The Potential of Energy from Sugar Cane Wastes in Tanzania

By:
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AFRICAN ENERGY POLICY RESEARCH NETWORK (AFREPREN)

ENVIRONMENT THEME GROUP

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THE AFRICAN ENERGY POLICY RESEARCH NETWORK

AFREPREN is an African initiative on Energy, Environment and Sustainable Development supported by the Government of Sweden.

The African Energy Policy Research Network, AFREPREN, brings together 97 African energy researchers and policy makers who have a long-term interest in energy research and the attendant policy-making process. AFREPREN has initiated policy research studies in 19 African countries, namely: Angola, Botswana, Burundi, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. AFREPREN also maintains close collaborative links with energy researchers and policy makers from Cote D'Ivoire, Ghana, Nigeria, Sierra Leone and Senegal.

OBJECTIVE

The key objective of the African Energy Policy Research Network (AFREPREN) is to strengthen local research capacity and to harness it in the service of energy policy making and planning. Initiated in 1987, AFREPREN is a collective regional response to the widespread concern over the weak link between energy research and the formulation and implementation of energy policy in Africa.

AFREPREN 1999-2002

AFREPREN launched a new research programme in mid 1999 with the following key focal themes:

1. **Renewables and Energy for Rural Development:** New and innovative ways of delivering energy services to the rural areas.

2. **Energy Services for the Urban Poor:** Review and analysis of the energy needs of the urban poor for household purposes and small and medium scale enterprises (SMEs).

3. **Energy Sector Reform:** Analysing the legal and regulatory framework for promoting and ensuring reform.

4. **Energy Efficiency, Environment and Climate Change:** Optimisation of energy use in key energy end-uses in the African context.

5. **Special Studies of Strategic Significance for the Energy Sector Development in Eastern and Southern Africa (ESA):** New and emerging issues and trends on energy, energy investments and their implications for Africa.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFREPREN	African Energy Policy Research Network
BP	British Petroleum
CALTEX	California Texas Oil Company
FWD	Foundation For Woodstove Dissemination
NEAP	National Environment Action Plan
NGOs	Non Government Organizations
RUBADA	Rufiji Basin Development Authority
SADC	Southern Africa Development Community
SAPs	Structural Adjustment Programmes
SUDECO	Sugar Development Organisation
TANESCO	Tanganyika Electric Supply Company
TPDC	Tanzania Petroleum Development Corporation
USAID	United States Agency For International Development

EXECUTIVE SUMMARY

This study reported herein shows that the three largest sugar factories in Tanzania, cultivate over 17,000 hactres of sugarcane farms and produce about 125,000 tons of sugar per annum, process over 1,300,000 tons of sugar cane per year. In the process, the factories produce about 40,000 tons of molasses (a good percentage of which is exported) and about 455,000 tons of bagasse as waste. A significant portion of this extremely high organic content sugarcane waste is treated without optimal resource recovery, and without regard to the GHG emissions into the environment.the sugar mills currently purchase a total of 63,540 MWh/year which is 63.54 GWh/year. By just using co-generation, they stand to generate excess (above their needs) a minimum of 28 GWh (28,000 MWh) and a maximum of 546 GWh (546,000 MWh) electric power per annum, depending on the option chosen.

Environmentally, the savings on GHG emissions would be for as follows:

- option I would be 2.9 million cubic metres of methane
- option II would be 42.7 million cubic metres of methane
- option III would be 53.4 million cubic metres of methane
- option IV would be 56.3 million cubic metres of methane

There is a dire need to carry out an intensive and economic analysis with the final goal of implementing these resource recovery options.

1.0 INTRODUCTION

1.1 Background to the Study

Energy is a pre-requisite for the proper functioning of nearly all sub-sectors of any economy. It is an essential service whose availability and quality can determine the success or failure of development endeavours. The importance of energy as a sector in any national economy cannot, therefore be overemphasised. Tanzania, after investing heavily in hydro-electric schemes to alleviate the adverse effects of the oil shocks in the 70's and early 80's, has, in the recent past, an energy crisis. Environmental degradation and seasonal changes had led to heavy siltation and lowering of water levels, respectively, in hydroelectric dams thereby greatly reducing the generating power of the hydroelectric power stations. This, coupled with increased demand due to population and economic growths, forced TANESCO to revive most of its thermal power stations and, at times institute power rationing in all regions for months long between 1993 and 1997. In September and October 1997, power rationing resumed with unprecedented severity: industries and residential areas are cut off for five days a week for 18 hours! From November 1997 to May 1998 the *El Nino* rains came with unprecedented intensity and flooded the dams although they also flooded some airports as well and washed away a number of railway and road bridges. From November 1997 to July 2000, there has been no load shedding although due to poor rains in the country during the 1999/2000 season, it may resume anytime from September.

In Tanzania, like in most developing countries in the Eastern and Southern African Region, biomass energy and in particular fuelled and charcoal, is the dominant energy source (Davidson and Karekezi, 1993). Most of this fuelled is collected from natural forests and woodlands. For instance, in Tanzania over 90 percent of the household energy is supplied by biomass energy. Bio-energy also supplies process heat for many rural industrial production activities (e.g. tobacco curing, tea drying etc.), small-scale industries (brick, lime and pottery firing, beer brewing, baking etc.) and in public and private institutions (e.g. schools, hospitals, restaurants, etc.) (Ministry of Water, Energy and Minerals, 1986). In larger industries i.e. sugar mills, saw mills, pulp and paper mills, Bio-energy is used to provide heat and electricity through co-generation processes. About one third of all wood consumed in Tanzania is converted into charcoal, primarily for urban energy use. More than 85 percent of Tanzania urban population depend on charcoal for cooking in households and commercial activities (Mwandosya and Luhanga, 1983; Ministry of Water, Energy and Minerals, 1986, Hosier and Kipondya, 1993).

Although Tanzania has substantial indigenous energy resources (hydro, coal, gas, solar, geothermal, wind, etc.; see chapter two), they are yet to be fully explored and exploited to meet the ever-growing energy needs of the country (The Energy Policy of Tanzania, 1992). For example, the country's hydro potential is estimated at 4500 MW of which less than 10% has been developed so far. This hydro capacity does not include the mini-hydro potential estimated at 80 MW total installed capacity. Consequently, Tanzania is forced to continue generating electricity through thermal power plants in some towns in the country. The country also has large coal deposits in the south-western part of the country estimated at 1,500 million metric tons, of which 304.3 million metric tonnes are proven. Also, significant natural gas deposit totalling to about 2-5 billion m^3 have been discovered at Songo Songo Island (the utilisation of this gas for electric and other energy purposes was initially expected to start in 1998, has been delayed and is expected to start in 2001/2002) (Ministry of Energy and Minerals, 1999).
Observations and studies of energy consumption patterns in Tanzania indicate that due to lack of affordable substitutes biomass energy will in the foreseeable future, remain the main source of energy both in urban and rural areas of Tanzania (Kauzeni, 1995). It is thus quite logical to carry out in-depth investigations into sustainable, new and renewable energy sources.

