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Identifying, Developing, and Moving Sustainable Communities Through Application of Bioenergy for Energy or Materials: Future Perspective Through Energy Efficiency

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ABSTRACT

The demand for energy continued to outstrip supply and necessitated the development of biomass option. Residues were the most popular forms of renewable energy and currently biofuel production became much promising. Agricultural wastes contained high moisture content and could be decomposed easily by microbes. Agricultural wastes were abundantly available globally and could be converted to energy and useful chemicals by a number of micro-organisms. Compost or biofertiliser could be produced with the inoculation of appropriated thermophilic microbes which increased the decomposition rate, shortened the maturity period and improved the compost (or biofertiliser) quality. The objective of the present research was to promote the biomass technology and involved adaptive research, demonstration and dissemination of results. With a view to fulfil the objective, a massive field survey was conducted to assess the availability of raw materials as well as the present situation of biomass technologies. In the present communication, an attempt had also been made to present an overview of present and future uses of biomass as an industrial feedstock for production of fuels, chemicals and other materials. We may conclude from the review paper that biomass technology must be encouraged, promoted, invested, implemented and demonstrated, not only in urban areas but also in remote rural areas.

Keywords: *agricultural wastes, biomass resources, energy, environment, sustainable development*

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INTRODUCTION

Energy is an essential factor in development since it stimulates and supports economic growth and development. Fossil fuels, especially oil and natural gas, are finite in extent, and should be regarded as depleting assets, and efforts are oriented to search for new sources of energy. The clamour all over the world for the need to conserve energy and the environment has intensified as traditional energy resources continue to dwindle whilst the environment becomes increasingly degraded. The basic form of biomass comes mainly from firewood, charcoal and crop residues. Out of the total fuel wood and charcoal supplies, 92% was consumed in the household sector with most of firewood consumption in rural areas.

The term biomass is generally applied to plant materials grown for non-food use, including that grown as a source of fuel.

However, the economics of production is such that purpose-grown crops are not competitive with fossil-fuel alternatives under many circumstances in industrial countries, unless subsidies and/or tax concessions are applied. For this reason, much of the plant materials used as a source of energy at present are in the form of crop and forest residues, animal manure, and the organic fraction of municipal solid waste and agro-industrial processing by-products, such as bagasse, oil-palm residues, sawdust and wood off-cuts. The economics of use of such materials is improved since they are collected in one place and often have associated disposal costs [1].

Combustion remains the method of choice for heat and power generation (using steam turbines) for dryer raw materials, while biogas production through anaerobic digestion or in landfills is widely used for valorisation of wet residues and liquid effluents for heat and power generation (using gas engines or gas turbines). In addition, some liquid fuel is produced from purpose-grown crops (ethanol from sugarcane, sugar beet, maize, sorghum and wheat, or vegetable oil esters from rapeseed, sunflower and palm). The use of wastes and residues has established these basic conversion technologies, although research, development and demonstration continue to try and improve the efficiency of thermal processing through gasification and pyrolysis, linked to combine cycle generation. At the same time, considerable effort is being made to increase the range of plant-derived non-food materials. To achieve this, several approaches are being taken. The first is to provide low-cost raw materials for production of bulk chemicals and ingredients that can be used in detergents, plastics, inks, paints and other surface coatings. To a large extent, these are based on vegetable oils or starch hydrolysates used in fermentation to produced lactic acid (for polylactides) or polyhydroxybutyrate, as well as modified starches, cellulose and hemicellulose. The advantages are biodegradability, compatibility with biological systems (hence, less allergic reaction in use) and sparing of fossil carbon dioxide emissions (linked to climate chance). Associating an economic value to these environmental benefits, linked to consumer preferences, has contributed to increased production in this area. The second expanding activity is the use of plant fibres, not only for non-tree paper, but also as a substitute for petroleum-based plastic packing and components such as car parts. These may be derived from non-woven fibres, or be based on biocomposite materials (lingo-cellulose chips in a suitable plastic matrix). At the other end of the scale, new methods of gluing, strengthening, preserving and shaping wood have increased the building of large structures with predicted long lifetimes. These include a wide range of natural products such as flavours, fragrances, hydrocolloids and biological control agents. In spite of decades of research and development, engineering (recombinant DNA technology) is being widely investigated to achieve this, as well as to introduce new routes to unusual fatty acids and other organic compounds. In addition, such techniques are being used to construct plants that produce novel proteins and metabolites that may be used as vaccines or for other therapeutic use. Processing of the crops for all these non-food uses will again generate residues and by-products that can serve as a source of energy, for internal use in processing, or export to other users, suggesting the future possibility of large multi-product biomass-based industrial complexes.

TECHNICAL DESCRIPTION

Bacteria form biogas during anaerobic fermentation of organic matters. The degradation is a very complex process and requires certain environmental conditions as well as different bacteria populations. The complete anaerobic fermentation process is briefly described in Table 1. Biogas is a relatively high-value fuel that is formed during anaerobic degradation of organic matter. The process has been known, and put to work in a number of different applications during the past 30 years, for rural needs such as in food security, water supply, healthcare, education and communications [2].

