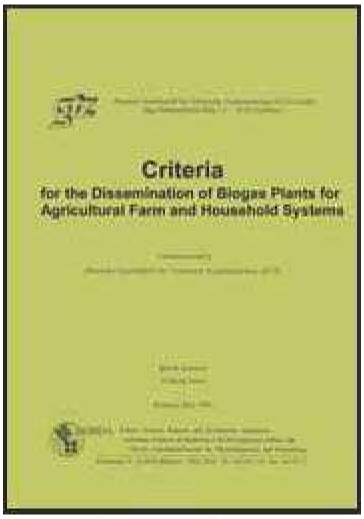

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1. Preface

This list of criteria is to give technicians, economists, agricultural engineers and social scientists the opportunity to assess the feasibility and possible structure of a project for the dissemination of **biogas** technology. The most important details are explained to readers who are not familiar with this technology. Experienced **biogas** experts will be able to use this to refresh their memory when working abroad. The most important questions are contained in the chapters "Criteria" and in "Data collection".

This work focuses on dissemination programmes for simple household plants and medium-sized plants with simple technology which is suitable for use on small and medium-sized farms.

Technically extensive plants equipped with heating, control, pumps or other devices are not being treated here. These are more individual solutions for industrial plants, larger settlements and large-scale farms whose wastewater constitutes a hazard to the environment or the health of the population. Technical personnel have to define the conditions essential for reliable operation in such cases. A description of the criteria relevant here would be beyond the scope of this publication.

Basically, the problems of the target group define the selection of the measures necessary or the technologies to be applied. A technological concept for **biogas** dissemination programmes has been agreed upon, which involves the target group being described and identified. After the extent, the method of production and the life style of the target group which can actually be reached are known, the technology has to be modified to correspond to these. This modification not only includes the technical variations but also the integration of the **biogas** plant into the prevailing agricultural farm and household system. To guarantee the efficiency of a dissemination programme it is essential to extensively standardise the technical components.

The most important problem areas can be defined as follows:

- structural-political conditions (in particular the political willingness and financial resources of administrative bodies and governments to become involved in **biogas** dissemination)

- structure, competence and budget of the institutions participating in the dissemination programme

- extent, structure and economic situation of the target group and the socio-economic conditions in the project region (to define the **biogas** potential)

- the time available for individual project phases

- the construction costs of the **biogas** plant and the costs of the dissemination structure

- the potency and competence of local building and craftsmen's trades

- the availability of the building materials and the gas appliances necessary

Normally, the projects only have a small degree of influence on these parameters, which consequently have to be initially accepted as given and unchangeable.

The following tasks have to be solved during the course of a **biogas** dissemination programme:

- precise familiarity with the a.m. problems

- selection, modification and continual improvement of the technology to be applied in line with the problems recognised

- definition of the plant potential and the area and time within which this potential is to be exploited

- definition of the components which can be realistically handled by the project and those which are to be passed on to other parties (private economy, extension services etc.) either initially or during the course of the project.

- definition of a dissemination structure which takes the potential, the funds available, the economic building situation and the individual features of the institutions involved in dissemination into consideration

- compilation of a scenario for sustainable dissemination activities subsequent to the end of the project.

It is imperative to identify favourable locations and to realistically estimate the suitability of counterpart organisations for the sustainability of the dissemination of the technology. Wherever a number of question marks appear, the project should be dispensed with in view of saving the resources which are in short supply. A decisive factor in successfully assessing a project location is ultimately the sensitivity for how the local conditions can be harmonised with the demands of **biogas** dissemination.

This publication is consciously limited to being an initial aid in deciding for or against a **biogas** dissemination programme. It attempts to outline the tasks involved according to the problem areas using examples in some cases. It would be an error to believe that a general catalogue of relevant criteria could contain all possible constellations with the aid of questions and answers and still remain manageable. Nevertheless, we hope this work will be of assistance to our colleagues. We always welcome any ideas or criticism.

Bernd Gutterer Ludwig Sasse

2. **Biogas** technology

2.1. Digestion

Biogas plants are an element of a waste recycling concept in which a part of the organic matter is converted into energy during a process of fermentation. In addition to the production of a high-grade source of energy, quite comparable to bottled gas, the biomass is processed into a valuable fertilizer referred to as slurry. A household **biogas** plant is normally a closed container in which animal and human excrement ferments under air-tight conditions. Theoretically, all organic materials can ferment or be digested. Only homogenous and liquid substrates can be considered for simple **biogas** plants: faeces and urine from cattle, pigs and possibly from poultry and the wastewater from toilets. When the plant is filled, the excrement has to be diluted with about the same quantity of water, if possible the urine occurring should be used. Waste and wastewater from food-processing industries are only suitable for simple plants if they are homogenous and in liquid form. During the digestion process, various kinds of bacterial cultures which harmonise with each other split large molecules typical for organic materials into smaller and more simple molecules in phases. The two main phases of this process are the acidic phase during which mainly CO_2 is formed and the methanogenic phase. The quality of methanogenesis is centrally dependent on the carbon-hydrogen ratio of the substrate and on the bacterial communities existing in the substrate. Cattle dung is favourable for the beginning of methanogenesis. So-called starter material should normally be added to all other substrates to initiate the process. Starter material, which should comprise 10 - 20% of the total organic mass, can be cattle dung or slurry from a **biogas** plant which is already in operation.

Bacteria are living organisms which are dependent on certain environmental conditions. They can be poisoned by antibiotics, heavy metals, acids and detergent solutions which could, under some circumstances, lead to a complete breakdown of digestion.

At too low temperatures, bacteria reproduce and work so slowly that no production of gas worth mentioning occurs. In general, a **biogas** dissemination programme is only feasible where mean annual temperatures amount to around 20°C or where the average daily temperature is at least 18°C. Within a range of 20° - 28°C gas production increases over-proportionately. If the temperatures are low, methanogenesis will slow down. If the temperature of the biomass is below 15°C gas production will be so low that **biogas** plants are no longer worthwhile. Conditions for methanogenesis will be more favourable if the temperatures do not fluctuate too greatly since a different family of bacteria reproduces optimally at different temperatures.

The technical reaction to low temperatures is normally to construct a larger digester to increase specific gas production by longer retention times and so to meet the demand for energy as well as possible in colder seasons. Larger digesters prolong the retention times (HRT = hydraulic retention time). The temperature fluctuations between day and night are no great problem for plants built underground since the temperature of the earth below a depth of 1 m is practically constant. A large digester volume also creates a better buffer effect against toxins. However, larger digester volumes are reflected in higher costs. On the whole, methanogenesis is a very hardy process and adapts easily. In practice, apart from too low temperatures and unsuitable feedstock, there are hardly any biochemical problems which are relevant in deciding for or against a dissemination programme.

During methanogenesis many of the odorous materials connected with animal husbandry and the spreading of manure are degraded. Thus, e.g. fertilising with liquid slurry is also possible in the proximity of settlements due to this anaerobic treatment.

In addition, some pathogens and weed seeds are killed. The biological oxygen demand (BOD) is reduced by up to 80% which is important for wastewater released into open waters. The pollution of surface and groundwater can possibly be substantially reduced by anaerobic treatment.