The major renewable energy resources in Tanzania include the following:

- Biomass production estimated at more than 2 billion m^3 of solid wood per annum.
- Agricultural, municipal, and industrial wastes and residues, and animals waste estimated at 9 million metric tonnes per annum.
- Solar energy, with a high potential of mean insolation of between 4 and 8 kW/m^2/day.
- Wind energy, with wind regime of between 2.5 and 4m/sec.
- Geothermal energy in eight regions, some of which give geothermal steam at temperatures as high as 150^oC (Mwandosya and Luhanga, 1983).

With the exception of biomass and hydropower, none of the above indigenous energy resources contributes significantly to meeting the current energy needs of the country (Kauzeni, 1997). Since, as we have already seen, the unsustainable exploitation and utilisation of biomass contributes to environmental degradation through continuous vegetation cutting which eventually affects traditional water sources and causes soil erosion, and finally leads to reduction in crop yields; and both solar and wind energies are capital intensive, just like coal, one of the most appropriate renewable energy sources which are technically and capital least demanding is sugar cane wastes. As a bonus, the use of such wastes for energy production will greatly alleviate the environmental and public health hazards associated with poor management of these wastes, thereby turning an environmental and public health liability into an economic asset.

1.2 The Rationale of Concentrating on Industrial Sugarcane Wastes as a Source of Energy

Currently, the three largest sugar factories in Tanzania, cultivate over 17,000 hactres of sugarcane farms and produce about 125,000 tons of sugar per annum, process over 1,300,000 tons of sugar cane per year. In the process, the factories produce about 40,000 tons of molasses (a good percentage of which is exported) and about 455,000 tons of bagasse as waste. A significant portion of this extremely high organic content sugarcane waste is treated without optimal resource recovery, and without regard to the GHG emissions into the environment. The project will lead to reduction of GHG emissions by:

- Methane recovery that would have been released into atmosphere, and
- Substitution of fossil fuels which would have otherwise been used

It will also lead to

- Cleaner air (NEAP 1994, Environment Policy, 1997)
- Reduction of public health risk (NEAP 1994, Environment Policy, 1997).
- Renewable energy production (Energy Policy, 1992).

Utility cost reduction which benefits to:

- Sugarcane farmers through better prices
- The farm workers by improving the standard of living.
- TANESCO, by reduction of power demand by the sugar factories
- Cost saving to the industries.
- Improved sugarcane waste management (NEAP 1994, Environment Policy, 1997)
- Recycling of effluent (NEAP 1994, , Environment Policy, 1997)
- Ample and reliable supply of high nutrient irrigation water

Overall, it will be turning environmental/public health liability into a social-economic asset.

1.3 Objectives of the Study

The overall objective of the study is to investigate in detail and incorporate into the national energy policy, the potential of energy production from municipal waste, in an economically viable and environmentally sustainable manner.

The specific objectives of the project are the following:

(i) To collect information and prepare an in-depth country background in all aspects pertinent to energy - physical and economic characteristics relevant to the country's energy sector, energy supply and demand; institutional structure and the energy-environment bond.
(ii) To conduct a thorough literature review on MSW production, collection and disposal and review the appropriate technologies which can be used to generate energy from such waste in Tanzania.
(iii) To develop an appropriate and effective methodology for data collection on the parameters in objective (ii).
(iv) To conduct an in-depth and critical analysis of the data collected in objective (iii).
(v) To analyse in detail the national policy with respect to the following policy filters: institutional, legal, economic and financing, management and human resource requirements with respect to the institutionalisation of generation of energy from MSW in Tanzania.
(vi) To give appropriate recommendations to policy and decision makers, based on the solid findings of the study.

Study Hypotheses

(i) Environmental and public health problems are likely to worsen in the future if the constraints facing the development of the optimal sugar cane wastes to energy conversion options are not overcome.
(ii) The enhancement of sustainable and renewable production of energy from sugar cane wastes will not only alleviate the chronic problems of sugar cane wastes management and associated urban environmental and public health problems in Tanzania, thereby turning an environmental and public health liability into a socio-economic asset, but also provide a solution to the endemic shortage of electric power supplies in urban centres in Tanzania.
(iii) There is a great potential of energy which can be generated from sugar cane wastes in Tanzania and there are sugar cane wastes to energy conversion technological options which are suitable to the conditions in Tanzania.

1.4 Scope of the Study

Originally, this study was intended to cover only Mtibwa Sugar estate, but on the recommendation of a key stake holder, it was decided to include the other two large sugar estates in the country, namely Kilombero and TPC.

2.0 BACKGROUND ON TANZANIA, THE ENERGY SECTOR AND KILOMBERO, MTIBWA AND TPC SUGAR FACTORIES

2.1 Introduction

The United Republic of Tanzania whose total area is some 940,000 sq. km (nearly 360,000 sq. miles) of which 20,000 sq. km is covered by water; is made up of the mainland, formerly Tanganyika, and Zanzibar (composed of the islands of Zanzibar and Pemba which together have an area of 2,500 sq. km.). To the north, Tanzania shares borders with Kenya and Uganda, to the West with Rwanda, Burundi and the Democratic Republic of Congo, to the southwest the common borders are with Zambia and Malawi while it borders Mozambique in the South. The current population is estimated to be about 27.5 million (URT, 1997). Geographically, the country is located between longitudes 29 and 40^o East and latitudes 1^o and 11^o South. It occupies an area between Lake Victoria to the north, Lake Tanganyika to the west, Lake Nyasa to the south and the Indian Ocean to the east; with a coastline extending some 800 kilometres from Umba River in the north to Ruvuma River in the south.

2.1.1 Physical Economic and Demographic Characteristics Pertinent to the Energy Sector and the Sugar Industry in Tanzania

Tanzania's energy situation is characterised by a low per capita consumption of commercial energy (petroleum, coal and electricity) and a relatively large dependence on biomass energy in the form of firewood, charcoal and bio-waste. All petroleum products are imported and table 1 shows the quantities and value of the imported petroleum products.

Table 1: Tanzania's Oil Imports 1985–96

Year	Refined Volume MT	Value US $ '000	Crude Volume (MT)	Value US $ '000
1985	512,296	135,273.0	199,549	52,053.2
1986	561,170	117,713.7	293,604	49,512.1
1987	484,726	71,713.3	258,711	44,689.4
1988	628,819	84,524.5	306,643	46,251.9
1989	652,691	91,310.6	331 885	61,086.1
1990	495,777	101,810.3	434,600	110,036.2
1991	440,168	55,802.8	357,715	87.027.2
1992	526,969	76,676.6	541,335	114,734.0
1993	530,408	71,657.7	482,348	92,392.0
1994	563,643	70,237.0	426,106	71,257.0
1995	433,282	72,912.8	566,900	70,125.9
1996	514,800	96,856.0	525,458	78,600.0

SOURCE: Budget Speech 1997/98, Ministry of Energy and Minerals (1997).