Table 1. *Anaerobic degradation of organic matter [3].*

Level	**Substance**	**Molecule**	**Bacteria**
Initial	Manure, vegetable, wastes	Cellulose, proteins	Cellulolytic, proteolytic
Intermediate	Acids, gases, oxidised, inorganic salts	CH_3COOH, $CHOOH$, SO_4, CO_2, H_2, NO_3	Acidogenic, hydrogenic, sulphate reducing
Final	Biogas, reduced inorganic compounds	CH_4, CO_2, H_2S, NH_3, NH_4	Methane formers

During the last decades, thousands of biogas units are being built all over the world, producing methane gas for cooking, water pumping and electricity generation. In order not to repeat successes, in-depth studies on local conditions and conscientious planning are urged [4]. The goals should be achieved through review and exchange of information on computer models and manuals useful for economic evaluation of biogas from biomass energy; exchange of information on methodologies for economic analysis and results from case studies; investigation of the constraints on the implementation of the commercial supply of biogas energy; investigation of the relation between supplies and demand for the feedstock from different industries; and documentation of the methods and principles for evaluation of indirect consequences such as effects on growth, silvicultural treatment and employment.

Biogas technology cannot only provide fuel, but is also important for comprehensive utilisation of biomass forestry, animal husbandry, fishery, agricultural economy, protecting the environment, and realising agricultural recycling, as well as improving the sanitary conditions in rural areas. The introduction of biogas technology on wide scale has implications for macro-planning such as the allocation of government investment and effects on the balance of payments. Factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of general macro-policy, as do the allocation of research and development funds [5].

Biogas is a generic term for gases generated from the decomposition of organic material. As the material breaks down, methane (CH_4) is produced. Sources that generate biogas are numerous and varied. These include landfill sites, wastewater treatment plants and anaerobic digesters. Landfills and wastewater treatment plants emit biogas from decaying waste. To date, the waste management industry has focused on controlling these emissions to our environment, and in some cases, tapping this potential source of fuel to power gas turbines, thus generating electricity. The primary components of landfill gas are methane (CH_4), carbon dioxide (CO_2), and nitrogen (N_2). The average concentration of methane is ~45%, carbon dioxide is ~36% and nitrogen is ~18%. Other components in the gases are oxygen (O_2), water vapour and trace amounts of a wide range of non-methane organic compounds (NMOCs) [6].

For hot water and heating, renewable's contributions come from biomass power and heat, geothermal direct heat, ground source heat pumps, and rooftop solar hot water and space heating systems. Solar-assisted cooling makes a very small but growing contribution. When it comes to the installation of large amounts of the PV, the cities have several important factors in common. These factors include a strong local political commitment to the environment and sustainability; the presence of municipal departments or offices dedicated to the environment; sustainability or renewable energy; information provision about the possibilities of renewable and obligations that some or all buildings include renewable energy.

BIOGAS UTILISATION

The importance and role of biogases in energy production are growing. Nowadays, a lot of countries in Europe promote utilisation of renewable energies by guaranteed refund prices or emission trading systems. A general schematic of an agricultural biogas plant, with the anaerobic digester at the 'heart' of it, is shown in Figure 1. Pre-treatment steps (e.g. chopping, grinding, mixing or hygienisation) depend on the origination of the raw materials.

Biogas is a mixture containing predominantly methane (50%–65% by volume) and carbon dioxide, and in a natural setting, it is formed in swamps, anaerobic sediments, etc. Due to its high methane concentration, biogas is a valuable fuel. Wet (40%–95%) organic materials with low lignin and cellulose contents are generally suitable for anaerobic digestion. A key concern is that treatment of sludge tends to concentrate heavy metals, poorly biodegradable trace organic compounds and potentially pathogenic organisms (viruses, bacteria and the like) present in wastewaters. These materials can pose a serious threat to the environment. When deposited in soils, heavy metals are passed through the food chain, first entering crops, and then animals that feed on the crops and eventually human beings, to whom they appear to be highly toxic. In addition, they also leach from soils, getting into groundwater and further spreading contamination in an uncontrolled manner. European and American markets aim to transform various organic wastes (animal farm wastes, industrial and municipal wastes) into two main by-products: a solution of humic substances (a liquid oxidate) and a solid residue.

Biogas can be converted to energy in several ways. The predominant utilisation is combined heat and power (CHP) generation in a gas engine installed at the place of biogas production. There are mainly two reasons for this. First, biogas production is an almost continuous process; it is rather difficult or, in the short-term, even impossible, to control the operation of anaerobic digesters according to any given demand profile. Second, promotion of renewable energies is focused on electricity production. Because of that, biogas plant operators receive the predominant fraction of revenues from the guaranteed feed-in tariffs for electricity. Summarising the results of the eco-balances, it becomes obvious that – not only by using fossil fuels but also by using renewable fuels like biogas – CHP cogeneration is the optimal way for fighting climate change. From a technical point of view, it can be concluded that biogas production, i.e. the conversion of renewable resources and biowaste to energy, can be seen as state-of-the-art technology [9–13].