However, anaerobic treatment cannot be considered to completely purify the substrate. For this, other aerobic treatment phases or special processes would be necessary to e.g. eliminate phosphates, halogens or heavy metals. **Biogas** plants do not withdraw any plant nutrients from the substrate so that the fertiliser value of the original substrate is retained in total. During digestion, part of the total nitrogen is mineralised and can thus be more rapidly taken up by many plants. In a number of applications, slurry from **biogas** plants is even superior to fresh dung especially when the slurry is spread directly on fields with a permanently high nitrogen demand (e.g. fodder grasses) or when using slurry compost to improve the structure of the soil. When the slurry is dried a large proportion of the nitrogen is lost. For this reason, dry slurry is more suitable as fertiliser for roots and tubers than to generally improve the soil. How the farmers ultimately make use of the slurry primarily depends on the extent of transport and labour involved in spreading it and on their traditional methods of fertilising.

2.2. The biogas plant

Each **biogas** plant consists of the digester and the gasholder. The size of the digester depends on the amount of substrate occurring daily at given temperatures. The size of the gasholder depends on the daily gas production and mainly on the gas consumption times. For reasons of economy and construction, it is not feasible to store the gas over several days. For household plants, the digester volume (VD) is about five times as great as the volume of the gasholder (VG). The gas is fed directly from the gasholder to the burner through pipes. For reasons of costs and gas pressure, it is an advantage when the point at which the substrate occurs and where the **biogas** plant normally stands is not too far from the place where the gas is used. Saving **biogas** in pressurised containers or in bottles in liquid form is not economical.

There are three types of plant which would basically and technically be suitable for households. These are the floating-drum plant, the plant with a plastic balloon-type gasholder and the fixed-dome plant. Only the fixed-dome plant has proven successful for dissemination programmes for household plants as it is hard-wearing and requires little maintenance.

The technology of fixed-dome plants today - in contrast to earlier years - is no longer a great problem. The type of plant which has asserted itself in German development cooperation is the one developed by CAMARTEC in Tanzania with the so-called "strong ring" and the gas-tight dome plastered with the aid of cement agents. When this has been erected technically perfectly its service life is practically unlimited. Periods of 15 - 20 years are most frequently assumed for economic efficiency calculations. However, specific training of masons is necessary if this model is to be built to operate correctly.

In the fixed-dome plant, the gas is stored in the upper area of the digester. The gas then pushes part of the substrate into a compensation chamber. This then flows back into the digester as soon as gas is taken out. The compensation chamber is consequently the same size as the inner gasholder. The gas pressure then falls or rises depending on the quantity of gas stored. The gas pressure occurs due to the deference in level between the level of liquid in the digester and that in the compensation chamber. To avoid gas pressure which is too high, the maximum size of a fixed-dome plant with a digester-gasholder ratio (VD:VG) of 5:1 at about 50 m^3 VD. During construction, a household fixed-dome plant requires an area of about 7 by 4 metres. After construction has been finished, the plant will only take up a space of about 5 m^2.

For the floating-drum plant, which was previously preferred, the demands on quality in production can be met more easily. The corrosion on the steel gas dome which can hardly be avoided and the higher costs mean that this model is less suitable for dissemination. Even Indian entrepreneurs specialised in the construction of floating-drum plants are now beginning to build fixed-dome plants.

Experiments on replacing the steel by ferrocement, fibre glass or other materials currently have to be seen as unfruitful. Floating-drum plants today are only considered for digester volumes over 50 m³. The steel drum then floats in a water bath.

The plant with plastic foil is the most low-cost in its production but, due to its short service life, incurs high operation costs. **Biogas** dissemination programmes still using these plants need a secure service structure. In individual cases however, the foil plant has proven itself for larger plants (VD > 100 m³ (e.g. Ferkessedougou/lvory Coast).

2.3. Supply of dung and gas production

Biogas, consisting of 60% methane and 40% carbon dioxide, is a high-grade source of energy.

However, the calorific value is lower in comparison to bottled gas. One m³ of **biogas** only replaces about 0.4 kg bottled gas. One kilogram of cattle dung produces about 40 litres of **biogas** and one kilogram of pig dung about 60 litres of **biogas** per day. To produce 1 m³ **biogas**, 25 kg cattle dung or 17 kg pig dung are necessary. The amount of dung occurring is approx. proportional to the live weight of the animals. Random measurements of the amount of dung occurring per animal are essential to define the gas potential on the farm since the biomass produced per animal varies greatly from region to region. A zebu cow in Orissa/India provides e.g. about 5 kg dung per day; a Javanese zebu cow crossed with a Friesian for high milk output, in contrast, produces 15 kg per day. The amount of dung must be known to allow the energy potential occurring daily in the housing to be estimated. Where animals are put out to pasture during the day and only housed at night, experience shows that only about half of the total amount of dung occurs in the housing and thus is available for the **biogas** plant. Livestock systems, where animals are only out to pasture, cannot be considered for **biogas** plants as the collecting of the dung dropped is too labour-intensive. This would also mean depriving the pasture of the dung.

A **biogas** programme can only be considered for pig farming if the animals are kept in sties with concrete floors. It is more difficult to determine the quantity of dung than in cow sheds. The changing numbers also make rapid estimation of the substrate quantities more difficult. However, the number of brood sows often provides the basis for an adequate estimation.. In this respect however it is important to know whether piglets or pigs for slaughter are being reared. Pig breeders often normally know what quantities of dung occur daily or annually. As a rough idea, it can be assumed that each pig with a live weight of over 50 kg produces about 2.5 kg dung. The piglets are then neglected when counting, or they are counted in proportion to their weight.

Established values in literature which mostly comes from industrialised nations only rarely apply to developing countries.

2.4. The energy demand

Although simple **biogas** plants embody multi-functional agricultural technology, the benefit of energy is almost always primary in the farmer's decision to buy. The demand for fuel in the household - and with this the need for **biogas** - varies extremely from region to region. Whilst gas from household plants is used for cooking, lighting and cooling, larger plants could be interesting as agricultural inputs. Where there are larger quantities of gas (over 15 m³ per day), motors, incubators, heaters or generators can be operated by the gas. The size of the **biogas** plant will essentially be linked to the amount of substrate occurring. The gas consumption is then adapted to the gas quantity available. The recurring consumption patterns which are feasible and, primarily, which are realistic is a matter which will have to be investigated.

There are no overall and generally valid values for gas consumption since the consumption patterns and quantities depend on other energy supplies and on the possibilities and preferences for the utilisation of the gas. Lighting is particularly attractive for farming families in regions where there is no electrification. 0.5 m³ gas/per day should be assumed per **biogas** lamp.

The household demand for energy is greatly influenced by eating and cooking habits. Gas demand for cooking is lower in regions where e.g. preserved vegetables are eaten with white bread or millet soaked in milk than in areas where rice or beans are part of daily nourishment. The supply of energy from **biogas** plants reaches the limits of its capacity when cooking is carried out only once or twice a week and then as a supply for several days. This method is common e.g. in Central Africa for beans. The **biogas** plant would then have to be designed for this peak consumption pattern. A disproportionally large gasholder combined with a larger digester would correspond to this peak demand. For reasons of construction, this would lead to high costs particularly for the fixed-dome plant.

