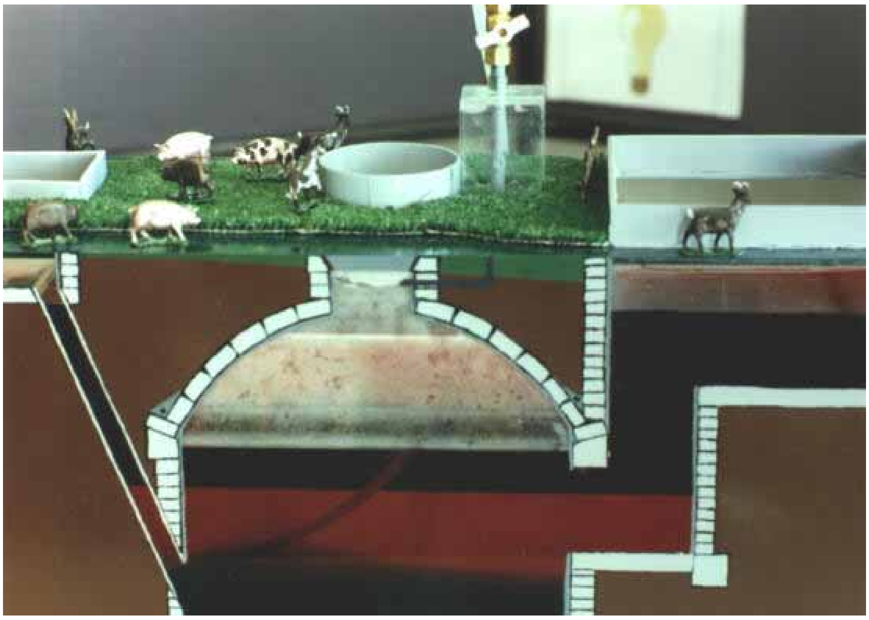

Biogas Digest

Volume III

Biogas - Costs and Benefits

and

Biogas – Programme Implementation

Information and Advisory Service
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Imprint

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Table of Contents

Biogas - Costs and Benefits

Economy and Financing

Techno-economic assessment

Before a biogas plant is built or a biogas program is implemented, a techno-economic assessment should be made. For this, two sets of cost-benefit analyses have to be carried out:

- The macro-economic analysis (economic analysis) which compares the costs of a biogas program and the benefits for the country or the society.
- The micro-economic analysis (financial analysis) which judges the profitability of a biogas unit from the point of view of the user.

In judging the economic viability of biogas programs and -units the objectives of each decision-maker are of importance. Biogas programs (macro-level) and biogas units (micro-level) can serve the following purposes:

- the production of energy at low cost (mainly micro-level);
- a crop increase in agriculture by the production of bio-fertilizer (micro-level);
- the improvement of sanitation and hygiene (micro and macro level);
- the conservation of tree and forest reserves and a reduction in soil erosion (mainly macro-level);
- an improvement in the conditions of members of poorer levels of the population (mainly macro-level);
- a saving in foreign exchange (macro-level);
- provision of skills enhancement and employment for rural areas (macro-level).

Comparison with other alternatives

After selecting objectives and counterchecking if biogas technology can fulfill the objectives at an acceptable cost-benefit ratio, it is still not certain, that expenses are invested in the best possible way. For this, a comparison with other alternatives to biogas programs and biogas plants is necessary. The expected cost and benefits are to be shown in the form of suitable investment criteria to allow statements regarding the economic advantage of the project. Often, alternatives to biogas have only a ’benefit-overlap’ with biogas and several alternatives have to be combined to ’produce’ the same quantity and quality of benefits.

On the other hand, alternatives to biogas programs may have benefits that a biogas program cannot deliver. Afforestation programs, for example, deliver energy and soil protection, but also building material.

Apart from the viability of the project, its financial effects on the decision-makers and the parties it touches financially are important: are a certain group of farmers able to invest in a long-term project like biogas generation? The cost per m^3 of biogas and the cost for the same amount of alternative energy forms the basis for most economic comparisons.

Considering development tendencies

The economic analysis should not only be limited to the initial period of operation of a biogas plant. Development tendencies should also be considered which influence the amount and structure of the costs and benefits set against the economic lifetime of the plant. Here, special attention should be paid to the development in supply from other sources of energy which compete with biogas. The national economic development of the country in question features in as well. If import substitution to save foreign currency is one of the primary objectives, biogas energy and biogas fertilizer may be valued highly. If a stronger world market integration is envisaged energy and fertilizer from biogas has to compete directly with internationally traded energy and fertilizers.

Economic evaluation of a biogas plant

- The benefits for individual households (biogas, biodung, etc.)
- Costs of a biogas plant (production, running and capital costs)
- Cost benefit relation
- Macro-economic evaluation (ecological and social effects, etc.)
- Financing and public support

Social policies

Biogas technology not only supports national economies and the environmental protection, but as its main outcome for the local population it provides for a wide range of improvements in overall living conditions. Sanitary and health conditions improve and the quality of nutrition is enhanced by an improved energy availability. Through the provision of lighting and the reduction of time-consuming fuel gathering cultural and educational activities are supported.

Employment, professional qualification and overall food supply of the local population can be improved as well. But biogas technology can also contribute to an accentuation of existing differences in family income and property. Establishing community-level biogas systems is a way to ensure that the technology benefits a greater number of residents.

If social policies of a developing country are clearly focusing on poverty alleviation, biogas technology may not be the first choice among other "village technologies". It’s place is shifting rather towards the rural agricultural middle class, communities (for waste water treatment) and industries.

Benefits for the environment

For many years the rational behind using biogas technology (or anaerobic technology) was the search for renewable sources of energy. In the meantime, other environmental protection aspects gain additional importance: A technology which previously just filled a "niche" is now becoming a key environmental technology for integrated, solid and liquid waste treatment concepts and climate protection both in industrialized and developing countries. Biogas technology is linked to the atmospheric budgets of many greenhouse gases. Another major environmental target is the mitigation of deforestation and soil erosion through the substitution of firewood as an energy source. The macro-economic benefits from biogas use in this field should be approached within the scope of the specific condition in the household energy sector and possible alternative protection measures.

The Benefits for Biogas Users

Individual households judge the profitability of biogas plants primarily from the monetary surplus gained from utilizing biogas and bio-fertilizer in relation to the cost of the plants. The following effects, to be documented and provided with a monetary value, should be listed as benefits:

- expenditure saved by the substitution of other energy sources with biogas. If applicable, income from the sale of biogas;
- expenditure saved by the substitution of mineral fertilizers with bio-fertilizer. Increased yield by using bio-fertilizer. If applicable, income from the sale of bio-fertilizer;
- savings in the cost of disposal and treatment of substrates (mainly for waste-water treatment);
- time saved for collecting and preparing previously used fuel materials (if applicable), time saved for work in the stable and for spreading manure (if this time can be used to generate income).

Monetarizing individual benefits

The economic evaluation of the individual benefits of biogas plants is relatively simple if the users cover their energy and fertilizer demands commercially. In general, the monetary benefits from biogas plants for enterprises and institutions as well as from plants for well-to-do households should be quite reliably calculable. These groups normally purchase commercial fuels e.g. oil, gas and coal as well as mineral fertilizers. In industrialized countries, it is common practice to feed surplus electric energy, produced by biogas-driven generators, in the grid. Biogas slurry is a marketable product and the infrastructure allows it's transport at reasonable cost. Furthermore, treatment of waste and waste water is strictly regulated by law, causing communes, companies and farmers expenses which, if reduced with the help of biogas technology, are directly calculable benefits.

In contrast, small farmers in developing countries collect and use mostly traditional fuels and fertilizers like wood, harvest residues and cow dung. No direct monetary savings can be attributed to the use of biogas and bio-fertilizer. The monetary value of biogas has to be calculated through the time saved for collecting fuel, the monetary value for bio-fertilizer through the expected increase in crop yields.

Both in theory and in practice, this is problematic. In practice, a farmer would not value time for fuel collection very highly as it is often done by children or by somebody with low or no opportunity costs for his/her labor. In theory, it is difficult to define the value of unskilled labor. Similarly, the improved fertilizing value of biogas slurry will not be accepted by most farmers as a basis for cost-benefit analysis. They tend to judge the quality of slurry when counting the bags after harvest. Because a monetary calculation is not the only factor featuring in the decision to construct and operate a biogas plant, other factors come in which are less tangible: convenience, comfort, status, security of supply and others that could be subsumed under 'life quality'.

Acceptance by the target group

Besides the willingness and ability to invest considerable funds in biogas technology, there is a complex process of decision making involved when moving from traditional practices to a 'modern' way of producing fertilizer and acquiring energy. Hopes and fears, expected reactions from the society, previous experiences with modern technology, all these feature in a decision. For a biogas program, it is important to realize that economic considerations are only part of the deciding factors in favor or against biogas technology. All these factors can be subsumed under *acceptance*.

Acceptance is *not* a collection of irrational, economically unjustifiable pros and cons that a biogas extension project is called upon to dissolve. Rural households, as a rule, take rational decisions. But rural households *and* biogas programs often have information deficits that lead to non-acceptance of biogas technology by the target groups. Bridging this information gap from the farmer to the project and vice versa is a precondition for demonstrating the economic viability in a way that is *understandable, relevant and acceptable* to the farmer.

Energy

The main problem in the economic evaluation is to allocate a suitable monetary value to the non-commercial fuels which have so far no market prices. For the majority of rural households biogas is primarily a means of supplying energy for daily cooking and for lighting. They use mainly firewood, dried cow dung and harvest residues as fuel. But even if the particular household does not purchase the required traditional fuel, it's value can be calculated with the help of fuel prices on the local market. Theoretically, the firewood collector of the family could sell the amount that is no longer needed in the household

As an example, the rural households in India use the following quantities of non-commercial fuel per capita daily:

- firewood: 0.62 kg
- dried cow dung: 0.34 kg
- harvest residues: 0.20 kg

For rural households in the People's Republic of China the daily consumption of firewood is similar: between 0.55 - 0.83 kg per person.

Which sources of energy have been used so far and to what extent they can be replaced must be determined for the economic evaluation of biogas by means of calorific value relations. The monetary benefits of biogas depend mainly on how far commercial fuels can be replaced and their respective price on the market.

1 m^3 Biogas (approx. 6 kWh/m^3) is equivalent to:

- Diesel, Kerosene (approx. 12 kWh/kg) 0.5 kg
- Wood (approx. 4.5 kWh/kg) 1.3 kg
- Cow dung (approx. 5 kWh/kg dry matter) 1.2 kg
- Plant residues (approx. 4.5 kWh/kg d.m.) 1.3 kg
- Hard coal (approx. 8.5 kWh/kg) 0.7 kg
- City gas (approx. 5.3 kWh/m^3) 1.1 m^3
- Propane (approx. 25 kWh/m^3) 0.24 m^3

Bio-fertilizer

Improvement in quality of farmyard manure

If and to which extent biogas slurry can be monetarized as benefit, depends largely on the previous use of the substrate to be digested. The more wasteful the present method of utilizing farmyard manure is, the easier it is to monetarize benefits. In most traditional systems, for example, the urine of livestock is not collected as manure. Often, the dung and fodder residues are heaped in the open, leading to heavy losses of minerals through sun radiation and wash-out by rain. The following seven steps can lead to an approximate assessment of the monetary value of bio-fertilizer:

1. Assess quantities (tons dry matter) of farmyard manure which reaches the fields per year.
2. Analyze a cross section of the farmyard manure for plant macro-nutrients (N, P, K) per kg dry matter shortly before the manure is spread on the field.
3. Calculate the amount of NPK which is available for the farm from 'traditional' farmyard manure.
4. Assess quantities of biogas slurry (tons of dry matter) to be expected with the given numbers of livestock, amounts of plant residues to be digested and numbers of persons using the latrine attached to the biogas plant.

5. Analyze the biogas slurry of a comparable biogas owners nearby for plant macro-nutrients (N, P, K) per kg dry matter.
6. Calculate the amount of NPK which would be available on the farm through commercial slurry.
7. To value the monetary difference in NPK availability, the most commonly used fertilizer in the area should be chosen which can close the nutrient gap. If compost or other organic fertilizers are traded, they should be given preference (and a nutrient analysis undertaken beforehand).

The analysis above is obviously a method which cannot be employed for every potential biogas user as it is expensive and time-consuming. A biogas program would analyze the monetary value of bio-fertilizer exemplary for a number of cases and approximate others on this basis. This method, however, is superior to judging increased crop yields with the help of bio-fertilizer. Crop yields depend on a multitude of factors, the fertilizer being only one of many.

Depending on the topography, distributing slurry can save labor or add to the labor demand. The additional time needed or savings in time must feature in the calculation. In some cases, it is not possible to spread the slurry in liquid form, it has to be dried or composted first. In this case, NPK contents have to be measured in the compost or dried slurry and labor for composting or drying recorded.

Increased yield

Biogas programs, however, should not neglect the argument of improved yields. Increases in agricultural production as a result of the use of bio-fertilizer of 6 - 10 % and in some cases of up to 20 % have been reported. Although improved yields through biogas slurry are difficult to capture in a stringent economic calculation, for demonstration and farmer-to-farmer extension they are very effective. Farmers should be encouraged to record harvests on their plots, before and after the introduction of biogas.

Statements of farmers like: "Since I use biogas slurry, I can harvest two bags of maize more on this plot" may not convince economists, but they are well understood by farmers.

Saved disposal cost as benefit

Saving disposal cost as a benefit of a biogas system applies mainly in countries where the disposal of waste and waste water is regulated by law and where disposal opportunities exist. In industrialized countries, these costs are known and calculable.

In developing countries, industrial waste or waste from large agricultural enterprises are being taken increasingly serious. But often it is only after creating a conflict with local authorities or the local population, that the management is forced to consider proper waste disposal. The cost of continued conflict may be high and go as far as a forced closure of the enterprise. The entrepreneur will search for the cheapest acceptable solution to treat the waste. Taking the energy generation of anaerobic digestion into account, biogas technology may indeed offer the most economic solution.