ECOLOGICAL ADVANTAGES OF BIOGAS TECHNOLOGY

An easier situation can be found when looking at the ecological effects of different biogas utilisation pathways. The key assumptions for the comparison of different biogas utilisation processes are biogas utilisation in heat demand controlled gas engine supplied out of the natural gas grid with 500 kWe; electrical efficiency of 37.5%, thermal efficiency of 42.5% and a methane loss of 0.01; biogas utilisation in a local gas engine, installed at the biogas plant with 500 kWe; electrical efficiency of 37.5%, thermal efficiency of 42.5% and a methane loss of 0.5; biogas production based on maize silage using a biogas plant with covered storage tank; methane losses were 1% of the biogas produced and biogas upgrading with a power consumption of 0.3 kWhe/m^3 biogas; and methane losses of 0.5.

Figure 2 presents the results of the greenhouse gas (GHG) savings from the different biogas utilisation options, in comparison to the fossil-fuel-based standard energy production processes. Before adopting biogas production on commercial scale, it is very necessary that one should take various factors into consideration like economic factors, social factors, technical factors and ecological/ health factors as summarised in Table 2.

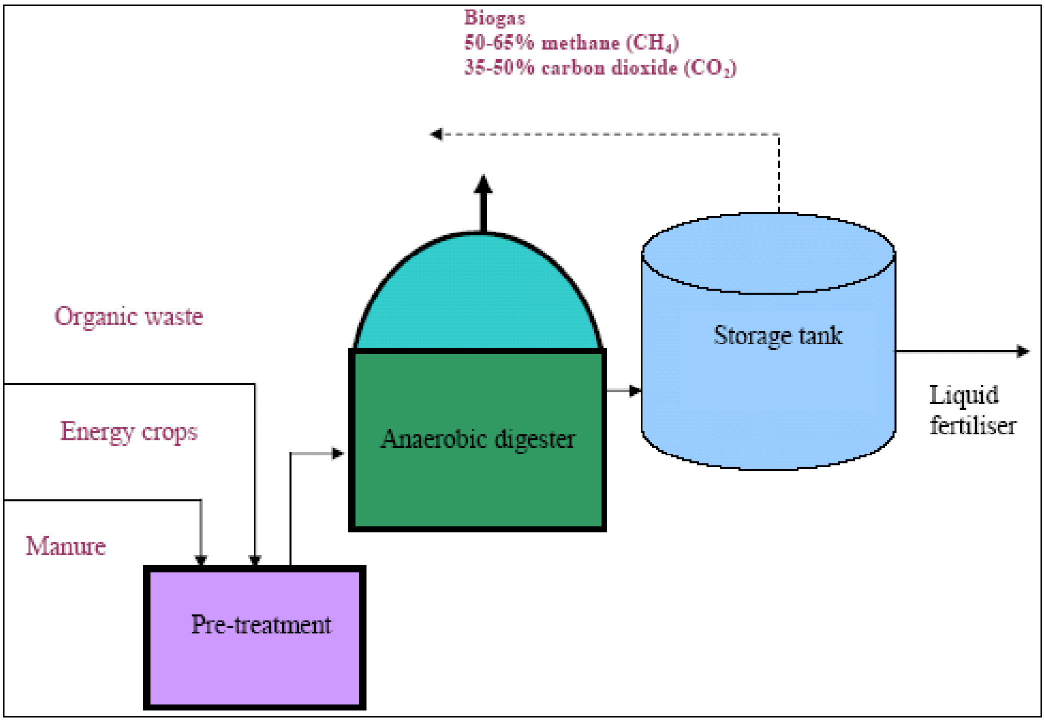
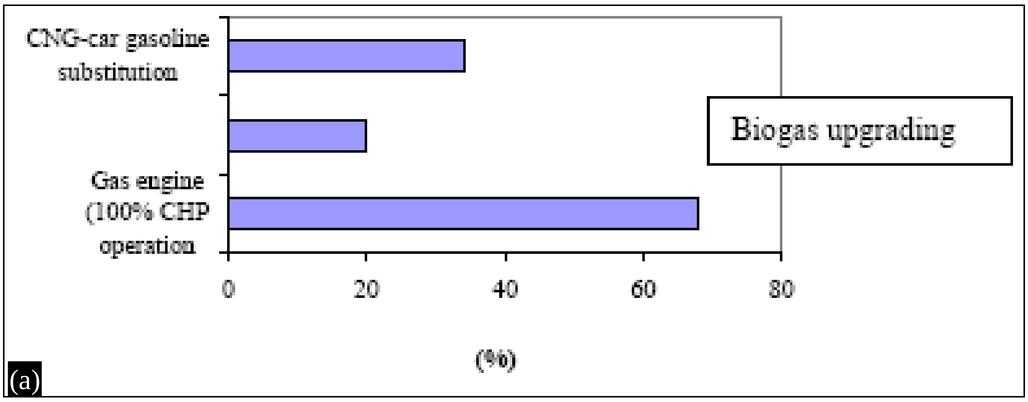


