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Electricity from bagasse in Zimbabwe

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Abstract

Zimbabwe has suffered electrical power shortages resulting in electrical energy imports rising to between 40% and 50% of total energy needs. Electricity generation capacity has stagnated at around 2000 Megawatts (MW_e) since 1985, when two thermal units totaling 440 MW_e were completed at Hwange. The effective capacity is 1.75 GW_e. The current plan is to increase capacity by installing 600 MW_e at Hwange at a cost of at least US $ 600 million. Raising this level of capital is difficult hence over the last 15 years there has been a failure to increase capacity. This article is based on a study of bagasse cogeneration in Zimbabwe and Mauritius conducted over a two-year period. It discusses technology improvements that can be made in the sugar sector to improve process and energy efficiency for the purposes of becoming an independent power producer that supplies power to the grid continuously throughout the year. Power plant investment in the sugar industry offers a bridging and realizable alternative for electricity generation in Zimbabwe. Investment in a 35 MW_e bagasse (moisturized fiber left when sugar has been extracted from sugarcane) system would require a capital of about US$ 35 million using modern technology based on experiences in Mauritius and Reunion. A technical and economic evaluation and analysis reveals that bagasse power development is technically and economically feasible if electricity is priced at the long-term marginal cost. At current import prices, financial assistance from the global environment facility and/or the clean development mechanism of the Kyoto protocol would be necessary. The solving of the current political and economic problems in the country would pave the way for attracting a technical partner and development, of bagasse power using domestic and international financing.

Keywords: Zimbabwe bagasse cogeneration; Independent power producers; Biomass; Bioenergy

1. Introduction

It has been shown that Zimbabwe has not been able to increase its electricity generation capacity since 1985 even though demand has been growing steadily. The country has had to rely on importing about 40% electrical energy from neighboring countries [1]. However the country's failure to improve export earnings has resulted in foreign currency shortages and this has meant inequitable allocation of hard currency to the energy sector, hence crippling the other sectors that need imported inputs. Small to medium scale power generation units have a role to bridge the power deficit at hand considering that it is very expensive to invest in large-scale units. There is a plan by the local utility, Zimbabwe Electricity Supply Authority (ZESA) to invest in two thermal power stations of 300 MW_e each in the year 2005 at a total cost of about US$600 million [2]. (All costs in

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this paper are quoted in the United States dollar of the year 2002.) This is despite the fact that at its peak, electricity imported touches 50% of total consumption at times currently. Capacity addition in 2005 will be very late and the capital to bring these units on line has not been secured yet. This situation provides an ideal opportunity, not only to allow the introduction of independent power producers (IPPs) in the sugar industry to bridge the electricity demand gap, but also to introduce usage of renewable energy in Zimbabwe on an affordable scale requiring lower capital input and saving on foreign currency in the medium to long term.

If state-of-the-art technology in bagasse power cogeneration is introduced in Zimbabwe, it can generate up to 210 MW_e of firm power [3]. Firm power is the continuous supply of electricity throughout the year, even during the sugar off-crop season using alternative fuel, enabling its use for base loading. Experiences in other countries like Reunion and Mauritius have shown that there would be a need to ensure that the electricity tariffs and incentive schemes available can sustain such a level of investment. The Zimbabwean electricity tariffs should be set at a level that takes into account long-range marginal cost. This, if put in place, could offer an incentive for a direct business arrangement between the sugar companies and the utility ZESA, without a need for government intervention and subsidies. It is noted that the current tariffs have been eroded by further devaluation of the Zimbabwean dollar. They are generally set at about US\$ 0.04 kWh^{-1} [1]. When completed, the proposed projects in the sugar industry can provide at least 5% of current power requirements [3].