In 1991, the per capita consumption of energy was 20.7 GJ, of which 92% was from biomass energy, mainly from the forest products: charcoal and firewood (Sawe, 1995). In Tanzania, like most other countries in Eastern and Southern African Region, Bo-energy resources are not used on a renewable basis and thus continue to be depleted. There is a rapid depletion of woodland resources due to growth in demand resulting from population increase, agricultural expansion, over-grazing by livestock and over exploitation of forest resources for commercial gains, including supplying fuelled and charcoal to urban markets (Kauzeni, 1995). These bio-energy problems have been noted to be most acute in areas surrounding main urban centres, agro-processing industries and other small industries in areas with high population densities. In areas where there is serious scarcity of fuelled, there is a growing shift towards the use of other Bo-energy resources such as crop residues and animal wastes in the rural households and small scale industrial sectors. Some of these materials were formerly used for preserving soil fertility.

2.1.2 Electricity Supply

The importance of electricity in any modern urban environment and economy cannot be overemphasised. Without electricity, industrial production stops and the provision of key social services becomes crippled. In the past five years, there has been an under-supply of electricity in Tanzania. This has triggered an urban power crisis in the country. To be able to understand the urban energy crisis in Tanzania, we have to examine the provision of electric power in the country. In Tanzania electricity supply is the responsibility of TANESCO (Tanzania Electric Supply Company), a parastatal under the Ministry of Energy and Minerals (the Water Department became a full ministry in November 1995). TANESCO supplies about 93% of the electricity consumed in the country. The balance is self-generated by parastatal and private organisations. The power system of TANESCO consists of 23 isolated load centres with an installed capacity of 29 MW; and of an interconnected system (ICS) with an installed generating capacity in 1992 of 470 MW - 333 MW of hydroelectric (71%) and 137 MW of thermal capacity. With the exception of one gas turbine, the thermal capacity of both systems consists of 159 diesel generators (Ministry of Water, Energy and Minerals, 1993). Table 2 gives the total electricity supply for the years 1986 – 98.

In l991, the transmission system consisted of 1,620 km. of 220 kV lines, 1,160 km of 132 kV lines and 132 km of 66 kV lines. The rehabilitation of the distribution network since 1986 covered some 3,600 km of 33 and 11 kV main distribution lines and related low voltage lines. The isolated service areas accounted for 4% of total sales of electricity and served 23,000 customers in 1991. The ICS which accounted for the balance of sales served 153,000 customers. The residential sector accounted for about 25% of demand, the commercial sector for 19%, industry for 50% and others for 6%. Of the 176,000 customers, 133,000 were households, which amounts to an electrification rate of national households of 5%. Since few rural electrification projects have been undertaken, the electrification rate of the urban population can be estimated to around 12%. In Dar es Salaam where 55,000 households were connected, the electrification rate was about 22 %. The highest electrification rate is found in Moshi, where more than 50% of households are electrified (Ministry of Water, Energy and Minerals, 1993; Mwandosya and Luhanga, 1993).

Table 2: Tanzania Electricity Supply 1986 - 98(GWH)

YEAR/TYPE	HYDRO	THERMAL	TOTAL	OTHER (Imported)
1986	1034	111	1148	1.01
1987	1149	121	1272	1.87
1988	1249	81.29	1320	0.27
1989	1419	94.40	1513	-
1990	1549	80	1629	-
1991	1713	96	1809	-
1992	1649	269	1918	-
1993	1797	180	1978	-
1994	1499	381.7	1881	-
1995	1539	253.7	1793	32
1996	1748	383.4	2022	33
1997	1458	514.5	1972	33
1998	2078	85.6	2163	33

SOURCE: Budget Speech 1999/2000, Ministry of Energy and Minerals (1999)

The maximum power demand in 1991 was about 300 MW. The typical daily load pattern shows a rapid load increase between five and seven in the morning, a daytime peak at noon and finally a peak from six until ten in the evening. The annual load factor in 1988 was 67 %. The seasonal load and demand variations are rather small, being 6-9%. Between 1990 and 2010 the forecast expects that power demand will increase by 5.9% per year. This is approximately half the growth rate which was achieved from 1988 to 1992 when maximum demand and generation grew at an annual rate of about 11%. However, the major reason for this extraordinarily strong growth in demand during the last five years is the import liberalisation policy which was introduced as part of the Structural Restructuring Programmes (SAPs) (Kulindwa, et al., 1990). This was a one for all jump in demand from connected households. From 1993 to late 1997, for at least three months yearly, peak demand has in most cases been 15-30 MW higher than available capacity in the ICS system, load shedding had to be introduced. In Dar es Salaam and all the other urban centres on Mainland Tanzania, selected districts were cut from power during parts of the day. Even industries were not spared causing great financial losses to the industries and TANESCO. In 1994, the situation grew worse due to the fall of the level of water in the hydroelectric dam at Mtera, the largest in the country. The extent of power shedding was such that most areas of Dar es Salaam were without electricity for 15 hours for four days a week. As already stated in the introduction, the El Nino rains gave the country a temporary relief between 1997 and 2000. Despite a large hydro-electric station, the second largest in the country, generating a total of 170 MW being commissioned in early July 2000 at Kihansi in Morogoro Region, power shedding may resume anytime from September 2000.

2.2 Sugar Production in Tanzania

The per capita consumption of sugar in Tanzania is about 5.38 kg. Which gives an annual consumption quantity of about 166,780 tons. The peak total local production of sugar in the country is about 123,000 tons. Currently, the three largest sugar factories in Tanzania, cultivate over 17,000 hactres of sugarcane plantations and produce about 125,000 tons of sugar per annum, process over 1,300,000 tons of sugar cane per year. In the process, the factories produce about 40,000 tons of molasses (a good percentage of which is exported) and about 455,000 tons of bagasse. Table 3 gives the production statistics of these industries for the past ten years.

Table 3: Sugar Production From Sugar Estates In Tanzania 1989/90 to 1999/2000

YEAR	2 FACTORIES/ KILOMBERO CO. TONS	MTIBWA ESTATE TONS	TPC LTD	TOTAL	AREA UNDER CULTIVATION (HACTRES)
1989/90	44016	22502	26455	92973	17,000
1990/91	43747	24610	39446	107803	17,000
1991/92	53674	25565	32681	111920	17,000
1992/93	52117	29149	37750	119016	17,000
1993/94	54059	30635	37854	122548	17,000
1994/95	45825	34238	19853	99916	17,000
1995/96	41762	32109	33605	107476	17,000
1996/97	38981	32584	39435	111000	17,000
1997/98	29517	20933	27883	78333	17,000
1998/99	42063	28260	40021	110344	17,000
1999/2000	50000	30000	37900	117900	>17,000

Source: SUDECO (2000)

The three major sugar plantations have a total of 17,000 hectares of cane fields, with a yield presently expected of 5-6 tons cane/month/ha. Every fifth year cane has to be replanted by vegetatively. The cane grows for 10 months before harvesting. Since there are no severe seasonal variations in climate in this part of the world, cane can be harvested an average of 8 months per year.