Fig. 1. *General schematic of an agricultural biogas plant [7].*



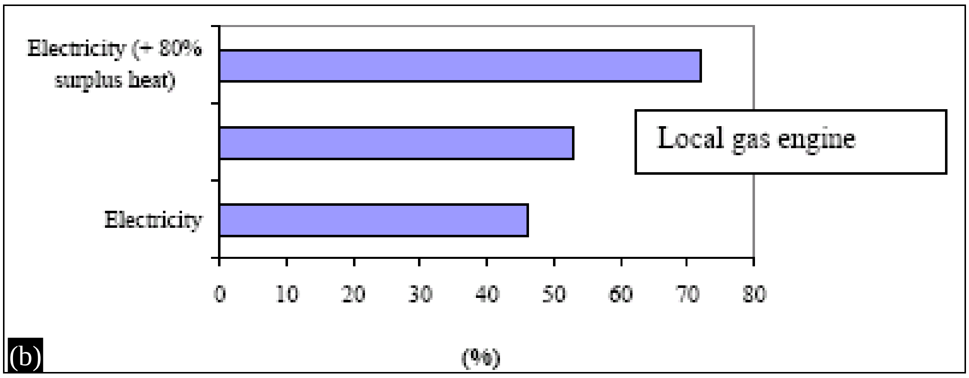


Fig. 2. *Greenhouse gas emissions savings for different biogas utilisation pathways in comparison to fossil energy production. (a) Biogas upgrading(b) Local gas engine*

BIOMASS POTENTIAL

CHP installations are quite common in greenhouses, which grow high-energy, input crops (e.g. salad vegetables, pot plants, etc.). Scientific assumptions for a short-term energy strategy suggest that the most economically efficient way to replace the thermal plants is to modernise existing power plants to increase their energy efficiency and to improve their environmental performance. However, utilisation of wind power and the conversion of gas-fired CHP plants to biomass would significantly reduce Sudan's dependence on imported fossil fuels. Although a lack of generating capacity is forecasted in the long term, utilisation of the existing renewable energy potential and the huge possibilities for increasing energy efficiency are sufficient to meet future energy demands in Sudan in the short term.

A total shift towards a sustainable energy system is a complex and long process but is one that can be achieved within a period of about 20 years. Implementation will require initial investment, long-term national strategies and action plans. However, the changes will have a number of benefits including a more stable energy supply than at present and major improvement in the environmental performance of the energy sector, and certain social benefits. A vision used a methodology and calculations based on computer modelling that utilised:

Table 2. *Factors to be considered in economic analysis.*

Economic factors	**Social factors**	**Technical factors**	**Ecological/health factors**
Interest on loan Current/future cost of alternative fuels Current/future cost of construction materials Saving of foreign currency Current/future labour cost Inflation rate	Employment created Less time consumed for fetching clean water Improved facilities in villages; thus less migration to cities Less expense for buying alternative fuels More time for additional income earning activities	Construction, maintenance and repairs of biogas plants Availability of materials and land required Suitability of local materials	Improved health Environment pollution abatement Improvement in yields of agriculture products

- Data from existing governmental programmes.
- Potential renewable energy sources and energy efficiency improvements.
- Assumptions for future economy growth.
- Information from studies and surveys on the recent situation in the energy sector.

In addition to realising the economic potential identified by the National Energy Savings Programme, a long-term effort leading to a 3% reduction in specific electricity demand per year after 2020 is proposed. This will require further improvements in building codes, and continued information on energy efficiency.

The environmental NGOs in Sudan are urging the government to adopt sustainable development of the energy sector by:

- Diversifying of primary energy sources to increase the contribution of renewable and local energy resources in the total energy balance.
- Implementing measures for energy efficiency increase at the demand side and in the energy transformation sector.

The price of natural gas is set by a number of market and regulatory factors that include Supply and demand balance and market fundamentals, weather, pipeline availability and deliverability, storage inventory, new supply sources, prices of other energy alternatives and regulatory issues and uncertainty.

Classic management approaches to risk are well documented and used in many industries. This includes the following four broad approaches to risk: avoidance includes not performing an activity that could carry risk; avoidance may seem the answer to all risks, but avoiding risks also means losing out on potential gain.

Mitigation/reduction involves methods that reduce the severity of potential loss. Retention/acceptance involves accepting the loss when it occurs. Risk retention is a viable strategy for small risks. All risks that are not avoided or transferred are retained by default. Transfer means causing another party to accept the risk, typically by contract.

DISCUSSIONS

Biogas is a generic term for gases generated from the decomposition of organic material. As the material breaks down, methane (CH_4) is produced as shown in Figure 3. Sources that generate biogas are numerous and varied. These include landfill sites, wastewater treatment plants and anaerobic digesters.

The technical achievability and the actual usage of these energy sources are different around Europe, but biomass is seen to have a great potential in many of them. An efficient method for the conversion of biomass to energy is the production of biogas by microbial degradation of organic matter under the absence of oxygen (anaerobic digestion). It is now possible to produce biogas at rural installation, upgrade it to bio-methane, feed it into the gas grid, use it in a heat demand controlled CHP and to receive revenues.