The paper discusses the sugar processing and bagasse power technologies, possible improvements of these technologies, presents results of an economic analysis of the proposed projects in comparison to the baseline and discusses feasibility issues in Zimbabwe. The feasibility of the projects depends on the ability of the Zimbabwean government to attract investment in cogeneration in the sugar industry. (Cogeneration in this case is defined as the simultaneous generation of electricity and steam in a single power plant. This saves primary energy when compared with separate generation of electricity and steam.) The provision of finance for such projects is important hence the possibility to attract funding from the Global Environment Facility (GEF), the clean development mechanism (CDM) and commercial banks is discussed. Bagasse power development offers a solution to power and foreign currency problems that Zimbabwe is facing. The sugar companies benefit from an additional revenue line to leverage against falling sugar prices, the utility would have access to more power without a need to spend commensurate capital and the economy will save foreign currency and avoid contraction due to power shortages. When the right environment is created, bagasse power cogeneration offers an efficient win–win opportunity for all the stakeholders. The current economic and political problems, which are assumed to be transient and not sustainable, are a temporary barrier against this. Regulatory issues would also need to be addressed to attract capital into the sector.

2. Cogeneration in the sugar industry

It has become standard to produce both the steam and the electricity necessary for driving the sugar processes. This sequential generation of electrical power and thermal energy (steam) is referred to as the production of combined heat and power or cogeneration. The Topping Cycle, whereby primary heat at the higher temperature end of the Rankine cycle is used to generate high-pressure and high temperature steam and electricity, has found wide usage in the sugar industry. The ratio of heat to electricity generated varies depending on the type of arrangement. The steam-electric power plant with the extraction-condensing turbine is widely used because it can be arranged to give a wide range of ratios to suit the processing requirements of the sugar factory. The current technology involves sugar milling and extraction using a diffuser line or tandem mills. When the sugar has been extracted, the remaining fibrous residue after dewatering, which is called bagasse is conveyed to the boilers for burning as fuel or to storage facilities. Its moisture content is around 45–55% [4,5]. The sugar processes use low-pressure steam from the turbo-generators/alternators and other prime movers like shredders, de-watering mills, drying-off mills and steam-feed pumps. In some plants, high-pressure steam is used for sugar processing and by an ethanol plant after cooling it and reducing its pressure. This use of pressure reducing valves wastes energy, which could be used to power a turbo-alternator.

The bagasse percentage cane can vary from 23% to 37% and it averages 30%. This depends on the fiber percentage cane, which normally ranges from 12% to 19%. The rest of the bagasse is made up of trapped dissolved matter, trash and water. Its moisture content can be reduced by better de-watering, improved processing or by simply leaving the bagasse to dry. At zero moisture, bagasse calorific value is about 19.25 MJ kg^{-1}. The net calorific value of bagasse with a moisture content of 50% is 7.62 MJ kg^{-1} [5]. The bagasse is burnt in boilers that are normally designed to use both bagasse and/or coal. The average steam to bagasse ratio is normally 2.2. At a density of 130 kg m^{-3}, storing bagasse takes a lot of space, hence the need to use boilers that burn as much of it as possible [4]. The boilers generally range from 35 to 150 ton of steam per hour, at pressures varying from 15 to 82 bar (a bar is 100 kPa) and temperatures ranging from 300°C to 525°C [6].

Traditionally, cogeneration was adopted as a means of incinerating bagasse in a useful way by generating steam in boilers for process heating and electricity generation. This was regarded as a clever way of converting waste into useful energy and efficiency was not a priority. Higher efficiency created safety problems since bagasse is of low density, highly flammable, ferments and loses calorific value when stored for very long periods. In order to balance the factory properly, most systems put in place inefficient combustion low-pressure boilers and used backpressure turbines to convert steam energy into mechanical energy for electricity generation. High-pressure steam was also used for prime movers for the mills, cane shredder and large pumps. Over time conventional sugar factories with integrated power plants evolved. The boiler and turbine were transformed to high efficiency units by changing the steam condition that is increasing the temperature to between 440°C and 460°C and the pressure to between 45 and 60 bar and by using extraction/condensing steam turbines. Generation is at 200 kWh ton^{-1} bagasse and 1440 kWh ton^{-1} coal in this case, giving thermodynamic efficiencies of the order of 25% [6].

