RENEWABLE ENERGY TECHNOLOGIES IN TANZANIA

BIOMASS - BASED COGENERATION

SECOND DRAFT REPORT

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EXECUTIVE SUMMARY

Renewable energy technologies can play a major role in providing clean and improved energy services. Despite the benefits that renewables offer to countries in the region, the level of dissemination is still low.

Most of the African governments were unable to respond to the 10% renewable energy target proposed at the World Summit on Sustainable Development (WSSD). (Karekezi, Waeni, 2003). At the summit, countries were asked to commit to meeting 10% of their national energy demand from renewables. With limited access to data and information, most African countries conceded to pressure from oil-exporting countries as well as other fossil-fuel proponents such as the USA and rejected the binding renewables target.

AFREPREN/FWD with support from HBF proposed a study to examine the viability of 10% renewable energy technology target proposed at Johannesburg WSSD Summit in selected African countries; and to assess the benefits and drawbacks of the 10% renewable energy technology target in the Eastern and Horn of Africa region.

As part of the study, this paper investigates the present biomass-based cogeneration in Sugar Factories in Tanzania and possible future modifications to obtain more power. Further more, it describes the benefits and drawbacks associated with development of 5% co-generation target in Tanzania.

The per capital consumption of sugar in Tanzania is about 5.38 kg which gives an annual consumption quantity of about 166,780 tonnes. The production of sugar within the country is about 123,000 tons per year. The three largest sugar factories in Tanzania cultivate more than 17,000 hectares of sugar cane plantations. About 1,300,000 sugar cane are being processed per annum and these lead to about 455, 000 tonnes of bagasse per annum. In the cogeneration process, the bagasse is burnt to generate steam in high-pressure boilers. The high pressure is subsequently converted to electricity in turbo alternators and exhaust steam both being used to meet the energy requirement for cane processing.

The global potential of the sugarcane industry world wide is around 88,500 GWh that can be exported to the grid on the basis of around 100 kWh per tonne of cane being generated using the latest commercially proven cogeneration technologies.

The current energy generation potential from excess bagasse in sugar factories is about 99 GWh per year which is 3.5% of the national electricity generation. With the availability of advanced co-generation technologies, sugar factories can harness the on site bagasse resource to go beyond meeting their own energy requirements and produce surplus electricity for sale to the national grid or directly.

Estimates show that up to 16 Sub Saharan African countries can meet significant proportions of their current electricity consumption from bagasse-based cogeneration in the sugar industry. Mauritius meets over 20% of its electricity demand from cogeneration.

Assessment of the potential contribution of biomass-based cogeneration (5%) to the electricity sector and the impacts of co-generation on other development sectors such as water, health, agriculture, environment, poverty and education have been discussed.

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LIST OF ACRONYMS

GoT	Government of Tanzania
GWh	Giga Watt hour
ha	Hectar
hr	hour
ICS	Improved Cook Stove
K 1	Kilombero 1
K 2	Kilombero 2
KARADEA	Karagwe Development Association
kg	kilogram
kWh	killo-Watt hour
KSC	Kilombero Sugar Company
m^3	Cubic meter
MSE	Mtibwa Sugar Estate
MW	Mega Watt
NEMC	National Environmental Management Council
NGO's	Non Governmental Organizations
SADC	Southern Africa Development Corporation
SME's	Small and Medium Enterprises
SIDO	Small Industries Development Organisation
STRECTA	Sustainable Rural Energy Centre of Tanzania
SUDECO	Sugar Development Corporation
t	Tonne
TANESCO	Tanzania Electric Supply Company Limited
TANWATT	Tanganyika Wattle Company
TaTEDO	Tanzania Traditional Energy Development Organization
TAZARA	Tanzania Zambia Railways Corporation
TPC	Tanganyika Planting Company
TRC	Tanzania Railway Corporation
UDSM	University of Dar es Salaam
USAID	United States Agency for International Development
USC	United State Cent
USD	United State Dollar

1.0 INTRODUCTION

In sugar factories when cane is processed, the cane stalks are shredded and crushed to extract the cane juice while the fibrous outer residue, known as bagasse, is sent to the boiler to provide steam and electricity for the factory. The fact that the sugarcane plant provides its own source of energy for sugar production in the form of bagasse has long been a special feature of the sugar industry. In the traditional approach, sugar factories and distilleries co-generate just enough steam and electricity to meet their on-site needs. Boilers and steam generators are typically run inefficiently in order to dispose of as much of the bagasse produced from crushing the cane as possible. Some older factories purchase oil or electricity, because their steam generating technologies and boilers are extremely inefficient. Any factory designed and constructed today would be at least efficient enough to cover its own energy needs. With the availability of advanced cogeneration technologies, sugar factories today can harness the on site bagasse resource to go beyond meeting their own energy requirements and produce surplus electricity for sale to the national grid or directly to other electricity users.

This study discusses biomass-cogeneration in sugar factories in Tanzania. Almost all sugarcane industries in Tanzania despite being connected to the national power grid have set up cogeneration systems, which supplement their power requirement. These include Kilombero Sugar Company in Morogoro region, Mtibwa Sugar Estates in Morogoro region, Tanganyika Planting Company (TPC) in Kilimanjaro region and Kagera Sugar Company in Kagera region.

Although biomass cogeneration technology has been practised in Tanzania for sometime now, its contribution to the country's energy supply is still low.

1.1 Status of Energy Sector

Tanzania's energy sector is characterized by a low per capita consumption of commercial energy (Petroleum and Electricity), and a relatively large dependence on non-commercial energy i.e. biomass (in form of firewood, charcoal and bio-waste) as well as human and animal waste.

The energy balance of Tanzania shows that biomass use accounts for over 90% of energy consumption. Petroleum and electricity accounts for about 8% and 1.2% respectively, 0.8% contribution from coal and other renewable energies.

This heavy dependence on wood fuel as the main energy source contributes to deforestation, while the importation of oil has forced the nation to spend between 25% and 35% of her foreign earnings.

To-date only about 10% of the country's population (34.9 million-2002 census) have access to electricity and it has also been found that extending the grid to many parts of Tanzania would not be economically viable and in some cases not practically possible. This means 90% of the population has inadequate energy for cooking, lighting, conditioning their homes, clinics, schools, and community centers, a situation that weakens the development process.

Currently, Tanzania is a net importer of petroleum products. Petroleum products are used in various development activities including transport, which consumes 50.9%, followed by manufacturing/industry consuming about 26.3%. Households consume 8.3% and the agriculture and fisheries consumes 7.1%. Other services consume 6.4 percent.