In rural households, human feces are collected in pit latrines. Once the pit latrines are full, they are filled with soil and a new pit is dug. Normally, this happens every two years. Excavation costs and costs for shifting or casting the slab can be saved and calculated as benefit. If a septic tank is used, the emptying cost can be counted as benefit. The saved construction cost of the septic tank can only be counted as benefit, if the toilet connection to the inlet of a biogas digester competes with the construction of a septic tank, i.e. the septic tank has not been built yet.

Time consumption

A critical shortage of energy, primarily of firewood, is reflected less in the market prices than in the time the households - especially women and children - need to collect fuelwood. The time commonly spent for collection varies from several hours per week to several hours per day. In some areas of Africa and Asia, firewood collection is the single most time consuming activity for a housewife. The open fire has to be attended almost permanently, in particular if low grade fuels like cow-dung or straw is burnt. Additional work is caused by the soot of an open fire - clean, shiny pots are a status symbol in many cultures. Compared to this, the time needed to operate a biogas plant is normally low so that in most cases a considerable net saving can be realized.

A financial evaluation of this time-saving is not easy. If the additional time can be used for productive purposes, the wages or the value of the contribution to production can be calculated. Frequently there are - in the short run - no suitable employment opportunities for women or children. To come to a proxy value of the saved time either the value of the collected firewood or the most likely employment opportunity can be employed for calculation.

Even if there is no income generating utilization of time saved there is a benefit to the individual and the household which could provide a convincing argument. The utilization of biogas saves time but also makes cooking more comfortable in comparison to the traditional methods, smoke and soot no longer pollute the kitchen. Especially in the morning rush, a biogas flame is much easier to start than an open fire. Again, it is a question of life quality, something which cannot be valued in monetary terms, but for which people are willing to pay.

Costs of a Biogas Plant

Exact estimations for the construction and operation of biogas plants serve the following purposes:

- to compare the costs of alternative models (optimal project selection)
- for the information of the users as far as future financial burdens are concerned
- the calculation of financing needs including public subsidies (budget planning)

Categories of costs

As far as costs are concerned there are three major categories:

- manufacturing or acquisition costs (production costs)
- operation and maintenance costs (running costs)
- capital costs

Production costs

The production costs include all expenses and lost income which are necessary for the erection of the plant e.g.: the land, excavation-work, construction of the digester and gas-holder, the piping system, the gas utilization system, the dung storage system and other buildings. The construction costs comprise wages and material.

The production costs of biogas plants are determined by the following factors:

- purchasing costs or opportunity costs for land which is needed for the biogas plant and slurry storage;
- model of the biogas plant;
- size and dimensioning of the biogas unit
- amount and prices of material
- labor input and wages
- the degree of participation of the future biogas user and his opportunity costs for labor.

Total costs

To gain a rough idea of the typical costs of a simple, unheated biogas plant, the following figures can be used: total cost for a biogas plant, including all essential installations but not including land, is between 50-75 US Dollar per m^3 capacity. 35 - 40% of the total costs are for the digester.

The specific cost of gas production in community plants or large plants is generally lower compared with small family plants. The cost for the gas distribution (mainly piping) usually increases with the size of the plant. For communal plants with several end-users of biogas, the piping costs are high and compensate the degression by 'economics of size' partly or wholly. In regions where plant heating is necessary, large-scale plants would be more economical .

To keep the construction costs low, labor provided by the future biogas users is desirable. Often, the whole excavation work is done without hired labor. On the whole, a reduction of up to 15% of the wages can be effected by user-labor. If periods of low farm activities are chosen for the construction of the biogas plant, opportunity costs for labor can be kept low.

Running costs

The operation and maintenance costs consist of wage and material cost for:

- acquisition (purchase, collection and transportation) of the substrate;
- water supply for cleaning the stable and mixing the substrate;
- feeding and operating of the plant;
- supervision, maintenance and repair of the plant;

- storage and disposal of the slurry;
- gas distribution and utilization;
- administration.

The running costs of a biogas plant with a professional management are just as important as the construction costs, for example for operation, maintenance, expenses for painting, service and repair.

Large-scale biogas plants

Large-scale biogas plants have a high water consumption. Investigations are necessary, if the water quantity required causes additional costs in the long run. These could be construction costs for water piping or fees for public water supply. The question of water rights has to be clarified. Steps to be taken to cover the demand for water during dry periods require thorough planning.

Capital costs

Capital costs consist of redemption and interest for the capital taken up to finance the construction costs. For dynamic cost comparison the capital fixed in the plant is converted into equal annual amounts.

Interest rate

The capital cost, apart from the depreciation rates or length of amortisation, is dependent on the interest rate at which the capital is provided. In each case current interest rates are to be laid down for the cost calculation, which reflect the opportunity costs of the invested capital. To avoid distortions of the financing costs the comparisons should always be calculated with the same interest rate.

Lifetime of plants

In calculating the depreciation, the economic life-span of plants can be taken as 15 years, provided maintenance and repair are carried out regularly. Certain parts of the plant have to be replaced after 8 - l0 years, e.g. a steel gas holder. The steel parts need to be repainted every year or every second year. As a rule, real prices and interest rates should be used in the calculations. For cost calculation inflation rates are irrelevant as long as construction costs refer to one point of time. However, in calculating the cash reserves put aside for servicing and repair the inflation rate must be considered.

Average costs

The cost per cubic meter of digester volume decreases as volume rises. Therefore, the appropriate size of the biogas plant should be estimated. For simple, unheated plants in tropical countries, the digester size is roughly:

- 120-fold the quantity of substrate put in daily at average expected digester temperatures over 25°C and
- 180-fold the quantity of daily feeding for temperature between 20 and 25°C.

Since the final method of construction is only determined during the first years of a biogas project, it is impossible to exactly calculate the building costs ahead of the actual implementation. The **GTZ** computer program called "**BioCalc**" (produced by BioSystem), 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 x m^3 digester volume plus
- the cost of 5 days work for a mason x m^3 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-economic evaluation

Objective

The economic analysis assesses a project in the context of the national economy rather than of the project sponsor (i.e. private enterprise or a public authority).This means that government economic policy has to take into account the effects of a project on the national or regional economy as a whole.

The decisive difference between the economic analysis and the financial analysis is the way in which inputs and outputs are valued. The financial costs of resources, which are expressed by market prices, differ from their economic values. This is due to the fact that market prices do not reflect true marginal social costs and thus do not match with the actual value of consumed scarce economic resources.

Economic effects of biogas plants

When evaluating biogas plants from a macro-economic point of view there are several reasons why price adjustments in favour of the biogas technology are required.

- The production of biogas creates external economies. It means that the biogas production influences the utility function of the consumer (i.e. better sanitary and hygienic conditions) and the social welfare function of the society (i.e. reduced health costs). Considering national wide effects on energy balance, the biogas supply creates external economies on the balance of payments to the economy (import substitution of fossil fuels). As well external diseconomies then should be included, amounting to less income of import duties because of substitution of traded fuel (i.e. petroleum) by biogas.
- Biogas use, replacing conventional fuels like kerosene or firewood, allows for the conservation of environment. It therefore, increases its own value by the value of i.e. forest saved or planted.
- The price of supplied energy produced by biogas competes with distorted prices on the national or regional level of the energy market. Monopolistic practices, which enable energy suppliers to sell their energy at a price higher than the competition price, still dominate the energy market in many countries. A decentralized, economically self-sufficient biogas unit therefore, - under competitive conditions - provides its energy without market distortions.
- Furthermore, other macro-economic benefits arise when comparing on the one hand the benefits of decentralized energy generation (improved power system security) and the disadvantages of centralized energy generation: incremental costs of investment in additional networks and the costs of losses on the transmission network, due to the distance of energy customers, may be added to the benefits of decentralized energy generation from the macro-economic point of view.
- Labour intensive decentralized biogas units, on the regional level, improve income distribution amongst income brackets and reduce regional disparities, enhancing the attractiveness of rural life.
- Investors should aim at carrying out the construction of biogas plants without any imported materials in the long run. The lower the import content of the total plant costs (i.e. amount of steel), the less the external diseconomies which may arise in consequence of sliding exchange rates.

In a macro-economic level these effects are significant and only unfold themselves fully if biogas plants are introduced over a wide area i.e. for closed settlement areas. This refers primarily to biogas plants as an improvement for inferior sanitary and hygienic conditions for members of the poorer classes. These are problems which cannot be solved on an individual basis but only by collective decisions and measures.

How far biogas plants in a definite case are the suitable and advantageous solution to a problem has to be discovered with reference to alternative sectoral measures. The macro-economic evaluation needs to account for effects of benefits within the fields:

- Energy and fertilizer supply
- Environment
- Health Sector
- Employment and foreign exchange

Energy and slurry

Energy

Many developing countries, especially the LLDC base their energy consumption upon traditional energy sources (wood, plants and crop residues and animal waste, as well as animal traction and human muscle power). Biomass energy use varies widely in developing countries from as little as 5% in Argentina to over 90% of the total supply of energy sources in countries like Ethiopia, Tanzania, Rwanda, Sudan and Nepal. In the case of wood, plant and animal waste, according to local necessities, the energy source is collected and used. Surplus of energy sources are traded informally on the local and regional level. In so far estimations on the potential effects of biogas use instead of the use of traditional energy sources do not have any impact on government‘s budget, presuming the non-existence of taxes on traditional energy sources.

Negative consequences on the income of the local traders may result, presuming less demand on traditionally traded energy sources, causing a slump of its prices. On the other side biogas users may continue with trading of traditional energy sources on more distant markets (or even will be encouraged to trade on regional levels), not willing to forego secure earnings.

Consequently, the substitution effect of biogas results primarily in environmental benefits due to less consumption of i.e. firewood, leading to less deforestation (under the presumption of a declining or constant price of firewood).

Commercially or monetarily traded sources like petroleum, coal and natural gas on the other hand have impacts on the balance of payments and therefore influence governmental budgets.

The macro-economic effect of a biogas use by import substitution of i.e. kerosene is due to decreasing duty income. On the other side petroleum import dependancy sinks, giving more relative stability to an economy.

Although only less than 10% of a country’s commercial energy is consumed by the rural population (LLDC and in some MSAC), the effects of biogas use, substituting systems for generation, transmission and distribution of electricity shall be mentioned.

The macro-economic benefits of a biogas plant result in its self-efficienciy and reliability (benefits from avoidance of black-outs and supply interruptions) and in less costs for networks and distribution infrastructure. On the other side a national wide operating power supplier competes with a biogas supplier as unserved energy implies by revenue forgone as a result of non-supplying its customers.

Slurry

On the assumption that the slurry of the biogas plant is used as fertilizer and, when spread on the fields, it increases the crop production, that is more productive than the undigested dung, the economies’ benefit amounts to a higher supply of fertilizer given the same output level of crops.

Moreover, the substitution of commercial fertilizers with slurry produced by biogas technology reduces the impacts on balance of payments (assuming a dependence on imports of chemical fertilizers).

The consequence of reliance on digested dung and residues (in a biogas plant) is that valuable nutrients and organic matter are led back to the soil in an improved stage, rising agricultural productivity and soil stability (combating devegetation and desertification). The higher productivity of crop production results in higher yields, maybe keeping pace with the increase in population (maybe: because one has to estimate the balance of populational fluctuations).

Environment

Consumption of firewood

Wherever a region is confronted with acute problems of deforestation and soil erosion resulting from excessive firewood consumption, biogas plants can provide a suitable solution. Biogas is able to substitute almost the complete consumption of firewood in rural households.

Traditionally, woodfuel claims the largest proportion of biomass fuels (in some regions up to 90%) used in developing countries, where about 40% of the total wood cut anually is used for domestic purposes (cooking and heating). Estimating an average per capita consumption of 3 kg of wood per day for energy (cooking, heating and boiling water) in rural areas in Asia and Africa, the daily per capita demand of energy equals about 13 kWh which could be covered by about 2 m^3 of biogas. A biogas plant therefore directly saves forest, assuming that not only deadwood is collected for fuel.

In order to predict the direct monetary savings to an economy, two procedures are to be carried out:

If the forest has not previously been used economically, shadow pricing has to be based on the valuation of saved biodiversity, respectively on the capacity of reducing the effects of global warming.

If the forest has been used economically, several procedures of shadow pricing can be carried out, like:

- Value of saved forest via price of firewood

  Given the price of cut firewood on the local market, the savings of forest by substitution of biogas can be determined by multiplication of the number of trees cut, its tree growth ratio per year and the average price of firewood.

- Value of saved forest as an area for nourishment (hunting, collecting fruits, etc.)

  The value of the forest equals the sum of income forgone from these activities. The correct shadow pricing would be based on the prices of the goods on the formal consumer markets (i.e. price of meat).

- Value of saved forest as a recreation area

  The value of the forest equals the sum of the incomes obtained by charges for admission to National Parks, Wildlife Areas, etc.

Deforestation

Without any effective political measures, the problem of deforestation and soil erosion will become more and more critical. As the population increases the consumption of firewood will increase more steeply.

Without biogas the problem of deforestation and soil erosion will steadily become more critical as firewood consumption rises relative to higher density of population. The demand for nourishment also rises accordingly, which means that constant extension of agricultural land increases at the expense of forested areas.

Deforestation contributes considerably to soil erosion which, in its advanced state, reduces quantitively and qualitatively the potential of agricultural land. Finally, this leads to future increases in the cost of food production. Moreover, the advancing soil erosion increases the frequency and extent of floods and their disastrous consequences. According to an Indian estimation, a biogas plant of e.g. 2.8 m^3 capacity can save a forested area of 0.12 ha. In each case it has to be discovered the contribution of biogas plants to a reduction in land usage and costs for reforestation or protection of remainig forests.

Health sector

In order to estimate the impacts on the health sector, benefits arise on the individual level, as well as on the level of the society.

Biogas plants serve as methods of disposal for waste and sewage and in this way directly contribute to a better hygienic situation for individual users. By collecting centrally dung and by connecting latrines, open storage is avoided. Apart from this, pathogenes are extensively eliminated during the digestion process. All in all quite an improvement of sanitation and hygiene is achieved and therefore a biogas plant can contribute to a higher life expectancy.