Although the women become quickly accustomed to using the **biogas** stove and can adapt to the use of this new source of energy without any trouble, substitution of conventional sources of energy by **biogas** also has its limits. In this respect, the following questions have to be answered: can the **biogas** plant, due to cooking habits, only meet a relatively low share of the energy demand? Does the source of energy which is otherwise used (firewood, charcoal) serve as a source of heating for the inhabitants during winter months? Does the smoke from the open fire conserve foodstuffs or control insects? Does the kitchen also serve as a smoking chamber?

The possible and probable substitution of firewood by **biogas** should thus be investigated particularly in programmes with specifically ecological objectives where the saving of firewood is a central question.

To define the demand for gas, the previous energy consumption can be taken as a rough value.

Here, the profiles of utilisation are to be compiled and these converted into **biogas** equivalents using standard figures and more exact measurements. The standard figures which are based on experience can be taken from the following list (cf. also the chapter on "Data collection":

Gas for cooking in an Indian or West African household:

1.3 to 2.5 m³/day (depending on family size and eating habits which also depend on the prosperity of the family).

Gas for cooking in an East African household: 2.4 - 3.0 m³/day

Gas requirement for one lamp for three hours: 0.5 m³/day

Gas requirement for one refrigerator (100 - 160 1): 2.8 - 3.5 m³/day

Gas requirement to produce electric energy in a generator: 0.8 - 1.2 m³/kWh

Gas requirement for power engines with 20% diesel: 0.5 m³/h* hp.

3. The biogas dissemination programme

3.1. Geographic and climatic conditions

As already mentioned, the most important geographical parameter for a **biogas** dissemmation programme is temperature. Mean temperatures of between 20 and 250C throughout the year with low seasonal fluctuations are the most favourable for **biogas** plant locations. As gas production tends to follow the curve of the average daily temperatures, the course of the temperature for one year will show the months for which insufficient gas production can be assumed.

Another favourable geographic characteristic for optimum use of the **biogas** plant is a slightly hilly terrain. In this case, the spreading of the liquid slurry will be possible due to natural slopes. Very rocky underground or a high groundwater table would be unfavourable. In both of these cases more work is involved in building the plant which also increases the costs.

3.2. The biogas plant in the agricultural farm and household system

3.2.1. The target groups

3.2.2. The demand for **biogas** plants

3.2.3. The potential

3.2.1. The target groups

When **biogas** dissemination began, the opinion was that **biogas** plants should be built wherever they were ecologically necessary and feasible (thus e.g. also in the Sahel). Today, after about 15 years of experience with **biogas** programmes, it is now known that **biogas** plants can only be disseminated where, as agricultural technology, they can become an integral element in the living and working world on the farm. This central condition for a **biogas** dissemination programme requires "**biogas** favourable" farm and household systems to have definite structural features. A typical and ideal location for a **biogas** plant could be described as a farm on which animals are permanently kept indoors and where, as far as possible, mixed farming is practised. The farmer is the owner of the farm and has the power of disposal over his land so that he is able to profit from the investment in a **biogas** plant over the long term. The cattle are kept indoors every day and are put to pasture for a few hours at the most. The amount of dung occurring on the farm amounts to over 30 kg fresh weight daily. The quantity of water necessary for filling the plant and corresponding approximately to the amount of dung, can be constantly obtained without any unreasonable amount of work, also by women and children; water is not in short supply. Stabling with a concrete floor from which excrement and urine can be directly pushed into the inlet tank of the **biogas** plant would be ideal. The floor of the stabling is high enough for the overflow of the compensation chamber to lie above the terrain so that the slurry can flow down a slope into the neighbouring fields where, as far as possible, fodder grass is grown. (The floor of the stabling has to be at least 35 cm higher than the overflow of the **biogas** plant). The toilet could also be connected to the **biogas** plant; there is no prejudice against a toilet being connected. The gas is used as regularly as possible and completely in the direct vicinity of the plant. Experience in the use of organic fertiliser would be of advantage for optimum utilisation of the slurry. It would be favourable for regular filling of the plant if the people using the gas and those operating the plant were identical. Although in recent years the technical concept has been more and more successfully modified to the needs of the users, e.g. increasing operator friendliness, the integration into the farm and household routines remains a central criterion for the selection of a location. Where and which compromises on the ideal "**biogas** farm" described above are possible depends on very many factors which have to be examined in each individual case. (Colleagues with experience in **biogas** dissemination programmes should always be consulted in cases of doubt.) For example, the requirement of a short distance to the point of gas consumption could be deviated from. Long pipelines are only a cost factor and the function of the plant is retained even at distances of over 100 m (too great a loss of pressure can be counteracted by larger diameter of pipes). Also the connection to stabling favoured within German development cooperation is e.g. in India and Nepal, not a standard. Also toilets should only be connected to the **biogas** plants according to the express wishes of the customer.

Family structures could also be stated here as central criteria in the success of a dissemination programme. Division of labour and allocation of tasks in the household and on the farm according to sex, i.e. particularly the position of the women have to be carefully observed. In polygamous households where each woman has her own kitchen, the integration of **biogas** plants is hardly possible in the living and working world of the woman.

It is far less of a problem when the women take it in turns to cook in one kitchen. In this case it would be particularly important to investigate how the operation of the plant would be organised, or if coordination between the women is probable. If the women take it in turns to gather fuel, then operation of the **biogas** plant in turn could be organised. Despite this, it would have to be investigated who would be in absolute charge and whether, e.g. the first wife had the priority to supervise operation of the plant.

In Africa, the man is normally in charge of lighting in the household. In these cases, there could be a conflict of interests between the man and the woman concerning the use of gas for lighting and for the stove. The man who (normally) pays for the plant, naturally wants to save on his budget for lamp oil. The woman, who under some circumstances fills the plant and is in charge of firewood, wants primarily to use the gas for cooking. If there is no reconciliation of interests, the ruins of a **biogas** plant could appear on the farm in due course. It can be assumed that the woman who is responsible for cleaning the stabling, will neglect the plant if the husband insists on using "his" **biogas** plant for "his" light.

3.2.2. The demand for **biogas** plants

Although theoretically, all farms with the a.m. structural features may be considered for **biogas**, the actual dissemination is defined mainly by how willing the farmers are to invest in this technology. For the farmers, the **biogas** plant is a capital good binding a high amount of funds which will improve the energy, agricultural and hygienic situation of his farm and of his household. The attraction of a **biogas** plant for the farmers initially stems from the use of the gas. In view of this, dissemination concepts focussing on the utilisation of slurry have hardly been able to move the farmers to an investment unless some kind of simultaneous energy benefit, which was in a ratio to the amount of the investment, existed. Favourable regions for **biogas** dissemination have proved to be where farms have a bad supply of energy sources, but where a healthy economic substance exists. In these regions, the factor "comfort" plays a considerable role in the development of the demand - in particular on farms with a high to medium farm or family income.

