Biogas as clean energy alternatives for rural poor

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Introduction (Rationale)

In many rural areas, most of the inhabitants are dependent on dung and organic residue as fuel for cooking and heating. Sudan is characterized by high dependence on biomass energy (fire wood, charcoal, and agricultural residues), it constitute 78% of total energy consumption. It is composed of 69% fuel wood (firewood and charcoal) and 9% residues. Households consume about 60% of total energy consumption and 72% of total biomass energy. Sudan is facing real environmental degradation due to combine factors (drought, desertification, over-grazing expansion of agricultural land, firewood/charcoal production, etc) and depletion of forest resources. Farmers in developing countries are in dire need of fertilizer for maintaining cropland productivity. Nonetheless, many small farmers continue to burn potentially valuable fertilizers, even though they cannot afford to buy chemical fertilizers. At the same time, the amount of technically available nitrogen, potassium and phosphorous in the form of organic materials is around eight times as high as the quantity of chemical fertilizers actually consumed in developing countries. Especially for **small farmers**, biogas technology is a suitable tool for making maximum use of scarce resources after extraction of the energy content of dung and other organic waste material, the resulting sludge is still a **good fertilizer**, supporting general **soil quality** as well as **higher crop yields**.

Today, the highest degree of market maturity can be found in the area of **municipal sludge treatment, industrial wastewater purification and treatment of agricultural wastes**. The use of the technology in municipal wastewater treatment is currently experiencing an upswing in Asia (India in particular) and Latin America. **Anaerobic treatment** of municipal organic waste is experiencing a boom in **Northern Europe**. Agricultural biogas plants in **developing countries** are usually promoted on a large scale in connection with energy and environmental issues, and are installed particularly where water pollution through liquid manure from agriculture is most severe.

The increasing emission of greenhouse gases, increasing water consumption and water pollution, declining soil fertility, unsatisfactory waste management and the growing rate of deforestation must be seen as parts of the unsustainable resource use systems that prevail worldwide. Biogas technology is one of the important hardware components in a chain of measures to counteract the above problems.

Popularization of biogas technology has to go hand in hand with the actual construction of plants in the field. Without the public awareness of biogas technology, its benefits and pitfalls, there will be no sufficient basis to disseminate biogas technology at grassroots level. At the same time, awareness within the government is essential. Since impacts and aspects of biogas technology concern so many different governmental institutions (e.g. agriculture, environment, energy, economics), it is necessary to identify and include all responsible government departments in the dissemination and awareness-raising process.

Technical description of appropriate biogas plant

A biogas digester is a physical structure, commonly known as a biogas plant. As various chemical and microbiological reactions take place in the digester, it is also known as bio-reactor, biogas generator or anaerobic reactor. The main function of this structure is to provide anaerobic conditions within it. As a chamber, it should therefore be air and water tight. It can be made of various construction materials and in different shape and size. With the world wide introduction of the improved fixed dome Chinese model at the end of the 80s, the floating drum plants became obsolete because of comparatively high investment and maintenance costs along with other design weaknesses. Fixed dome Chinese model biogas plants were built in China as early as 1936 and in the currently known round shape since the 1970s. It consists of an underground brick masonry compartment (fermentation chamber) with a brick dome, concrete or prefabricated plastic dome on the top for gas storage. In this design, the fermentation chamber and gas holder are combined as one unit. This design eliminates the use of expensive steel gas holder which is susceptible to corrosion and depends on metal workshop and transport facilities.

Required components and materials

The construction materials to be used in the plant construction are cement, sand, and aggregate should be of good quality, and a water proof agent is added to the cement for gas tightness. Installation of a testing unit as part of the standard digester design allows convenient technical monitoring of the digester and piping system. It was found helpful and necessary to install a combination of T-joint, main valve and T-joint directly adjoined to the gas outlet pipe of the digester, to allow technical monitoring of the installation while in use. Pressure tests of the digester and the piping system can be easily organized and a gas meter can be installed without interfering in the piping system in the kitchen. This standard of the design provides convenient access to the gas pipe system for learning and understanding.