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The success of promoting any technology depends on careful planning, management, implementation, training and monitoring. Main features of gasification project are:

- Networking and institutional development/strengthening.
- Promotion and extension.
- Construction of demonstration projects.
- Research and development, and training and monitoring.

Biomass is a raw material that has been utilised for a wide variety of tasks since the dawn of civilisation. Important as a supply of fuel in the third world, biomass was also the first raw material in the production of textiles [14].

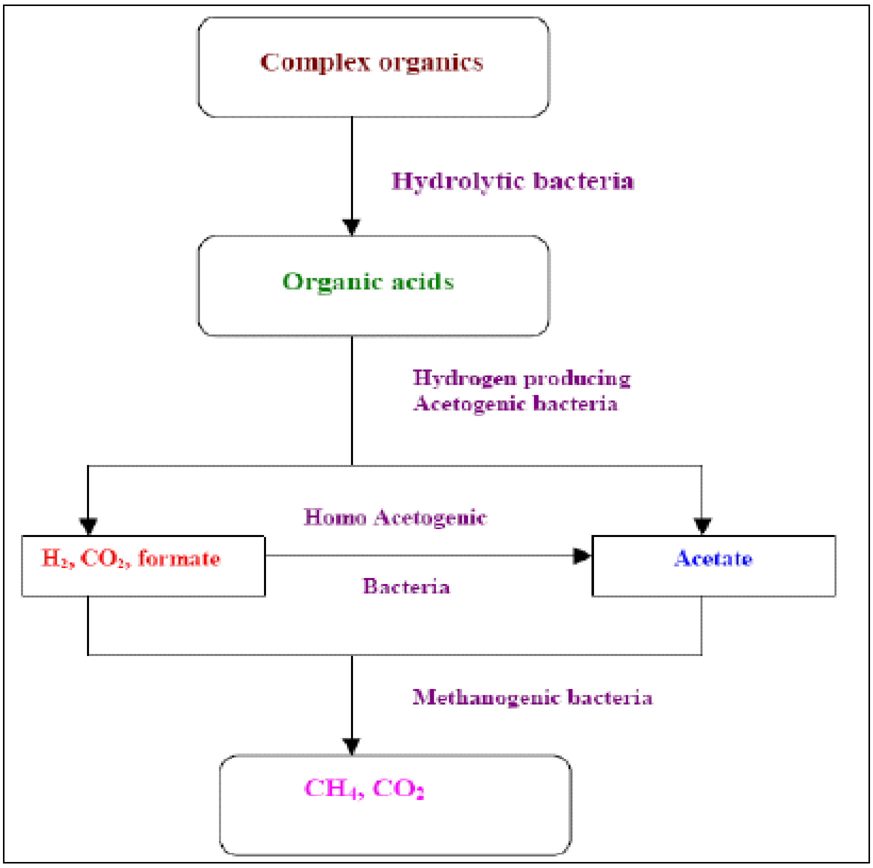

Fig. 3. *Biogas production processes [7].*

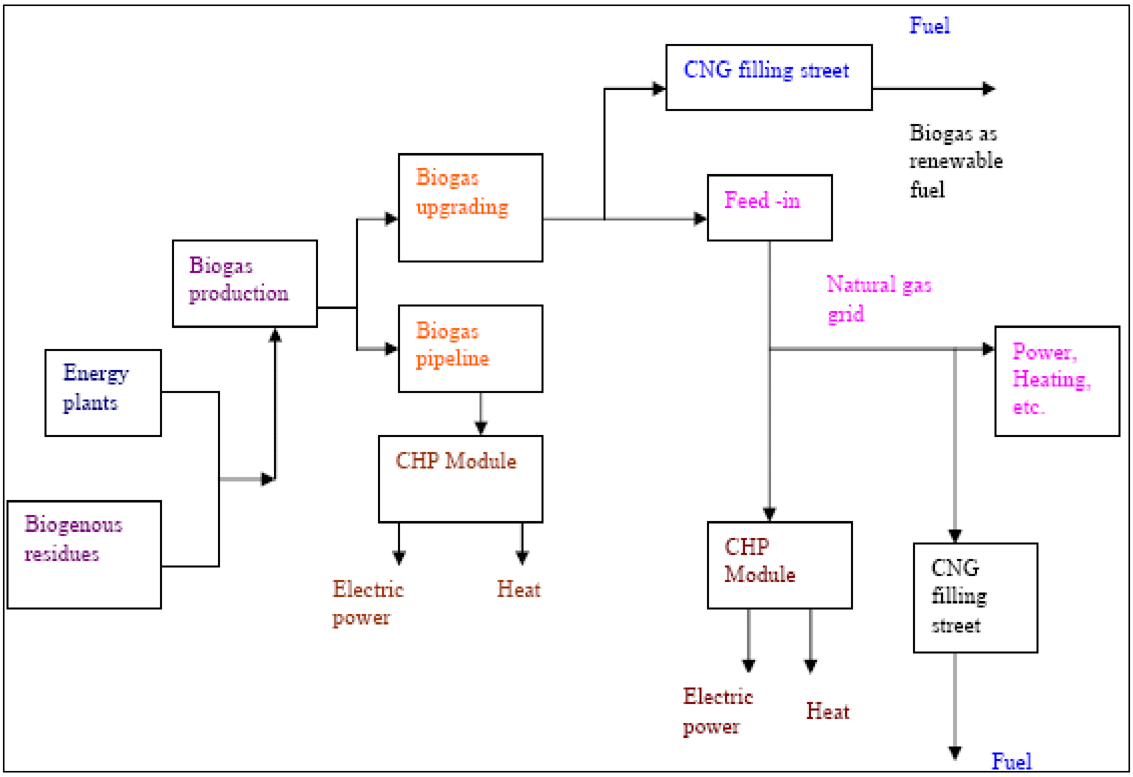

Fig. 4. *Overview of biogas utilisation pathways [18].*

Table 3. *Comparison of various fuels.*

Fuel	Calorific value (kcal)	Burning mode	Thermal efficiency (%)
Electricity, kWh	880	Hot plate	70
Coal gas, kg	4004	Standard burner	60
Biogas, m^3	5373	Standard burner	60
Kerosene, l	9122	Pressure stove	50
Charcoal, kg	6930	Open stove	28
Soft coke, kg	6292	Open stove	28
Firewood, kg	3821	Open stove	17
Cow dung, kg	2092	Open stove	11

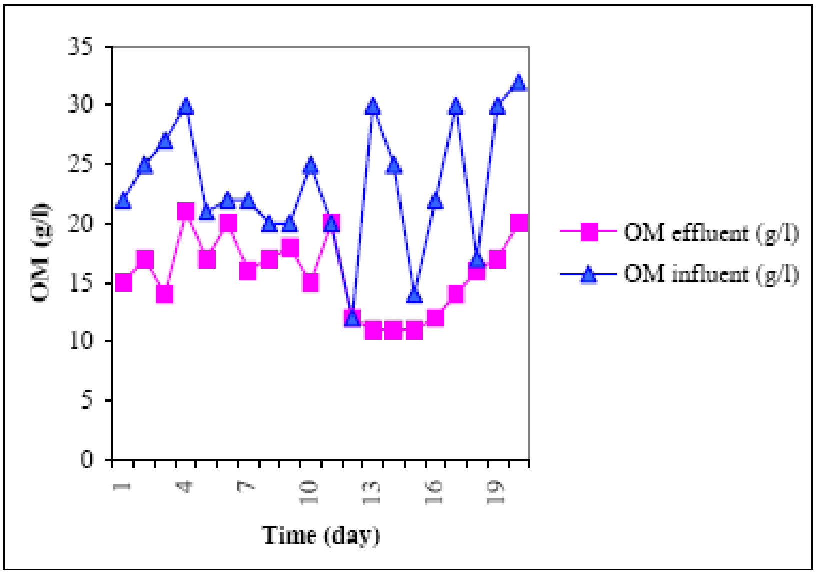

Fig. 5. *Organic matters before and after treatment in digester.*

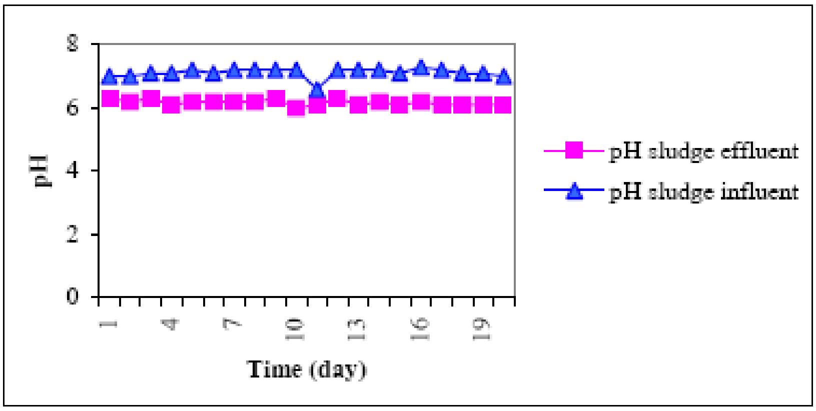

Fig. 6. *Potential of hydrogen (pH) sludge before and after treatment in the digester.*

FACTORS TO BE CONSIDERED IN ECONOMIC ANALYSIS

The introduction of biogas technology on wide scale has implications for macro-planning such as the allocation of government investment and effects on the balance of payments. Factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of general macro-policy, as do the allocation of research and development funds.

In some rural communities, cultural beliefs regarding handling animal dung are prevalent and will influence the acceptability of biogas technology. Co-ordination of production and use of biogas, fertiliser and pollution control can optimise the promotion and development of agricultural and animal husbandry in rural areas.

The technology is available, it is economically feasible and it is reliable. An additional benefit of using these gases as a fuel source is minimisation of the environmental impacts that result from gas venting or flaring. The burning of such gases releases air-borne pollutants, which can also enter groundwater sources and pollute farmlands. The optimum range in Table 4 is for ambient temperatures during hot seasons of Sudan tropical climates. The potential gas volumes produced from wastes vary depending on many factors, and can be expressed based on head count.