Before harvesting, the cane fields are burnt to eliminate cane tops and leaves. Harvesting is manual. The cane is transported to the sugar mill by train carriers. At the mill, the cane is crushed with water for extraction of the sweet juice. The juice is heated, clarified and converted into syrup during several heating steps, as illustrated in Figure 7. The syrup is boiled and crystallised in three steps before the final products, sugar and molasses, are produced. The residue obtained from the crushing the cane, bagasse, is used as primary fuel for the steam boilers.

General data for the TPC sugar factory (which can be taken to be representative of the other factories), obtained from the energy audit carried out by Jenefors; et al. (1993), are given in Table 4. In comparison with "typical data" from other countries, the process steam consumption is almost 40% higher than an average factory in the Philippines or Mauritius. The electricity requirement is about normal for a factory with turbine driven cane crushers.

3.0 MANAGEMENT OF WASTES AND BY-PRODUCTS IN SUGAR FACTORIES IN TANZANIA

3.1 Introduction

- A normal sugar plantation and factory has four types of wastes and by-products, namely:
- cane tops and leaves
- cane trash (the residue left in the farm after harvesting)
- bagasse
- mollasses

As already stated above, before harvesting, the cane fields are set on fire to eliminate cane tops and leaves. This also helps clear the farms of wild animals and snakes, especially pythons, which migrate into cane fields when the cane grows.

3.2 Cane Trash

The amounts of cane trash vary with plant varieties, climate and soil conditions, cultivation procedures and harvesting practices (Gabra and Kjellstrom, 1995). A USAID (1989) study in the Dominican Republic concluded that an average of 0.67 tons of cane residues are left in the field (at 50% moisture) for every ton of cane stalk harvested. Extrapolating this mean value for sugar cane plantations in Tanzania gives the annual cane trash to be 871,000 from 1.3 million tons of cane harvested annually. This trash is usually retained in the fields as a soil conditioner after decay.

If cane trash were to be collected and used as fuel, the crucial question becomes how much can be removed without adverse effects on the productivity of the cane field. The main influences of cane trash on soil that need to be considered are (Gabra and Kjellstrom, 1995):

- the blanketing effect which improves weed and erosion control, and retention of moisture in the upper level,
- addition of organic matter, and
- addition of important minerals.

Needless to say, the amount of cane trash that can be removed depends on local conditions. The problem of mineral balance in the soil is most easily handled, since the minerals may be returned to the soil by spreading the ash on the fields. The other issues are more complex, and site specific field studies for prolonged periods are required in order to determine their effects. Some experiences have been reported in the USAID financed Cane Energy Assessment Programme. These indicate that at least a fraction of the cane trash can be removed without detrimental effects. Experience in burned fields shows that the benefits of a cane trash blanket can be obtained with only a fraction of the total volume of cane trash. Experiments in Puerto Rico (USAID, 1986a) indicate that 30 to 50% of the cane trash is sufficient to maintain the organic content of the soil. Research by the Hawaiian Sugar Producer's Association suggests that the removal of cane trash will actually enhance the availability of nitrogen, and thus be beneficial (USAID, 1986b).

3.3 Bagasse

According to Jenefors; et al. (1993), the amount of bagasse per ton of cane in Tanzania is 35%. This gives an annual amount of 455,000 from the 1.3 million tons harvested processed annually. The bagasse is used for as a boiler fuel, together with coffee husk and fuel oil. Bagasse is the major fuel forming 94% of the lot. All the bagasse is used up ias a fuel, but as already stated above, the technology is very inefficient compared to that in use in other countries like Mauritius.

3.4 Molasses

The annual production of molasses in Tanzania is about 40,000 tons. This is sold to companies within and without the country. None of this by-product is used at the factories.

4.0 SUGAR CANE WASTE TO ENERGY CONVERSION TECHNOLOGIES

4.1 Introduction

There are known and well tested technologies for the conversion of sugar cane wastes, both solid (bagasse and cane trash) and liquid (molasses). These are elucidated below.

- hot air turbine with external firing;
- integrated, pressurised gasifier supplying combustible gas to the gas turbine
- combustor;
- integrated atmosphere gasifier supplying combustible gas to be pressurised by a compressor and supplied to the gas turbine combustor; and
- direct use of the residual fuel in a modified pressurised combustor.

4.2 Hot Air Turbine With External Firing

These options are illustrated in Figure 1. None of these processes are presently used in a commercial installation. The major problem is to find a way to stop mineral matter in the solid fuel from causing erosion, deposits, and corrosion in the gas turbine. Gas turbines are designed to run on very clean fuels like natural gas or light petroleum fuels. Solid fuels have relatively high ash contents which can lead to a gas with a high dust content. Some elements in the ash, in particular sodium (Na), potassium (K), and vanadium (Va), form corrosive compounds with low melting points which may deposit in the turbine and cause corrosion. Nevertheless, the problem can be eliminated by external firing. A high efficiency process with a high inlet temperature to the gas turbine, however, requires an expensive heat exchanger made out of temperature resistant material.

4.3 Integrated, Pressurised Gasifier Supplying Combustible Gas To The Gas Turbine Combustor

The gasification process generally includes cooling and filtering of the gas before combustion. This presents the possibility of reducing the amounts of dust and corrosive compounds but leads to some efficiency loss and investment in a gas filter. The process is, however, much simpler and can therefore be expected to require the lowest investment. All the processes are currently subject to research and development and include the following:

(i) Externally Fired Gas Turbines

In this cycle, the hot gases exiting from the atmospheric pressure combustor are used to heat compressed air in a high temperature heat exchanger. The air expands through the turbine and is used as combustion air in the combustor for solid fuel (Marksberry and Lindahl, 1979 and 1980). The gases leaving the heat exchanger can be used to produce steam in a heat recovery steam generator (HRSG) (Figure 2).The turbine for this type of cycle are long-lasting (since only clean air is passed through the turbine) but expensive.