Renewable energy technologies, which are currently in use in the country, include hydro, biomass, solar thermal, photovoltaic (PV), geothermal and windmills for water pumping. These applications are at various stages of development in terms of demonstration and commercialization.

1.2 Overview of Electricity Sector

Electricity supply is from hydro (70%), diesel oil and imports from neighboring countries of Uganda and Zambia (30%). The supply consists of both interconnected and isolated grid systems.

The national electricity installed capacity is 863 MW out of which the effective capacity is about 806 MW. Out of this effective capacity 555 MW is from hydro and 251 MW is thermal. The suppressed demand is 500 MW and the annual growth in demand is about 8% up to year 2015 (according to power demand forecast in the master plan). The annual electricity generation is 3,000 GWh.

1.3 Status of Renewable Energy Technologies

The application of renewable energy technologies in Tanzania is at various stages. The focus is on wind, solar, micro/mini hydro and biomass, since it is felt that technologies on use of these energy sources could be disseminated in the short term. Geothermal energy also has a potential in Tanzania although its exploitation may be in the long term due to the costs of its development.

1.3.1 Wind Energy

Based on the available information much of the wind resource in Tanzania is located along coastlines, the highland plateau regions of the Rift valley, on the plains and around the Great Lakes. Currently, wind energy is used to pump water for irrigation and to meet domestic and livestock water needs. By 1996, about 129 windmills were installed but 40% of which were out of order. Very limited number of attempts has been made to install wind turbines for electricity generation. The known wind turbine installations amount to 8.5 kW.

The existing installations have been privately imported. These have had limited performance successes even in areas with good wind regimes due to:

- lack of reliable wind resource data for sitting of wind turbines,
- poorly designed or expensive prototypes,
- lack of trained local support personnel, and
- lack of maintenance and spares.

Wind speed range from 0.9 to 4.8 m/s. At some locations, on the spot measurements are to the tune of 12m/s. A wind resource assessment at four selected sites is underway with the assistance from the Danish Government. Through this project wind speeds and solar insolation are being measured continuously. By special computer software, the long-term wind regime is expected to be predicted and hence indicate the feasibility of wind energy harnessing at the investigated areas. It is expected that after these pilot sites, if resources allows, the measuring instruments would be used to assess other areas as a process of coming up with a wind energy resource map for the country.

1.3.2 Solar Energy

There exists an extensive body of literature on the potential of solar energy in Tanzania for heating water (thermal systems). This has been due to the efforts of individuals, public and private institution. The majority of existing solar water heaters have been imported and many are not in use because of the following:

- Many were installed as part of project-oriented research and development, and the direct dissemination of commercial technologies was not a goal.

- Many projects were hampered by inadequate attention to the local capabilities/needs for operation, maintenance, repair, spare parts and technology transfer.

The recent initiatives like those of SONET, Merry Water, Dynamic Electronic Systems Ltd., Northern Energy Saving Co. Ltd., Likungu Investment, etc. are yet to be documented.

Solar cooking, pasteurizing and advanced solar crop drying technologies' application is still in its infancy stage. More research and development is required to address the identified social and technical barriers

In recent years solar photovoltaics (PV) have been used for telecommunication, lighting, refrigeration, water pumping and powering other electronic equipment at individual residences, schools and health centers/ rural dispensaries, TAZARA, TRC and missionaries. The estimated current installed PV capacity in Tanzania is to the tune of 550kWp with an annual growth rate of about 20%.

1.3.3 Biomass Energy

Biomass comes in a variety of forms, which can be utilized as an energy resource. It is possible to classify the material into two main groups: woody biomass and agro-forestry waste (that is, crop wastes, animal manure and forestry processing wastes). These materials can be burnt directly or first converted into solid (charcoal), liquid (ethanol) and gaseous fuels (biogas, producer gas). Which form of fuel is used depends on what conversion technologies are available, as well as the physical properties of the biomass.

In Tanzania there is a woody growing stock of about 4.39 billion m^3, with mean annual increment of 140 million m^3. For the biomass residues there are about 15 million tons/annum of crop residues, animal droppings from 14 million cattle, 11 million goats and sheep, etc., 200,000 ton of volatile solids of sisal waste and 1.1 million tons/annum of forest residues.

1.3.4 Micro/mini hydro

The country's hydro potential is estimated at 4,500 MW of which only around 563 MW is developed. It is estimated that 100 GWh/yr could be produced from micro/mini systems. Currently only around 32 GWh/yr is produced from these smaller systems, many of which are private schemes run by religious missionaries.

1.3.5 Geothermal

Given the country's diversity of indigenous energy resources, geothermal potential could be assessed for long term energy development planning by the sector ministry. However, the private sector could play a major role in the development of geothermal energy. Once this resource has proved to be economically feasible, electrical energy and other forms of energy may be generated in form of independent power production.

1.4 Status of Co-generation

The estimated co-generation potential in Tanzania is more than 315 GWh per year. This is 10.5% of the national electricity generation. Table 1.1 shows some details of the existing biomass fuelled power plants in Tanzania. The current energy generation potential from excess bagasse in sugar mills is about 99 GWh per year that is 3.5% of the national electricity generation.

Table 1.1 Existing biomass fuelled power plants in Tanzania

Name of the Plant	Region	Power (MW)	Fuel
Kilombero Sugar Company K1	Morogoro	2 x 3 (ST)	Bagasse
Kilombero Sugar Company K2	Morogoro	1.2 + 2 x 0.8 (ST)	Bagasse
Mtibwa Sugar Estate	Morogoro	2.5 + 1.5 + 9.0 (ST)	Bagasse
Tanganyika Planting Company	Kilimanjaro	2.5 + 3.0 (ST)	Bagasse
Kagera Sugar Company	Kagera	2x2.5 (ST)	Bagasse
Sao Hill Saw Mill	Iringa	1.025 (ST)	Sawmill waste
Tanganyika Wattle Company	Iringa	2.5 (ST)	Woodlogs

Legend:
ST: Steam Turbine

2.0 COGENERATION IN SUGAR INDUSTRY

The primary technical condition for cogeneration is the existence of a demand for steam that coincides with a demand for electricity. In Africa this is the case in sugar factories, food processing plant, pulp and paper mills, timber sawmills, smelters and distillers. Each case offers it's own unique circumstance hence the viability of cogeneration varies throughout the sectors. The simplest plant setup (see Figure 2.1) involves the installation of a boiler producing higher steam pressure than required for the process. This steam is passed through a steam turbine where some of the energy is used to generate mechanical power for driving an alternator for electricity. The steam exits the turbine at a reduced pressure and is then returned to the boiler as condensate or hot water. The primary objective of the energy system is the production of steam hence the electricity that is produced is governed by the demand for process steam. In some cases especially in sugar mills the electricity becomes a primary product when the steam is excess to requirements such as is the case after milling season. The turbine would then be a condensing one where the steam is returned to the boiler without having to pass through the process. Under these circumstances the plant operates as a bagasse fired power station.