The **biogas** lamp as a source of light cannot compete with an electric light bulb. A connection to the electricity supply however does not have to be a reason for excluding a possible **biogas** programme. A low-cost **biogas** plant can turn out to be an interesting investment especially in regions where the fossil sources of energy are traded at high prices.

It is difficult to reach small farms with a low capital background with dissemination programmes although these farms, in comparison to the economically stronger ones, often suffer from a bad supply of energy. Their insufficient solvency and their weak capital background make the purchase of a **biogas** plant costing several hundred US dollars a hurdle which is often too high to take. The poorer classes of smaller farmers could only become members of the target group in India where subsidy programmes could be implemented on a long-term basis and in countries where the prices for plants are very low. To link the introduction of a new technology directly to the social question has proven to be a demand which could rarely be fulfilled in reality in past projects.

In the initial phase of a dissemination programme at least, orientation to economically more healthy farms seems advisable. They can be the forerunners which' when the technology has been established and no longer constitutes an investment risk, the weaker farms could possibly follow.

3.2.3. The potential

The development of demand is, on the whole, part of a long-term process during the course of which **biogas** technology grows into a generally accepted part of agricultural technology. Experience in India has shown how approx. seven years pass between the introduction of the technology to one region and the appearance of a dynamic demand. A dynamic demand develops where high potential exists. The potential increases with unfavourable energy supply conditions and with the number of farms (families) with sufficient livestock and a high and secure income from their farms. Important in estimating the potential is not only the expected number but also the possible density of **biogas** plants. If a high density of potential "**biogas** customers" exists, the positive demonstration effects of the plants within the rural region influence the development of demand more rapidly. Apart from this, the potential density of plants and the potential number are important basic values when calculating the infrastructural demand of the dissemination programme. If the farms of potential **biogas** customers are scattered throughout the region, a greater demand can be expected on customer acquisition, advisory services and servicing. If ultimately only a few plants could be built the infrastructural expenditure for **biogas** dissemination would be in an unfavourable ratio with the macroeconomic benefit expected. Critical orientation values pro or contra a dissemination programme could be if less than 10% of all farms in the region were "**biogas** capable" or if less than 3 farms per km^2 could be considered for a **biogas** plant.

3.3. Dissemination structure

3.3.1. Dissemination Institutions

3.3.2. Craftsmen's qualifications

3.3.3. The availability of building materials and gas appliance

3.3.4. Standardising **biogas** plants

3.3.5. Government consultation.

Even if today the technical performance of **biogas** plants no longer constitutes a problem, and even if regions favourable for **biogas** can be relatively easily identified, the establishing of an efficient and sustainable dissemination structure continues to remain the key problem of numerous **biogas** projects. The success of a dissemination programme is not only calculated from the total number of well functioning demonstration plants plus farmers who are interested and are able to pay for plants plus trained masons. **Biogas** technology is in need of a professional dissemination structure to offer the product **biogas** plant, to supply it ready to function and to provide an adequate "after-sales" service. The **biogas** plant must be a quality product and requires the relevant measures. To be able to keep to the quality standard demanded, the interaction of various components (execution of building, planning, advisory service) is essential. The importance of this central point cannot be stressed enough. A newly introduced technique or technology is normally continuously optimised by manufacturers and users during the course of time and finally improved to attain the utmost maturity. With **biogas** plants however, it is imperative for the technology to be more or less perfect from the beginning, i.e. a plant must be gas-tight in every case, inlet and outlet must not become blocked and the gas pipes have to be laid so that no condensed water blockages occur. If these basic requirements are not met, the plant will not only operate more badly - it will not function at all. (The fact that plants can still be optimised by technical improvements is not contradictory here.) These process control necessities ultimately define the technical building standards which the dissemination structure must guarantee. In the initial phase, the executing organisation will have to carry out considerable tasks: technical modification, advice of potential customers, liaison with and qualification of the private sector, quality control, promotional measures towards developing a market etc. Although it should be made sure at the planning stage that the private sector is integrated as far as possible into **biogas** dissemination, independent artisanal tradesmen will only disseminate plants independently in exceptional cases. Dissemination of **biogas** plants by the private sector will need institutional support in the medium term. Only in programmes during which a market had been developed by institutional involvement was **biogas** technology interesting for the private sector. However, the profit margin for the simple household plants is so small that complete integration of the technology into the private sector will be very improbable in the long term without financial assistance from third parties in the form of topping-up funds. A cooperation between the private and the public sector will then be essential. The dissemination organisation is ultimately to contribute to creating an economic relationship to provide **biogas** plants with the quality standards described and in line with the potential demand. This also includes extension services and possibly backstopping for the craftsmen in the realms of organisation, calculation and technology.

3.3.1. Dissemination Institutions

As the potential customers all keep cattle and considering that **biogas** technology has the character of agricultural technology, it seems obvious to entrust those organisations with **biogas** which are normally in direct contact with the farmers. The proximity to potential user groups is an elementary criterion for the selection of the organisation or institution. Normally it is the agricultural development organisations or their extension services which are in constant contact with the farmers.

The organisations which also have a particularly favourable background are those who have experience in technical innovations and their demands on dissemination policy. These organisations normally have experience in integrating or the institutional authority to integrate credit programmes in the context of their business relationships with the agricultural development banks.

The demand for integration of **biogas** dissemination into agricultural development organisations can, of course, not be prescribed basically, as the extension services vary greatly in organisation and manpower from country to country. What is decisive when making the selection is that the institution entrusted with this not only has the organisational capacity, the proximity to the target group, the financial backing but also and primarily, the interest in the **biogas** dissemination planned which will make it a motor in the development and not a brake.

Especially where matters concern budgets, cooperation between organisations under various ministries is feasible and often also desirable. Distributing competences to varying executing organisations, e.g. to energy agencies and agricultural agencies simultaneously, is often anything but smooth. Any division of tasks has to be organisationally established by clearly allocating tasks and lines of competence and communication.

As the success of the project depends directly on the counterpart organisations identifying themselves with the technology, long-term interest should be a central criterion in selecting the dissemination institution. What is often overlooked where projects of technical cooperation are concerned, is the fact that the mandate of the counterpart organisation is not the dissemination of the technology per se but to solve problems identified on highest political levels in line with the situation. **Biogas** technology can be the solution to a problem here. However, it is e.g. not the task of a water conservation authority to build **biogas** plants, but to identify and execute measures geared to protecting water resources. Likewise, it is not the job of national energy authorities to build **biogas** plants but to find solutions to quantitatively and qualitatively improve the supply of energy in rural regions. In the past, counterpart organisations not infrequently lost interest after abstract dreams of wanting to build some thousand plants within a short period had vanished and reality, despite intensive work, resulted in only twenty plants per year. Particularly in planning within the organisations which think in terms of nationally and quantitatively impressive categories, the qualitative benefit of **biogas** plants to the individual farms is of little importance. In this respect, organisations working with the farmers on a daily basis, have a far better view of the situation.

3.3.2. Craftsmen's qualifications

The building of the plant itself should be placed in the hands of the private sector. Whether it can work independently of institutional support and supervision is a matter which is ultimately defined by qualifications, the profit margin and the interest of the craftsman in handing over a **biogas** plant to the customer which is able to function. Qualifications, mainly of the masons, is very significant where fixed-dome plants are concerned. Supervision of construction can only be dispensed with in cases where self-employed entrepreneurs are interested in the quality of the plant and this is linked to guarantee agreements. Normally, a separate building control capacity is indispensable if the gas-tightness of each plant is to be guaranteed.