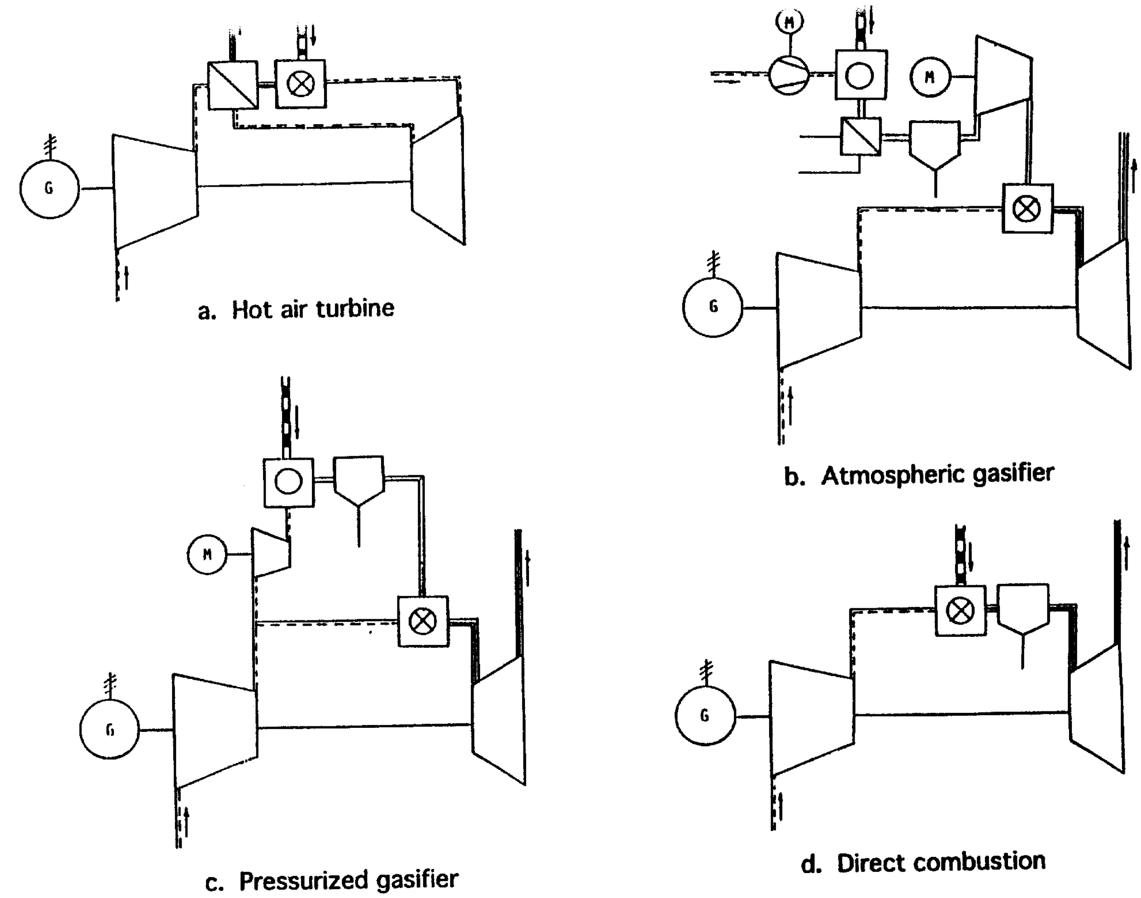

Figure 1. Options for using solid fuels to run a gas turbine.

The most promising combustion technology for heating compressed air is the atmospheric fluidised bed combustor (AFBQ used as an air heater (USAID, 1986a). This technology is well established for steam generation using biomass fuels, but no commercial AFBC air heater installation exists.

(ii) Integrated Atmospheric Gasifier

Gasification of solid fuels by means of partial combustion with air is an old technology which was in wide-spread use during the first half of this century. For gasification of sugar cane residue for operation of a gas turbine in combined cycle at a sugar mill, only gasifiers based on either counter-current flow in a fixed bed or the fluidised bed technology can be considered. Co-current fixed bed gasifiers are not suitable for feedstocks with the low bulk density associated with bagasse and shredded cane trash. The maximum capacity of fixed bed counter-current gasifiers is about 10 MW(fuel), whereas fluidised bed gasifiers can be designed for at least 5 times as large capacities. Both types of gasifiers are being operated in Sweden using wood residue as fuel and providing fuel gas to furnaces for process heat generation. There seems to be no documented experiences from use of bagasse or cane trash as feedstock for these gasifier types.

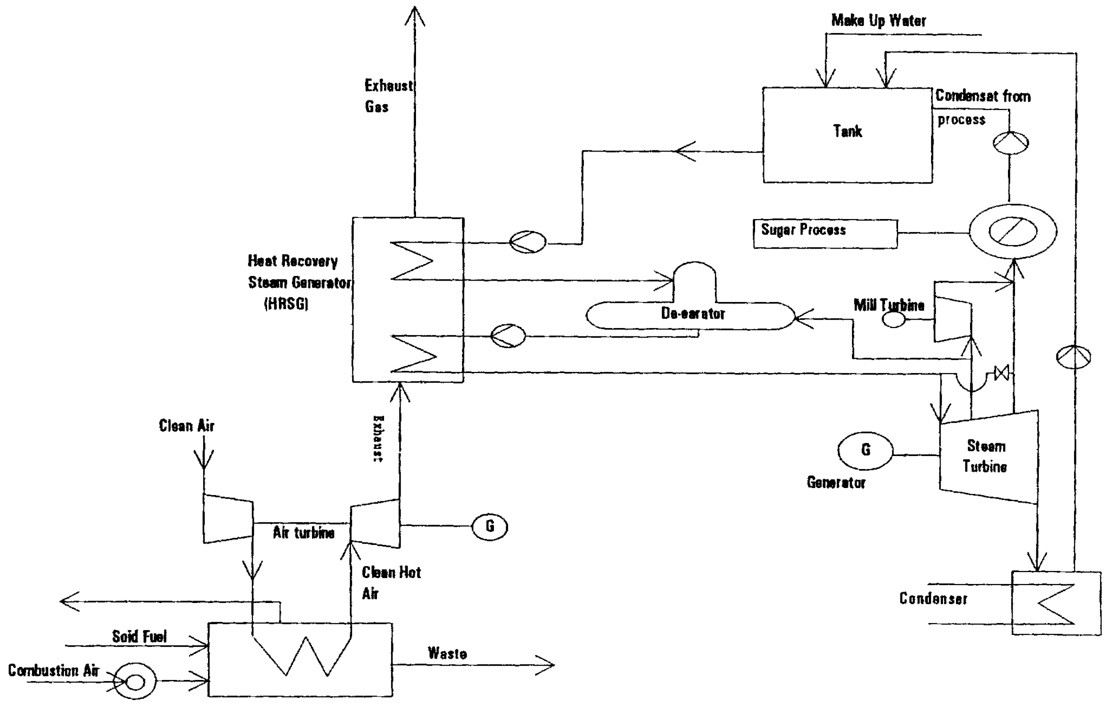

Figure 2. Externally fired gas turbine with heat recovery steam generator.

The scheme for integrating an atmospheric gasifier with a combined gas turbine/steam turbine process is illustrated in Figure 3. This is the process suggested by the Swedish company TPS for the Global Environment Facility project in Brazil (Elliott and Booth, 1993; Waldheim, 1993; and USAID, 1992). A plant based on the same process, using short-rotation plantation wood as fuel was recently sold by TPS to a utility in Great Britain.

The atmospheric circulating fluidised bed gasification process offered by TPS has been demonstrated in a 2 MW(thermal) pilot plant operated for 1,700 hours on wood fuels. During much of this test period the gas was used to drive a 500 kW diesel generator set, operating in dual fuel mode. Attractive features of this process are the relatively simple fuel feeding, the proven gasifier technology, the very clean gas and the use of commercially proven technology for gas cleaning. Disadvantages are the need for two large reactor vessels, which can be expected to increase the investment, and the power lost from compression of the product gas to the pressure in the gas turbine combustion chamber, which tends to reduce the cycle efficiency.

