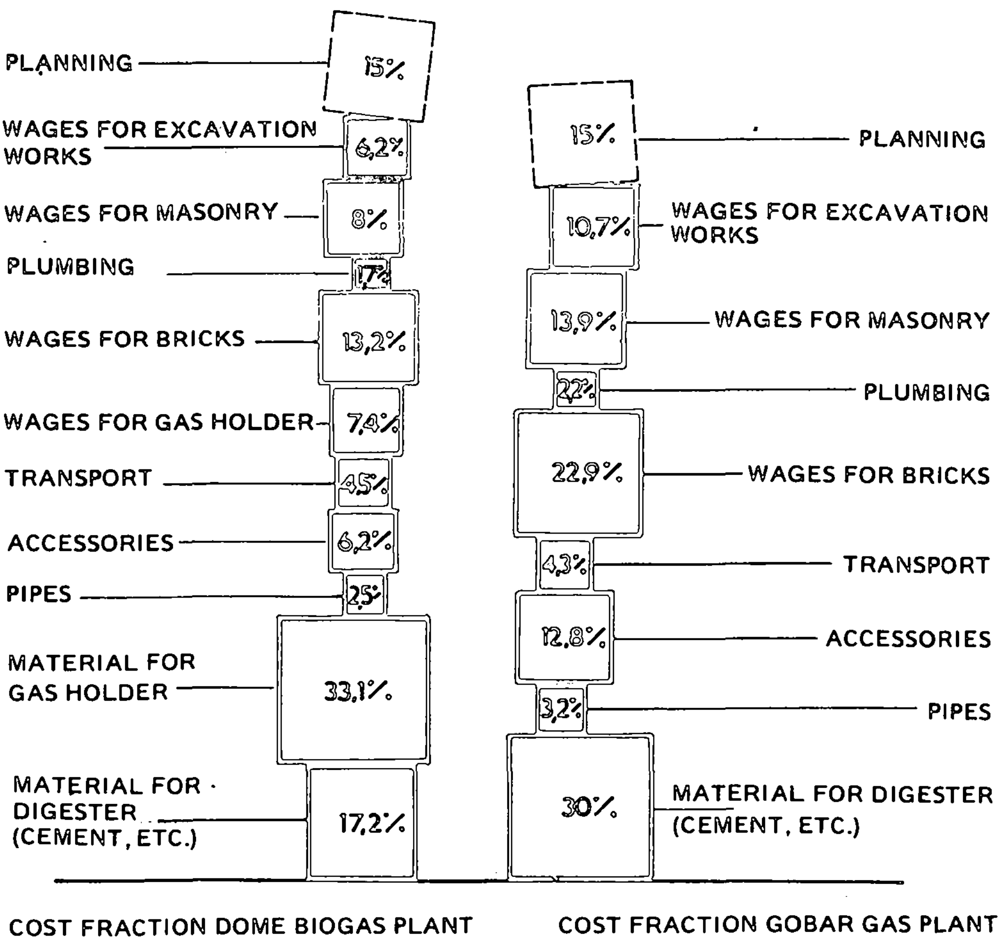


Table 40: Classification of cost fractions

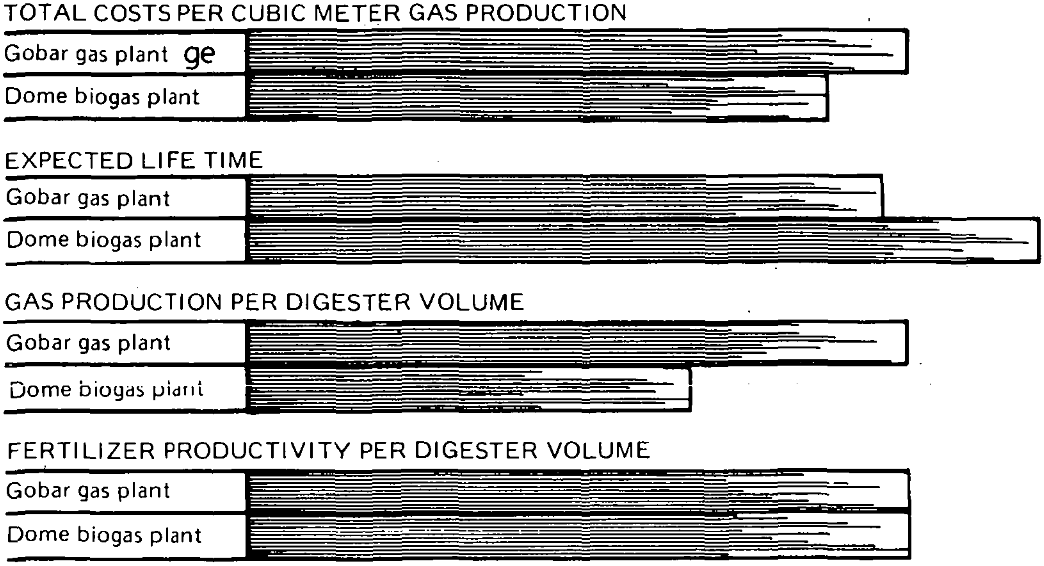


***Table 41**: Cost-profit-comparison of the gobar gas plant as against the dome biogas plant*

The comparison between the Indian and the Chinese plants shows clearly that costs, construction and work organisation are not only functions of the respective socio-economic situations prevailing, but are rather influenced by the political priorities of the region.

Operational and maintenance costs for individual plants are low. The gas holder of the gobar gas plant needs a new coat of paint once annually or every second year only. Repair costs for the dome biogas plant depend, above all, on the quality of the masonry.

Operational and maintenance costs for community plants, however, are comparatively high. They may amount up to 25 or 30% of the total benefit.
Supply, gathering and transport of waste for feeding of the plant, operational supervision, maintenance and repair, discharge of the slurry; additional equipment, necessary for utilisation of biogas, as well as management and administration have in most cases to be remunerated and are therefore to be considered as cost factors.

5.4. Biogas plants in building and settlement structure

Biogas plants should not be considered in isolation from their surroundings. As already repeatedly mentioned, only with the concentration of many plants in one location or one region, the manyfold advantages of this technique become fully effective.

In addition to this, the effectiveness of a biogas plant depends upon its location within the economical sphere to which it belongs.

Thus the plant should be situated near the place of consumption (the distance not exceeding 25 m), but also in the vicinity of the raw material (stable or latrine). With larger plants the closeness to the raw material is of essential importance.

Suitable water should be available near the plant. Due to the danger of infection a minimum distance of at least 20 - 25 m to the nearest well should be observed. The location should, however, also be chosen according to the habits of the users.

For demonstration plants the demonstration effect is most important for the decision regarding the location of the plant. Here again it has to be emphasized that only a well operated and functioning plant has a positive demonstration effect.

When planning new buildings or groups of buildings, especially stables, a location should principally and right from the beginning be chosen. Under no circumstances should the subsequent construction be impeded or even be made impossible.

For the installation of biogas plants, farms with cattle and field cultivation are particularly advantageous. By the circle "more dung, more forage, more cattle being more resistant, more excrements, more fertilizer" the agricultural yield can be improved through a biogas plant. The observation of the acceptable cattle/pasture ground/proportion must not, however be neglected in this connection, if the advantages of the biogas plant are not to have a reverse effect due to negative side-effects.

On farms the choice of the location is relatively unproblematic, as often natural integration of the biogas plant is given.

If cattle urine is to be used in order to increase gas production, the animals have to be stabled, which also facilitates the gathering of the dung. Are the animals stabled only during night time, 50% of the possible dung and urine capacity will be available only.