Commercial generation in sugar factories takes ones of the following forms:

(a) Own generation where electricity is produced to supplement or replace the grid supply

(b) Intermittent cogeneration, where excess electricity is sold to the grid only when fuel is available. Sometimes used to reinforce the grid during peak times.

(c) Continuous intermittent cogeneration, where supply is developed and regulated to run as far as the fuel exists, that is power supply ceases during off-season.

(d) Firm generation where cogeneration provides continuous amount of power and energy.

This paper discusses biomass- based cogeneration in Tanzania with emphasis in Sugar factories.

2.1 Methodology

On assessing how co-generation in Tanzania may contribute to 5% of electricity supply in the country, the following methodology was adopted:

A number of published reports related to renewable energy technologies were used to collect some useful information and material on renewables. Through the proceedings, an overview on the renewables as well as an awareness of the importance of the renewable technologies in the region was availed.

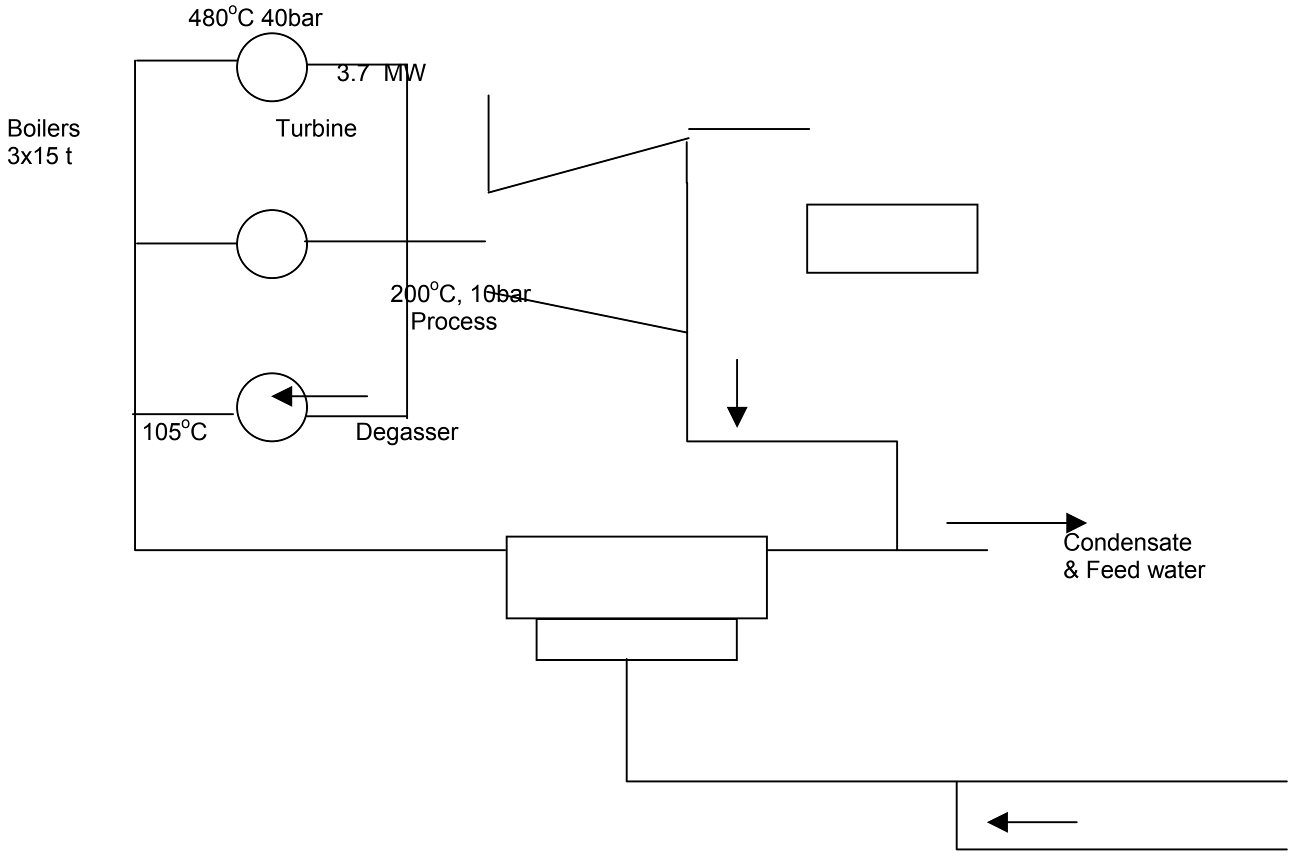
A two-year working experience at one of the Sugarcane factory-Kilombero Sugar Company in Morogoro region was advantageous in understanding more the processes within the sugar company. This enabled to have a feeling of how other sugar factories within the region and outside, function. Working experiences of other researchers in sugar industries also gave some inputs to the study.

A number of consultative visits were made to the Ministry of Finance, Ministry of Energy and Minerals, Planning Commission, Sugar Development Corporation (SUDECO), Kilombero Sugar Company (KSC), National Environmental Management Council (NEMC), University of Dar Es Salaam (UDSM), Ministry of Water, Tanzania Traditional Energy Development Organization (TaTEDO), Tanzania Electric Supply Company Limited (TANESCO), NGO's, some SME's in order to get data for this study.

By visiting different web sites in the Internet, it was possible to get lot of material on renewable energy technologies in Tanzania, Africa and global in general. Co-generation papers written by different researchers were also obtained. Contributions from my colleagues on co-generation technology and particularly in Tanzania were of great help in performing this study.

Data pertaining to the above sources are reasonably good. Although improvements can be made, the current data on cogeneration potential in Tanzania provides a useful and basis for examining future cogeneration improvements/installments. I hope that this study will be useful to researchers working not only in Tanzania, but in other developing countries in Africa as well.

Figure 2.1 Structure of a simple cogeneration plant



3.0 ANALYSIS

3.1 Technical Assessment

3.1.1 The rationale of considering biomass-cogeneration in sugar factories.

3.1.1.1 <u>Sugar Production in Tanzania</u>

In Tanzania the sugar factories have more than 17,000 hectares of sugarcane plantations from where they process more than 1,300,000 tons of sugar cane per year. These include Kilombero Sugar Company (KSC) in Morogoro region, Mtibwa Sugar Estates (MSE) in Morogoro region, Tanganyika Planting Company (TPC) in Kilimanjaro region and Kagera Sugar Company in Kagera region. Each of these factories runs a bagasse cogeneration plant and is also connected to the grid. In normal operation they use grid power for off-season operations and back up. They produce about 125,000 tons of sugar per year and about 455,000 tons of bagasse per year. Table 3.1 shows the production of sugar industries for the past years.