In the People's Republic of China this effect became apparent in the bilharziosis, worm and gastro-disease endangered areas where the number of people suffering was greatly reduced. Theoretically, a reduction in the frequency of disease comprises economically a saving in medicine and consultation costs. Regarding the leakage of health services in rural areas, another approach to savings is suggested: Labour productivity rises due to elimination of potential disease-causing agents due to the better hygiene situation in consequence of biogas plants.

Applied to individual biogas projects, these economic effects cannot be credited directly to biogas projects in monetary terms, as there are plenty of influences on the health sector.

If the main goal of a biogas plant is to achieve a higher standard of hygiene, one possible method of shadow pricing would be the answer to the question:Which alternative investment in providing the same result of hygiene equals the positive hygiene results of a biogas plant?. The evaluation of sanitary and hygienic effects can be made i.e. by means of the alternative costs for a purifying plant.

But the incisive doubts of "correct" shadow pricing the benefits in the health sector remain.

Employment

During construction of biogas plants unless these are built by the investors themselves, there are effects on regional/local income and employment which subsequently continue. Permanent jobs, unless users participate, are created for the operation personnel and indirect effects result in contracts with local and regional companies for the service and maintenance of a plant including the gas-burners in the households and resulting from the procuring and processing of increased agricultural production. The utilization of biogas contributes to an enlarged range of energy fuels offered on the market. In this way the local basis of the energy supply can be extended and secured, and it also simplifies the setting of additional commercial activities where the factor energy has so far proved to be a problem.

Final remarks

Biogas gained by a three-step digestion process (two hydrolysis phases followed by one acid phase) containing 60-80 per cent methane and 20-40 per cent carbon dioxide makes it a potencial source of renewable energy.

Given a heating value of about 5,5 kcal/m^3, its uses for electricity generation, as a heat resource, for internal combustion engines, boilers, as a suplementary fuel for diesel engines or substitution of firewood for cooking purposes in rural areas are widely reported.

Especially the economic benefits of biogas utilization in selected agro-industries (palm oil mills, tapioca starch factories and alcohol destilleries) amount to savings due to electricity generation by biogas, fertilizer savings and rising productivity in agriculture. Moreover, the environmental benefits due to substitution of energy sources based on wood (firewood, charcoal) or on fossil energy sources are outstanding.

To assess correctly the macro-economic benefits of biogas production in small size biogas plants is a difficult undertaking. Generally, very optimistic assumptions on positive effects on employment, balance-of-payments and health sector can cause overwhelming expectations on planning biogas based energy systems.

Nevertheless, these external economies are substantially influenced by the quantity and (regional) density of biogas plants, contributing to the countries' share of energy sources.

Without any doubt -even if there would be constructed only one biogas plant in a country - the following valueable assets of biogas use from the environmental point of view can be determined.

As CO_2 generation by burned biogas only amouts to 80 per cent of the CO_2 generation of fired fuel oil (per kWh electrical energy) and is even more advantageous in relation to coal (about 50 per cent), the environmental benefits of biogas in relation to fossil fuels are indisputable.

Due to the high cohere efficiency of wood (0.7 kg CO_2 per kWh gross energy), the substitution of the wood based biomasses by biogas rise the national and global storage capacity of CO_2.

Facing more and more the challenging phenomena of global warming and setting global standards of polluting potentials, environmental external economies are getting steadily very important issues and may stimulate a government to start investing in appropriate energy technologies rather than to follow the conventional way to solve the problem of generating energy in remote areas by rural electrification based on fossil fuels.

A financially viable and well structured joint implementation concept may help to generate (financial) facilities to governments in order to invest in energy generation, based on sustainable energy sources. In how far and to which partner (of the partnership) the positive effects of the project shall be ascribed to, may be determined politically. In the long run each saving of irretrievable damage of environment helps to saving the world in a whole.

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Economic Viability (Financial Analysis)

Objectives, methodology and decision criteria

As soon as the cost and benefit components of a biogas plant in planning can be quantified, and as soon as other important parameters (time horizon, interest rate, annual allowances, exchange rates, inflation rates) are determined, the economic viability of a biogas plant can be calculated.

Typically, the financial analysis of projects points out the financial viability of investment alternatives.

Three types of questions need to be answered:

8. Which project is the least expensive among an array of options that produce the same output (***least cost analysis***)?
9. Which project shows the highest net benefit (benefit minus cost) among an array of options (***cost benefit analysis***)?
10. Is a project a financially viable solution to the problem on hand? (***absolute viability***, i.e. the question is dealt with whether the project's revenues are sufficiently high to meet capital cost and operating cost), and:

    Is a specific project more economical than others? (***relative viability***).

Procedure of dynamic approach

Due to the fact that the same amount of a credit or debit can have a very different value depending on **when** the transaction takes place, dynamic analysis differ from the static methods.

The need for a dynamic approach results from the fact that, as the costs and benefits of each option arise in different years, it is necessary to make them comparable.

The value which says how much a future or past payment is worth at the **present** time is described as its **present value** (PV).

Example:

Given an investment of a biogas plant of 2000 US$ in two years (**discounting**), having paid three years ago 120 US$ for the necessary landed property (**compounding**), with a given interest rate of 8%, the PV is as follows:

$$PV = [2000/(1,08)^2 + 120*(1,08)^3]$$

It is calculated from its past amount by **compounding** or from the future amount by **discounting** with the aid of a factor which depends on the interest rate adopted and the length of time between the payment and the present period.

Investment criteria

The dynamic approach deals with a consideration of benefits and costs over several years and therefore shall be pointed out more detailed:

Investment criteria are, as follows:

A) Net Present Value (NPV)

The most common investment criteria is the NPV and is defined as follows:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+k)^t}$$

PV - Net Present Value
C_t - Costs in year t
B_t - Benefits in year t
k - discount rate
t - number of years from the present
n - total number of the years of the analysis period

Example:

Given a biogas plant with an investment cost of 2000 US$ within the first year of the project and assuming annual running costs of 70 US$ during the following 9 years of operation and estimating an annual benefit of 450 US$ during the operation time (due to incomes from gas production and fertilizer production), the NPV results as follows:

NPV = $2000/(1,08)^0 + [(450/(1,08)^1 + 450/(1,08)^2 + ... + 450/(1,08)^9) - (70/(1,08)^1 + 70/(1,08)^2 + ... + 70/(1,08)^9)] = 374$ US$

Applying the net present value method the investment can count as being profitable as its NPV is positive. It means that the interest rate on capital is higher than the assumed discount rate. Investing in the biogas plant would allow a higher return to the investor than an investment on capital market.

The methodology described is suitable for analysing the relative viability of a project, i.e. it can tell us whether one project is more economical than another (or others). It can therefore be used for the analysis of the absolute viability of a project. This step answers the question as to whether the return on investment for a project is sufficiently high to cover its average capital costs.The net present value method is preferable for comparison of viability of different options, as it easily copes with changes of costs and revenues over time.

B) Internal Rate of Return (IRR)

A further criterion which can be applied for the purpose of viability calculation is the internal rate of return (IRR).

It is the discount rate at which the present value of cost is equal to the present value of the benefits. In other words, it is the discount rate at which the net present value is zero:

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0$$

i = IRR

Example:

Assuming the project data of the example of NPV, the internal rate of return results as follows:

$0 = 2000/(IRR)^0 + [(450/(IRR)^1 + 450/(IRR)^2 + ... + 450/(IRR)^9) - (70/(IRR)^1 + 70/(IRR)^2 + ... + 70/(IRR)^9)]$

The resulting interest rate (IRR) at which the NPV is zero amounts to 12,45%. The investors decision to deal with a biogas plant investment leads to high capital gains, since an IRR of 12,45% exceeds the minimum acceptable rate of 8% (interest rate).

The IRR method is closely linked with the NPV-method and is recommendable for viability calculation for a single project, as the project’s IRR is compared with the IRR of the market.

C) Dynamic Unit Cost criterion (C_{dyn})

To gain additional transparency, the Dynamic Unit Cost criterion (C_{dyn}) stands for the calculation of the financial analysis performed on a per unit basis (if $C_t > B_t$):

$$C_{dyn} = \frac{\sum_{t=1}^{n} \frac{C_t}{(1+k)^t} - \sum_{t=1}^{n} \frac{B_t}{(1+k)^t}}{\sum_{t=1}^{n} \frac{O_t}{(1+k)^t}}$$

C_{dyn} - Dynamic Unit Costs
O_t - Output in year t
Other parameters and index numbers like above

As this criterion is linked to the NPV-method, no differences in calculation procedure occur.This decision criterion enables the various options with different outputs to be compared on a per unit basis. The main advantage of the concept is that options of different sizes (output) can easily be compared with each other regarding to their financial viability.

D) Dynamic Annuity criterion (A_{dyn})

Another decision criterion for financial viability is the Dynamic Annuity criterion (A_{dyn}). It evaluates the relative favourability of investment projects of similar type on the basis of constant annual payments. Likewise the Dynamic Annuity criterion is a variant of the NPV-method. In the left part of the equation the present value of the costs and the present value of the benefits are converted by the recovery factor into annual payments. Additionally the annuity of investment costs and the annuity of the liquidation yield is considered. Moreover the liquidation yield represents tied capital during the useful life of the asset and therefore interest charges are accumulated during the project ($L \cdot k$). Then the annuity of the investment project is defined as the sum of the mentioned annuity components:

$$A_{dyn} = \left[\sum_{t=1}^{n} \frac{C_t}{(1+k)^t} \cdot RF(k,t) - \sum_{t=1}^{n} \frac{B_t}{(1+k)^t} \cdot RF(k,t)\right] + (I-L) \cdot RF(k,t) + L \cdot k$$

A_{dyn} - Dynamic Annuity
I - Investment
L - Liquidation yield (end of lifetime)
RF - Recovery factor

(**Note:** The amount of the recovery factor (RF) depends on the assumed interest rate and the time horizon. Given an interest rate of 8% and a project lifetime of nine years, the RF (k = 1,08; t = 9) is: $[1{,}08^t (1{,}08 - 1)] / [1{,}08^t - 1] = 0{,}16$.)

Other parameters and index numbers like above

An asset is considered favourable, when its annuity is positive, meaning that interest on the capital invested involves a higher surplus than the interest rate on capital market. This method permits an evaluation of both the individual and comparative favourability of investment projects.

A shortened form of the annuity method without the inclusion of benefit payments in the calculation is the Dynamic Cost Annuity criterion (A_{dyn}).

The aim of the Dynamic Cost Annuity criterion is to identify the most cost-effective plant by contrasting the costs of two or more alternatives for a manufacture. To get more detailed results, the costs can be related to a **defined** output. If there are several alternative assets for providing a desired output then the asset with the lowest dynamic cost annuity (per output) should be selected.

Example:

Given the above performed example (NPV), but presuming in the ninth year of operation running costs of 80 US$ and a benefit of 470 US$ and assuming a liquidation yield of 100 US$ by the end of lifetime, the Dynamic Annuity results as follows:

$A_{dyn} = [70/(1{,}08)^1 + 70/(1{,}08)^2 + ... + 80/(1{,}08)^9] * 0{,}16 - [450/(1{,}08)^1 + 450/(1{,}08)^2 + ... + 470/(1{,}08)^9] * 0{,}16 + 2000 * 0{,}16 - 100 * 0{,}16 + 100 * 0{,}08 = 68 - 436 + 320 - 16 + 8 = -56$.

As the equation proceeds from the costs, a negative result comes out. The asset is economically favourable, as the investor can expect annual net returns for the amount of 56 US$.

Input data

To the calculation of the viability of a project a complete compilation of all input data should occur carefully. The costs and revenues depend on the particular project and technical system and can, therefore only be accurately determined when all the parameters of a specific application are known:

Cost data

A significant factor on the cost side is the size of the required investment. The following elements make up the total investment outlays:

- planning and surveys
- land acquisition
- civil works
- plant buildings and structure
- connecting systems
- mechanical equipment
- transport (including insurance)
- customs, duties, taxes
- other costs

Another significant cost component are the operational costs. Depending on the plant characteristics, the maintenance and repair costs they are not fully predictable.

Other important items are the costs for manpower, costs for auxiliary materials and administration costs (system attendance).

Benefit data

The annual benefits comprise the monetary flow from evaluable returns, savings, etc. yielded by the investment. If the benefits arise in financial (micro-economic) terms or already include economic (macro-economic) benefits, this is due to definition of the main goals which shall be achieved by an investment in a biogas plant. According to the main objectives of a biogas plant, in financial terms the benefits may derive from:

- **Power generation**: Naturally, only the net energy gain can be counted, i.e. the process energy fraction (for agitators, pumps, heating, and any outside energy input) must be substracted from the total gas yield. If the generated power is sold, the returns are included in the calculation. Any energy used to replace previous outside energy inputs counts for savings. One has to take into account a certain discount of energy price if the generated power shall be sold because of linkage costs per output (due to small gas yield of small plants).
- **Sludge**: The substitution of digested sludge for chemical fertilizers can often yield savings in developing countries, where in the past big amounts of the material used as substrate had so far not been used as fertilizer. Accurate monetary evaluation is difficult, because the fertilizing effect of digested sludge is substantially influenced by the type of storage, the climate, the techniques employed in spreading out the sludge on the fields and working it into the soil, etc.

  To estimate economically the gains of digested sludge suitable for agriculture (with the same output performance as with chemical fertilizers), one has to value the benefits of **not** spending money on chemical fertilizers (approach of opportunity costs: see macro-economic evaluation).

  Savings attributable to the superior properties to digested sludge: These may result from the improved fertilizing effect of the sludge, its hygienization, reduced odour nuisance, and more advantageous handling properties such as reduced viscosity, improved homogeneity, etc. These kind of benefits are hardly valuable. Further information on methods of shadow pricing can be achieved in: macro-economic evaluation.

Parameters and assumptions

Price basis and escalation

The financial analysis has to be performed on the same price basis, i.e. on the constant money value of a determined year. Then the costs are expressed in real terms.