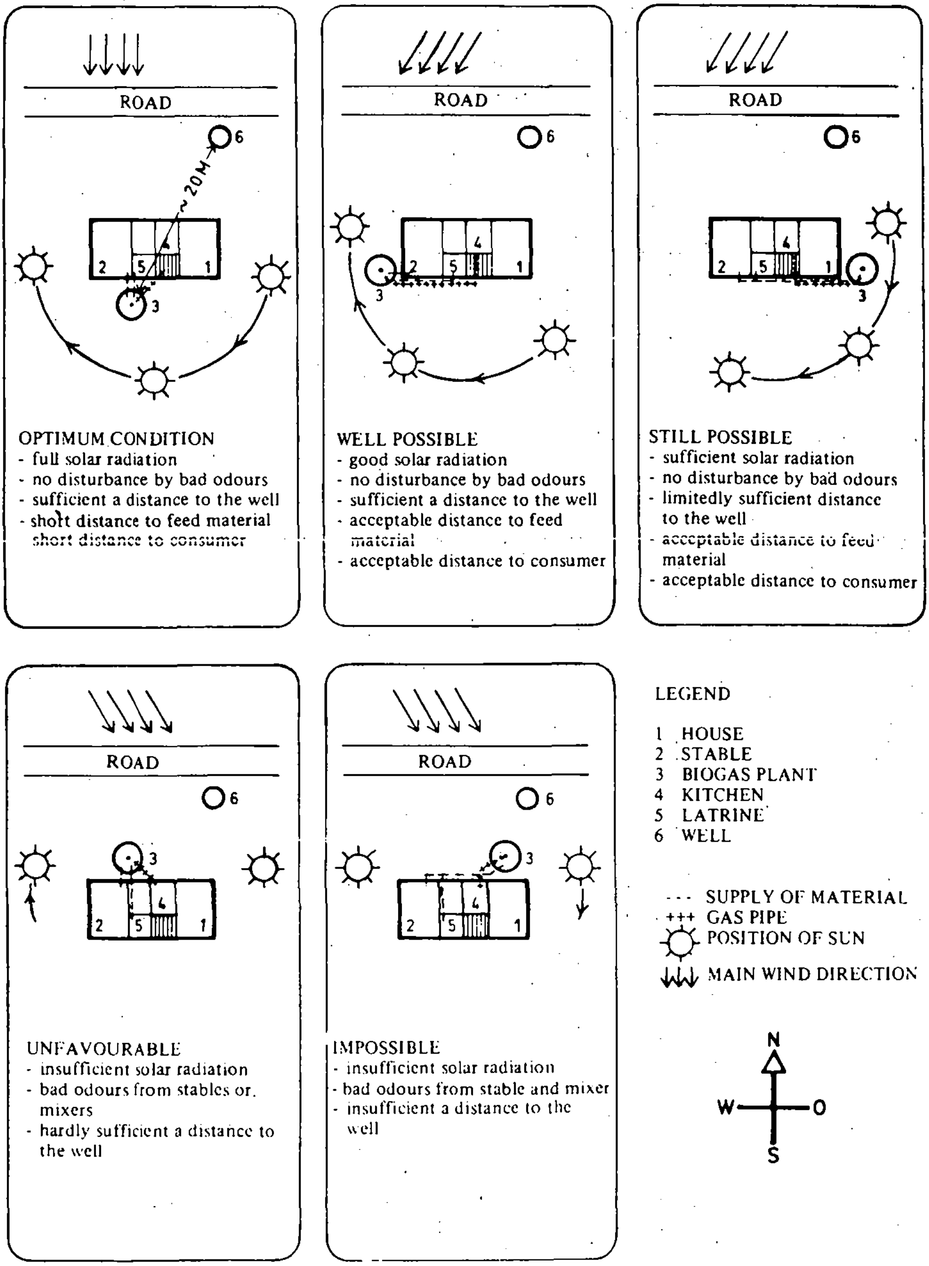


Table 42: Evaluation of different locations of biogas plants