Table 3.1 Sugar production in Tanzania

Year	KSC (Tons)	MSE (Tons)	TPC (Tons)
1989/90	44016	22502	26455
1990/91	43747	24610	39446
1991/92	53674	25565	32681
1992/93	52117	29149	37750
1993/94	54059	30635	37854
1994/95	45825	34238	19853
1995/96	41762	32109	33605
1996/97	38981	32584	39435
1997/98	29517	20933	27883
1998/99	42063	28260	40021
1999/00	50000	30000	37900
2000/01			42,018
2001/02			49,650
2002/03			54,848
2003/04			62,277

3.1.1.2 <u>Sugar Plants Assessment in Tanzania</u>

- **Tanganyika Planting Company Limited**

TPC Limited was established in early 1930’s by a company which was registered in Denmark in the name A/S Tanganyika Planting Company Limited. In 1980, the Government bought back the Company from the Danish owners. In 2000, Sukari Investment Company Limited purchased 75% shares of TPC Limited, and became the majority shareholder of the company. SUKARI investment Company Limited registered in Mauritius is owned by Mauritian and French companies namely, Deep River Beau Champ Limited and Sucriere de la Reunion respectively.

TPC is the largest sugar factory in Tanzania with a cane crushing rate of 130 TCH. Since privatization sugar production has increased steadily as shown in Table 3.1. It currently produces around 62,000 tonnes of sugar even though it has the potential to produce around 85,500 tonnes.

- **Mtibwa Sugar Estate**

Mtibwa Sugar Estate is owned by Tanzania Sugar Industries Company (75%) and the remaining shares belong to GoT. It is under management contract with DCDM consulting of Mauritius. The factory started operating in 1975. A 9 MW Turbo-alternator was commissioned in November 2003.

A total of 4,200 hectares of cane plantation is annually harvested. The average cane yield is close to 80 tonnes per hectare.

- **Msolwa (Kilombero K1)**

The sugar factory Msolwa (K1) is an 80 TCH factory located in Kilombero in Morogoro region. It started operating in 1960. Illovo Sugar Company of South Africa owns the plant and the GoT is a minority shareholder with 25% shares.

A total of 2,960 hectares is currently harvested and the average yield achievable is 70 tonnes per hectare.

- **Ruembe (Kilombero K2)**

Illovo Sugar Company owns this 100 TCH sugar mill. K2 is the name that is commonly used to refer to this second sugar mill in Kilombero that is owned by Illovo. This factory started operating in 1970 and is currently running at 50% capacity.

A total of 3,400 hectares of sugar cane is harvested annually. The cane yield is about 70 tonnes per hectare.

- **Kagera Sugar Company**

Only around 860 hectares of cane plantation are harvested around Kagera and the plant is crushing cane at 60 TCH. Cane yield is close to 70 tonnes per hectare. High fibre cane is grown and this has boosted the bagasse percent to 50%.

The technical data for sugar factories in Tanzania is shown in Table 3.2.

Table 3.2 Technical data for sugar factories in Tanzania

Factory	MSE	K 1	K 2	TPC	Kagera
Annual area harvested (hectares)	4,200	2,960	3,400	6,100	860
Cane crushing capacity (TCH)	350	80	100	130	60
Sugar cane yield (tones/hectare)	80	70	70	80	70
Bagasse percent cane (%)	30	52	40	35	50
Steam/bagasse ratio (t. steam/tonne bagasse)	2.3	2.2	2.2	2.3	2.2
Spec. steam consumpt. (tones steam/tonne cane)	0.54	0.5	0.5	0.54	0.5
Bagasse moisture (%)	51	52	50	50	52
Excess bagasse (tonnes/year)	100,435	103,040	76,000	91,679	72,000

3.1.1.3 <u>Excess Bagasse Potential</u>

- ***Bagasse***

The sugar cane plant can meet the demand for food products and a sizeable portion of fuel and fibre requirements. The fact that this plant provides its own source of energy for sugar production in the form of bagasse has long been a special feature of the sugar industry. If well planned, the bagasse can relieve the pressure on the limited resources of fuel and fibre available in Tanzania. From the experiences in sugar industry (Mtibwa Sugar Estate- Cogeneration Workshop in SADC, November 2003), if processed in efficient manner, 1 hectar of cane field can yield 10 tonnes of valuable fibre for fuel, paper and board, 10 tonnes of food products including sugar, 1 m^3 of alcohol and 2 tonnes of fertilizers.

- **Factory Capacity**

The sugar factories in Tanzania are considered to have the specific steam consumption of about 54% of cane, steam generation about 2.3 kg per kg of bagasse and bagasse generation about 30-50 % of cane depending on quality of the cane. From these data, we can have baggase production and consumption as shown in Table 3.3 below, for different plant crushing rates.

Table 3.3 Bagasse production and consumption

TCH	Steam (t/hour) 54%*TCH	Bagasse req. (t/hour) Steam/ 2.3	Bagasse gen. (t/hour) 30%*TCH	Excess bagasse (t/hour) gen.- req.
50	27.0	11.74	15.0	3.30
85	45.9	19.96	25.5	5.54
100	54.0	23.48	30.0	6.52

TCH	Steam (t/hour) 54%*TCH	Bagasse req. (t/hour) Steam/ 2.3	Bagasse gen. (t/hour) 30%*TCH	Excess bagasse (t/hour) gen.- req.
150	81.0	35.22	45.0	9.78
250	135.0	58.70	75.0	16.3
350	189.0	82.17	105	22.83
400	216.0	93.91	120	26.09

Legend:
req. ⟶ required
gen. ⟶ generated

From Table 3.3, it can be seen that bagasse generation is higher than sufficient for fuel requirement of the factory. The bigger the factory capacity, the larger the quantity of excess bagasse, therefore this extra quantity can be used for extra electrical energy generation that can be sold to the national grid.

- **Energy Generation Potential**

A boiler with normal efficiency will generate approximately 2.3 kg of steam per kg of bagasse and turbo alternator sets can consume about 10 kg of steam per 1 kWh power generation. Assuming the number of crushing days is 200 per year, then with data shown in Table 3.3, energy generation potential of factories with different capacities can be calculated as shown in Table 3.4 below.