Table 4. *Optimum conditions for biogas production.*

Parameter	Optimum value
Temperature (ºC)	30–35
pH	6.8–7.5
Carbon/nitrogen ratio	20–30
Solid content (%)	7–9
Retention time (days)	20–40

IMPROVED SANITATION, WATER AND INDOOR AIR QUALITY

Health problems associated with leakage of human wastes into the wider environment can occur due to pit toilets becoming overfull due to inadequate pit depths and toilets being cited too close to water sources. Human wastes can also leach into ground water from a functioning pit toilet if cited on a highly permeable soil type. Contamination of groundwater and reservoirs by running storm water and flash floods can result in significant sporadic pollution events.

The type of contamination includes enterobacteria, enteroviruses and a range of fungal spores. Some key human/animal pathogens that may be spread in this way include *Salmonella typhi*, *Staphylococus* spp., *Escherichia coli*, *Campylobacter coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Hepatitis* B and C viruses, *Rotavirus, Aspergillus* spp., *Candida* spp., *Trichophyton* spp., *Cryptosporidium*, mycobacteria, *Toxoplasma* and *Clostridium botulinum.* Many of these can be passed between animal and human populations.

Cattle slurry introduces a range of pathogens including *Clostridium chavoie* (black leg disease); *Ascaris* ova, *E. coli* and *Salmonella* spp. as reported in cow dung slurries in Bauchi state, Nigeria [15]; *Salmonella* spp, *E. coli*, yeasts and aerobic mesophilic bacteria in poultry wastes in Cameroon [16]. Pathogen prevalence in the environment is affected by local climate, soil type, animal host prevalence, topography, land cover and management, organic waste applications, and hydrology.

Interest in the use of small-scale biogas digesters for household energy generation and treatment and utilisation of organic wastes in rural areas of sub-Saharan Africa (SSA) has been increasing with numerous organisations promoting their adoption for both socio-economic and environmental benefits. In this study, we review energy production using small-scale biogas digesters in SSA, a technology that is already improving the lives of poor people in many parts of the developing world, but has to-date had only limited uptake in Africa. Small-scale biogas digesters have great potential to contribute to sustainable development by providing a wide variety of socio-economic benefits, including diversification of energy (cooking fuel) supply, enhanced regional and rural development opportunities, and creation of a domestic industry and employment opportunities. Potential environmental benefits include reduction of local pollutants, reduced deforestation due to logging for fuel, and increased sequestration of carbon in soils amended with the digested organic waste. Ecosystem services that are potentially delivered through implementation of biogas digesters include carbon sequestration, improved water quality and increased food production. Carbon can be directly sequestered in the soil through application of soil organic matter originating from the digested material. Indirect carbon sequestration can also be achieved through reduced carbon losses due to logging as household fuel is replaced by methane produced by the digester. Replacement of household fuel by biogas has added benefits to household air quality. Water quality can be improved through reduced runoff of waste material and reduced erosion of sandy soils due to stabilisation of the soil through increased input of organic matter. Food production can be improved by application to the soil of digested material containing readily available nutrients. The productivity of the soil can also be improved through improved soil structure and water holding capacity achieved by the organic amendments of digested material to the soil.

In most developing countries, for example, Bangladesh, Burundi, Bolivia, Ivory Coast, Tanzania and Thailand, biogas is produced through anaerobic digestion of human and animal excreta using the Chinese fixed-dome digester and the Indian floating cover biogas digester [17]. These plants were built for schools and small-scale farmers, in most cases by non-governmental organisations. Most of the plants have only operated for a short period due to poor technical quality. There is thus a need to introduce more efficient reactors to improve both the biogas yields and the reputation of the technology.

Factors that control crop production include uptake of nutrients, water and oxygen, light interception, and temperature. The environmental constraints that directly impact these factors include availability of nutrients, organic matter content of the soil, water availability and climate. The widespread introduction of biogas digesters is likely to have an impact on all of these environmental constraints.

Access to an improved water source is not prevalent in Africa and contaminated or polluted water sources present a major health risk. Access to water is a precondition for sedentary agriculture and livestock husbandry, improved sanitation and the proper operation of a biogas plant. Occurrence of diarrhoea is closely related to polluted water sources and poor sanitation practices. For African children, diarrhoea is a very serious health threat. All countries in the central east–west band of Africa suffer major health and sanitation problems.

Many of these countries have the potential to improve their sanitation through use of domestic biogas digesters, and improvements in the technology may further increase the potential for use of biogas digesters. Biogas digesters have the potential to reduce the risks of encountering these pathogens if properly operated. However, risks could be increased due to the person handling the materials undergoing increased direct contact with these pathogens, the digester amplifying the growth of certain pathogens, or the processed material from the digester being used as a fertiliser for agricultural crops where it would not otherwise have been used. The risks from these pathogens can be mitigated by developing a toolkit that includes safe operating instructions.

Microbiological data should be generated for the pathogens or indicator organisms to determine the extent to which the levels change during the anaerobic digestion process. Advice on the use of the processed materials in agricultural production should also be provided.