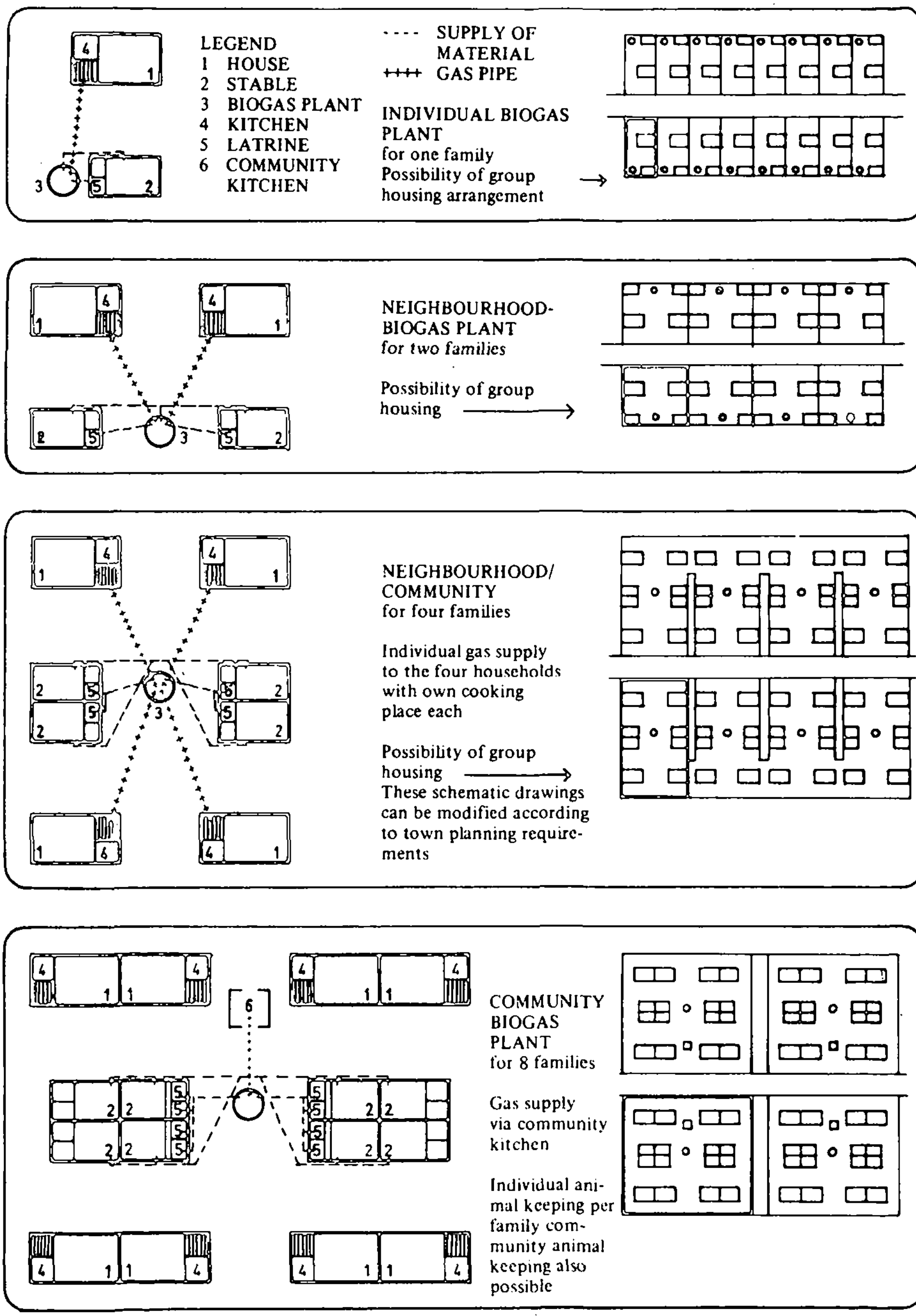


Table 43: Location interrelations of individual, neighbourhood- and community plants