Table 3.4 Energy generation potential

TCH	Excess bagasse (t/h r)	Excess bagasse For 200 days (t)	Potential steam (t)	Potential energy (GWh)
50	3.3	14,520	33,396	3.3
85	5.5	24,200	55,660	5.6
100	6.5	28,600	65,780	6.6
150	9.8	43,120	99,176	9.9
250	16.3	71,720	164,956	16.5
350	22.8	100,452	231,040	23.1
400	26.1	114,840	264,132	26.4

Excess bagasse for 200 days (t) = Excess bagasse (t/h) * 22 (h/day)* 200days
Potential steam (t) = Excess bagasse * 2.3
Potential energy (GWh) = (Potential steam /10)/1000

3.1.1.4 Co-generation Options

Currently the generation capacity in most of the sugar factories is designed to cover the requirements of the factory only. Generation is often restricted to the milling period of about 8 months, though could continue during off-season. The efficiency of electricity generation in many sugar mills is poor due to low steam pressure and temperature. In some cases, the electricity generation may be as low as 15-25 kWh/tonne cane. Although some increase in electric power output can be obtained in old sugar mills by use of a more advanced steam process, further increase in power generation requires employment of a combined gas/turbine process and maximum utilization of residual fuels.

There are in principle four possibilities for cogeneration of process heat and electricity in a sugar factory:

- back pressure steam turbine, exhausting steam
- condensing steam turbine with extraction of steam
- combination of any of these steam processes with a gas turbine exhausting to a heat recovery steam generator
- combination of any of the steam processes with a gas turbine and a heat recovery steam generator with supplementary firing.

The back-pressure steam turbine is commonly used. Figure 2.1 shows a schematic diagram of the main components of a cogeneration plant. Electricity output is normally sufficient for the direct needs of the sugar factory when moderate steam pressure and temperature is used. Some increase in the electricity output is possible if a more technically advanced steam process is selected. The condensing steam turbine process makes it possible to increase the electricity generation further. With current technology, bagasse can be used as fuel with these processes.

The combined gas turbine/ steam turbine processes allow an additional increase in electrical output as a consequence of more favourable thermodynamics. However the utilization of such processes for cogeneration in sugar factories is prevented by lack of proven technology for utilization of the residual fuel for running gas turbines.

3.1.2 Presentation of Mtibwa Sugar Estate

3.1.2.1 <u>Energy scenario for MSE (November, 2003)</u>

MSE has two steam boilers of 30 tonnes MCR each, 20 bar steam pressure, one new boiler of 80 tonnes MCR, 24 bar pressure, two sets of back pressure turbo-alternators of 2.5 MW and 1.5 MW. MSE generates 10 GWh during production season only which is from June to January. This power is used for factory operations and company offices. It also imports 4.0 GWh per annum from the national grid at about Three hundred million shillings (300,000,000/=). This electricity is mainly used for irrigation and domestic and during off-season is used also in the factory. The grid energy uses during production and off-season is shown in Table 3.5 below.

Table 3.5 Grid energy uses

Period	Factory (%)	Irrigation (%)	Domestic (%)
Production season	3	85	12
Off-season	10	80	10

3.1.2.2 <u>Factory Capacity and Energy Planning</u>

The present old mill has a capacity of 105 TCH and the new mill has a capacity of 160 TCH. This mill was commissioned in October, 2003 and is operating on stand alone basis. There are plans to increase the capacity of the new mill to 250 TCH. These two mills will run concurrently to have overall capacity of 350 TCH. With this capacity MSE will have the potential to generate approximately 20 GWh of electrical energy annually.

In order to achieve the above, there are plans to upgrade the two old steam boilers to 45 tonnes MCR each. With the 80 ton MCR boiler, the total MCR will be 170 which will be enough for 350 TCH crushing capacity. A new 9.0 MW Turbo alternator set was commissioned in November 2003.

3.1.2.3 <u>Energy Generation Potential in Sugar Mills in Tanzania</u>

Considering the analysis done at MSE and taking technical specifications for sugar factories in Tanzania shown in Table 3.2, the energy generation potential in sugar mills based on excess bagasse potential, can be calculated as indicated in Table 3.6. The current energy generation potential is about 99 GWh per year. This is about 30 % of the cogeneration potential in Tanzania and is about 3.5% of the total national electricity generation in Tanzania.

Table 3.6 Energy generation potential from excess bagasse (present)

Factory	Capacity TCH	Steam (t/hr)	Bagasse required (t/hr)	Bagasse generated (t/hr)	Excess bagasse gen.-req. (t/hr)	Total excess bagasse (t)	Potential steam (t)	Potential Energy (GWh)
MSE	350.00	189.00	82.17	105.00	22.83	100,434.78	231,000.00	23.10
TPC	130.00	70.20	30.52	46.80	16.28	91,679.17	210,862.08	21.09
K 1	80.00	40.00	18.18	41.60	23.42	103,040.00	226,688.00	22.67
K 2	100.00	50.00	22.73	40.00	17.27	76,000.00	167,200.00	16.72
Kagera	60.00	30.00	13.64	30.00	16.36	72,000.00	158,400.00	15.84
						TOTAL		**99.42**

Table 3.7 Energy generation potential from excess bagasse (future)

Factory	Capacity TCH	Steam (t/hr)	Bagasse required (t/hr)	Bagasse generated (t/hr)	Excess Bagasse gen.-req. (t/hr)	Total excess bagasse (t)	Potential steam (t)	Potential Energy (GWh)
MSE	350.00	189.00	82.17	105.00	22.83	100,434.78	231,000.00	23.10
TPC	200.00	108.00	46.96	72.00	25.04	141,044.87	324,403.20	32.44
K 1	80.00	40.00	18.18	41.60	23.42	103,040.00	226,688.00	22.67
K 2	200.00	100.00	45.45	80.00	34.55	152,000.00	334,400.00	33.44
Kagera	60.00	30.00	13.64	30.00	16.36	72,000.00	158,400.00	15.84
						TOTAL		**127.49**

Total excess bagasse for 200 days (t) = Excess bagasse (t/hr) * 22 (h/day)* 200days
(For TPC production period is 256 days)
Potential steam (t) = Total excess bagasse * 2.3
Potential energy (GWh) = (Potential steam /10)/1000

From the paper presented by TPC at Cogeneration Workshop in SADC, held in Dar es Salaam, Tanzania, in November 2003, the plant capacity can be increased from 130 TCH to 200 TCH crushing rate. If Kilombero 2 in Morogoro can operate at full capacity, the production could be doubled. Considering these assumptions, the energy generation potential in all sugar cane factories in Tanzania, based on excess bagasse potential is about 127 GWh per year as shown in Table 3.7. This is about 40 % of the cogeneration potential in Tanzania and is about 4.5 % of the total national electricity generation.