Due to the fact that certain goods and input data do not increase/decrease in line with the general rate of inflation/deflation, and thus do not remain constant in real terms, a necessary analysis of adjustment of prices by escalation rates is to be performed.

Often, the costs of manpower are presumed to raise more than the general rate of inflation which implies an increase of income of employees in real terms.

Discount rate

To determine the rate of discount is a crucial problem of project evaluations.

The discount rate derives from bearing in mind the intertemporal valuation of values of costs and benefits. In one sentence: interest is what is charged for not being able to use the money for something else.

For financial analysis, interest is expressed as a percentage.

It should be noted that the discount rates used for the analysis must be real rates, i.e. nominal rates minus the rate of inflation. As all the input data are applied in real terms, the discount rate must be applied in real terms as well.

This means that the interest rates taken from the capital market (i.e. interest rate for long-term borrowing) are expressed in nominal terms and have to be reduced by the inflation rate.

The prospection of both, the ‘"correct" nominal terms of capital market (due to market distortions) and the development of national inflation rates during the lifetime of the project remain difficult tasks for project planning.

Foreign exchange rate

The foreign exchange rate prevailing at the time of conducting a project and its future development is another element of difficulty for the investor.

There is also a close relationship between the forecast of a national rate of inflation and the forecast of the development of the foreign exchange rate.

According to the purchasing power parity theory, the development of the foreign exchange rate of two currencies reflects the difference in inflation rates of the countries (or areas).

Given a national inflation rate of 10% p.a. and a world inflation rate of 3% p.a., a depreciation of the national currency against the US Dollar can be expected.

The purchasing power parity theory means that the depreciation expected will offset the difference in infaltion rates so that the prices of imported goods in local currency will develop in line with the overall national rate of inflation.

Final remarks

The financial analysis assesses the viabiltity of the project from the investors view. The financial objective of investing funds in any activity is to maximize the resulting flow of income while remaining within the level of risk acceptable in relation to that return.

Therefore, estimations on project outcomes which represent secure data streams, "only"interfered by price escalations or changes in demand behaviour, are dominant investment criteria.

Other possible (external) economies and diseconomies of a project as well shall be included in the investors decision process. The macro-economic evaluation may reveal, in how far this can occur.

Cost benefit relation (investment calculation, sensitivity analysis)

Methods

As soon as the cost and benefit of a biogas plant in plan can be expected, collected and analysed, and as soon as a rate of interest for the calculation is determined it can be worked out with the assistance of a dynamic investment calculation if the plant is economical or not. Where there are several alternatives relative advantage can be ascertained. There are three generally accepted methods for this:

- the capital value or discounting method
- the internal rate of interest method
- the annuity method

These methods are principally equivalent. The selection is effected according to the purpose and plausibility, e.g. distinctness of each advantage key. In practice the discounting method is used most frequently. According to this method the cost and benefit of different periods of time are concentrated onto one point in time, normally the current value or cash value, discounted and so made comparable. When comparing alternatives with different economic lifetimes and investment costs the annuity method is especially suitable. For the calculation of user fees the annuity method should be used. According to this method the non-recurring and aperiodical investment costs are converted into equal constant annual amounts for the economic lifetime of the plant and related to the quantity of gas distributed. This occurs by means of a capital return factor which states the annual amount of depreciation an interest which has to be used at the end of each year during n years to regain the original capital with interest and compound interest.

Difficulties

In order to avoid misinterpretations the basic weakness of efficiency calculations from a micro as well as macro-economic point of view have to be pointed out. For reasons of operational ability these calculations extensively comprise monetary effects. This means that cost and benefit are only determined with a view to monetary aims. There are, then, ’intangible’ aims and thus, ’intangible’ cost and benefit for which a final valuation lies within the judgement of the decisionmaker.

Further difficulties arise with the uncertainties combined with the determining of most of the basic influencing factors involved in the economic and financial profitability of biogas plants. To pinpoint the importance of possible fluctuations of any exceptions or data for the profitability calculated, sensitivity analyses should be carried out. The extent of any effects on the result of the profitability calculation should be investigated especially for the following factors:

- available quantity of substrates
- expected gas production, especially the reduction for colder seasons
- the proportion of effectively utilizable gas production on total production
- type and quantity of replaceable fuels
- price of the fuels replaced (also in time-lapse)
- type and quantity of the replaced mineral fertilizer
- price of the mineral fertilizer (also in time-lapse)
- extent of the increase in agricultural production as a result of biodung
- economic lifetime of the plant, respectively its most important components
- rate of interest for capital invested
- amount and development of the running costs

Observation of the development

It would be practical to observe the development of the most important determinants in the profitability over a period of time and compare them now and again with the assumptions made at the planning stage. A year after being taken into operation the plant should be subjected to a renewed assessment concerning the economic advantage and the financial productivity.

Further reading:

H. Finck, G. Oelert: A guide to the financial Evaluation of Investment projects in energy supply. GTZ No/63.

The Annuities Method

Compared to other approaches, the annuities method is more suitable for assessing absolute economic efficiency and for comparing various investments with very divergent projected lifetimes. The annuities method is a reliable means of comparing the economic viability of various investment options. It takes into account reinvestments and differences in system mortality.

According to the simplified approach presented here, however, a single cost increase factor is applied for all inputs, i.e. energy, services, spare parts, etc. As we have seen in the course of the past few years, though, the cost of energy and of wares with a close tie-in to the cost of energy (such as chemical fertilizers) has been increasing more rapidly than, say, the national wage index of most countries. Also, discrepancies can always be expected to be particularly pronounced in countries where the state intervenes in the price structure. Thus, if the economic efficiency of a particular system is to be projected with any real degree of accuracy, the price-increase rates for each individual product must be taken into account.

Basically, the annuities method converts the investment into fixed annual costs suitable for direct comparison with the annual benefits.

$AN = B - C - I0\ CR\ (i,T)$ *or*

$AN = R - ANI$

where

AN = *annuity, i.e. the annual gain, calculated for the first year (year 0)*
ANI = *annuity of the investment*
B = *annual benefits (savings and/or returns on investment), calculated for the year 0*
C = *annual costs, calculated for the year 0*
R = *annual reflux* ($R = B - C$)
$I0$ = *total initial investment volume, calculated for the year 0*
CR = *capital recovery factor*
i = *assumed interest rate (discount rate)*
T = *projected service life or time required for amortization of the investment*

Annuity (AN)

The purpose of the annuities calculation is to convert all net payments in connection with an investment project to a series of uniform annual payments - the so-called annuities. Conversion is effected by multiplying the individual payments by the capital recovery factor CF.

$AN = ANR - ANI$
$AnI = I0\ CR\ (i, T)$
$ANR = R$ *for constant annual benefits*

As long as the annuity AN is positive, the project may be regarded as profitable in absolute terms under the postulated conditions. If it is negative, the project must be regarded as unprofitable. The annuity can be equated with the anticipated mean annual profit/loss. It is calculated for the year 0, i.e. the year in which the investment is undertaken.

Annual benefits (B)

The annual benefits comprise the monetarily evaluable returns, savings, etc. yielded by the investment. These may derive from:

- Power generation

  Naturally, only the net energy gain can be counted, i.e. the process energy fraction (for agitators, pumps, heating, and any outside energy input) must be subtracted from the total gas yield. If the generated power is sold, the returns are included in the calculation. Any energy used to replace previous outside energy inputs counts as savings.
- The substitution of digested sludge for chemical fertilizers can often yield savings in developing countries, where in the past, much of the material used as substrate has so far not been used as fertilizer. Accurate monetary evaluation is difficult, because the fertilizing effect of digested sludge is substantially influenced by the type of storage, the climate, the techniques employed in spreading the sludge and working it into the soil, etc.
- Savings attributable to the superior properties of digested sludge: These may result from the improved fertilizing effect of the sludge, its hygienization, reduced odor nuisance, and more advantageous handling properties such as reduced viscosity, improved homogeneity, etc. However, it is normally quite difficult to attach a monetary value to such benefits. Legal regulations pertaining, for example, to reducing odors or improving hygiene can be of decisive influence.

Annual costs (C)

The current annual costs are made up of the expenses incurred for:

- maintenance and repair,
- plant operation,
- inspection fees. etc..
- system attendance.

Most such items can only be estimated, whereby 1 - 3 % of the investment volume is generally accepted as rule-of-thumb quota for maintenance and repair. For simple biogas systems in developing countries, the percentage is usually somewhat lower, though it could be even higher for the more complicated types of systems used in industrialized countries.

Operating costs are largely attributable to the depletion of consumables (such as desulfurizer cleaning agents) and to outside energy requirements, e.g. electricity for running agitators and mixers.

Inspection fees usually arise in connection with pressurized biogas systems. (According to German standards, a system is defined as pressurized if it operates on an internal pressure of 1.1 bar, = 0.1 bar gage, or more.)

Expenses in connection with system attendance by the owner-operator himself or by his employees should usually be taken into account, whereby the hourly wage and time expenditure are subject to wide variance.

Total investment volume (I0)

The total investment volume includes the capital outlay for:

- the digester, including agitating, mixing and heating equipment,
- gas storage and safety provisions,
- gas usage, including integration into existing systems,
- linkage between the biogas system and the farm estate, i.e. liquid-manure and gas lines, structural alterations on stabling structures, etc,
- planning, construction supervision, licensing fees, etc.

Reinvestment costs for the replacement of individual components (pumps, floating gas holder, etc.) with service lives that expire prior to the end of the projected system service life

T must be included in the total investment volume. For the purposes of this simplified approach, the cost of such reinvestments may be quoted for the year 0:

$$I = I0 + I1 + I2 + ...$$

where

I = *total investment volume*
$I0$ = *initial investment volume*
$I1, I2, ...$ = *reinvestments*

Capital recovery factor (CR)

CR accounts for the cost of financing a project for which the investment volume has to be raised by way of loans (interest, compound interest) . If the capital outlay is covered by cash funds, CR is used to account for ceasing gain in the form of lost interest and compound interest on assets.

CR is calculated according to the formula:

$$CR (i,t) = (qt (q-1)) / (qt-1) = ((1+i)t\ i) / ((1+i)t - 1)$$

where

$q = 1+i$
i = *assumed interest rate in percent*
t = *time in years*

Assumed interest rate (i)

The assumed interest rate must be determined with due regard to specific individual conditions. In this context, the assumed interest rate is defined as a real interest rate, i.e. after adjustment for inflation. In the case of cash outlay, the real interest rate would equal the rate of interest that the capital would have borne on the money market. Accordingly, the assumed interest rate is equal to the current mean debt interest rate demanded by the bank for the loan capital, when the entire project is financed with borrowed money. Moreover, money costs in the form of bank service charges, the owner’s own administrative overhead, etc. must also be included. Since, however, most projects involve a certain degree of mixed financing, the assumed interest rate will take on a value located somewhere between the debt interest rate and the credit-interest rate, depending on the case situation. (Note: All rates adjusted for inflation!).

Benefits and Impacts of Biogas Technology

Improvement of sanitary and health conditions

Reduction of the pathogenic capacity

The processing of animal and human excrement in biogas systems obviously improves sanitary conditions for the plant owners, their families and the entire village community. The initial pathogenic capacity of the starting materials is greatly reduced by the fermentation process. Each new biogas system eliminates the need for one or more waste/manure/latrine pits, thereby substantially improving the hygiene conditions in the village concerned. From a medical point of view, the hygienic elimination of human excrement through the construction of latrines, connected directly to the biogas systems constitutes an important additional asset. In addition, noxious odors are avoided, because the decomposed slurry stored in such pits is odorless.

Reduction of disease transmission

Since biogas slurry does not attract flies or other vermin, the vectors for contagious diseases, for humans and animals alike, are reduced. Furthermore, eye infections and respiratory problems, attributable to soot and smoke from the burning of dried cow dung and firewood, are mitigated.

Gastrointestinal diseases

In the rural areas of China and numerous other subtropical countries, gastrointestinal diseases are the most widespread type of affliction. Epidemics of schistosomiasis, ancylostomiasis, dysentery and others are caused by the transmission of pathogens via ova contained in fecal matter. Contagion is pre-programmed by the farmers themselves when they use night soil or liquid manure to fertilize their fields. As long as inadequate sanitary and hygienic conditions prevail, the health of the rural population will remain threatened. The anaerobic digestion of human, animal and organic wastes and effluents extensively detoxifies such material by killing most of the ova and pathogenic bacteria. It is not surprising, that the widespread popularization of biogas in China has had immediate beneficial effects on the sanitary conditions of the areas concerned. As soon as the introduction of biogas technology fully covered an area, no more human, animal or organic wastes were deposited in the open. This eliminated some of the main sources of infectious diseases. Schistosomiasis, previously a widespread, menacing disease in rural China, was reduced by 99% through the introduction of biogas technology. The number of tapeworm infections has been reduced to 13% of the pre-biogas level.

Economic value of disease reduction

For the user of biogas technology, health effects are tangible with regards to the smoke reduction in the kitchen. The reduction of parasitic diseases can only be felt if the numbers of biogas systems in an area reaches a critical threshold. Similarly, for a larger entity like village, district or nation, health impacts of biogas systems do not grow as a linear function of the numbers of biogas units installed. Biogas subsidies can compete with expenditures for other forms of health care only, if the funds are substantial enough to reach a high coverage with biogas units.

As morbidity is, generally, a multi-factor issue, impacts of widespread biogas dissemination can only be assessed by an ex-post analysis: expenditures for the treatment of key diseases before and after the widespread introduction of biogas technology. Analyses of that kind can - with caution - be used to estimate the value of health benefits in a comparable region that is targetted for a biogas program.

Nutrition

The permanent availability of cooking energy in a household with a well functioning biogas plant can have effects on nutritional patterns. With easy access to energy, the number of warm meals may increase. Whole grain and beans may be cooked longer, increasing their digestibility, especially for children. Water may be boiled more regularly, thus reducing water-borne diseases.

Culture and education

The use of biogas for lighting can lead to profound changes in the way families integrate in the cultural and educational sectors. Biogas lighting makes it possible to engage in activities at night such as reading or attending evening courses. The women and children, of whom it was previously expected that they gather fuel, now have more free time and are more likely to attend school. Experience also shows that the use of biogas systems gives women more time to devote to the upbringing of their children.