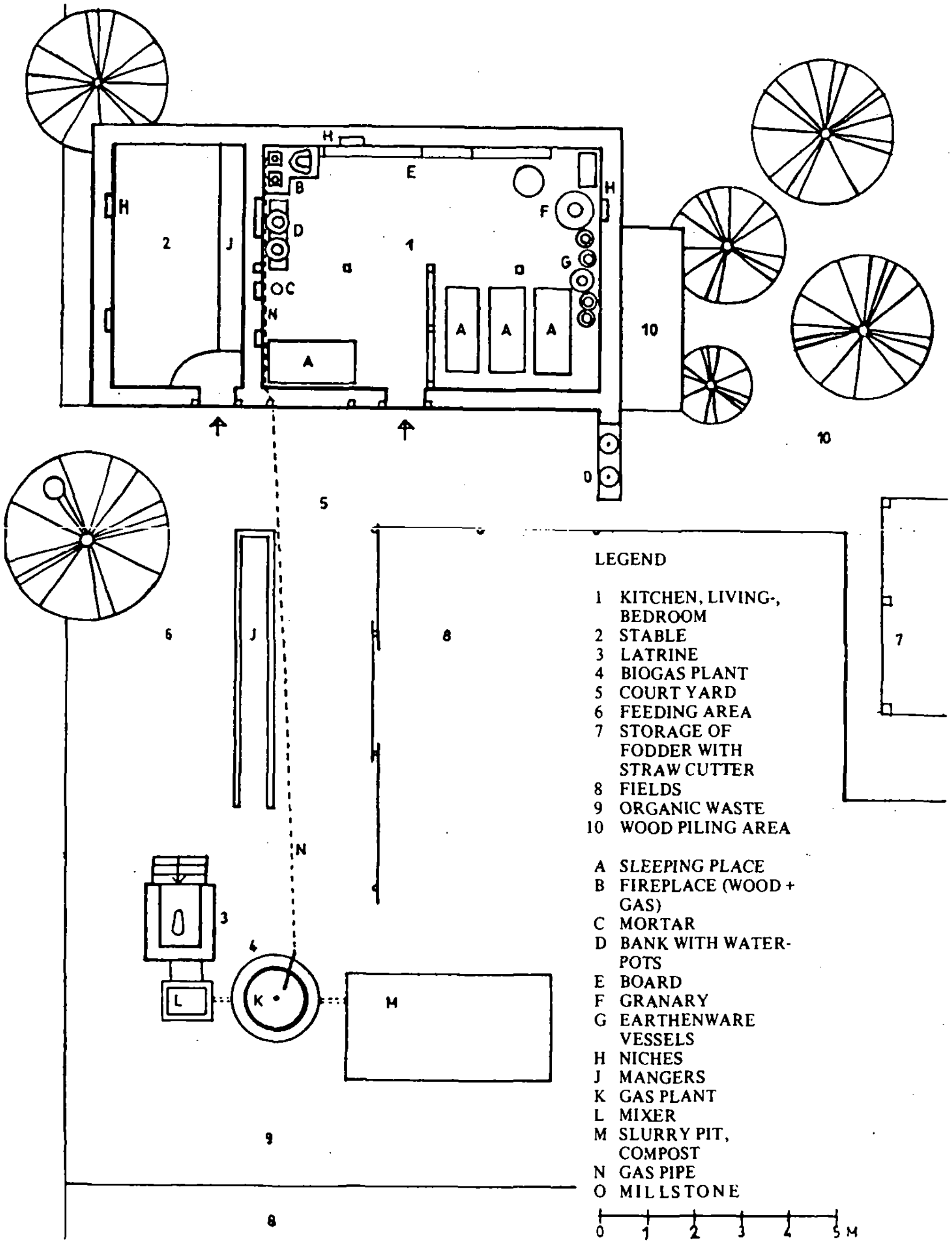


Table 44: Farmhouse with biogas plant in India. Given the prevailing situation, toilets may be attached to the biogas plant without problems

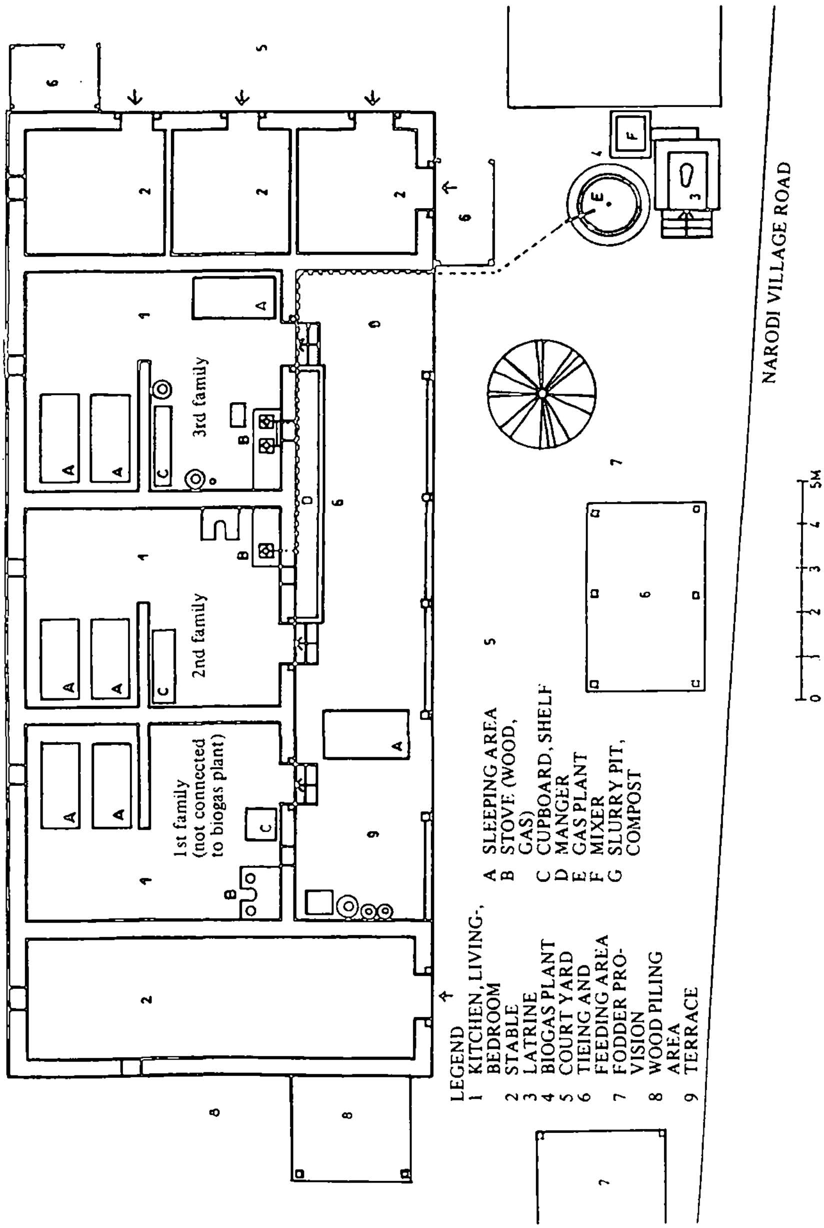


Table 45: *Neighbourhood plant in a multi-family rural house. The first family could not decide for biogas yet. This did not prevent the neighbours, however, from realizing the most appropriate for the time being, namely the cost saving neighbourhood plant.*

Especially suitable for effective utilization of night soil in biogas plants are infrastructural official buildings, permanently attracting a great number of people such as, for instance, railways stations, bus stops, schools, hospitals and markets. Location is of special importance in this connection, as soiling is to be reckoned with. Regular maintenance has to be given preferential consideration in planning.