3.1.3 Theoretical cogeneration potential

In Tanzania there is a woody growing stock of about 4.39 billion m^3, with mean annual increment of 140 million m^3. For the biomass residues there are about 15 million tonnes/annum of crop residues, animal droppings from 14 million cattle, 11 million goats and sheep, etc., 200,000 ton of volatile solids of sisal waste and 1.1 million tonnes/annum of forest residues.

For agriculture residues, there is no exact number of what quantity is used as an energy source. However, it is estimated that most of these are either thrown away or disposed of by burning. Some industries already utilize some of their residues for providing process heat and electricity, for example, the sugar factories. There are four big sugar factories in Tanzania. These include Kilombero Sugar Company, TPC, Kagera Sugar Company and Mtibwa Sugar Estate. There is evidence that these could be utilized more efficiently and generate more electricity for feeding into the national grid or forming the basis of local grid (as in case with Tanganyika Wattle Company – TANWATT, in Njombe). There is still potential for expansion in the sugar factories.

Based on experiences reported by USAID (1986 b and 1989), that 50% of the cane trash in the cane field can be removed and used as fuel without negative effects on field productivity, it is assumed that cane trash, once it is available at the plant and physically prepared to resemble bagasse, can be used without special problems as a substitute for bagasse (Kjellstroem, 1995). But these assumptions must be checked by further studies.

Forestry residues also contribute to cogeneration as sawmills generate residues in form of sawdust and off-cuts. Only 50% of wood (with bark removed) is used as timber, and the residues are either used for power generation, as cooking fuel by people surrounding the sawmills or are burnt.

Animal waste can be anaerobically digested to produce biogas that can be used for cooking, heating, lighting and for generating electricity while the slurry is used as a fertilizer.

3.1.4 Technical potential of cogeneration

The national electricity generation at present is about 3,000 GWh per year. The estimated co-generation potential in Tanzania is more than 315 GWh per year. This is 10.5% of the national electricity generation. Table 1.1 shows some details of the existing biomass fuelled power plants in Tanzania. The current energy generation potential from excess bagasse in sugar factories is about 99 GWh per year; see Table 3.6, which is 3.5% of the national electricity generation.

If TPC increases its plant capacity to 200 TCH (which is possible), and if Kilombero 2 operates at present full plant capacity, then the energy generation potential from excess bagasse in sugar factories will be about 127 GWh per year which is about 4.5% of the national electricity generation.

The country installed electricity generation capacity is 863 MW.
5% of this is 43.15 MW.
Cogeneration installed capacity at present is 35.825 MW.
Required cogeneration capacity to meet 5% target is 7.325 MW

3.1.5 Jobs and Enterprises resulted from Cogeneration Plant

3.1.5.1 <u>Number of Jobs (Jobs/MW)</u>

Considering TPC as an example (refer to Table 3.7): TPC has 2,667, permanent, 591 temporary and 636 seasonal employees. The factory has a total of 16,000 hectares of land out of which about 6,100 hectares is under cane cultivation. The tonnage of cane at present is about 604,000 tonnes but the field potential in cane production is more than 775,000 tonnes. Assuming that all seasonal employees work in the field during production period then:

636 persons cultivate 604,000 tonnes; Therefore 775,000 tonnes will require (775,000x636)/604,000=816 person;

636 persons generate 2.5 MW; 816 persons generate 12.9 MW;

Therefore (816-636) persons generate (12.9-2.5) MW ;
180persons generate 10.4 MW > 17person/MW.

Therefore cogeneration can generate more than 17 jobs (persons/MW).

Also referring Goldenberg's GFSE Presentation in Austria, 2002, ethanol making (from sugar cane) can generate 36 jobs (persons/MW).

3.1.5.2 <u>Number of Enterprises</u>

Table 3.8 Number of Enterprises

Activity/business	***Remarks/Enterprise***
Small-scale sugar cane producer	*- sugar cane growing* *- sugar cane weeding* *- sugar cane harvesting* *- sugar cane transporting*
Using can trash as fuel	*Use of cane trash as fuel during off-season requires that it be collected, stored until needed, transported to the sugar mill and prepared for combustion. Local Manpower would be required*
Modernization and rehabilitation of sugar plants	*-Some organizations will be required to fabricate some spare parts* *-Employment of some Engineers and technicians or capacity building of the present Engineers and technicians*
Modernizing the rural areas	*-Technicians will do the electrical installations in areas to be electrified* *-shops to sell the wiring materials and electrical appliances will be opened* *-workshops for repairing electrical appliances will be opened*

3.1.5 Job/Enterprises Creation-Cogeneration V/S Conventional Energy

Referring Goldenberg's GFSE Presentation in Austria, 2002, hydro can generate 3 jobs (persons/MW). From item 3.1.5.1, cogeneration can generate 17 jobs (persons/MW) and ethanol making (from sugar cane) can generate 36 jobs (persons/MW). This concludes that the job creation potential is higher in cogeneration than in conventional energy technology.

Likewise, the potential for the enterprises creation is higher with cogeneration technology than the conventional energy, depending on the cogeneration technology employed.

3.2 Economic/ Policy/ Gender Assessment

3.2.1 Economic

By utilization of this technology it would be possible for Tanzania to reduce its spending of foreign currency on import of petroleum fuels. In a longer time perspective this technology would make it possible to eliminate the constraints upon economic development imposed on Tanzania by the limited amount of foreign currency available for import of petroleum fuels.

The local society would benefit from increased economic independence, primarily by substitution of fuels purchased from the outside by fuels produced locally. This means that a larger fraction of local earnings are spent locally. The users of the technology would benefit from lower energy costs and improved security of supply.

3.2.2 Cost of Investment

From literature it is known that depending on type of cogeneration, the investment cost ranges between 1,600USD/kW to 3,500 USD/kW installed. This can be easily proved by using the data available from one of our sugar factories in Tanzania, TPC in Kilimanjaro region.

The costs of investments for cogeneration at TPC are based on paper presented by this factory in "Cogeneration in SADC Workshop" which took place in Dar Es Salaam in November, 2003. Table 3.9 shows different scenarios for capacity increase and cogeneration at TPC.

At present TPC generates 11.2 GWh to supplement the grid during crop production. This power is not enough so it also imports 18.7 GWh per year from the national grid for irrigation network, factory and estate utilities use.

In order to generates electricity to carter only for the plant use, one boiler of capacity 90 tonnes MCR for steam generation and one turbo alternator (back pressure type) of 14 MW for power generation should be installed. Also the pressures and temperature should be raised to 45 bar and 430^{o}C respectively. The total cost for this is estimated to be US$ 28.5 million**.** On the other hand for further increase in electricity generation for exporting 7.6 MW to the national grid, one boiler of capacity 140 tonnes MCR for steam generation and one back pressure and condensing turbo alternator of 22 MW for power generation will be required. The temperature and pressure for the process will remain the same that is 430^{o}C and 45 bar respectively. The cost for this is estimated to be US$ 35.5 million.