Distribution of income

One possible drawback of the introduction of biogas technology could be an accentuation of existing differences in family income and property holdings. Poor tenant farmers could be coerced into selling - or even delivering free of charge - their own manure supplies to the landlord or other more prosperous farmers for use in their biogas plants. Obviously, this would be of great disadvantage with respect to the already low yields and energy supplies of small and/or tenant farmers.

If the benefits of biogas technology are not to be limited to farmers with a number of livestock of above four TLUs (Tropical Livestock Units), biogas programs will have to consider biogas systems that integrate neighborhoods or villages, e.g. by building and operating community biogas systems.

Effects on regional employment

The construction phase of biogas systems provides short-term employment and income due to the need for excavation, metal-work, masonry and plumbing. As documented in reports from China, the construction of biogas systems encourages local industries to manufacture the requisite building materials and accessories. Practically every district in question has its own enterprises for the production of cement, lime, bricks, plastic pipes, T-bars, plugs, stoves, lamps, gas lines, etc. Obviously, the subsequent operation and maintenance of the finished systems can have long-term beneficial effects on regional employment and income. Skilled craftsmen can be recruited not only for construction, but for service and repair. Community plants require a permanent staff for plant administration, raw material procurement, plant operation and maintenance, distribution of the gas yield and disposal of the effluent sludge.

Improvement of living conditions

For the poor, the main advantage of higher crop yields is that they improve the family’s nutritional basis and reduce the danger of famines. The more prosperous farmers can sell their excess crops, thereby increasing their income. This has a snowball effect in that those farmers subsequently expand their mode of living and begin to spend more on such things as household appliances. Consequently, local and/or regional employment and income also benefit. However, the number of existing biogas systems has not yet become large enough to allow accurate quantification of the type and extent of the individual effects.

Rural-urban migration

To the extent that the introduction of biogas technology generates jobs and higher income while improving living conditions, it may be assumed that fewer rural inhabitants will be drawn away to urban centers in search of employment. While, as mentioned above, no accurate quantification is as yet possible concerning the effects of biogas technology on rural-urban migration, most Indian experts agree that the available information indicates a real and noticeable influence. Further investigation is required for obtaining reliable data on the nature and extent of such effects.

Reducing deforestation as benefit

Well functioning biogas plants can replace the entire consumption of firewood or charcoal of an individual household by biogas. In macro-economic cost-benefit analyses the amount of firewood or charcoal saved is often directly translated into hectares of forest lost. The monetary benefit of biogas would then be reflected in re-afforestation costs. This simplistic approach is questionable for four reasons:

1. Rural populations use, as much as possible, dry firewood. Live trees are only harvested, if no dead wood is available. But even then, careful pruning of trees instead of felling may not cause extensive damage.
2. Afforestation sites or firewood plantations can by no means replace a natural forest. They can not re-establish the bio-diversity of a natural forest nor can they provide for the multitude of forest products that rural populations depend on for their nutritional, medical and other needs.
3. Between the destruction of a natural forest and the re-establishment of some form of tree cover lies a time gap with negative, often irreversible effects on soils, river beds, fauna and flora.
4. Firewood harvesting does not proceed by clear-felling hectare after hectare. First, dry branches, then dry twigs and leaves are collected. Then, the first green branches are harvested, followed by the cutting of smaller trees. Gradually, a large area is thinned out. Until a certain minor degree of destruction, natural regeneration is still possible, provided there is adequate protection. In this case, it is the cost of protection that determines the value of biogas.

For national or regional planning, however, the reduction of deforestation and consequent soil erosion is one of the main arguments to allocate public funds for the dissemination of biogas technology. While a ready-made formula cannot be offered to calculate the monetary value of biogas in terms of reducing deforestation, some guiding questions may assist the planner to realistically assess the profitability of biogas compared to other environmental interventions.

- What part of the household energy needs is covered by green wood? How much is from forests, how much from sustainable plantations?
- What part of the household energy needs of the area in question could realistically be covered by biogas?
- Which interventions of damage-prevention would have similar effects (e.g. improved stoves, forest protection, firewood plantation, solar and other alternative technologies, etc.)?
- Which interventions of damage repair would have similar effects (reforestation, erosion control, protection of reforestation sites, etc.)?
- How do we value the difference in ’environmental quality’ which exists between a preserved natural forest and an area, once bare of trees and now replanted with trees?

Global Environmental Benefits of Biogas Technology

With anaerobic digestion, a renewable source of energy is captured, which has an important **climatic twin effect**:

1. The use of renewable energy reduces the CO_2-emissions through a reduction of the demand for fossil fuels.
2. At the same time, by capturing uncontrolled methane emissions, the second most important greenhouse gas is reduced:

1m^3 cattle manure = 22,5 m^3 biogas = 146 kWh gross = 36 kg CO_2- Emissions

Smaller agricultural units can additionally reduce the use of forest resources for household energy purposes and thus slow down deforestation (about 1 ha of forest per rural biogas plant), soil degradation and resulting natural catastrophes like flooding or desertification.

1 m^3 biogas (up to 65% CH_4) = 0,5 l fuel oil = 1,6 kg CO_2

1 m^3 biogas = 5,5 kg fire wood = 11 kg CO_2

When applied for industrial or municipal wastewater treatment, surface waters and other water resources (rivers, sea, ground and drinking water resources) are being protected. Often the purified wastewater can be reused, e.g. as process water in industry or as irrigation water in agriculture. Costs saved for providing additional water can be directly translated into benefits.

The introduction, promotion and broad-scale dissemination of anaerobic technology into agro-industrial, domestic and agricultural sector combined with efficient power and heat generation or household energy appliances allows by now an efficient and viable reduction of environmental pollutants.

The impact on the greenhouse effect

The greenhouse effect is caused by gases in the atmosphere (mainly carbon dioxide CO_2) which allow the sun’s short wave radiation to reach the earth surface while they absorb, to a large degree, the long wave heat radiation from the earth’s surface and from the atmosphere. Due to the "natural greenhouse effect" of the earth’s atmosphere the average temperature on earth is 15°C and not minus 18°C.

The increase of the so called greenhouse gases which also include methane, ozone, nitrous oxide, etc. cause a rise of the earth's temperature. The World Bank Group expects a rise in sea levels until the year 2050 of up to 50 cm. Flooding, erosion of the coasts, salinization of ground water and loss of land are but a few of the consequences mentioned.

Until now, instruments to reduce the greenhouse effect considered primarily the reduction of CO_2-emissions, due to their high proportion in the atmosphere. Though other greenhouse gases appear to a smaller extend in the atmosphere, they cause much more harm to the climate. Methane is not only the second most important greenhouse gas (it contributes with 20% to the effect while carbon dioxide causes 62%), it has also a 25 times higher global warming potential compared with carbon dioxide in a time horizon of 100 years.

Table 1: Relative climatic change potential caused through different greenhouse gases within a period of 100 years after the emission, data mass equivalent of CO_2

Gas	Relative global warming potential 20 years after emission	Relative global warming potential 100 years after emission
CH_4	63	24,5
N_2O	270	320
$FCKW_{12}$	n.	8.500
CF_3Br (Halon 1301)		5.600
C_2F_6 (Perflourethan)		12.500

Source: 'Klimaänderung gefährdet globale Entwicklung'. Enquete-Comission "Schutz der Erdatmosphäre" of German Bundestag, 1992

The reduction of 1 kg methane is equivalent to the reduction of 25 kg CO_2. The reduction of greenhouse gases with a high global warming potential can be more efficient compared with the reduction of CO_2.

Sources of methane emissions in the agricultural field

The amount of worldwide methane emissions from agricultural production comprises about 33 % of the global anthropogenic methane release. Animal husbandry alone comprises 16 %, followed by rice fields with 12 % and animal manure with 5 % . While methane released through digestion of ruminants (about 80 Mil t CH_4 per year) can rarely be reduced, methane emissions from animal waste can be captured and energetically used through anaerobic treatment. The amount of methane emission mainly depends on fodder, animal type and animal waste systems. For example: the methane emission potential from dairy cattle in industrialized countries is about 0,24 m^3 CH_4/kg volatile solids (influence of fodder), in developing countries it is only about 0,13 m^3 CH_4/kg volatile solids. But taking into account the aerobic condition of solid dung systems (only 5 % of the methane emission potential is released) it is mainly the liquid waste management systems which contribute through anaerobic conditions with a high methane release to the climate change (up to 90 % of the methane emission potential is released).

From the worldwide 30 Mil t of methane emissions per year generated from the different animal waste management systems like solid storage, anaerobic lagoon, liquid/slurry storage, pasture etc. half of the emissions could be reduced through anaerobic treatment.

Eastern Europe, Asia and Far East contribute with the highest amount of 6,2 Mil t methane emissions/year each. While in Eastern Europe the emissions are caused by anaerobic animal waste management system, in the Far East they are caused by the high numbers of livestock.

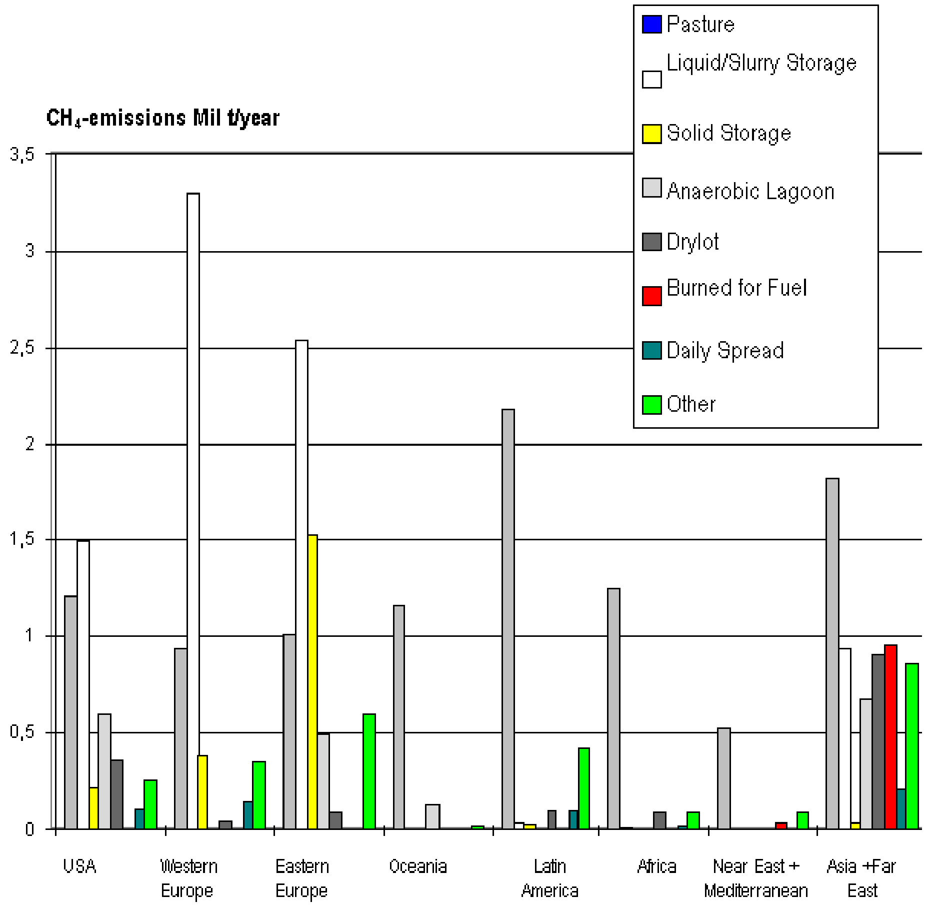

Figure 1: Methane-emissions from different animal waste management systems
Source: Cassada M. E., Safley L.M.Jr., 1990: "Global Methane Emissions from Livestock and Poultry Manure". EPA CX-816200-010.

Methane reduction potential through the application of biogas technology

Through anaerobic treatment of animal waste, respectively through controlled capture of methane and its energetic use, about 13,24 Mil t CH_4/year can be eliminated worldwide. This figure includes methane emissions resulting from incomplete burning of dung for cooking purposes. By replacing dung through biogas, these emissions are avoided. In total about 4 % of the global anthropogenic methane emissions could be reduced by biogas technology.

If fossil fuels and firewood is replaced by biogas additional CO_2-emissions can be avoided including a saving of forest resources which are a natural CO_2 sink. Including all these effects about 420 Mil t of CO_2-equivalents are avoidable.

Table 2: CO_2-Reduction through biogas utilization, saving of fossil fuels and fire wood resources.

		CO_2 Reduction [Mil t CO_2/year]
CH_4	13,24 Mil t/year CO_2-equivalent: methane x 25	330,9
Biogas	33.321 m^3/year	
Substitution of fossil fuels		44,7-52,7
Fire wood savings		4,17 - 73,8
Total		388 - 449 = 418,5

Reduction potential of nitrous oxide emissions from agriculture

The relative climatic change potential of nitrous oxide is up to 320 times higher as that of CO_2. Nitrous oxide generation is a natural microbial process. It is produced during nitrification and de-nitrification processes in soils, stables and animal waste management systems. In general, nitrous oxides emissions appear in soils without anthropogenic influence. Fertilizing as well as special conditions during storage can immensely increase the emissions.

Little detailed information is available about the reduction potential of nitrous oxides through anaerobic digestion of animal waste. There is still a big need for further research. Nevertheless, ongoing research results indicate that anaerobic digestion of animal waste significantly reduces nitrous oxide emissions by:

1. avoiding of emissions during storage of animal waste,
2. avoiding of anaerobic conditions in soils,
3. reducing N_2O-emissions through increased nitrogen availability for plants and a faster nitrogen absorption through crop plants,
4. reducing application of inorganic nitrogen fertilizer by which N_2O-emissions are reduced during production of nitrogen fertilizer.

Considering all these effects a N_2O-reduction potential through anaerobic treatment of about 10 % can be assumed. This means that 49.000 t N_2O/year or 15,7 Mil t CO_2-equivalents could be reduced on average.