In areas where loam mortar is used for building training is absolutely essential in the field of craftsmanship. It can be assumed that masons who are used to working with cement or lime-sand mortar are in possession of the necessary skills. A dome construction which appears complicated is far easier to build than a straight or cylindrical. On the other hand, it cannot be assumed that skills exist for particular skills for particular details of construction. The masons are in need of clear instructions on mixing ratios, the quality of bricks and, mainly, on plastering methods for the gas-tight dome. If the masons are able to read and write (as e.g. in Java), and are accustomed to working from drawings their training becomes far more simple. Intensive explanations of the drawings combined with a visit to a **biogas** building site could be sufficient here. If it cannot be assumed that this knowledge exists, the masons will have to be trained intensively not only in the field of quality but will also have to be made familiar with construction dimensions. In this case a **biogas** programme has to rely on a permanent team of trained and constantly upgraded masons who do not always have to be specialised in the construction of **biogas** plants.

3.3.3. The availability of building materials and gas appliances

An important factor of sustainable **biogas** dissemination is the local availability of suitable building materials. Basically, good bricks, clean sand, Portland cement and cement agents for waterproofness (which also guarantees gas-tightness) are needed. An advantage also, but materials which can be substituted, are gravel and stones from the fields, bricks can be replaced by cement blocks. If these materials are not among locally available ones they can normally then not be obtained at affordable prices. In this event, a plant modified within the scope of an R&D project may have to be developed. Only subsequent to successful development which has to be oriented to the economic capabilities of the country, can the question of a dissemination programme be considered again.

Where water pipes exist, the acquisition of gas pipes provides no problem. As **biogas** is stored and transported only under low pressure, practically all water pipes are suitable for use as gas pipes if the pipe connections can be made gas-tight. Most favourable in this respect are PVC pipes bonded with couplers as these are inexpensive and easy to handle. In contrast, good-quality ball valves for use as main gas cocks are rarer - because they are expensive - on local markets. As each plant only requires one or two such cocks, these could be easily obtained centrally. What is important here is that these are ball valves and not stop valves. The best ones are here only just good enough even if their price sometimes amounts to 2 or 3% of the total cost of building. If the material is available generally, this will have a decisive influences on continuation of building after the project has finished. If gas taps and especially gas appliances are difficult to obtain after the end of the project, e.g. when no convertible currency is available, this can lead to serious problems. Direct imports of gas appliances from India, Brazil or China should only be allowed during the demonstration phase of a project as an interim solution; or if large quantities are needed constantly where a private dealer could set up a worthwhile sales system. Before thinking of imports however, investigations must be made into which locally available market products can be converted for use with **biogas** (e.g. pressure lamps, gas stoves).

If larger quantities of gas are available (over 15 m^3/day), the gas can be used in motors, incubators, heaters or generators. Such devices for using gas are normally not available on the local market. Kerosine and bottled-gas appliances can be converted for **biogas** with relatively few problems in simple workshops. When planning a project it must be remembered that every material which is not available on the local markets places extra demands on the structure of dissemination. The following questions should be answered here:

- can materials and appliances be obtained on neighbouring markets?
- can local dealers be commissioned to obtain material at affordable prices?
- can common market appliances be converted?
- or are imports necessary which cannot be carried out by local dealers?

3.3.4. Standardising **biogas** plants

Standardising **biogas** plants in the dissemiantion region is a focal element for a successful dissemination programme. Every **biogas** dissemination programme for household plants can and should restrict itself to standard sizes regarding digester and gasholder volumes (e.g. VD = 6, 9, 12, 18 m^3). Standardisation provides clear instructions for building and thus reduces the spectrum of individual improvisation. Individual planning for each plant is then unnecessary.

Standardisation is also possible for larger plants if the range of applications is limited. Where the amount of substrate available, the geographic location and the structure of potential farms greatly vary, individual solutions become essential. In this case, a technical planning office has to be set up within the dissemination programme to react to various demands with specialist knowledge.

3.3.5. Government consultation

Government consultation is a central and significant element in establishing a **biogas** programme. The government has to provide the material and financial basis for a **biogas** project by issuing directives and by providing a budget and has to place a mandate with other relevant state institutions as well as with executing institutions. Without such political will equipped with a budget, even the greatest interest of farmers in **biogas** technology, the most intensive involvement on the part of project staff and the best qualified craftsmen could hardly ever be converted into significant and sustainable dissemination. It is very improbable that, e.g. an agricultural development organisation would or could re-allocate its budget in favour of **biogas** technology without this kind of political and financial support.

On a state level, the complexity of **biogas** dissemination is normally underestimated. It is often referred to as "simple technology" and the essential personnel, organisational and financial investments are overlooked. Added to this, there is the problem that the benefit of the technology when the project is handed over is modest, in view of a few dozen plants which had been built contrasting with the targets globally formulated at planning workshops like "reduction of logging", "improvement in rural energy supply" or "substitution of fossil sources of energy". Especially where the supply of energy is concerned, **biogas** projects and **biogas** technology are often greatly overestimated. In hardly any country in the world does **biogas** technology provide more than 5% of the total rural energy demand, more probable is a share of 1 - 2%, and this only provided that an efficient **biogas** dissemination programme can be set up. The benefit of **biogas** technology is primarily derived for individual farms from the provision of infrastructure with diverse positive factors (energy, hygiene, less work, modernisation of the household, improvement in agricultural production etc). The availability of this ecological waste recycling concept increases the level of self-sufficiency and the availability of resources for the farm and the household, and by achieving this, ultimately improves the efficiency of regional agriculture. In this respect, the broad qualitative aspects of **biogas** technology can, over the long term, constitute a quantitative benefit for the overall economy.

In view of this, government consulting has the task of making the benefits of this technology and the efforts necessary for its dissemination transparent. Glossing things over proves to be counterproductive in the long run, too high expectations later turn into disappointment and lack of interest.

Solely the number of plants built and actually in use will show the macroeconomic benefit. It must be emphasised that the construction of **biogas** plants during the consolidation of the dissemination structure and the formation of a market is only hesitant. This relatively low rate of growth compared to the infrastructure expenditure however, becomes overproportional when a demand has formed and the supply level has proved to be efficient. The establishing of a dissemination structure should be seen and communicated as an initial investment which will only begin to amortise after a certain duration. If, e.g. a **Biogas** Office with established posts for one engineer and two technicians, is formed in one region, the construction of only ten plants per year can be expected. With the consolidation of **biogas** technology in rural regions and the increasing efficiency of the dissemination structure, the construction of several dozen per year will be the next step and, when extended to other regions, a production of some hundred plants per year will follow. What is important, is to compile a dissemination concept with the state to conform to the rural productive powers. In this respect the following questions are important:

- which tasks should be taken over by state agencies permanently and which temporarily?

- what role can the private sector actually play?

- or is it more favourable to support dissemination by non-governmental organisations?