Technology for sanitation and waste water treatment

Biogas technology could offer a system to make significant improvements in the national sanitation sector, given the following facts: sanitation coverage in Sudan,

with wastewater treatment systems present poor performance. Septic tanks with soak away to receive this wastewater are comparatively expensive and require regular sludge maintenance while no safe method of faecal sludge treatment can be provided. Modernization in rural areas, increased formal education, mobile phones, motor bikes and cars, and television promote the awareness on lacking toilet facilities; this leads to discussions in the villages about the most appropriate sanitation system. Latrine coverage in rural areas remains very low, traditional latrines do not meet standards. Facilities that prevent humans, animals and insects from contact with human excreta are classified as improved technologies.

Raw material

Available raw material for biogas production on farm household level includes

- **Agricultural waste**

Leaves, grass and (pre-composted) shredded straw could be used as biogas raw material, but could even be used for the post-composting of digester effluent in the often already existing compost pits. Pre-composted or presilage ligneous fibres and stalks could produce huge amounts of biogas if shredded and mixed in a biogas plant. Silage or chopped compost can be fermented in a biogas plant and used for supplementary biogas production.

- **Animal waste**

Domestic biogas plants convert livestock manure into biogas and slurry. This technology is feasible for small holders with livestock producing 50 Kg manure per day, an equivalent of about 3 cows or 20 small ruminants.

- **Food leftover and kitchen waste**

This consists mainly of organic matter and is relatively digestible. The solid contents of this organic waste are between 20% and 30%. In considering the biogas substrate the basic diet is of great importance,

- **Toilet effluent**

A septic tank is beyond the means of the average rural household due to the high cost and the unavailability of the mechanical devices for periodic cleaning. Openly disposed human wastes are hazardous to public health and the environment; recycling of human excreta for biogas generation is therefore an important option in order to avoid these health hazards.

Household appliances

Biogas is mainly used in stoves for cooking and in gas lamps for lighting. But also **refrigerators and incubators**, coffee roasters, driers, baking ovens and water heaters, chicken heaters, power engines for milling or generating electricity could be fuelled with biogas. The gas equipment market in Sudan offers stoves, lamps and refrigerators run by kerosene, which could be adapted to the characteristics of biogas for further marketing in a biogas dissemination programme.

Fertilizer use

All material discharged can be used to fertilize annual or perennial crops as well as trees and seedlings.

Target customers

Viable customer potential according to the availability of biomass for biogas production has been identified in:

- Small farms and rural households for biogas from livestock, sanitation and agricultural wastes.
- Peri-urban households for biogas from sanitation and organic domestic wastes.
- Small scale food processing industry for biogas from organic wastes and sanitation.
- Livestock markets for biogas from animal wastes and sanitation.
- Slaughterhouses and abattoirs for biogas from animal wastes and sanitation.

Actors in the formal and informal sector related to energy supply

As biogas plant construction in the past has been decided and carried out in a very limited number of sites and systems, a country programme needs to develop a Biogas Network consisting of governmental, civil society and private sector partners:

- For energy supply in the urbanized centres the **Municipality is responsible** for maintaining the limited grid.
- In rural areas, association of residents, farmers, grass root organizations and women's groups are quite active in auto promotion: small income generating activities are promoted through group loans, improved agricultural and animal keeping techniques are disseminated by local NGOs in close contact with international development agencies. These local organizations play an important role for awareness raising and introduction of new technologies, advanced techniques and agroecological systems, in which biogas plants would fit in. Some communities are already supported through co-financing priority projects like schools, hospitals, water and sanitation projects.
- Construction enterprises are concentrated in Khartoum state, at village level, trained masons are hard to find; nevertheless, the opportunity to learn a job by being trained in the construction of biogas digesters aroused the interest of several interview partners. While ultimately biogas plants will be installed and maintained at household level, there are still several advantages in supporting and/or creating village-level institutions and implementing the programme through them:
- Motivation and client identification are easier if an institution comprising members of the local community is involved in the process.
- Women's participation in the programme, which will be essential due to their leading role in ensuring household sanitary conditions, is easier, if an institution operating at local level carries out the programme. Developing and managing a local repair and maintenance network including training, construction, maintenance could be facilitated by an already existing institution.

Financial and economic feasibility

Possible benefits could be:

- **Improvements** in the physical quality of life as a result of a wider range of energy supply
- Improvement of soil fertility and food security
- Improvements in the local economic structure
- Reduction in environmental pollution especially ground water pollution and green house gases (GHG) emissions
- Creation of employment opportunities
- Improvement in the trade balance through the substitution of imported energy sources
- Long-term training effects
- Reduction of rural migration
- Reduction in deforestation
- Reduction in desertification or external costs such as:
- loss of income for firewood and charcoal merchants
- shortage of capital and increase in interest rates because funds which could be used as future operating costs in systems utilizing conventional energies become immediately payable as investment costs for the utilization of renewable energies.