The waste water of laboratories, as for instance, from hospitals and secondary schools must not be fed to the biogas plants. Special absorbing wells are to be provided for this purpose.

Settlement planning correlations are of particular importance for community plants. Social, economic and esthecical demands are to be brought into relation with one another. The efficient operation of the biogas plant is, if necessary, to be secured through compromises without thereby creating negative effects on the environmental conditions.

The distribution of costs and yield of a community plant directly depend upon the location selected. On grounds of social justice the right location is therefore of utmost importance.

Due to the characteristic settlement structure in slum areas, suffering from lack of space and overpopulation, community plants represent the only possible solution.

Legal domiciles for the slum population is unavoidable prior condition for participation in a community plant.

In already existing or to be built settlements, personal efforts are an essential factor in cost saving implementation of biogas plants. Contact centres and organisational examples for working groups as well as training courses can offer effective guidance.

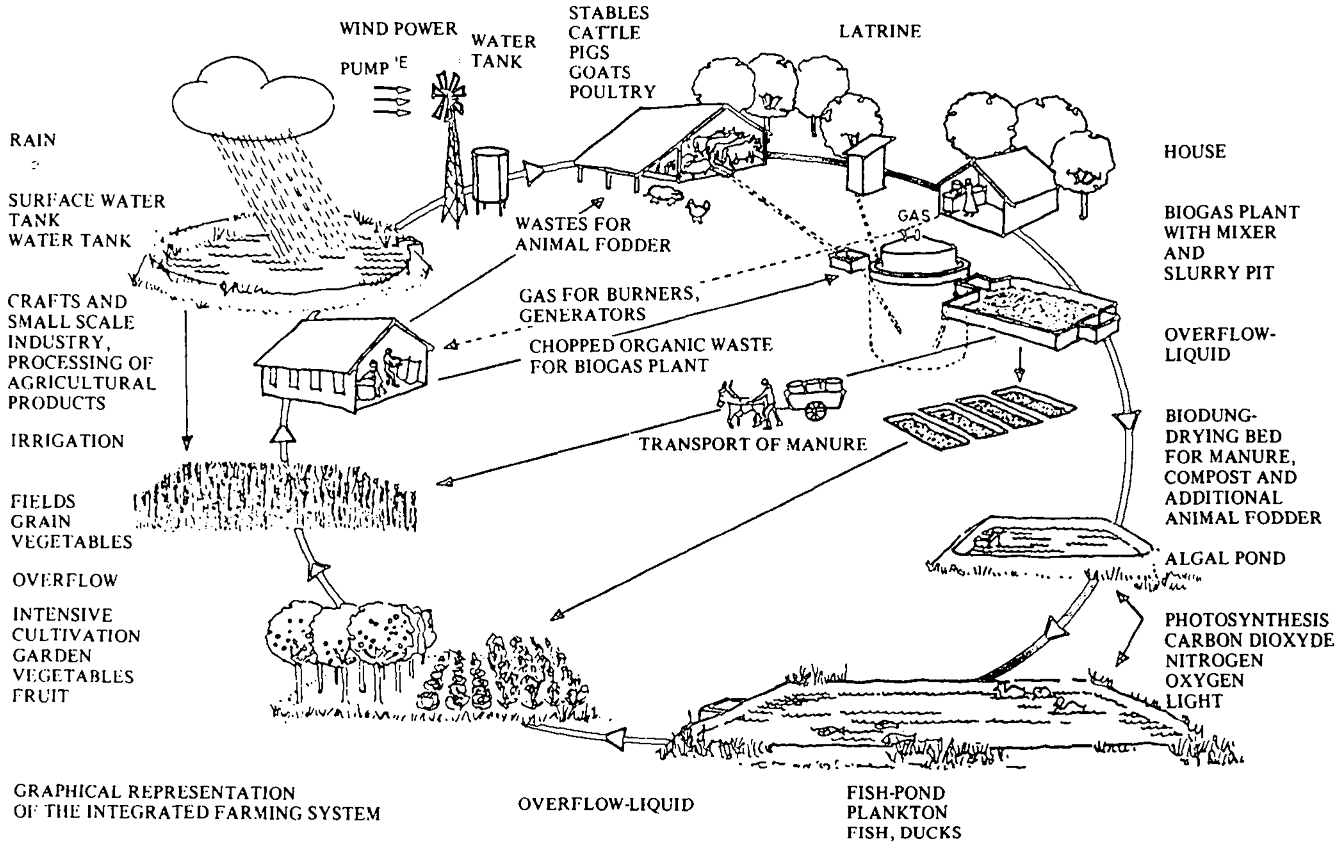
5.5. The Integrated Farming System

The question of location gains particular importance if all advantages of the biogas plant are to be made use of. This is to a high extent the case in the framework of the Integrated Farming System.