It should be remembered that with such a dissemination concept the financial aid from the state (subsidies, tax relief etc.) increases individual profitability, accelerates demand and thus improves the infrastructural expenditure through a lower advertising expenditure, and finally allows a better ratio of plants built to the investment of resources. Financial aid is very often the cheapest way of promoting **biogas**. The scope for decision the governments have regarding such topping-up payments for individual plants, is nowadays often defined by structural adaptation measures and sector priorities defined over the long term in addition to the actual state household position.

3.4. Larger plants

So far, the household plants mainly focussed on have ranged from 6 to 20 m^3 VD. What has been said so far also applies to plants for larger farms. For an analysis of potential, the larger plants have to be seen in relationship to their higher costs of construction. For these plants, greater involvement of the private sector is possible due to the higher volume of the order and the relevant profit margin. For plants of this size, environmental aspects are frequently very significant, consequently the macroeconomic benefits have to be evaluated differently. For the clarifying of wastewater, there is no alternative "yes or no", but only different, competing technical processes. Anaerobic processes, i.e. **biogas** plants, are here only one of many options. However, they do have the advantage of needing only a small amount of space and do not consume energy in warm countries, but provide it.

4. Selected case studies

The following case studies are to illustrate the interaction of the various factors described above by means of concrete experience gained during dissemination programmes or projects.

4.1. Location: Sechuan/southwestern China

In China, **biogas** plants are built under the pigsty. The kitchen is in the direct vicinity of the plant. The toilets are always connected to the plant, meaning that the plant also serves as a septic tank. The liquid slurry is scooped off every day. This method, involving a great amount of work, is only possible because human excrement has been used traditionally as a fertiliser without taboos for hundreds of years. Buckets of liquid manure are carried on a yoke, something which would be impossible in predominantly Islamic countries. In this region the **biogas** plants are promoted by the state and the province by means of mass campaigns and dissemination programmes and have thus become part of normal agricultural technology. The purpose of promotion was mainly to improve the energy situation of rural households who found it difficult to meet their demand of energy due to high population density and the bad supply of firewood and fossil sources of energy. Apart from this' the "comprehensive" use of **biogas** plants, i.e. the efficient use of the slurry, was promoted. Since almost complete privatisation of **biogas** dissemination and the better supply of energy for rural households, the number of plants disseminated per year has fallen from several ten thousands to some thousands. The lower profit margins in rural areas are leading to an increasing number of qualified entrepreneurs moving to urban areas to construct wastewater plants.

4.2. Location: Orissa/Central India

The **biogas** plant stands somewhere on the farm, often near to the kitchen. The cattle are tethered in the open air. Many farmers have their own wells, or the village well is in the near vicinity. The women collect the dung with their hands from the ground and dilute it with water mixing the substrate - also with their bare hands. This method is only possible because cow dung is seen as being "clean". There is a long tradition of plastering the floor in the house and the terrace with cow dung every week. Dried cow dung is common as fuel. A **biogas** plant is very welcome as the dung can be used as a source of energy and also provides nutrients for the plants, which is not possible when the dung is burned. Collecting the dung daily and touching it with bare hands is the tradition in farm households. Where societies are not Hindu, this methods encounters great prejudice. The cattle are taken to the river to drink. This means they only leave small quantities of urine on the farm. In the summer months it is so hot and so dry that the slurry cannot be channelled to the fields in open ditches as it immediately dries up. The slurry flows into a depression where it is covered from time to time with agricultural or kitchen waste. During the preparation for seeding, the "compost" is transported to the fields by ox and cart. **Biogas** dissemination is possible here since the operation of a plant can be smoothly integrated into previous working procedures. In this region, plant dissemination is carried out mainly by one highly professionalised non-governmental organisation which employs approx. 500 permanent members of staff. There are approx. 2,000 trained masons available for construction at given points. Thanks to the integration of **biogas** technology in the administrative structures which considerably facilitates the acquisition of customers and the handling of finance matters, to the state subsidy programme and to the financial involvement of foreign donors who cover the costs of overheads, the organisation today disseminates approx. 8,000 plants annually.

4.3. Location: Korhogo/lvory Coast

The method of keeping animals and the climate here are similar to the situation described above in Central India. Despite this' **biogas** dissemination encounters great difficulties. Farmers and their wives are not used to collecting dung since there is plenty of fuelwood growing around the scattered settlements. Collecting wood means no extra work for the women as they bring it with them when coming home from the fields. The fields are often far away from the farms, there are no ox-carts. Organic fertilisation here is carried out by driving the cattle over the fields after the harvest. Cow dung is normally considered "unclean". There is a shortage of water and only few farmers have their own well. Under such conditions, **biogas** technology hardly has any chance of seeing a great demand. In order to make use of **biogas** extensively, the farmers would have to completely change their farming and working procedures. A complete re-structuring of the agricultural systems would be necessary: indoor stabling of dairy cows and a regular production of fodder grass would have to be introduced. The animals would have to be given water in the sheds to save water for the **biogas** plant;

the amount of work involved in looking after the cattle would have to be substantially increased. In addition to these problems on the demands side, there are also problems on the supply side. The agricultural extension services are in an overall structural crisis. The counterpart organisation, despite its high involvement, is not able to support a **biogas** programme with the funds it has available.

4.4. Location: Boyolali region/Central Java

The conditions at this project location in contrast are almost ideal. Normally, composting is carried out directly in the sheds by covering heaps of dung with straw and then pushing them to the side every day. Flies and insects in the sheds are quite common. The farmers are interested in a solution to this problem. A dairy cattle programme introduced by a private cooperative which attaches great importance to hygiene in the sheds makes it clear for the farmers that the compost heap in the shed can be an economic disadvantage. Organic fertilisation is a tradition and is carried out carefully. When a **biogas** plant is built, dung and urine are pushed into the **biogas** plant or collected outside the shed. The slurry overflowing, either flows directly onto the fodder fields or is processed into compost which can be transported. The composting of slurry only means little adjustment for the farmers. These favourable conditions are enhanced by a healthy economic situation of the farmers. The counterpart organisation also has expert competence and good access to the target groups. Highly qualified craftsmen also make it easier to establish know-how for building. However, future financing of the **biogas** programme is still uncertain. The task for the project here is to establish **biogas** technology also financially on a state level.

4.5. Location: Arusha region/northern Tanzania

The dissemination situation in the Coffee-Banana Belt of Mt. Meru in Tanzania is contradictory. A number of factors favourable to dissemination meet in this region. The area is marked by a bad development of the infrastructure. There is a need for an improvement in the supply of energy for farms and households. Large numbers of the target group carry out intensive mixed farming and have a relatively high income. Organic fertilising is hardly practised in the region. As the volcanic soils are rich in nutrients, the farmers can only be interested very slowly in organic fertilisation. One point on the programme of the project entails distributing the slurry to neighbouring fodder fields via simple irrigation ditches. In the region there are, in the meantime, approx. 250 well functioning **biogas** plants over a relatively small area which have made the **biogas** plant a well-known capital and durable investment. The demand is balanced by a competent supply. The project activities produced a number of well qualified craftsmen and technicians who now build plants independently of the counterpart organisation However, the price of the plant is an obstacle to widespread dissemination. With economic liberalisation, larger consumer and investment alternatives have appeared for the farmers with a higher income and have had a limiting effect on the development of demand. Although the government is interested in **biogas** technology, the future of the counterpart organisation is still uncertain due to the non-existence of state funds.