So far, the environmental costs of greenhouse gas emissions have not been calculated. One means, proposed by the US administration on the climate conference in Kyoto, is the introduction of emission rights which can be traded. In doing so, national economies could attribute a monetary benefit to the avoidance of greenhouse gas emissions.

Financing and public support

Sources for financing

The cost necessary for the construction of biogas plants frequently exceeds the means at the disposal of the investor, in other words he cannot cover them from his regular income or savings. This could also apply to the larger replacement investments occurring at certain intervals during the economic lifetime of the plant. Besides the non-recurring i.e. a-periodical costs, the running costs of the plant have to be borne. This solvency outflow however, is set against solvency inflow in the form of regular revenue. A solvency analysis can show how far the net solvency outflow has to be financed and how much scope there will be from net solvency inflow. Usually the construction and operation of biogas plants involve a demand for financial means which can only be covered by borrowed capital. In general the following can be seen as sources:

- Grants and credits from institutes for economic aid
- Means from the national budget of the developing country (public support)
- Credits from national (developing) banks
- Resources of the project initiator
- Fees/contributions from the user

The various sources have to be individually examined for their ability to provide the means.

Running, maintenance and repair costs

The financing of investments and of the operation of the plant should be clearly settled at the preplanning stage. It has to be ensured that the quota derived from public funds is firmly planned in the budget. Special attention has to be paid to the question of how the running, maintenance and repair costs can be financed. Means for servicing and repairing are of essential importance and have to be available in sufficient quantity and in good time in order to make full use of the possible lifetime of the plant and also to insure the confidence of the user in the reliability of the plant.

Financing by credit

When financing by credit the questions of liability and debt provisions should be clarified. The borrower should always be able to bear the possible risk or be immune to this risk by having state credit guarantees. The debt provisions should be worked out so that they conform to the development of cost and yield. Credit repayment terms are frequently much shorter than the lifetime of a project e.g. 5 years compared to 15 - 20 years. The bringing up of capital often becomes an invincible barrier for the investor.

State support

When the profitability of biogas plants are negative on a private scale, but on a national scale lead to positive results, state support measures are required.

On principle the following can be seen as starting points for the distribution of biogas plants to such an extent that would make them macro-economically feasible and socio-politically desirable:

- the creation or alteration of structural conditions for individual investment decisions in favour of biogas plants, e.g. more critical control of firewood consumption and tree-felling, regulations concerning the treatment and disposal of substrates (waste water, faeces)
- the subsidising of private and institutional community biogas plants by means of grants or inexpensive credits
- the construction and operation of biogas plants as public utility enterprises especially as municipal community plants, in appropriate instances by allocation of appropriated means to the municipalities.

Families with low incomes

The more plants are extended to families with low incomes, the less can the costs for construction and operation of the plant be met by contributions from the users. On village community plants in India providing energy for the households practical experience has indicated that not even the running costs can be met by user fees. Consequently, not only the investment costs but also a proportion of the running costs has to be covered by general tax revenue. The resolution of the Indian Government provides a guideline for the extent of public support whereby from case to case 50 to 100% of the cost for community biogas plants are subsidised.

Since the implementation of biogas plants necessitates considerable investment from public funds, sufficient public means for parallel socio-techno-economic investigations should be provided for, which allow a suitable feedback to promotion and distribution strategy.

Biogas - Program Implementation

Dissemination of biogas technology

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. In various countries, experiences with the dissemination of agricultural biogas systems exist. Depending on the stage of biogas development in a country or region, the structure of a biogas programme reflects the phases of implementation:

- Research and development
- Pilot programs
- Dissemination
- Networking

A criteria list with excluding, critical and ideal factors for the dissemination shows if, in a concrete case, the building of biogas plant is advisable. Reference information and addresses of organizations concerned with funding, implementation and networking in the field of biogas development can be found in chapter **Organizations and Networks**.

Implementation planning

Dissemination and implementation of biogas technology has to be organized and planned. Biogas projects are usually quite complex as multiple disciplines like construction, agriculture, economics, sociology besides planning and management are involved. It is advisable to create a program of implementation that contains the problem analysis, the objectives, region of dissemination, target groups, the strategy, necessary activities, achieved outputs, required inputs etc.

Regional level

Biogas projects may have general or specific objectives. In general it has been proven that the energy aspect alone does not justify the cost for biogas technology. The overall objective, to which biogas technology contributes is the environmental amelioration which includes energy-related objectives and the improvement of living conditions (including economical conditions) of biogas users.

The following aspects have to be taken into account at regional level to prepare biogas dissemination:

- region with the favorable climatic conditions
- existence of a potential target group
- private sector involvement
- informal sector involvement
- government involvement
- organizations/networks to cooperate with
- economic viability on micro- and macro level
- financing program and the cost of program
- material requirements
- technological standards
- available know-how on planning, management, technician and artisan level
- the role of subsidies
- kinds of information, propagation, awareness creation
- assessment of sustainability

Local level

The ultimate goals of any biogas program are to make maximum use of the available organic material and to provide benefits of biogas technology to as many families as possible. In particular, measures must be developed for those whose economic situation so far does not allow their participation in the biogas program.

Representatives of the local population must be involved in finding the most workable solution. The idea of constructing a community biogas plant should not be forced upon the group concerned, even if only by the power of persuasion.

If a decision is made to attempt a blanket coverage with biogas technology, various organizational measures must be taken at the local level to successfully execute the program:

- Assignment of a person responsible for the program (frequently, that person will be the promoter himself).
- Verification of basic data concerning the availability of dung and other suitable substrates, the anticipated gas consumption figures, the size of standard plants and the economic/financial aspects.
- Assessment of the capacities of local craftsmen, of the limitations of material supplies at the right time and the assignment of any work to be contracted.
- Training of personnel and organization of maintenance and repair services.
- Selection of suppliers for accessories and spare parts.
- Securing of loans and subsidies at the time required.
- Securing of binding pledges for all self-help activities.
- Stipulation of the sequential order of construction of the individual biogas system as agreed between all parties concerned.
- Ensuring that all those concerned are willing and able to gather sufficient amounts of substrate.

Factors for a successful dissemination

Cost of investment

An obvious obstacle to the large-scale introduction of biogas technology is the fact that the majority of the rural population cannot afford the cost of investment for a biogas plant. A further difficulty is that the overall social advantages can only take hold for the individual in the case of blanket implementation. This applies in particular to the preservation of forests, the improvement of hygiene, energy access for the poorest groups of the population and to the promotion of artisan business, training systems and service facilities. Such advantages cannot be secured for all through the installation of a few biogas plants that only better-off farmers can afford. The gap between their standard of living and that of the poor would thus become even more apparent.

Benefits of biogas technology

The essential benefits of biogas plants are not manifested in individual cost-efficiency calculations. They can only take effect on a general economic scale, and then only when entire areas have become fairly well "saturated" with biogas systems. Thus, individual decisions to invest in biogas plants can contribute little to the propagation of biogas technology, even if its introduction already appears necessary from a general economic standpoint. Public measures for the promotion of biogas technology are therefore indispensable, whereby special attention should be paid to widespread introduction.

If the installation of biogas plants is to serve as part of a social development progress, the decision in favor of biogas has to be made by the future users or owners of the plants themselves. In order to achieve that goal, the following prerequisites must first be met:

- the technology must be made known;

- the advantages for the economy in general and the economic benefits for the individual must be adequately quantified and publicized;
- the technical conditions for the construction of plants must be appropiate;
- maintenance and repair services must be provided within a reasonable radius and made available without an excessive amount of time-consuming official procedure;
- investment costs must be reasonable and the necessary loans and subsidies must be accessible.

Biogas programs that do not satisfy these conditions can only be materialized by persuasion, political pressure or exaggerated financial assistance.

A successful implementation strategy will require steps within the following fields of activity:

- Information and public relation campaigns
- Educational and training programs
- Financial promotion
- Politico-administrative and organizational aspects
- Social acceptance

Biogas Programme Structure

The structure of a biogas program depends on the stage of biogas development in which the program operates. We have listed below a number of typical forms of biogas programs with their important structural elements. In reality, these programs often represent stages of a longer biogas program. For example, a biogas dissemination program can have a research and development (R&D) phase, a pilot phase, a dissemination phase and a follow-up phase. Often, these phases have large overlaps.

Biogas research and development programs

R&D programs do not aim at widespread dissemination of the technology. They work on improving existing technologies, on innovative designs or on optimizing bio-technological processes. In such applied research it is desirable to communicate and cooperate closely with the potential target group. The laboratory and the research construction sites should actually be on a farm rather than in an isolated compound in town. R&D programs can be attached to implementation programs, they can be part of a national or international agricultural research center or they can be an independent supra-regional project doing research for biogas projects in the region.

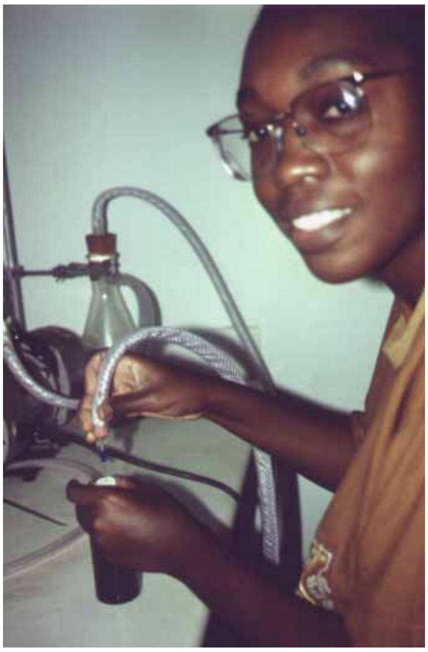

Figure 2: Test of the biochemical methane potential (BMP-Test): The bench-scale method is used to adapt and analyse wastewater and an inocculum for anaerobic treatment.
Photo: Verink

Typical structural elements of an R&D program would be:

Central Laboratory to examine chemical composition of substrates, slurry, biogas. To examine qualities of building materials, paints, pipes etc. The head of the lab should be an experienced, practical chemical engineer.

Mobile Laboratory to do on-farm research.

Construction Team consisting of a civil engineer and a small team of technicians and artisans to build and test innovative technological solutions under farm conditions.

Agricultural Team consisting of an agricultural engineer and agro-technicians to research on the use of slurry and stable designs.

Data Bank and Monitoring Unit to collect and process data from the own research and from literature.

Communication Unit headed by the program manager to link the program with international research and implementation programs.

Biogas pilot programs

Pilot programs operate in countries or regions where biogas is not known and biogas technology is not tested. They rely largely on an existing and tested technology which has to be fine-tuned to be fit for widespread dissemination. At the same time the suitability of the region and the selected target groups is counterchecked. The main objective of pilot programs is to receive a constructive feedback of target groups and to alter the technology accordingly. To gain experience under a variety of conditions, typical climatic, topographic and ethnic areas are selected. Their main objective is to make the technology and dissemination approaches fit for widespread dissemination.

Typical structural elements of a pilot program are:

> ***Construction and Agriculture Units*** for the designated pilot areas, headed by a civil engineer, each consisting of a small team of technicians and artisans. The construction teams may have a store in the respective pilot area with a stock of material and appliances. They construct pilot plants, set up slurry-use facilities and follow-up closely the performance of pilot biogas units.
>
> ***Training Unit*** organizes training courses for artisans, technicians and for the pilot farmers. The training unit also uses training facilities in neighboring countries.
>
> ***Communication Unit*** is responsible for the communication with NGOs, churches, government institutions and private enterprise in the region. They also keep in touch with international developments.
>
> ***Data Bank and Monitoring Unit*** collects data from pilot plants and data from research and literature.

Biogas dissemination programs

At a stage when the development of biogas technology is mature enough and target group parameters seem conducive, widespread dissemination can be envisaged. Parallel to the widening of the scope should start a reduction of direct program involvement. In particular the construction part, but also advisory service, planning and follow-up should be increasingly (and the earlier the better) handled by private entrepreneurs. Farmers do not risk technology failure anymore, for that reason they can be expected to carry most of the cost of their biogas unit.

> ***Commercialization Unit*** develops approaches to make biogas dissemination increasingly independent from program inputs. Elements of their work can be the setting up of credit schemes for biogas farmers and biogas constructors, equipping biogas constructors with tools and other facilities, training entrepreneurs in pricing and accounting and linking biogas enterprise with potential customers.
>
> ***Quality Control Unit*** monitors built biogas units and gives feedback to constructors. If necessary they advise on re-training or sanctions against unreliable constructors.
>
> ***Public Relations Unit*** supports the biogas entrepreneurs with PR campaigns to advertise for biogas technology. The PR unit keeps in touch with various government departments to create a conducive atmosphere for biogas.
>
> ***Data Bank and Monitoring Unit*** (see above).

Biogas networking program

Networks usually operate at a supra-national level. They support ongoing initiatives, research and private enterprise in the countries of their region. They normally do not get operational at farm level. Typical tasks would be to organize workshops, training courses or conferences to enhance a south-south technology and know-how transfer. Typical structural elements would consist of:

> ***Documentation Center*** including a library and a data bank.
>
> ***Organizational Unit*** to prepare, organize, carry out and follow up workshops, seminars and conferences. This unit supplies the communication unit with documentation on their activities.

Communication Unit to lobby at a government level and with international organizations for biogas, to disseminate relevant information among biogas promoters and researchers in the region and to keep in touch with international developments.

Criteria for the Dissemination of Biogas Technology

Following, are the criteria (excluding or critical factors) which make biogas dissemination in developing countries impossible or more difficult. The ideal project location will rarely be found.

Excluding factors

If only one of the following criteria is evident, then the widespread dissemination of simple household biogas plants is not possible. As an exception, suitable farms in the region could allow individual measures that make biogas a feasible technology.