Capital requirements & cash flow

The economic feasibility of biogas generation varies a great deal depending upon the factors such as the availability of domestic energy sources, the cost of imported fuel, the uses and actual benefits of biogas production, location and local factors such as climates and cropping systems. All these factors have to be taken into account in any benefit analysis.

Total Capital Cost

The total construction cost for a 6 m^3 (slurry volume) biogas fixed dome digester in Sudan with all fittings and basic appliances is 1,000 US$. **Rapid Household Survey** for 500 villages at North Kordofan is willing to contribute with soft loan for 7 years. Therefore it is obvious that for market penetration a micro-financing system has to be established.

Annual operation & maintenance cost

As biogas is a proven technology, the lifespan of a fixed dome biogas plant can be expected to be at least 20 years. Besides the biogas plant construction cost as capital investment in the first year, annual cost includes operation, maintenance and repair expenditures. Following experiences in Asian countries, annual repair and maintenance cost is estimated at 1.5% of the total construction

cost. Annual financial cost for operating the plant dung and water collection and mixing - are basically calculated at zero; although in locations, where households have to pay for water or water transport these expenditures have to be taken into account.

a) Energy market

The rural household energy market is dominated by fuel wood, charcoal, kerosene and batteries. Solar energy home systems are not yet well accepted due to fairly high prices of the equipment, and LPG distribution encounters still logistic problems. Household biogas has no commercial value, as it could not be sold to the neighborhood. Thus it is to be compared economically with other conventional sources of fuel which are free of charge, like fuel wood and agricultural residues. Traditionally firewood is so to say free of charge, and its supply is only an investment in women's time. Increasing numbers of women however encounter problems in collecting firewood close to their homestead. They have to invest more time now walking kilometers whereas previously only some minutes were needed. Some communes have already introduced tariffs for fuel wood; others have introduced a tax on wood collection. Charcoal availability is reduced and production has been limited by law, as the production of charcoal has lead massive deforestation. Energy for lighting in rural areas is predominantly provided by kerosene lamps or torches. Kerosene for lighting purpose is subsidized by the government; but still energy resources for lighting are expensive, which fail to provide a comfortable, reliable, healthy light.

b) Fertilizer market

Market for organic fertilizer exists mainly in those places introducing compost pits.

Benefits expected from a biogas plant for potential clients

a) Small farms and rural households

Energy: cooking, lighting, food conservation

- Saving of firewood: environmental protection through reduced deforestation. For women and girls: less time for fuel wood collection, reduced **vulnerability** in terms of health risks, increased time for other activities (e.g. use of health service, income generating activities, literacy programmes etc.).
- Agricultural improvements in plant and animal production yields: improved nutrition and increased household income. Fertilizer production with subsequently protection and/or recovery of soil fertility.
- Sanitation: controlled disposal of animal manure and organic waste; grey water collection and reuse; improved hygiene and sanitary conditions in the household
- Health: reduction of diseases related to waste water and solid waste; reduction of exposure to smoke and flue-gas during to cooking hours
- Modernity: clean and efficient fuel.
- Climate protection.

b) Small scale food processing industry

- Energy: hot water; transformation and conservation; production of renewable electricity; reduction of energy bill.
- Saving of fuel wood: environment protection through reduced deforestation
- Sanitation: controlled treatment and discharge of waste water from processing and cleaning; controlled treatment and discharge of organic waste; controlled treatment and discharge of animal waste.
- Fertiliser production as additional income potential
- Modernity: clean and efficient fuel
- Climate protection

c) Peri-urban households

- Energy: cooking, lighting, food processing and conservation, saving of energy expenditures.
- Savings in fuel wood: environmental protection by reduced deforestation.
- Sanitation: controlled discharge and treatment of waste water, controlled discharge and treatment of organic waste.
- Recycling of sanitation sub-products: organic matter and water: Urban environment improved by parks, flowers, trees
- Modernity: clean and efficient fuel
- Groundwater and climate protection

d) Livestock markets, Slaughterhouses and abattoirs

- Energy: heating, cooling, lighting
- Saving of energy expenditures
- Savings in fuel wood: Environmental protection by reduced deforestation
- Sanitation: Controlled discharge and treatment of waste water, controlled discharge and treatment of organic waste, less fly and vector breeding
- Modernity: clean and efficient fuel
- Groundwater and climate protection

Steps of implementation

1- Installation of 200 biodigester at village level at Kamas, North Kordofan state.