From the above, the cost for investment of a cogeneration plant of 13 MW is about 2,210 US$/kW and that of 20.5 MW is about 1,730 US$/kW.

Similarly, for hydro power plants up to 20 MW the cost for investment ranges between 2,000 USD/kW and 6,000 USD/kW. Taking costs for cogeneration at TPC as an example and comparing the worst case cost for hydro plant, indicates that the cost of investment for a cogeneration plant varies between 30% - 40% that of a conventional power.

Table 3.9 Capacity increase and cogeneration scenarios at TPC

	Present scenario	**Scenario 1**	**Scenario 2**
Crushing rate (TCH)	130	200	200
Cane Production (t)	604,000	775,000	775,000
Sugar Production	62,000	85,500	85,500
Boiler capacity (t MCR)	96	90	140

	Present scenario	Scenario 1	Scenario 2
Pressure (bar)	12	45	45
Temperature (^{o}C)	290	430	430
Turbo alternator type	Back pressure	Back pressure	Back pressure & condensing
Turbo alternator capacity (MW)	5.5	14	22
Factory use (MW)	1.8	7.4	7.4
Irrigation use (MW)	3.4 (import)	4.6	4.6
Estate utilities use (MW)	0.9(0.2=import)	0.9	0.9
Export to grid (MW)	Nil	Nil	7.6
Total Power (MW)	**6.1**	**12.9**	**20.5**
Investment (Mil. US$)		28.5	35.5

3.2.3 Total Cogeneration Cost

The installed capacity of electricity in Tanzania at August 2003 is 863 MW. 5 % of this is 43.15 MW. The installed capacity of the existing co-generation plants is 35.825 MW.
Total cogeneration capacity required to meet 5% of the installed capacity is:
43.15MW-35.825MW=7.325 MW

Considering the cost of investment discussed in section 3.2.2., to increase cogeneration capacity by 7.325 MW requires: 7,325 kW x 2,210 US$/kW = 16,1888,250 US$.

Therefore the total cogeneration investment cost required meeting 43.15 MW is about sixteen million, one hundred and eighty eight thousand, two hundred and fifty United States Dollars (16,188,250 US$) depending on the technology chosen.

Table 3.10 indicates cost variations in connection with different fuel-technology combination for electricity generation.

Table 3.10 Cost for electricity generation by various fuel technology

Fuel Type	Comparison capital US$/kW(000's)	Oper. & maintenance cost USC/kWh	Delivered power cost USC/kWh
Coal	1-2	2-4	5-10
Fuel oil	0.5-1	3-6	9-14
Natural Gas	0.4-0.9	2.5-5.5	6-12
Nuclear	1-1.5	1.5-3	6-15
Small Diesel	0.4-1	8-30	10-80
Solar	4-10	0-1	9-90
Wind	0.5-0.9	0.5-1	6-50
Large Hydro	1.1-3.0	0.5-1	5-15
Small Hydro	2-6	0.5-1	5-30
Biomass	0.5-2.5	1-7	5-30

Source: World Bank

3.2.4 Impact of Cogeneration on other sectors.

For people living in poverty, the most pressing is the satisfaction of basic human needs, which includes access to food, shelter, water supply and sanitation and other services that will improve their standard of living, such as health care, education, and better transport. Problems of poverty in all dimensions can be addressed with the improved provision of energy services. While reliable and adequate energy supplies do not guarantee economic growth and employment generation, their absence typically limits growth.

3.2.4.1 Health

A large amount of population is deprived of proper health care due to absence of electricity in remote areas. Cogeneration together with other renewable energy technologies can be used by the rural health clinics for lighting and vaccine refrigeration. This can reduce child and maternal mortality also will increase immunization coverage. On the other hand getting electricity will reduce people without access to clean and safe drinking water, through construction of water pumping and treatment plants.

3.2.4.2 Education

Like health clinics, most of the rural off-grid schools don't have electricity. These schools could benefit from getting electricity from plants practicing cogeneration systems. Modern benefits will not only attract more students, but will also retain quality teachers and staff currently unwilling to be posted in the un-electrified areas. In the evening, the school facilities can be utilized for other social services like adult education, health education or recreational activities.

However, providing electricity to areas mentioned above would require some sort of electrical network. This implies some cost implication to the utility.

3.2.5 Co-generation and Environment

The options for increasing electricity generation in sugar factories have a positive environmental impact. The factory may contribute to the reduction of green house gas emissions by replacing fossil fuelled thermal power plants with biomass-powered plants. Compared to oil and coal fuels, biomass has much lower sulphur content. This reduces SO2 emissions and lowers the risk of soil and water acidification. The ash content in biomass is lower than in coal, meaning fewer problems with ash disposal and leakage of heavy metals. Replacement of old boilers with more modern ones can be expected to reduce emissions, despite the fact that fuel through-put will be almost doubled.

3.2.6 Gender dimension

Cogeneration can be implemented in rural areas with women participation. The sugar factories buy sugar cane from some surrounding small-scale producers. Both men and women may participate in growing this plant. They can be employed by sugar cane small scale producers in planting, weeding and harvesting the sugar cane plant. Also those with transport may be hired to transport cane to the factory. This increases the income to rural people. Such activities could reduce rural to urban migration. However, the growing of cash crop in a rural economy would bring negative impact if that land would be diverted to cash crop production at the expense of food production.

4.0 KEY CONCLUSIONS

Electrical energy from bagasse is a commercially proven technology and its exploitation by sugarcane producing countries allows them to substitute a readily available renewable biomass for imported fossil fuel. This result in economic benefits to the country, financial benefits to the sugar industry and positive environmental benefits in terms of reduced greenhouse gas emissions.

4.1 Technical Viability of 5% Cogeneration Target

Currently the generation capacity in most of the sugar factories is designed to cover the requirements of the factory only. Generation is often restricted to the milling period which is about eight months, though could continue during off-season. The efficiency of electricity generation in many sugar mills is poor due to low steam pressure and temperature. In some cases, the electricity generation may be as low as 15-25 kWh/tonne cane.

- ❖ With the availability of advanced cogeneration technologies, sugar factories can harness the on site bagasse resource to go beyond meeting their own energy requirements and produce surplus electricity for sale to the national grid or directly.
- ❖ The national electricity generation is 3,000 GWh per year.
- ❖ The cogeneration generation potential is more than 315 GWh per year which is about 10.5% of the national electricity generation.
- ❖ The current energy generation potential from excess bagasse in sugar factories is about 99 GWh per year, see Table 3.6 which is 3.5% of the national electricity generation
- ❖ The installed capacity of electricity in Tanzania at August 2003 was 863 MW.
- ❖ 5 % of this is 43.15 MW.
- ❖ The installed capacity of the existing co-generation plants is 35.825 MW which is 4.2%.
- ❖ Total cogeneration capacity required to meet 5% of the installed capacity is 7.325 MW which is 0.8%.