- 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 kg in night stabling
- no stabling or livestock in large pens where the dung cannot be collected
- no building materials available locally
- no or very little water available
- integration of the biogas plant into the household and farm routines not possible
- no suitable institution can be found for dissemination

Critical factors

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

- low income or unstable economic situation of the target group
- unfavorable macro- and micro-economic conditions
- gas appliances not available regionally or nationally
- irregular gas demand
- very good supply of energy throughout the year, therefore only moderate economic incentives for the biogas plant
- high building costs
- low qualification of artisans
- counterpart organization has only limited access to the target group
- weak structure of the counterpart
- no substantial interest of the government is evident

Ideal conditions

If each of the following conditions is fulfilled then household biogas plants will definitely be a success. A dissemination program is then strongly recommended.

- even, daily temperatures over 20°C throughout the year
- regular gas demand approximately corresponding to gas production
- full stabling of animals (zero-grazing) on concrete floors
- at least 30 kg/day dung available per plant
- dairy farming is the main source of income
- use of organic fertilizer is traditionally practiced
- farmers are owners of the farm and live primarily on the farm. Farm products are their main source of income.

- plants can be located in favorable positions to the stables and to the point of gas consumption
- operating the biogas plant can be integrated into the normal working routine of the house and the farm
- gas utilization and attendance of the plant can be clearly regulated within the household
- moderate price of plant in relation to the income of the target group
- economically healthy farms open to ’modernization’
- insufficient and expensive supply of fossil sources of energy
- building materials and gas appliances available locally
- qualified artisans exist locally
- counterpart organization has access to and experience in contact with the target group
- efficient counterpart organizations with the experience in cooperating with the private sector
- counterpart organization has experience in programs comparable to biogas dissemination
- political will of the government to support biogas technology and other small and medium-scale farm technologies
- secured financing of the dissemination structure

Information and Public Relation Campaigns

Implementation campaigns

The biogas concept must be promoted at national, regional and communal levels. The basic prerequisite for successful, comprehensive introduction of biogas technology is the effective motivation and mobilization of potential target groups. Motivation and mobilization are the two main pillars of the actual development process. The subsequent factual existence of biogas systems is merely the logical result of that process.

Thus, implementation campaigns can only be advanced and materialized in a decentralized manner by those concerned. Information campaigns, in contrast, can be planned and controlled in a centralized manner and carried out with lower participation levels on the part of the target group.

A successful PR campaign builds on experience in implementation, on direct contact with the target groups and on the confidence of having developed a sound and appropriate technology. Information transmitted in such a campaign must react to the doubts, limitations, fears of the potential users as they are encountered in the field. Typically, a fully fledged PR campaign starts at the end of a pilot phase and runs throughout the implementation phase of a biogas program.

Information material and PR channels

Magazines, newspapers, films, radio programs, posters, leaflets and manuals are suitable vehicles for the dissemination of information on biogas. It is not always possible to arrive at a clear distinction between information and advertising. The best publicity effect is achieved by providing a steady stream of information:

- on the technology per se
- on the economic effects for the household
- on the impacts on life quality
- on the overall economic and ecological impact

Of major importance in that context is the effective use of information vehicles such as local agricultural fairs, roadside billboards, market-square posters and, of course, the ubiquitous "grapevine". It must be regarded as unfortunate that no internationally recognizable biogas symbol or "logo" has been introduced to date; therefore, the development of national symbols is the more important.

Targeting information

Somewhat simplified, the target groups for information campaigns could be stratified on three levels: The national level, the regional or district level and the local or village level. In supporting or accepting biogas, all these levels play a role but must be approached in different ways.

The language of information should always be close to the language of the respective target groups. Those who read the printed information are more likely to be the top-echelon multipliers, not the semi-literate - or illiterate - ultimate consumers. The type of information and the complexity of information will vary from level to level, so does the presentation of information.

National level

PR work targets government (various ministries), national and international development agencies and companies with commercial interest in biogas. Vehicles for information flow would be high-level meetings like conferences and invitations to project area visits. Articles in the national press, radio programs and TV programs also contribute to create awareness on this level.

Regional or district level

The campaign targets government authorities on this level, churches and grass-root organizations working in development, environment and appropriate technologies. Suitable approaches are workshops, contribution to agricultural fairs and integration of the program into agricultural and development committees. The media (press, radio, TV) also have an impact on this level. On this level, agricultural colleges and high schools are approached as well. Demonstration plants for communal and industrial use are conceivable.

Local and village level

On this level, the end-users of biogas technology are directly approached through demonstration- or pilot plants, public meetings, billboards, leaflets and other means of mass-communication. On the village level, TV and print media are of lesser importance. Radio programs, in contrast target mainly the village level.

Costs of campaigning

Information campaigns are expensive. While the spread of general information is usually dependent on the availability of public or project funds, the private industry can often be persuaded to promote biogas plants or accessories in their commercial advertising. The media are often committed to developmentally relevant themes. Editorial contributions are not expensive but require a great deal of work. As a rule, the concept for a radio program portraying biogas farmers, for example, must be worked out by the biogas program.

The production of posters, leaflets or videos will have to be fully covered by the PR budget of the project. The most efficient, but also the most expensive and time consuming PR activity for biogas is the building of demonstration plants and organizing farmers to visit these plants. As much as possible, demonstration plants should be ’normal’ biogas plants operating on a farm to save on building and operation costs. The farmer operating a demonstration plant cannot be expected to be the ’tour guide’ for frequent visitors. Some kind of arrangement, e.g. free maintenance and repair, must be offered.

Demonstration plants

No potential biogas user can be expected to blindly trust in biogas technology, if none of the more respected members of the society has taken that risk before and succeeded. But demonstration plants are risky: any malfunction in a demonstration plant will have negative consequences for the entire program. Thus, demonstration plants are also a last test for the maturity of the technology. Since some demonstration plants serve no other purpose than that of a showpiece, the maintenance aspect is often in danger of being given insufficient attention, an eventual malfunction is practically inevitable. It is therefore highly recommended that several demonstration plants are installed at the same time in different locations, preferably on farms which have a keen interest in operating the plant. Organized maintenance services should be guaranteed for a period of at least the first three years. The cost of personnel, equipment and transportation must be included in the cost calculation for the demonstration plant, and it must ensured that the required funds are actually provided when needed. Past experience has shown that system malfunctions are frequently the result of minor deficiencies requiring no extensive repair work. Consequently, the housewives (and only subsequently their husbands) must from the very start be put in a position to perform minor repairs themselves, whereby the requisite knowledge base can be provided by the maintenance personnel.

Model farmers

As a rule, the more prosperous farmers need little prodding to install a biogas system, as long as they are provided with adequate information and guaranteed support in case of arising problems. The group that was targeted in early, poverty-oriented biogas programs, namely the less prosperous small farmers, are inherently reluctant in their commitment, because they cannot afford the cost of investment and are afraid that they may not be able to keep up the payments on a loan. In addition, few of them own enough livestock for generating the required amount of substrate. Rich farmers do not act as a model for smallholders, they are known to have connections and funds that a small farmer will never be able to acquire. Experience of the last decade of rural biogas dissemination has closed this gap between the rich model farmer and the poor ’target-farmer’. First, model farmers are selected from the more successful farmers among the potential users. They should be outstanding to some extent, but other farmers should be still able to accept them as a role model. Second, the target group of recent rural biogas programs has shifted upwards. Biogas technology is no longer regarded as a means to alleviate poverty.

Educational and Training Programs

Theoretical and practical training

One of the essential elements in the implementation of a biogas program is the proper training of those to be responsible for planning, constructing, operating and repairing the plants. Theoretical and practical training must therefore be regarded as an indispensable part of the implementation strategy. Training, in contrast to education, focuses on those who are actually in touch with biogas technology, either as part of the biogas program or as end-users.

Target groups for practical training

In addition to the general knowledge conveyed in vocational programs, special training centering on the practical skills required for everyday plant operation should be made available to:

- the owner-operators of biogas systems, mainly housewives and farmers;
- servicing and maintenance personnel;
- masons, fitters, plumbers and factory personnel involved in the construction or manufacture of biogas systems and system components;
- planners of biogas units and developers of biogas technology;
- organizers, promoters and multipliers, whereby the latter may be a social worker, the head of a biogas task force, foundation or self-help organization, or even a reporter or film producer working on a biogas-related project.

Teaching methods

Depending on the objectives of a particular training program, not only the content, but also the teaching methods involved must be tailored to the respective target group. The success of a training program is largely dependent on the time and duration of its presentation. The target group must be "available", i.e. most housewives can only spare time for instruction during certain hours of the day, and then only directly at or close to home, and farmers can rarely afford the time during harvesting season.

Relevance for the target group

The content of a biogas training program must also reflect the real needs of the individual for more information. The construction of biogas systems, for example, if taught to masons, should not be given mere theoretical treatment. On-the-job training combined with theoretical teaching (half day each over four weeks) has proven successful in training courses for engineers in Tanzania. The information being conveyed must be of direct and recognizable relevance for the target group. It is of particular importance that training seminars offered to craftsmen and servicing personnel, combine practical demonstration and practicing with simple theory.

The first few seminars held in a region usually involve certain difficulties due to a lack of teaching aids, illustrative material or classrooms. It may also be difficult to convince a farmer that students of a training course want to build a biogas digester on his farm. In many instances, the use of school rooms during school vacation and a single demonstration plant will have to suffice in the beginning. Most technical and agricultural schools will gladly offer their support.

Educational programs

Educational programs are defined as formal know-how transfer in schools, colleges or courses for the general public and potential users. They create awareness about biogas technology which goes beyond of what is transmitted in PR campaigns. Educational programs must be professionally supported, integrated and administered on a national, regional and communal scale by the respective ministries and authorities responsible for agriculture, education, health & hygiene and other relevant fields. Private educational institutions or the biogas program itself can as well get operational in carrying out educational programs.

Curriculum development

Biogas technology can be included in the curricula of elementary and secondary schools in two ways: first, it can be included in subjects such as biology, physical science, chemistry or agriculture. Second, it can be taught in a block, to which the mentioned subjects 'donate' time and teaching capacity. Teachers would need to be educated first, in order to develop a curriculum together with the biogas program.

Often, individual schools are not free to develop their own curricula. To create a conducive atmosphere for integrating biogas technology into school curricula, this has to be lobbied for on the national level, where nationwide applicable curricula are developed.

Agricultural colleges and universities are more free to offer specific biogas-courses than schools. Here, it is more the personal enthusiasm of lecturers and deans of faculties that plays the decisive role if or if not biogas technology is taught in a course. At least the practical use of biogas systems should be included in the curricula of medical schools. The professional know-how of planning and constructing a biogas plant should be conveyed within the framework of technical/vocational school training.

Demonstration models of biogas systems should be available in schools which have included biogas in their teaching. Excursions to nearby biogas plants will greatly awaken the interest of students in biogas technology.

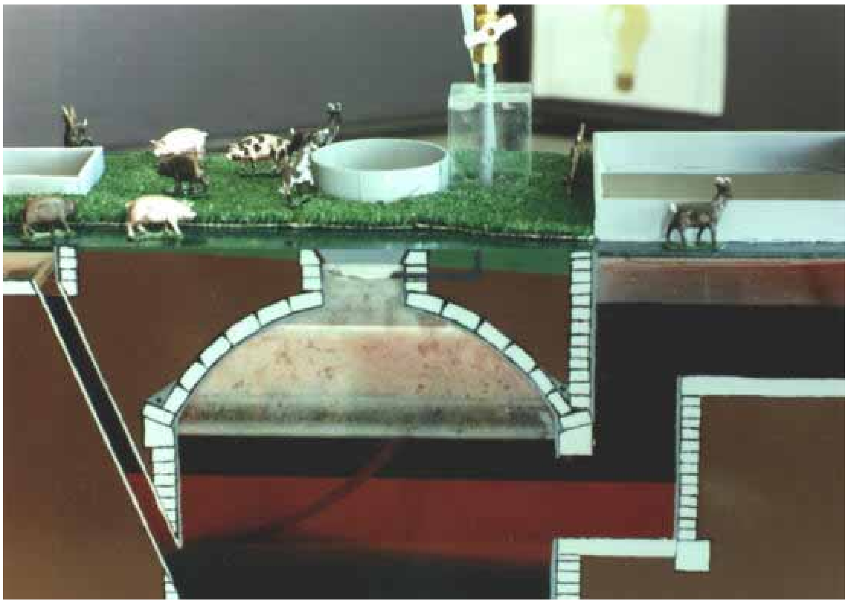

Figure 3: Model of a biogas plant for instruction purposes in schools
Photo: Bender

Financial Promotion and Public Support

Sources of financing

The investment costs necessary for the construction of biogas plants frequently exceed the means at the disposal of the investor. They cannot be covered from his regular income or savings. This could also apply to the larger investments occurring at certain intervals during the economic lifetime of the plant. Besides the non-recurring, periodical costs, the running costs of the plant have to be borne. These expenditures, however, should be set against income in the form of regular revenue. A liquidity analysis can show how far the net expenditures have to be financed from outside and how much contribution can be expected from the expected income. Usually the construction of biogas plants demands financial means which can only be covered by outside capital. In general the following can be seen as sources:

Running, maintenance and repair costs

The financing of investments and of the operation of the plant should be realistically assessed at the planning stage. It has to be ensured that the quota derived from public funds is carefully calculated in the budget. Special attention has to be paid to the question of how the running, maintenance and repair costs can be financed. Funds for servicing and repairing are often forgotten but are of essential importance in order to make full use of the economic lifetime of the plant and also to insure the confidence of the user in the reliability of the plant.

Financing by credit

When financing by credit the questions of liability and debt provisions should be clarified. The borrower should always be able to bear the possible risk or be immune to this risk by having state credit guarantees. The debt provisions should be worked out so that they conform to the development of cost and yield. Credit repayment terms are frequently much shorter than the lifetime of a biogas plant e.g. 5 years compared to 15 - 20 years. The re-payment of credits in this rather short time often becomes an invincible barrier for the farmer.

State support

When the profitability of biogas plants is negative on a private scale (financial analysis), but are favorable on a national scale (economic analysis), state support measures would make sense economically.