2- To achieve massive dissemination**,** Standardization and quality control. The plant has to meet the customers' needs. Standards for gas appliances will match with after-sales-services to facilitate users' access to spare parts whenever and wherever needed. Standardization should also contribute to a long term guarantee that the biogas plant will be convenient in operation and will deliver all possible benefits.

3- Training of users will take place in the villages where households have applied for biogas plants. Responses will be to such questions: (i)How to keep the overflow point free from slurry? (ii) How to check the water trap from time to time, especially when there is no gas produced? (iii) How to clean the burner regularly like other cooking vessels? (iv) How to poke from time to time the inlet and outlet pipe, especially if substrate does not

enter the plant? (v) How to change the mantle of the gas lamp, keeping it at a distance from food? (vi) What is the meaning of the slurry level in the expansion chamber? (vii) Where to ask for help in case of problems the household cannot solve alone? Quality control will refer also to the biogas production and use of slurry as fertilizer. Biogas plant clients should be trained in using simple methods of control in order to monitor their installation closely and to benefit most from the investment. Already now the list of organizations which expressed their interest in cooperation

4- **Training** of masons, plumbers and constructors will focus on quality control related to standards and outputs of the whole biogas system. The user should have access to equipment which performs according to national and international standards. To assure the availability of high quality products referring to the biogas plant, the related installations and gas appliances, ATTS will set up a catalogue of quality and standard criteria. Energy efficiency, affordability, user friendly access and handling, long lifetime and safety will be among the most important parameters local production and imported accessories have to comply with.
5- **Training of private sector** will focus on technical and business training for private enterprises and/or interested craftsmen to start up their own biogas business. The participants in the training programs should receive all biogas and customer related information required for promotion, construction and after-sales services. It will be an on-going training for updating and quality control. An important and new field of private sector promotion lies in the production of biogas equipment lamps, burners and gas pressure measurement facilities in Sudan to supply the local market with low-cost high quality products.

Technical skills once established in an enterprise will lead to job creation and sustainable development of local economy. In communities where the ATTS will set up clusters for biogas dissemination, hardware stores could benefit from the program by deliverance of construction material and spare parts for biogas equipment. Construction and piping work will be carried out by local enterprises and craftsmen only, thus enhancing not only employment and income, but also long term know how development and local economies.
Involving professional media enterprises, will create a demand which will be covered by the private sectors' offer. After several years the cost of a biogas plant should cover also promotional costs for maintaining an ongoing publicity campaign.

Public consultation meeting for biogas implementation and outputs
A consultative public meeting was carried out in North Kordofan, it was attended by government institutions, humanitarian affair commission, academics, government enterprises, national and international NGOs. They all declared their general interest in acting actively in biogas technology. 500 households at village levels are willing to adopt the technology. To develop mechanisms and procedures for programme implementation, ATTS will:

- Identify adequate actors to establish MoUs with partner institutions, national, international NGOs and CBOs.
- Define responsibilities for required activities such as marketing, training, financing and construction,
- Support appropriate site selection for the first 200 biogas digesters for marketing and training purposes,
- Promote the elaboration of procedures for standardization and certification, determine methodologies for quality control and M&E,
- Promote the development of subsidies, micro-finance mechanisms and requested support programs for different target groups.
- Provide ATTS with updated information about progress and barriers of biogas implementation.

Conclusion

Creating a favorable climate for biogas dissemination depends almost always on a whole range of decision makers. For example:

- The Ministry of Finance will decide on subsidies and tax wavers for biogas users.
- The Ministry of Energy can propose laws regarding the feeding of biogas-produced electricity into the grid. It can also propose financial and other assistance.
- The Ministry of Agriculture and Livestock can include biogas in the training curriculum of extension officers and agricultural colleges.
- The Ministry of Education can include biogas in the curricula of high schools and promote the construction of bio-latrines for schools.
- The Ministry of Health can include biogas in the curricula of public health workers and encourage the building of bio-latrines for hospitals.
- Radio Programs are an effective means in rural areas to familiarize the population with basics of biogas technology.