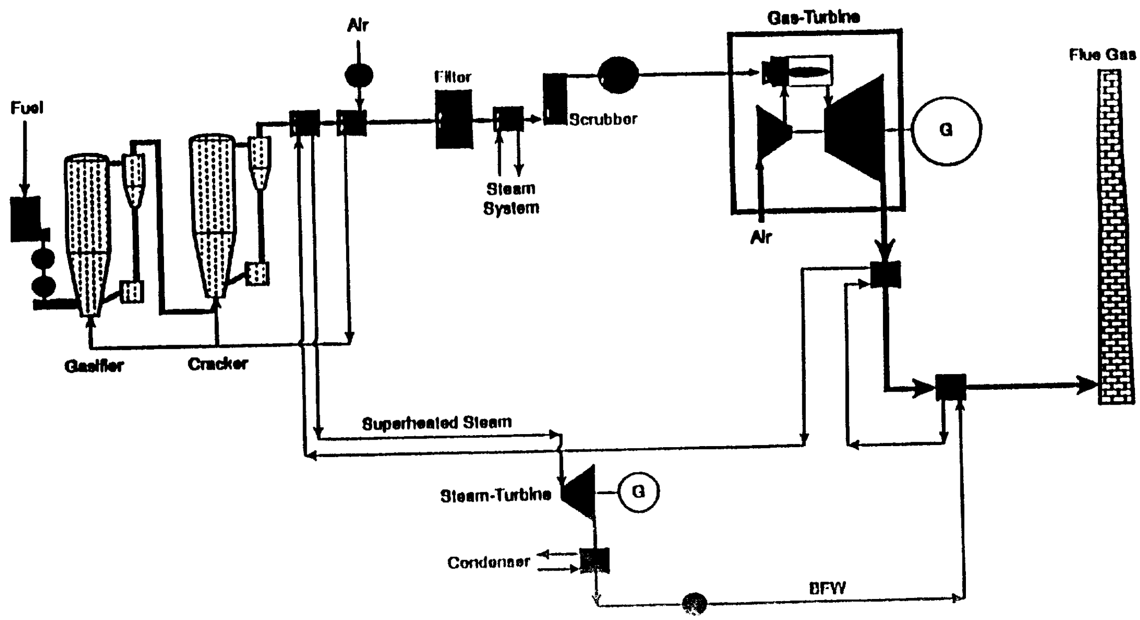

Figure 3. Combined cycle with integrated atmospheric gasifier. Source: USAID, 1992. See figure 6.14.

(iv) Integrated Pressurised Gasifier

With a General Electric LM2500 gas turbine, and a condensing steam turbine, the plant is estimated to give 30 MW(e) with an efficiency of 45%. Capital investment estimates for this capacity are not available. The V5 Malmo pilot plant of 6 MW(e), which is a district heating installation with an electric yield of 33%, has been reported to cost about 3,500 USD/kW The main advantages of integrated pressurised. gasification are the potentially higher efficiency and that the process is slightly less complicated. The main disadvantages are anticipated problems with feeding the solid fuel into the pressurised gasifier and lack of verification of the hot pressurised fuel cleaning. An illustration is given in Figure 4.

(v) Pressurised Biomass Combustor

Direct combustion of coal is practised in the pressurised fluidised bed combustion (PFBC) process used by ABB Carbon in a few large power plants with combined gas turbine/steam turbine process operating in different parts of the world. The first of these plants has operated since 1992 for cogeneration of electricity and district heating in Stockholm. Coal is fed into the pressurised combustor. The combustion gases expand through the gas turbine after removal of larger particles in a cyclone. The gas turbine, a modified version of the ABB Stal GT 35 model, is adapted so that it can tolerate a gas with a higher dust load than normal. The inlet temperature to the turbine is lower than in most modem designs in order to avoid problems with deposition and corrosion caused by ash compounds carried with the hot gas into the turbine (figure 5).

The projected total efficiency for the first co-generation plant giving 4.4 MW(e) is 83% and the electric yield is 29%. The specific investment for this plant has been estimated at 1,600 USD/kW. The main advantage of this process is its simplicity, which is expected to require a lower capital investment than the other options, in particular at small capacities. The main disadvantages are lower cycle efficiency, caused by low inlet temperature to the gas turbine, and more expensive fuel. Based on the Swedish experiences, the added fuel cost for obtaining the dried, powdered fuel amounts to about 6 USD/MNVh if part of the fuel produced is used for the drying.

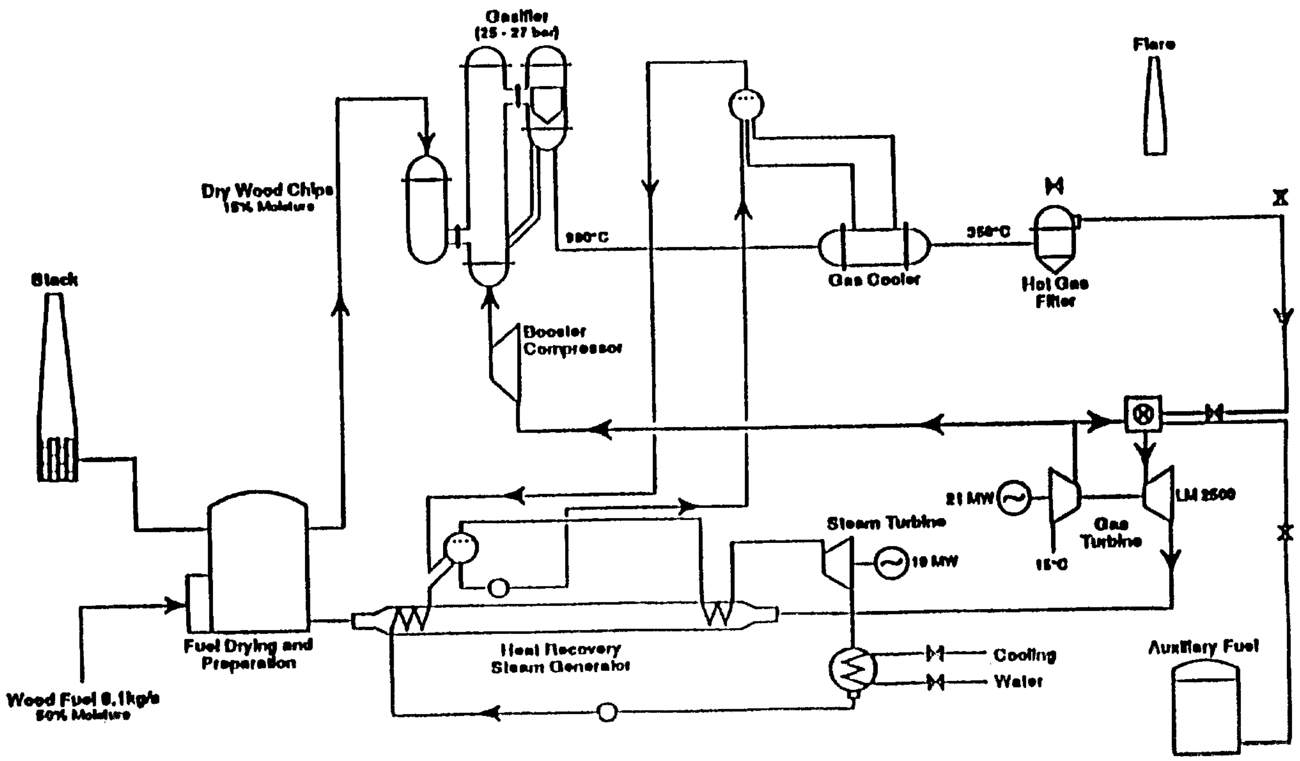

Figure 4. Combined cycle with integrated pressurised gasifier.