In principle, the following measures can be seen as supportive measures for the dissemination of biogas systems to an extent that would make them macro-economically feasible and politically desirable:

- the creation or alteration of structural conditions for individual investment decisions in favor of biogas plants, e.g. more critical control of firewood consumption and tree-felling, regulations concerning the treatment and disposal of substrates (waste water, feces)
- the subsidizing of private, institutional and community biogas plants by means of grants or inexpensive credits
- the construction and operation of biogas plants as public utility enterprises especially as municipal community plants through appropriate support to the municipalities.

Families with low income

The more biogas plants are constructed by families with low income, the less can the costs for construction and operation of the plant be met by contributions from the users. With village community plants in India, providing energy for households, practical experience has indicated that not even the running costs can be met by user fees. Consequently, not only the investment costs but also a proportion of the running costs has to be covered by general tax revenue. The resolution of the Indian Government provides a guideline for the extent of public support whereby from case to case 50 to 100% of the cost for community biogas plants are subsidized.

Research and Development

Financial promotion from public or development funds is always necessary for research and development and for the organizations concerned with the implementation of biogas programs. Only in exceptional cases have private companies carried out research and product development, but even then, they sometimes relied on assistance from external donors. Research and development on the following aspects of biogas technology are particularly worthy of sponsorship:

- reducing the cost of system construction
- increasing the gas yield, most notably of dome-digester systems
- storage and application of digested sludge
- socio-economic prerequisites and consequences
- financial analysis of biogas units and economic analysis of biogas programs
- plant design and operation modifications to suit locally available materials

Subsidies

Subsidies for biogas plants may consist of grants, low-interest or no-interest loans and/or supplies in kind (materials). The response of the target group will usually depend to a large extent on the types of subsidies, the amounts available, and bureaucratic obstacles in gaining access to funding. The popularization of a subsidy program naturally plays an important role, too. The perceived reliability of the subsidy program is essential. Subsidy arrangements should therefore be underpinned by binding agreements with several years validity.

Graduated subsidies, the granting of which depends on, for example, the type of fuel in use prior to system installation or on the social situation of the applicant, are conceivable. In practice, this leads to socially justifiable differentiation in the extent of support granted.

Economic benefits for the target group

The most important incentive for any potential investor are the monetary returns to be gained by installing a biogas system. Promotional programs and subsidies for biogas systems should therefore be oriented along the lines of the benefits to be expected.

The economics of a biogas system depend, first, on the type of construction and cost of operation and, second, on the resultant benefits and/or cost savings provided by the system. Since the savings can be quite considerable in relation to the cost to the individual, even modest subsidies can yield a net economic advantage for households considering biogas as an option. If, on the other hand, individual expenditures for fuel and fertilizer were relatively low, higher subsidies will be required. Thus, the subsidies should be geared to the respective regional and social situation. Financial assistance for individual households should not be based on fictitious market values for gas and fertilizer, but rather on the actual costs and benefits involved.

Financial incentives

As a rule of thumb, financial incentives can be regarded as an essential prerequisite for the success of a large scale biogas program. If at least 70% of all households within the target area are to be supplied with biogas, all investors should be granted special allowances. The process of discussion requisite to defining the range of participation within the target area or community can, in itself, have a favorable impact on the project. Nonetheless, the maximum possible personal contribution should, as a matter of principle, be demanded of each household involved in a subsidized program. A maximum of contribution from the owner during construction of the biogas plant is conducive to the personal involvement of the system’s future owner.

Biogas - Organizations and Networks

Funding Organizations

International Organizations

United nations Environment Programme (UNEP)

General Services Section

P.O.Box 30552

Nairobi Kenya

National Organizations

Bangladesh: Food and Agriculture Organization of the UN

P.O.Box 5039 (NEW Market)

Dhaka

Tel.: 310311 / 2

Bolivia: Food and Agriculture Organization of the UN

CP 20479

La Paz

Tel.: 326162, 369005

China: Food and Agriculture Organization of the UN

Jianguomenwai 4-2-151 and 152

Beijing

Tel.: 53 22 835 / 6 / 7;

Colombia: Food and Agriculture Organization of the UN

Apartado Aereo 5773

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Tel.: +57 1 241 1930, 242 0520

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Cuba: Food and Agriculture Organization of the UN

PO Box 16004

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Indonesia: Food and Agriculture Organization of the UN

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Tel.: +62 21 324939, 321308

Fax: +62 21 335516

India: Food and Agriculture Organization of the UN

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Jamaica: Food and Agriculture Organization of the UN

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Fax: +1876 9298351

Kenya: Food and Agriculture Organization of the UN

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Fax: +254 2 727584

Mauritania: Food and Agriculture Organization of the UN

PO Box 665

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Morocco: Food and Agriculture Organization of the UN

PO Box 1369

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Tel: +212 7 65756, 65865;

Fax: +212 7 66468

Nepal: Food and Agriculture Organization of the UN

PO Box 25

Kathmandu

Tel: 523200, 523239

Thailand: Energy Conservation & RenewableEnergy Division

National Energy Policy Office NEPO

394/14 Samsen 12, Dusit

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Tel.: +66 2 28009517

Fax: +66 2 282 4607, 282 4682

Tunisia: Food and Agriculture Organization of the UN

B.P. 863

Tunis

Tel: 782686, 894824;

Implementing Organizations

Bolivia: Fundación Integral de Desarrollo

Planning and construction of biogas systems and anerobe waste water treatment

C. Guillermo Rivero Nr.9

Sta Cruz de la Sierra

Casilla 1911

Tel.: +591 3 339 607

Fax: +591 3 331243

Bolivia: GTZ Proyecto Biogas UMSS(Castillo Co)

Planning and construction of biogas systems

Av. Petrolera Casilla 2672

Cochabamba

Tel.: +591 42 41503

Fax: +591 42 41503

Burundi: Direction Generale de l'Eenergie (DGE)

Research and development advisory service

B.P. 745

Bujumbura

Tel: +257-22-2203;

China: Shanghai Biogas Engineering Development

Planning and construction

Central Jiang Xiroad 136.3

Shanghai

Tel: 212336;

China: Asia-Pacific Biogas Research and Training Centre

Research and development, training, mass dissemination of family plants

No. 13, Section 4, Remning Nan Road

610041 Chengdu - Sichuan

Tel.: +86 28 522 1571, -3032, Fax: +86 28 5227610

Email: tybrtc@acdisn.cd.sc.cn

China: Bejing Municipal Research Institueof Environmental Protection

Research and development

Fuwai Avenue

100037 Beijing

Tel: 0086 1068313146;

Fax: 0086 10683 14675;

Colombia: BIOTEC Colombia S.A.

Planning and construction (waste water treatment)

Calle 55 No. 69-29

Bogotá

Tel.: +57 1 2632509, 2632256

Fax: +57 1 4106553;

Germany: TBW GmbH

Planning and construction of biogas plants and anaerobe technology

Baumweg 16

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India: Centre for Environmental Studies Anna University

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Fax: +91 44 2350397

India: AIC Watson Consultants

Planning and construction, waste water treatment

Nariman Point Rajeha Centre,13th floor

400021 Bombay

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Fax: +91 22 2040398

Email: AICW@giasbm01.vsnl.net.in

Indonesia: Indonesian Chamber of Commerce &Industry

Waste water treatment

Compartment of Emvrionment

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Fax: 8311185

Indonesia: Agency for the Assessment and Application of Technology BPPT

Research, development, planning

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10340 Jakarta

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Indonesia: Nusantara Water CentreIntercom Plaza

Planning (waste water treatment)

Jl. Marujallir Raja, Blok A3/16

Jakarta, Barat

Fax: +62 21 5490543

Jamaica: Scientific Research Council SRC

Coordination of anaerobe technology development

Hope Gardens Box 350

Kingston 6

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Fax: +1867 927 5347

LAO PDR: Renewable Energy Centre for Science,Technology and Environment (STENO)

Research and development

PO Box 2279

Veintiane

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Fax: +856 21 213472

Malaysia: Standards & Industrial Research Institute of Malaysia (SIRIM)

Research and development

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Email: bgyeoh@sirim.my

Morocco: Programme Speciale Energie GTZ

Implementation, training, anaerobe technology and small scale farm plants

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Morocco: Centre de Developpement des Energies (CDER)

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Nepal: Kathmandu Brick Landfill Gas (P) LTD.

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Nepal: Managing Director Development Partners Nepal

research and development waste water treatment

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Nepal: DevPart Consult - Nepal Pvt. Ltd.

private consulting construction of farm biogas systems

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Phillipines: ENVIROASIA Corporation

Private consulting for planning and construction

3rd Fl Skunac Bld.Alabang Zapote Rd.

Alabang Muntinlupa, Metro Manilla

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Fax: 00632 842 2180;

Phillipines: Integrated Biogas Generation and Wastewater Treatment System Cubao

Planning and construction advisory services

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Fax: +632 721 5057;

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Research and development
Hloboka 2
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Fax: +42 7 49 1524

Tanzania: CAMARTEC Biogas Extension Service
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Tanzania: Arusha Bio-Constructors and Consultants
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Sanford Kombe
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Tanzania: Biogas and Solar Co. Ltd.
private consultancy for training, planning and construction
Ainea Kimaro
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Thailand: Biogas Advisory Unit Chiang Mai University
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Thailand: RISE-AT Institute of Science and Technical Research & Development
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Research

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Tunesia: Agence de Maitise de l'Energie

Research and development

8, rue Ibn El Jazzar,

B.P. 213

1002 Tunis Belvedere

Tel: 787700;

Vietnam: CEFINEA Research&Training Center onWater & Environmental Technology

Ho Chi Minh City Polytechnic Univ.

288 Ly Thuong Kiet - Q.10

Ho Chi Minh City

Vietnam: Renewable Energy Center

Planning and advisory services

Can Tho University

Can Tho

Tel: 8471838757;

Fax: 8471838474;

Networks for biogas and anaerobic digestion

Networks are built to share experiences on several issues, in this case on anaerobic digestion (AD) of agricultural and industrial biomass and communal and industrial wastes. Databases can cover AD experts and organizations, biogas plant design, research and funding organizations, literature and further information. The main objective of AD networks is information exchange on the performance of technically and commercially successful AD facilities and findings of scientific research on AD.

Name (Country)	Focus	Contact
AD-Nett (Europe)	Anaerobic digestion of agro-industrial wastes, less the generation of energy; mainly network of users, producers in agriculture and agro-industry; data-bank: agricultural plants; contacts	Herning Municipal Utilities Enghavevey 10 DK 7400 Herning Tel.: +45 99 26 82 11 Fax: +45 99 26 82 12 Email: hkvadm@post4.tele.dk Dr. Pat Howes ETSU Harwell Didcot OX11 0RA UK Tel.:+44 12 35 43 28 10 Fax: +44 12 35 43 39 90 Email: pat.howes@aeat.co.uk
ANESAPA (Bolivia)	Asociación Nacional de Entidades de Servicio de Agua Potable y Alcantarillado Seminars on waste water treatment	Av. Villazon 1966 P-7 La Paz Bolivia
AT Verband (Germany)	Association of German NGOs and consultants active in the field of Appropriate Technology, also biogas technology; promotion of socially and environmentally appropriate technologies	German AT-Association Alexanderstr. 17 53111 Bonn Germany Tel.: +49 228 631421 Fax: +49 228 431427
BORDA (Germany)	Bremen Overseas Research and Development Association Promotion of low-cost biogas systems in developing countries. Newsletter: Biogas forum	Breitenweg 55 D-28195 Bremen Tel: +49 421 13718 Fax: +49 421 165 5323
CEPIS (Peru)	Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente dissemination of information, technical advice, promotion of regional programs, network of cooperation centers, education;	Los Pinos 259 Casilla Postal 4337 Lima 100 Tel.: +51 1 4377081 Email: scaporal@cepis.org.pe
FAO/SREN (EU)	European Sustainable Rural Environment and Energy Network working groups: 'Bio-Mass for Energy and Environment', 'Environmental Aspects of Anaerobic Treatments' publications: Newsletter; 13 volumes in **FAO/REU** Technical Series; organization of workshops, electronic mailing list on Anaerobic Technology	Rainer Krell FAO/Regional Office for Europe Viale delle Terme di Caracalla I - 00100 Rome Email: rainer.krell@fao.org
German Biogas Association ("Fachverband Biogas") (Germany)	Promotion and dissemination of biogas technology as a sustainable technology link within the nutrient circle; organization of excursions, seminars, conferences, exhibitions; provision of know-how and experts - technology transfer; working groups: public relations, safety standards, organic	Biogas Association Germany Am Feuersee 8 D-74592 Kirchberg/Jagst Tel: +49 7954 1270

	waste fermentation, agriculture	Fax: +49 7954 1263
IAWQ (United Kingdom)	International Association on Water Quality anaerobic digestion; operation and costs of large/small wastewater treatment plants; pretreatment of industrial waste-waters; pulp and paper industry waste-waters; water and waste technology and management strategies for developing countries	Chairman: Prof. E.R. Hall, Dept. of Civil Engineering; University of British Columbia, CAN Secretary: Prof. K.J. Kennedy, Dept. of Civil Engineering, University of Ottawa, CAN
RECBAM (Colombia)	Red Colombiana de Biotecnología Ambiental	Olga Rojas Ciudad Universitaria Melendez Colombia Tel.: +57 2 3312175 Fax: +57 2 3392335 Email: olgaro@petecuy.univalle.edu.co
RISE-AT	Regional Information Service - Center for South East Asia on AT Focal point for expert network South East Asia on anaerobe technology Biogas Advisory Unit	Institute for Science and Technology Research and Development (IST) Chiang Mai University P.O.Box 111 50202 Chiang Mai Thailand Tel.: +66 53 892189 Fax: +66 53 892224 Email: cnxnsmwm@chiangmai.ac.th
Waste for Energy Network (EU)	objective: industrial exploitation of waste for energy three sectors: wood & paper, household waste, biogas; organization of seminars and workshops	Centro da Biomassa para a Energia, Olívia Matos
WEDC (United Kingdom)	Water Engineering and Development Centre countries; dissemination to practitioners and researchers; registration possible to receive regular information	Dr. Jeremy Parr WEDC Loughborough University Leicestershire LE11 3TU Tel: +44 1509 222618 Fax: +44 1509 211079 Email: jeremy.parr@boro.ac.uk