Advanced cogeneration plants are in operation already. Two were set up by the French company, Societe Industrielle de Developpement de l'Energie Charbon et de la Cogeneration (SIDEC) in Reunion and started operating in 1992 and 1995, respectively. The company set up another one at Guadeloupe Island, whose construction started in 1998. It is a shareholder in the Compagnie Thermique de Belle Vue (CTBV) at Belle Vue in Mauritius, whose construction started in July 1998 and operation started in the second quarter of the year 2000. The plant at Belle Vue is completely dissociated from the sugar factory and it generates electricity for the grid and electricity and steam for the sugar factory. The advanced plants generally operate at 140 ton h^{-1} of steam when using bagasse and 130 ton h^{-1} of steam when using coal, both at 82 bar and 525°C. The boilers are single flue gas type, a design without any 180° turn in flue gas stream, resulting in less erosion due to centrifugal forces exerted by solid particles conveyed in the flue gas [6].

Each of the two turbo-generators at CTBV is capable of generating up to 35.6 MW_e. This was guaranteed by the suppliers and has been verified by an independent (third party) performance study during commissioning. A mixture of thermodynamic laws and experimental factors plus a safety margin was used to arrive at the operating characteristics. The actual thermodynamic efficiency of the plant depends on the fuel used, its particle size distribution, the atmospheric conditions, plant loading and other factors. When the plant does not supply the sugar mill with steam and electricity, the efficiency runs around 32% [6]. When burning bagasse and supplying the sugar mill with energy, the value rises since the multiple effect evaporating of juice reduces the losses to about 20% of the energy supplied in steam. The actual efficiency values depend upon crushing rate, fiber loading of mills and other operational conditions. The plant at Belle Vue has been able to increase the amount of electricity exported to the grid from crushing 850 000 ton of cane from almost nothing to 110 GWh. This is equivalent to 45 000 ton of coal or 21 000 ton of heavy fuel oil being replaced by renewable and cleaner energy [6].

3. Cogeneration in the Zimbabwean sugar industry

Zimbabwe has two sugar factories in an area known as the Lowveld. These are Triangle Sugar Limited and Hippo Valley estates. The two factories produce

Table 1
The sugar and power plant characteristics at CTBV, Triangle Sugar Limited and Hippo Valley Estates

	Compagnie thermique de Belle Vue (CTBV)	Triangle Sugar Limited	Hippo Valley Estates
TSC per year (mil)	0.85	2.5	2.2
Sugar (000s ton)	75	290	260
TSC daily (000s)	7.44	11.76	10.8
TCH	310	490–500	450–480
Crushing season	6–7 months	9–10 months	9–10 months
Bagasse %cane	30%	31%	30%
Bagasse (000s ton) per year	245	775	660
Technical partner	Societe Industrielle de Developpement de l'Energie Charbon et de la Cogeneration (SIDEC)	None	None
Shareholding	SIDEC, 27%: BVM Sugar 51%: SIT, 14%: SIC, 8%	100% Triangle Limited	100% Hippo Valley
Boilers	82 bar, 525°C and 260–280 ton h^{-1} ($t\ h^{-1}$) steam, 2 units single flue gas type.	4 out 10 used. 340 $t\ h^{-1}$ steam. 31 bar, 400°C	6 boilers, 31 bar, 400°C, 371 $t\ h^{-1}$
Turbo alternators	11 kV, 5305 rpm, 2 units each 35.6 MW_e, Condensing extraction turbines, multistage.	5 back-pressure, 1 condensing	4 back-pressure and 2 condensing
Installed capacity	70 MW_e, operates at 60–70 MW_e	35.5 MW_e operate 21 MW_e	46 MW (15 MW_e)
Steam per kW_e	4 kg kW_e^{-1} at maximum output	9.6–16.2 kg kW_e^{-1}	9–16 kg kW_e^{-1}
Energy exports 2002 target MWh	325	0	30
Exports kWh/TSC	130	0	13.64
Electrical energy per TSC	150	44	32

TSC is tons of sugarcane crushed; TCH is tons of cane per hour; BVM is Belle Vue Milling; SIT is the Sugar Investment Trust; an institutional trust representing sugar industry workers and planters; SIC is the State Investment Corporation of Mauritius.
Sources: [3–10,12].