4.6. Location: Export zone in Agadir region/Morocco

A study of potential shows a favourable picture for **biogas** dissemination. This region of approximately 575,000 hectares has a theoretical potential of approx. 20,000 plants for all areas of application of agricultural **biogas** plants. Infrastructure as regards electricity is insufficient. A large number of the farmers in the target group have a good financial position. Agriculture is extensively promoted by the state. Although local craftsmen cannot provide the same standard of quality as e.g. in Central Java, the establishing of an efficient dissemination programme should prove to be no problem. Regarding water management, the region has been developed in the past by an efficient organisation with modern management and selective methods. However, if sustainable dissemination is to be achieved, a coherent policy on the part of the Moroccan government will be necessary. This policy will have to provide the agricultural development agencies with a mandate and will have to ensure financial security for a future **biogas** programme. Limiting factors here could be the relatively easy access to fossil energy sources and the too low temperatures in some regions during the winter months.

5. The project

Principally, **biogas** projects or **biogas** dissemination programmes should only be initiated where the technology corresponds to the geographical, economic and in particular to the agricultural background conditions, and where the projects can concentrate on key tasks. **Biogas** programmes should only be carried out where sustainable dissemination of plants can be expected and where the public expenditure is in a reasonable relationship with the benefits expected. Unfavourable conditions and half-hearted involvement of the public sector only waste the resources of the partner country and of development cooperation which are in short supply anyway. Projects of development cooperation normally contain an orientation and an implementation phase. For **biogas** dissemination in contrast, three phases are typical: the demonstration phase, the pilot phase and the dissemination phase. Which of these is part of the implementation or orientation phase depends on the project purpose in each case.

Experience has shown that the transition from one phase to the next is very difficult as certain structures quickly become firm. Whether this is the integration of the technology in the counterpart organisation which only partly succeeded because speed had priority over cooperation in the initial phase, or whether high direct subsidies for demonstration plants prevent plant prices being adapted to market prices step by step. If the sense of a dissemination programme is to be judged in a preliminary study, one has to be conscious of the difficulty of this transition. The decision on how long the pilot phase should last or may last, has to be made. Which costs are related to this and who is to bear these costs for how long. To abruptly end a pilot phase which has a good background of funds and then to pass on dissemination to the counterpart with only minimum funds has often led to the destruction of successful bases for dissemination in the past. Project concepts cannot be set up stiffly or as stereotypes. As has already been described, the introduction of **biogas** technology is rarely carried out in one step. E.g., it can be quite feasible to maintain a pure demonstration or pilot programme for some years if one assumes that the transition to dissemination will not be probable until after a second "attempt". Assuming this, the **biogas** programme has to be structured accordingly. In this case, motivation and advertising do not stand in the foreground, but the production of as high a number as possible of absolutely immaculately operating **biogas** plants. The costs for direct subsidies will definitely be equal to the costs for a long and hard advertising campaign. Planning plants to conform to the locations and the most perfect execution of construction combined with slurry and gas utilisation concepts tailor-made to the individual user are then the defining yardsticks for the success of this demonstration phase. It is the purpose of such a project to present **biogas** technology associated with a positive image in this region - no more, but mainly, no less!

5.1. The tasks of a demonstration phase

After a feasibility study, each programme begins with the construction of demonstration plants on suitable sites. A well-proven model of plant is roughly modified to the regional and local conditions. Normally, the first few plants are constructed with only a small participation by farmers who can then take over a forerunner function in the village. These farmers are intensively familiarised with the technology and information events are carried out. The implementing organisation begins to set up, the engineering, conceptual and organisational know-how for a dissemination programme. Initial experience with the operation of the plant leads to the model for dissemination being modified accordingly and a standardised concept for the location of the plant on the farm is developed. All additional activities necessary (e.g. introduction of stabling or propagation of new fertilising methods on the basis of slurry utilisation) are determined and the gas appliances are adapted. At this stage, local masons and fitters are already commissioned to build the demonstration plant. With the intention of creating a broad basis for cooperation in the field of **biogas** technology, a network is set up with other institutions. The political decision-makers are continually informed on the status of dissemination activities.

5.2. Tasks during the pilot phase

The purpose of the pilot phase during which about 20 - 50 plants are built, is to finally define the model of plant and the dissemination concept. The course of this phase is less primarily oriented to technical matters but is more concerned with organisation. The dissemination activities are integrated more and more into the normal routine of the counterpart organisation. In the pilot phase, experience with the demonstration plants is evaluated and the plants are possibly modified. Technical standards, i.e. the range of products for the dissemination structure (size of plant, gas appliances) is defined. Most successful dissemination strategies have been those which by initially concentrating on a limited region created a high advertising effect there and then allowed a rapid development in demand (from point to area). The dissemination concept is examined and implementation is begun, i.e. the tasks of individual parties are coordinated with each other and defined (implementation organisation, private sector, specialised institutes involved). A training structure is set up for masons and technicians with the implementation organisation. A commercialisation concept is compiled and implementation of this is started (advertising concept, price policy, structure and implementation of credit and subsidy models). Here, close cooperation with the political decision-makers, the administration bodies concerned and lobby groups is necessary It is the purpose of such work to secure budgetary and legal security for **biogas** dissemination.

5.3. Tasks in the dissemination phase

Not until the type of plant and the dissemination concept have been clarified can the project go into the dissemination phase. This phase is characterised by the necessary dynamics being established for independent **biogas** dissemination. The project has now moved from a direct execution level to an organisational advice level and tries to support the consensus building and interest formation processes of counterpart organisations and of the political decision-makers. Decisions are made on whether it is possible to extend the **biogas** dissemination to other regions and which technical and conceptual amendments have to be made.

6. Criteria

So far, the areas of problems in **biogas** dissemination have been described. These are to assist in preparing coordinates for the assessment of a location for a project. It has been shown how **biogas** dissemination requires definite background conditions for its success. The reality of a location will be shown by favourable and unfavourable factors. It is the job of the expert to judge this mixture in favour of or against possible **biogas** dissemination.

Following, are the criteria which make **biogas** dissemination impossible or more difficult. The ideal project location will rarely be found. The "ideal conditions" stated are to make the individual factors clearer.

6.1. Excluding factors

If only one of the following criteria is evident, then the dissemination of simple household **biogas** plants is not possible (As an exception, suitable farms in the region could allow individual measures under some circumstances.)

- too cold or too dry region

- very irregular or no gas demand

- less than 20 kg dung/day available to fill the plant or less than 1,000 kg live weight of animals per household in indoor stabling or 2,000 in night stabling.

- no stabling or livestock in large pens where the dung cannot be collected

- no building materials available locally

- no water available

- integration of the **biogas** plant into the household and farm routines not possible

- no suitable institution can be found for dissemination

6.2. Critical factors

Each of the following factors will lead to great problems in **biogas** dissemination. Accompanying measures, particularly modified technical developments, high financial promotion or additional organisation structures within the dissemination programme are necessary to guarantee project success.