The Integrated Farming System secures, if correctly functioning, an almost autarkic way of life offering high standards of living under human conditions.

The Integrated Farming System comprises gas, forage and food stuff production as well as algal cultivation and pisciculture. The use of "weeds", as for instance water hyacinths, can be integrated herein.

Table 46: The Integrated Farming System



The basic principle of the Integrated Farming System has to be applied also in the case of less complex situations. Reforestation and irrigation programmes, for instance, encouraged by the introduction of biogas, have to be orientated towards coherent and overlapping general development.

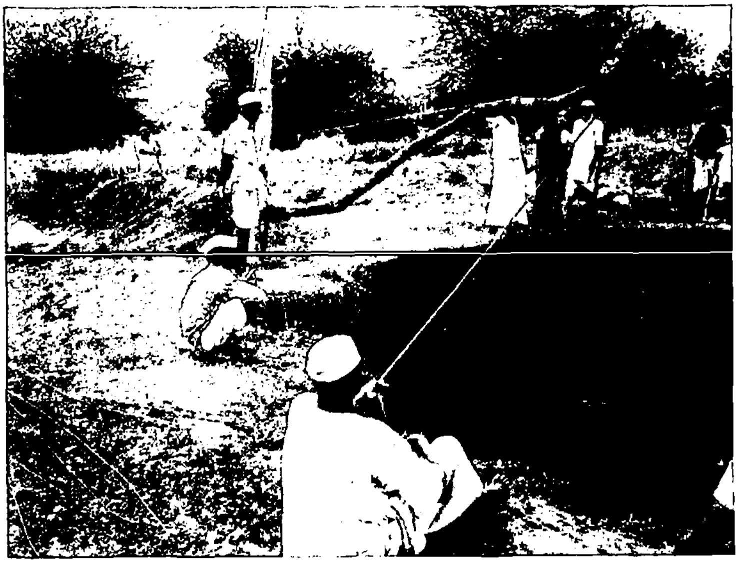


Fig. 28: Due to the biogas plants in this Indian village, the availability of manure has increased considerably. Irrigation of fields is even more worthwile. Deep wells have to be dug in order to secure the water required for the new irrigation system throughout the whole year. The positive incitation effected by the biogas plants, creates activities and new hope to materialize lasting improvements in the rural areas.

Biogas plants are part of the general development of a region. They can either be the consequence or the causing factor, of coherent, self-help processes. In this connection the type of technical system of the plants is only one question amongst others to be answered. Whatever plant proves to be the more favourable solution in view of the specific conditions of a region, depends upon the politically responsible and their decision as to whether the implementation of the biogas technology with its multiple advantages for prosperity of the whole country will succeed or whether the majority of the people, will also in the future, be deprived of the blisses of development programmes.

Appendix

6. APPENDIX

6.1. Formulas and terms

Heat

1 kcal = amount of heat needed to heat up 1 liter of water by 1^{o} C
1 kcal = 4187 Ws = 4187 J
860 kcal = 1 kwh

Performance

1 kw = 1,36 PS = 100 kpm/s
1 PS = 0,736 kw = 73,6 kpm/s

Work

1 kwh = the performance of 1 kw for the period of time of 1 hour
1 kwh = $3{,}6 \cdot 10^6$ Ws
1 Ws = 1 J = 1 Nm

Pressure

1 mWS = 1 m water column = 1 Mp/m^2 = 10 kp/cm^2 = 1 MN/m^2
1 at = 1 kp/cm^2

Units of measure

1 m^3 = 1 cbm = 1000 l
1 l = 10 cm x 10 cm x 10 cm = 1000 cm^3 = 0,001 m^3
1 m^3 = 35,31 cft
1 cft = 0,0283 m^3

Geometric formulas

Circle plane $= \pi r^2 = \frac{\pi d^2}{4}$
periphery $= 2 \pi r = \pi d$

rectangle plane $= a \cdot b$
periphery $= 2 (a + b)$

Cylinder volume $= \pi r^2 \cdot h$
surface area $= 2 \pi r \cdot h = \pi d \cdot h$

volume $= a \cdot b \cdot h$
surface area $= 2 (a + b) \cdot h$

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6.3. Addresses of importance