electricity from bagasse and coal to meet electricity requirements for irrigation activities, sugar plant machinery and equipment and for the local community composed mainly of the sugar companies' employees. The characteristics for the sugar and power plants are shown in Table 1 for easy comparison. The Hippo Valley Estates sugar plant is made up of two diffuser lines with good bagasse dewatering characteristics. On average, a ton of bagasse produces 2 ton of steam, provided the exhaust gas temperature is around 150°C [4]. The steam produced per ton of bagasse goes down with a rise in exhaust gas temperature. The company commissioned a 20 MW_e backpressure turbo-alternator in July 2001 and is exporting power to the grid on a trial basis up to the end of 2002. It disagreed with the utility company on electricity pricing, set at US$0.025 kWh^{-1}, but however signed a power purchase agreement for a period ending December 2002. Its own economic analysis showed that an electricity price of US$0.03 kWh^{-1} would give it a better return on investment [7]. The company used about 23% of the live steam for process heating, before the introduction of the new turbo-alternator [4]. This process of pressure reduction using valves is expensive, wastes energy and should always be eliminated by balancing the steam usage in the plant through investment in appropriate turbines and boilers. The best available technology in this area involves no pressure reduction at all, resulting in big financial savings, higher efficiencies and more electricity for export to the grid.

The Triangle Sugar Limited factory consists of an old tandem mill line rated at 200 ton cane per hour (TCH), which contributes most of the moisture in the bagasse and a modern diffuser line rated at 300 TCH. Some experiments conducted showed that temporary storage of bagasse for about 5 h reduced the moisture content to about 45%. A 1.4% increase in steam or heat content can be achieved if the moisture content is reduced by 10% [5]. The company therefore tries to store the bagasse temporarily, whenever possible in order to reduce its moisture content. Bagasse accounts for roughly 88–90% of energy requirements at the Triangle Sugar Factory and coal for the rest, when stored bagasse has run out [5]. In very rare cases, power from ZESA is used. The company uses most of its molasses for the production of ethanol. Some of the molasses for ethanol production is purchased from Hippo Valley Estates. The live steam is used to run the generators, the drying mills for dewatering, the 66-in shredder line, the boiler feed water pumps mill and to supply the factory letdown station and the ethanol plant letdown station. Exhaust steam from the generators is used for evaporation at the evaporator stations, for general process heating and for heating at the ethanol plant. The use of steam in power drives is inefficient and provides candidates for electrification. The company does not sell power to ZESA, because the price offered is below its cost of production [7].

A comparison of CTBV Mauritius and the two sugar companies in Zimbabwe shows that new technology can result in more power output to the grid. A technical partner can make the technology transfer process easier as was the case at CTBV. This also demonstrates that there are mature technologies offering superior technical specifications in terms of boiler, turbo-alternator and overall system performance. Typical parameters are compared in Table 1.

4. Improving bagasse power generation in Zimbabwe

Having observed that bagasse power production can be improved in Zimbabwe, this section considers technologies for implementing new projects, proposes specific projects with an economic analysis and finally examines technological developments in future. The current political and economic situation is assumed to be transient and not sustainable. The analysis and assessment done therefore assumes a change in the situation. The aim is to provide ZESA with a continuous supply throughout the year (firm power) as opposed to intermittent or seasonal power injection to the grid, removing the need to invest in extra standby capacity.