- low income or unstable economic situation of the target group

- unfavourable macro and microeconomic coefficients

- gas appliances not available regionally or nationally

- irregular gas demand

- very good supply of energy throughout the year and simultaneously only moderate economic coefficients for the **biogas** plant

- high building costs

- low qualification of artisans

- counterpart organisation has only indirect access to the target group

- weak structure of the counterpart

- no substantial interest of the government is evident over the medium term

- low regional or national potential

6.3. Ideal conditions

If each of the following conditions is fulfilled then household **biogas** plants will definitely get a foothold. A dissemination programme is then expressly recommended

- even, daily temperatures over 20°C throughout the year

- regular gas demand approximately corresponding to gas production

- full stabling of animals (on solid floors as far as possible)

- at least 30 kg/day dung available per plant

- dairy farming

- use of organic fertiliser is normal

- farmers are owners of the farm system and primarily of the farm

- plants can be located in favourable positions to the stables and to the point of gas consumption

- the **biogas** plant can be integrated into the normal working routine in the house and on the farm

- gas utilisation and attendance of the plant can be clearly regulated within the household

- low price of plant in relation to the income of the target group

- favourable economic coefficients for the **biogas** plant

- economically healthy farms open to modernisation

- insufficient supply of fossil sources of energy

- building materials and gas appliances available locally

- qualified artisans locally

- counterpart organisation has access to and experience in contact with the target group

- efficient counterpart organisations with the possibility of cooperating with the private sector

- counterpart organisation has experience in programmes comparable to **biogas** dissemination

- political will on the part of the government towards not only **biogas** technology but also towards strengthening small and medium-scale farm systems

- secured financing of the dissemination structure

7. Data collection

To examine the technical feasibility of a **biogas** dissemination programme the following data has to be reliably collected:

7.1. Daily gas demand of a farm household or farm

Cooking

The gas demand can be defined on the basis of energy consumed previously.

1 kg firewood	then corresponds to	0.2 m³ **biogas**
1 kg dried cow dung	" " "	0.1 m³ **biogas**
1 kg charcoal	" " "	0.5 m³ **biogas**
11 kerosine	" " "	2.0 m³ **biogas**

The gas demand can also be defined using the daily cooking times. The use of a stove per hour then corresponds to about 0.3 m³ **biogas**.

Lighting

1 lamp consumes about 0.5 m³ **biogas** per day (i.e. about 0.13 - 0.18 m³/h)

Cooling

For 100 I refrigeration volume, about 2 m³ **biogas** per day depending on outside temperatures must be assumed. A larger household refrigerator consumes about 3 m³/day

Heaters

Per heaters for pig or chicken rearing 0.2 - 0.3 m³ **biogas** per hour has to be assumed.

Motors

Any surplus gas can be used in addition in diesel motors. For this to be worthwhile, 10 m³ **biogas**/day should be available.

To generate 1 kWh electricity with a generator, about 1 m³ **biogas** is needed.

7.2. Expected gas production

If the daily amount of available dung (fresh weight) is known, gas production will approximately correspond to the following values:

1 kg cattle dung	0.04 m³ **biogas**
1 kg buffalo dung	0.03 m³ **biogas**
1 kg pig dung	0.06 m³ **biogas**
1 kg chicken droppings	0.07 m³ **biogas**

If the live weight of all animals whose dung is put into the **biogas** plant is known, the daily gas production will correspond to the following values:

cattle, buffalo and chickens	0.0015 m³ **biogas** /day per 1 kg live weight
pigs	0.003 m³ **biogas** /day per 1 kg live weight.

Where cattle are only partly stabled the gas quantity is reduced in the relation: number of hours to 24-hour day.

7.3. Economic efficiency

General

To calculate the possible economic efficiency of a **biogas** plant which is decisive for the farmer's investment, the whole economic situation has to be taken into account. A calculation geared only to the national averages is often too unprecise as the use of a **biogas** plant will normally have a positive effect on the general living and working conditions. Since **biogas** can be used as kerosine or natural gas the price of **biogas** can quite rightly be compared with the prices of fossil sources of energy. If wood has to be purchased, the price of wood can be assumed. As far as the calorific value is concerned, prices in most countries only vary minimally. However, subsidies on sources of energy can substantially alter the price ratios. The prices for kerosine, bottled gas, wood and charcoal should be investigated in every case. The quantities for a comparison using calorific value and effect have already been stated in the chapter "gas demand". It is also important to find out in which ratios the previous sources of energy have been used and whether they can actually be substituted by **biogas** (e.g. **biogas** can normally not be used for heating rooms or smoking). The previous methods of fertilisation are important when recording the influence of slurry fertilisation. If only cattle dung is burned, the monetary benefit from dung saved can be valued with 0.4 of the benefit from gas whereas in all other cases this should be:

- 0.2 of the gas benefit for possible liquid fertilisation and

- 0.1 for composting

Construction costs for the **biogas** plant

The costs per cubic metre of digester decrease as volumes rise, consequently the size for an average, representative plant should be estimated. The size of plant amounts to:

- 120-fold of the quantity of dung put in daily at average expected digester temperatures over 25°C and

- 180-fold for temperatures between 20 and 25°C.

Since the final method of construction is determined during the course of the first years of the project, it is impossible to exactly calculate the building costs prior to the beginning of the project. The GTZ has a computer programme called "BioCalc" produced by BioSystem, yet this kind of seemingly precise calculation can only provide an idea as it is based on only one type of plant. Consequently, the following system is sufficient for a rough calculation:

- the cost of 6.5 sacks of cement times m³ digester volume plus

- the cost of 5 day's work for a mason times m³ digester volume plus

- the costs of 100 m gas pipes (1/2"), plus

- the costs of two ball valves (1/2"), plus

- the cost of gas appliances which are feasible for this size.

The individual prices are to be determined for the project location. The sum then includes material and wages. The distance from the **biogas** plant to the point of gas consumption was assumed as being 25 m (the 100 m used in the calculation include costs for connectors and wages). Where greater distances are involved, the cost for gas pipes will have to be increased in proportion.

Macro and microeconomic coefficients

The calculations are based on a fixed-dome plant with an assumed service life of 15 years. Other data to be collected is:

- bank interest on small loans for possible agricultural credits

- the inflation rate and exchange rates

For a macroeconomic appraisal, it should also be determined in how far concealed subsidies are included in the form of varying exchange rates for the import and export of energy, building materials and mineral fertilisers exist, or which goods on the market are already subsidised. Apart from this, the anticipated potential of the plant should be estimated since the justified expenditure for a dissemination programme is based on this.

Simple estimations of potential are possible if the number of households which could use **biogas** is calculated as a percentage of the total number of households. This can be determined by dividing the rural population by the average number of people per household.

A rough estimation is that the macroeconomic benefit of a **biogas** plant corresponds approximately to the costs of its construction. If the **biogas** plants are relatively expensive in comparison to other goods, a lower value should be assumed, e.g. 50 - 70% of the construction costs for all plants to be built annually when defining the macroeconomically justified costs of dissemination per year according to this formula.

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