The organic carbon content of soils in SSA tends to be low due to the high temperatures, low clay contents (or cation exchange capacity) and low organic inputs due to poor crop nutrition. However, increasing the organic inputs increases the steady-state carbon content, and so sequesters soil carbon. If organic inputs were increased, for instance, by adding material from a biogas digester to the soil, the carbon content of the soil would increase until it reached a new steady-state level; after that no more carbon would be sequestered unless the organic inputs were further increased. The sequestered carbon is not a permanent store; it will only remain in the soil while the balance between the organic inputs and the rate of decomposition remains the same. If the organic inputs were reduced to their original level, for instance, because the material from the biogas digester was no longer available, the amount of carbon held in the soil would return to its original level. Furthermore, if the rate of decomposition increased, for instance due to increased temperatures associated with climate change, the amount of carbon held in the soil would also decrease.

The rate of decomposition of material added to the soil also depends on the quality of the organic matter. If sufficient nutrients are available to allow decomposition, fresh material tends to decompose more quickly than material that has been composted or digested. Composted and digested material decomposes more quickly than material that has been converted to charcoal, which is highly recalcitrant.

POTENTIAL OF SMALL-SCALE BIOGAS IN IMPROVING SOIL QUALITY AND REDUCING DEFORESTATION

Developing alternative energy source to replace non-renewable sources has recently become more and more attractive due to the high energy demand, the limited resource of fossil fuel, and environmental concerns around the globe. Biogas has become more attractive as an alternative to non-renewable fuels because it is an integrated system with multi-benefits such as diversification of energy (cooking fuel) supply, reduction of local pollutants, reduced deforestation due to logging for fuel; air quality, sanitation and crop yield improvement through sequestration of carbon in soils amended with the digested organic waste. The challenge does not lie in the development of the small-scale biogas digesters; the processes of digestion are already well understood and different designs for low-cost digesters are operational. What is needed is the translational research to make it possible for these digesters to become available to people in SSA who have little or no disposable income and access to only limited material resources.

Development is needed for effective, safe and affordable methods for using small-scale biogas digesters to provide household energy and improve sanitation in the range of special conditions found in SSA, while obtaining the maximum economic and environmental benefits from the digested products, which are an important source of scarce nutrients.

ENVIRONMENTAL ASPECTS

A great challenge facing the global community today is to make the industrial economy more like the biosphere, that is, to make it a more closed system. This would save energy, reduce waste and pollution, and reduce costs. In short, it would enhance sustainability. Often, it is technically feasible to recycle waste in one of several different ways. For some wastes there are powerful arguments for incineration with energy recovery, rather than material recycling. Cleaner production approach and pollution control measures are needed in the recycling sector. The industrial sector world widely is responsible for about one-third of anthropogenic emissions of carbon dioxide, the most important greenhouse gas. Industry is also an important emitter of several other greenhouse gases. And many of industry's products emit greenhouse gases as well, either during use or after they become waste. Opportunities exist for substantial reducing industrial emissions through more efficient production and use of energy. Fuel substitutions, the use of alternative energy technologies, process modification, and by revising materials strategies are to make use of less energy and greenhouse gas intensive materials. Industry has an additional role to play through the design of products that use less energy and materials and produce lower greenhouse gas emissions.

Environmental pollution is a major problem facing all nations of the world. People have caused air pollution since they learned to use fire, but man-made air pollution (anthropogenic air pollution) has rapidly increased since industrialisation began. Many volatile organic compounds and trace metals are emitted into the atmosphere by human activities. The pollutants emitted into the atmosphere do not remain confined to the area near the source of emission or to the local environment, and can be transported over long distances, and create regional and global environmental problems.

CONCLUSION

Biogas technology cannot only provide fuel, but is also important for comprehensive utilisation of biomass forestry, animal husbandry, fishery, evoluting the agricultural economy, protecting the environment, realising agricultural recycling, as well as improving the sanitary conditions, in rural areas. The biomass energy, one of the important options, which might gradually replace the oil in facing the increased demand for oil and may be an advanced period in this century. Any county can depend on the biomass energy to satisfy part of local consumption. Development of biogas technology is a vital component of alternative rural energy programme, whose potential is yet to be exploited.

A concerted effect is required by all if this is to be realised. The technology will find ready use in domestic, farming, and small-scale industrial applications. Support biomass research and exchange experiences with countries that are advanced in this field. In the meantime, the biomass energy can help to save exhausting the oil wealth. The diminishing agricultural land may hamper biogas energy development but appropriate technological and resource management techniques will offset the effects.

RECOMMENDATIONS

The introduction of biogas technology on wide scale has implications for macro-planning such as the allocation of government investment and effects on the balance of payments. Factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of general macro-policy, as do the allocation of research and development funds. In some rural communities, cultural beliefs regarding handling animal dung are prevalent and will influence the acceptability of biogas technology. Co-ordination of production and use of biogas, fertiliser and pollution control can optimise the promotion and development of agricultural and animal husbandry in rural areas.

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