Source: USAID, 1992. See Figure 6.26.

4.4 Fermentation to Produce Ethanol

Ethanol is mainly used as a substitute for imported oil in order to reduce their dependence on imported energy supplies. The substantial gains made in fermentation technologies now make the production of ethanol for use as a petroleum substitute and enhancer, both economically competitive (given certain assumptions) and environmentally beneficial. For example, subsidies for alcohol production in Brazil are now becoming regarded as detrimental to the stability of the ethanol market, and thus obsolete. In Zimbabwe, foreign exchange savings are seen as a major bonus which along with the employment and environmental benefits have made the long term future and expansion of the this programme a priority for the Zimbabwean government.

The most commonly used feedstock in developing countries is sugarcane, due to its high productivity when supplied with sufficient water. Where water availability is limited, sweet sorghum or cassava may become the preferred feedstocks. Other advantages of sugarcane feedstock include the high residue energy potential and modern management practices which make sustainable and environmentally benign production possible whilst at the same time allowing continued production of sugar (Scurlock et al. 1992). Other feedstocks include saccharide-rich sugarbeet, and carbohydrate rich potatoes, wheat and maize.

One of the most promising fermentation technologies to be identified recently is the "Blostil" process which uses centrifugal yeast reclamation, and continuous evaporative removal of the ethanol. This allows the fermentation medium to be continuously sterilized and munimises water use. The Biostil process markedly lowers the production of sullage, whilst the non-stop nature of the fermentation process allows substrate concentrations to be constantly kept at optimal levels and therefore fermentation efficiency is maximised. (Hall, 1991). Improved varieties of yeast, produced through clonal selection techniques have also raised the tolerance levels of the yeast to alcohol concentrations, again improving efficiency.

Recent advances in the use of cellulosic feedstock, may allow the competitive production of alcohol from woody agricultural residues and trees to become economically competitive in the medium term. Since 1982, prices have fallen from about US$ 45 per GJ (95 c/l) to about US$ 13 per GJ (28 c/l) for ethanol, and for methanol projected prices have been reduced from US$ 16 per GJ (27 c/l) to $15 per GJ (25 c/l) and could fall to prices competitive with gasoline produced from oil priced at US$ 25 per barrel (Wyman et *al.,* 1992). According to Coghlan (1996), the goal has been achieved by genetic engineering of the micro-organisms used in fermentation, thereby reducing the quantity of enzymes required for the process to 25% of the normal.

5.0 ENERGY POTENTIAL FROM SUGAR CANE WASTES IN TANZANIA

5.1 Introduction

The only data available from which estimations can be made is from TPC Sugar Factory. This will be extrapolated to estimate the potential from the three major factories in Tanzania. The current situation is elucidated in table 5.1 for TPC and Table 5.2 gives the current scenario for Kilombero, Mtibwa and TPC combined (assuming same efficiency).

Table 5.1: Current Scenario Technical Data At Tpc Mill, Kilimanjaro Region

Annual operating period	33 weeks
Effective operating time	136 hours/week
Effective crushing rate	82 tons cane/hour
Average fuel consumption:	
Bagasse	29 tons/hour
Coffee husk	0.4 tons/hour
Fuel oil	0. 17 tons/hour
Bagasse fraction of fuel	94%
Specific energy plant inputs:	
Fuel energy	774 kWh(fuel)/ton cane
Combustion air	27 kWh(thermal)ton/cane
Make-up water	12 kWh(thermal)/ton cane
Specific energy plant outputs:	
Process steam	0.76 tons/ton cane
Energy supplied with steam	549 kWh(thermal)/ton cane
Crushing power	7.8 kWh(mek)/ton cane
Electric power	23 kWh(e)/ton cane
Total efficiency	71%
Factory electricity supply:/	
Generating capacity	2.5 MW(e)
Average generation	1 .9 MW(e)
Electrical yield	3%
Total operation electricity supply:	
Peak power demand	5.5 MW(e)
Purchased electric energy	18,000 MWh/year

In principle, there are four options for increasing the electricity generation from sugar wastes at plantations in Tanzania and are evaluated below, basing on productivity assumptions given in Table 5.3:

i. using cane trash at the existing factories during the off season (option I);
ii. a new system with a more advanced steam process (option II);
iii. a combined cycle of gas turbine and back-pressure steam turbine using bagasse and cane trash (option III); and
iv. a combined cycle of gas turbine and condensing extraction turbine, also using cane trash and bagasse (option IV).

The extra energy generation from the four options are summarised in Table 5.4

Table 5.2: Current Scenario Technical Data in Tanzania Sugar Mills, 1999/2000

Annual operating period	33 weeks
Effective operating time	136 hours/week
Effective crushing rate	289.7 tons cane/hour
Boiler fuels	Bagasse, coffee husk, fuel oil
Average fuel consumption:	
Bagasse	102.37 tons/hour
Coffee husk	1.412 tons/hour
Fuel oil	0. 6 tons/hour
Bagasse fraction of fuel	94%
Specific energy plant inputs:	
Fuel energy	774 kWh(fuel)/ton cane
Combustion air	27 kWh(thermal)ton/cane
Make-up water	12 kWh(thermal)/ton cane
Specific energy plant outputs:	
Process steam	0.76 tons/ton cane
Energy supplied with steam	549 kWh(thermal)/ton cane
Crushing power	7.8 kWh(mek)/ton cane
Electric power	23 kWh(e)/ton cane
Total efficiency	71%
Factories' electricity supply:	
Generating capacity	8.83 MW(e)
Average generation	6.71 MW(e)
Electrical yield	3%
Total operation electricity supply:	
Peak power demand	19.42 MW(e)
Purchased electric energy	63,540 MWh/year

Table 5.3: Productivity Assumptions

PARAMETER	TPC	TANZANIA
Production Area (ha)	6,300	17,000
Cane production, tons/year	378,000	1,300,000
Crushing rate, tons cane/h	82	289.7
Annual milling hours	4,610	4,610
Weekly operating hours	136	136
Annual operating weeks	34	34
Bagasse (50% moist), tons	133,690	455,000
Cane trash (30% moist), tons	97,505	344.19