FEDERAL REPUBLIC OF GERMANY

Deutsche Gesellschaft für Technische Zusammenarbeit (German Association for Technical Cooperation) Postfach 5180 6236 Eschborn	Implementation of projects of technical cooperation of the Federal Government
German Appropriate Technology Exchange (GATE) Postfach 5180 6236 Eschborn	Transfer of technology
Deutsches Ministerium für wirtschaftliche Zusammenarbeit (Federal Ministry for Economic Cooperation) Karl-Marx-Straße 5300 Bonn	Division of Federal development policy
Bremen Overseas Research and Development Association (BORDA) Übersee-Museum Bahnhofsplatz 13 2800 Bremen	Studies, consultance, project implementation in the field of biogas
Senator für Wirtschaft und Außenhandel — Landesamt für Entwicklungszusammenarbeit — (Ministry for Economic Affairs and Foreign Trade of the Free Hanseatic City of Bremen — State Office for Development Cooperation —) Slevogtstr. 48 2800 Bremen	Project Appropriate Technology, Bremen Cooperation with developing countries
Interdisziplinäre Projektgruppe für angepaßte Technologie (IPAT) (Interdisciplinary Project Group for Appropriate Technology) Technische Universität Berlin Straße des 17. Juni 135 1000 Berlin 12	Research, studies, consultance, project realisation in the fields of appropriate technology and biogas

Lehrstuhl für Entwicklungsplanung und Siedlungswesen der Technischen Universität Braunschweig (Institute for development planning and settlement)	Planning and construction in developing countries
Bundesforschungsanstalt für Landwirtschaft (FAL) (Federal Research Institute for Agriculture) Institut für Landmaschinenforschung Bundesallee 50 3300 Braunschweig	Research in the field of biogas (Biogas research coordination in the Federal Republic of Germany)
Deutscher Entwicklungsdienst (German Development Service) Kladower Damm 299 - 325 1000 Berlin 22	Supplies experts for technical aid (voluntary agency)
German Embassies German Consulates	Supply information on governmental and non-governmental agencies, financial aid, etc.

EUROPE — USA

Institutions, working in the field of appropriate technology

TOOL Postbus 525 Eindhoven NETHERLANDS	Development of appliances for appropriate technology, projects abroad, technical consultance
Intermediate Technology Development Group Ltd. 9 King Street London WC 2 E UNITED KINGDOM	Development of appropriate technology appliances, testing in multiple projects abroad, technical consultance
VITA 3706 Rhode Island Avenue Mont Rainier Maryland 20 USA	Supplies on request solution to technical problems, technical consultance

ASIA

Khadi & Village Industries Commission Gobar Gas Scheme Irla Reas, Vile Parle Bombay 400 056 INDIA	Institution for promotion of biogas in India; great experience and many technical publications, supplies experts
Planning research and Action Division Kalkandar House Lucknow U.P. INDIA	Research and implementation of biogas; published technical manuals and supplies experts
National Committee on Science and Technology Government of India New Delhi INDIA	Responsible for research coordination in India; decision taking agency
Association of Voluntary Agencies for Rural Development (AVARD) c/o Sarfdajung Development Area New Delhi INDIA	Consultance and technical aid for projects of rural development
Maya Farms Angona, Rizal PHILIPPINES	Large scale farm with 20 biogas plants; organized training courses and implementation
Dian Desa Group Jalan Kerto Muja Muju 8 Jogjakarta INDONESIA	Implementation of rural development projects with biogas
Ministry for Agriculture Division of Soil Science Mr. Joshy Kathmandu NEPAL	Biogas Agency for Nepal; know-how of biogas plants in colder regions

AFRICA

GTZ
Biogas Project
Kamerun
Mr. Wesenberg

Testing of various biogas systems in Africa

Arusha Appropriate technology Unit
(AATU)
P.O.Box 764
Arusha
TANZANIA

UNITED NATIONS ORGANISATIONS

United Nations
Industrial Development
Organisation (UNIDO)
P.B. 707
1011 Wien
AUSTRIA

ESCAP
Sala Santithan
Bangkok 2
THAILAND

FAO
Food and Agriculture Organisation of the
United Nations
Via della Terma di Caracalla
Rome
ITALY

WHO
World Health Organisation
1211 Geneva
SWITZERLAND

UNDP
United Nations Development Programme
One United Nations Plaza
New York
USA

6.4. Source directory of the tables and photos

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