4.2 Economic Viability of 5% Cogeneration Target

- ❖ At macro-economic level, cogeneration can reduce the growth of national debt as well as improve the national balance of payments by reducing the import of fossil fuels. Unfortunately cogeneration was not given due attention in the past national policy and planning, but the recently approved National Energy Policy (February, 2003) has special emphasis on renewable energy and rural energy. Also the sugar factories produce only to meet their power requirements within their factories.
- ❖ Cogeneration helps to achieve full participation of both men and women in the development.
- ❖ Cogeneration can promote energy security and price stability by diversifying the energy supply.
- ❖ The local society would benefit from increased economic independence, primarily by substitution of fuels purchased from outside, by fuels produced locally. This means a larger fraction of local earnings are spent locally.
- ❖ The availability of sugarcane waste is good.

4.3 Benefits and Drawbacks of 5% Cogeneration Target

4.3.1 Benefits of 5% Co-generation

- Less money will be required to reach the target as already there is more than 36 MW installed capacity for cogeneration which is about 4.2 % of the national installed capacity.

- Co-generation can be increasing gradually, that is in modular manner. This may enable the projects to be financed locally. Also this could help to gain more experience from other factories within the region and outside.

- So far, most of the biomass co-generation plant engineers and technicians are skilled Tanzanians. This ensures the sustainability of the technology in terms of operations, maintenance and fabrication of spare parts.

Other advantages include:-

- It enables diversification in electricity generation thus increasing energy security.

- It defers the need for investment in electricity generation and reduces recourse to debts and the resulting financial costs involved.

- The systems were initially set up to supply required power or heat to individual industries, which are remotely isolated, without power from the grid thus these companies have been serious on preventive, corrective and scheduled maintenance of the equipment in order to keep on their production. Therefore, cogeneration encourages the modernisation and rehabilitation of the sugar industry.

- The option of combusting bagasse to produce power has been assisting the companies to get rid of their waste in a less costly way at the same time recovering energy, thus it alleviates green house gas emissions.

- Assists in modernising the rural areas. This it does by promoting sustainable rural growth points.

- From the utility point of view, cogeneration can inject electricity to the grid thereby, avoiding transmission constraints and reducing transmission losses.

4.3.2 Disadvantages of 5% Co-generation target

- The 5% cogeneration target is quite small taking into account that the energy generation potential in sugar factories alone based on excess bagasse energy potential can contribute about 4.2% of the present country generation. Assuming all agro residues from small and large farms are used for cogeneration, the contribution is already more than 10.5 %

- 5% target can make sugar industries ignore the improved technology for cogeneration to increase the power generation and hence some negative impact to environment as SO_2 emissions will be more.

Other drawbacks include:

- Deterioration of some equipment due to old age. This requires frequent replacement of some spare parts which means more expenditure in forex for the spares whose raw materials like stainless steel, are not locally available.

- There is a shortage of forex to service high technology and very sophisticated equipment. This means there is a need to shop around for technological levels that are manageable within the region.
- Non-availability of credit facilities in the country makes it difficult to set up more cogeneration systems.

5.0 RECOMMENDATIONS

It can be recommended that a number of strategies need to be put in place to address the barriers for cogeneration and renewable energy technologies in general. The following could be part of the many solutions to enhanced use of renewable energy;

5.1 Recommendations for Policy Makers

- ❖ The government will have to set down clear policies on co-generation and RETs in general to give the right signal to potential investors. The policy should encourage private sector participation in the energy sector.

- ❖ The policy should promote cogeneration and other RETs system that maximize natural resources utilization in a sustainable manner.

- ❖ Once the Government policies are set down, it is necessary to set up a regulatory framework. Generally, this gives confidence to all stakeholders and encourages investments in the sector.

- ❖ The Government in collaboration with private sector and public utilities to research and implement innovative RETs dissemination approaches.

- ❖ The Government and other key players (including energy/environment regulator) to institute proper legislation such that environmental and social costs are taken on board in energy pricing, this is envisaged to make RETs more attractive.

- ❖ The Government to work out fiscal and financial incentives on renewable energy technologies and appliances.

- ❖ The Government and RETs manufacturers/marketers to set standards and codes of practice for RETs gadgets in order to improve quality of products and after sales/installation services.

5.2 Recommendations for Implementers (manufacture, SMEs, financial institutions, informal investors, micro entrepreneurs, micro finance institutions, large private sector)

- ❖ To introduce campaign in the private sector on developing cogeneration systems from bioenergy resources which are available.

- ❖ Promoters of (cogeneration) projects have to accustom themselves with new technologies in the industry.

- ❖ To make available credit facilities within the country to encourage more cogeneration systems.

- ❖ To provide financial concessions to new investments or improvement of existing cogeneration equipment.

- ❖ To enhance information exchange by networking with others and provide the relevant data to the national co-ordinator of the energy sector i.e. the Ministry of energy.

- ❖ To enable research institutions to conduct more research on low cost renewable energy technologies so as to bring down the prohibitive investment costs.

- ❖ It is advisable for local investors to visit overseas installations to learn from the experiences there.

- ❖ The private sector in Tanzania may participate in joint ventures as it is done in rehabilitation of some sugar cane factories in Africa.

5.3 Recommendations for Lobbyists (civil societies, CBOs, NGOs etc)

- There should be a good institutional framework to support cogeneration.

- Lobbyists should ensure that the initiatives in setting up new or improving the existing cogeneration facilities, are such that they motivate productivity and efficiency in the industry, and social development.

- Cogeneration plants particularly those based on biomass are a good candidate for UN climate convention financing mechanism, therefore, they should be encouraged in trying to meet the convention requirements.

5.4 Recommendations for End Users (existing and potential users and customers)

- Cogeneration should be geared to meet national needs and should meet national policy objectives as well. Hence the operators of cogeneration plants should generate adequate profits through these projects and to make sure that the national needs of adequate energy supplies are met at reasonable costs.

- The utilities could develop appropriate Power Purchase Agreement (PPA) in conjunction with the co-generators.

- Customers can learn from others experiences e.g. Mauritius sets a good example of the role that sugar bagasse can play in energy supply. About 45% of grid electricity in Mauritius comes from sugar mills and the mills also produce ethanol for fuel.

- The need for teamwork is essential.

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