Annual fuel energy in residue:

Bagasse (50% moist), GWh(fuel)	281	991.9
Cane trash (30% moist), Wh(fuel)	298	1051.94

Table 5.4: Potential Energy Generation from Cane Wastes in Tanzania

	Options			
Milling operation:	**I**	**II**	**III**	**IV**
Fuel Input, GWh	**826**	**1123**	**1564**	**1567**
Electricity Generation, GWh	**31**	**177**	**414**	**414**
Electricity Consumption, GWh	**31**	**31**	**31**	**31**
Remaining Time:				
Fuel Input, GWh	**533**	**914**	**477**	**477**
Electricity Generation, GWh	**28**	**269**	**164**	**164**
Over-all input and Output:				
Total Fuel Input, GWh	**1567**	**2030**	**2040**	**2043**
Input as Cane Trash, GWh	**575**	**1037**	**1048**	**1051**
Net Electricity, GWh	**28**	**414**	**518**	**546**
Electricity Yield	**0.04**	**0.22**	**0.27**	**0.28**

As can be deduced from tables 5.2 and 5.4, the sugar mills currently purchase a total of 63,540 MWh/year which is 63.54 GWh/year. By just using co-generation, they stand to generate excess (above their needs) a minimum of 28 GWh (28,000 MWh) and a maximum of 546 GWh (546,000 MWh) of electric power per annum, depending on the option chosen (Table 5.4).

Thus savings on GHG emissions would be for as follows:

- option I would be 2.9 million cubic metres of methane
- option II would be 42.7 million cubic metres of methane
- option III would be 53.4 million cubic metres of methane
- option IV would be 56.3 million cubic metres of methane

6.0 POLICY ANALYSIS

6.1 Key Stakeholders in the Energy Sector

The Ministry of Energy and Minerals is responsible for energy development in Tanzania. The Commissioner for Energy and Petroleum Affairs is responsible for all energy issues. Under the commissioner there are four assistant commissioners heading departments dealing with petroleum and gas, renewable energy, electricity and energy development. The Ministry is the central government institution responsible for overseeing and guiding the energy sector to meet the goals of national development. This responsibility is discharged through evolving policy initiatives, assessment and analysis of developments in all sub-sectors of the energy sector. The Department of Energy Development fulfils its task by developing capabilities in the technical, economic, financial, social and legal aspects. The collection, storage and retrieval of information on all aspects of energy is the duty of this department. Since the energy sector merely provides a service to all other sectors, there are institutional links with other sectors in so far as policy - decision making is concerned. Due to this the projects and activities of the energy sector are linked with developments in the recipient sectors. There is a close working relationship between the Department of Energy Development and the Ministry responsible for natural resources exists. Thus the Department of Energy works closely with the Department of Forestry in biomass energy development. In the upstream, the Tanzania Electric Supply Company (TANESCO) is, so far, the only commercial producer of the electricity. However the government has given a mandate to other organisations to exploit the hydropower resources and to install thermal-based generators. The Rufiji Basin Development Authority (RUBADA) for example, has a mandate to develop the hydropower potential of the Rufiji Basin, which accounts for over 65% of the potential hydroelectric power sources in the country. The Tanzania Petroleum Development Corporation (TPDC) is the national petroleum enterprise of the government covering all aspects of the petroleum industry from exploration and production to distribution. The objectives of the TPDC are the development of an adequate industrial base for the petroleum industry, exploration and production of petroleum, and carrying out standard activities of an oil company including procurement of supplies, refining distribution and storage. In implementing its downstream activities TPDC uses British Petroleum (BP), CALTEX and AGIP. TPDC has recently been encouraged to enter into downstream activities directly and to expand its oil distribution fleet into a fully fledged oil distribution network (Ministry of Water, Energy and Minerals, 1992). For the development of an adequate industrial base in the petroleum sub-sector, there is a directorate of research and development which is currently being strengthened. A separate company GASCO has been established to deal with the marketing and distribution of natural gas. In the New and Renewable Energy area Non-Governmental Organisations (NGOs) are increasingly being very active.

Another important stakeholder in the energy sector in Tanzania is the private sector. It plays a major role in the importation, distribution and retailing of petroleum products and the central government and its parastatals have completely moved out of these businesses. There are plans also to privatise the distribution and sales of electricity. On the other hand, the private sector totally controls the dominant sources of energy - charcoal and firewood. These are in the hands of the private sector and all the government does, other than collecting levies and taxes, is jut to ensure that the harvesting of these forest products is not done in protected areas like forest reserves, national parks, etc.

The other key stakeholder, the consumer, is completely left out when it comes to participation. Energy consumers have no protection at all in Tanzania. The government and the private sector have a free hand in fixing prices for their products like petroleum products, charcoal, firewood etc.

6.2 Key Stakeholders in the Sugar Sector

The sugar sector has the following key stake holders:

The Sugar Development Corporation (SUDECO) which is a parastatal under the Ministry of Agriculture, Livestock and Co-operatives, has the government mandate to oversee the sugar industry and trade in the country; the sugar production companies which were all under SUDECO but have all been privatised over the past few years. The private sector which was up to the last few years only involved in the importation, distribution and marketing of sugar, is nowadays involved even in its production. The Ministry of Industries and Trade is responsible for the industrial and trade issues of sugar (Factories Inspectorate, trade licenses, etc.). The trade unions, Ministry of Labour and Social Welfare deal with labour issues. The Tanzania Revenue Authority oversees taxation, and with the Police force see to it that smuggling of sugar into the country – which is a thorny issue – and tax evasion, are effectively prevented. The Universities and The Sugar and Agricultural research Institutes deal with research and development of the sugar sector. Finally, and above all are the consumers who buy and use the sugar.

7.0 CONCLUSION AND RECOMMENDATION

This study has shown that the three largest sugar factories in Tanzania, cultivate over 17,000 hactres of sugarcane farms and produce about 125,000 tons of sugar per annum, process over 1,300,000 tons of sugar cane per year. In the process, the factories produce about 40,000 tons of molasses (a good percentage of which is exported) and about 455,000 tons of bagasse as waste. A significant portion of this extremely high organic content sugarcane waste is treated without optimal resource recovery, and without regard to the GHG emissions into the environment. the sugar mills currently purchase a total of 63,540 MWh/year which is 63.54 GWh/year. By just using co-generation, they stand to generate excess (above their needs) a minimum of 28 GWh (28,000 MWh) and a maximum of 546 GWh (546,000 MWh) electric power per annum, depending on the option chosen.

Environmentally, the savings on GHG emissions would be for as follows:

- option I would be 2.9 million cubic metres of methane
- option II would be 42.7 million cubic metres of methane
- option III would be 53.4 million cubic metres of methane
- option IV would be 56.3 million cubic metres of methane

There is a dire need to carry out an intensive and economic analysis with the final goal of implementing these resource recovery options.

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