4.1. Improvement by investing in new technologies

There is room for the sugar companies to improve the competitiveness of their operations and save energy, making it possible to export higher volumes of electricity to the grid. The current state-of-the-art power plant at Belle Vue in Mauritius, CTBV is used as a standard to be used for firm power production. The sugar factories that want to export power to the grid can start off by modifications and improvements at the factory level in order to improve steam efficiency and minimize internal power consumption. This can be done through measures such as; electrification of all steam driven equipment, minimizing breakdowns through improved maintenance, installing more efficient juice heaters, evaporators and pans, optimizing equipment like electrical motors and training and educating workers. These activities are further supported by increasing boiler capacity, upgrading the boiler pressure, installation of an economizer to recover heat losses in the chimney and upgrading of the steam turbine. All these improvements ensure more efficient combustion of bagasse to create surplus power, which can be exported to the grid. Installation of electrically driven hydraulic drives on the mills and the replacement of inefficient single stage steam turbines that drive the cane preparation equipment with electric motors have been shown to reduce total power requirements of the plants according to experiences at the Union Saint Aubin sugar factory in Mauritius. In fact this plant increased threefold its exports to the grid and reduced power consumption per tonne of cane processed. The specific steam consumption dropped from 10 to 6.55 kg kW_e^{-1} [10].

Fitting variable frequency controllers for electric drives, especially those for the pumps, can reduce internal energy consumption in a sugar plant. These enable the motor to reduce power consumption when the liquid flow rate is reduced. Typical payback period for such systems is one year [10]. Plate juice heaters can be used to replace conventional tube heaters resulting is savings on specific steam consumption and on cleaning costs. This system has positive effects since it can use steam bled from the first, second and third effect evaporators. The first set of evaporators can be retrofitted with falling film plate evaporators, which have been very successful in the sugar beet industry [10]. These reduce steam consumption considerably. Rain tray condensers can be used to replace the traditional counter-current cascade condensers. These reduce cooling water requirements and in addition reduce electricity consumption of the cooling pond pumps. The use of continuous pans for first grade sugar boiling and high capacity batch pans for low grade boiling help to smooth steam-bleeding requirements from the evaporators, improve syrup quality and improve overall evaporator setup. The use of first grade continuous centrifugals in place of conventional batch centrifugals decreases the large peak power demand characteristics associated with the high capacity batch machines [7,10].

Improvements in exhaust steam consumption at Union Saint Aubin sugar plant in Mauritius have resulted in the reduction of the specific consumption rate of the evaporators to 415 kg of steam per tonne of cane processed. The electricity exported rose in the process from 1 GWh of energy annually to 20 GWh, equivalent to an export rate of 52 kWh of energy per tonne of cane crushed after meeting factory power needs [15]. This is a big achievement compared to Triangle Sugar Limited and Hippo Valley Estates, which export 0 and 13.64 kWh ton^{-1}, respectively. Typical plants operate at 450–600 kg of steam per ton of cane processed. The evaporator performance in sugar factories can be further improved by bleeding steam to juice heaters down to the last effect of the quintuple effect and the use of the more efficient continuous pans, centrifugals and crystallizers in place of batch processing systems. All prime movers normally consisting of single stage steam turbines should be replaced by electric motors or hydraulic drives where applicable. Steam consumption rate in the beet sugar industry is of the order of 300 kg ton^{-1} beet sugar and these improvements suggested for the sugar cane industry can enable it to achieve similar efficiencies [9,10].

4.2. Proposed bagasse power projects in Zimbabwe

The proposed power projects are for six 35 MW_e turbo-alternators and require a total an investment of about US$ 242 million, split equally between the two companies [3]. This capital can potentially come from private investors, saving ZESA and the government in capital costs. ZESA's next capacity expansion is for two 300 MW_e thermal units at a cost of US$660 million to be commissioned by the year 2005 [1]. The capital cost per unit is comparable for the sugar industry and the proposed thermal plants, even though the 210 MW_e expected capacity is much lower. An appraisal of the proposed projects is shown in Table 2, in comparison to a baseline, whereby power continues to be supplied from the thermal power stations over a 25-year period, the lifetime of the new plants. The baseline assumes that power continues to be transmitted from the coal power stations at the long-term marginal cost of US$0.06 kWh^{-1} [3]. The sugar mills are investing in capacity expansion, sugarcane production expansion and bagasse handling so that they can process 500 tonne of cane per hour each for US$18 million [4,5,7]. The proposed power plants are separate from the sugar mills, getting condensate and bagasse from them in exchange for electricity and steam. An electricity export level of 130 kWh ton^{-1} of cane is assumed based on CTBV performance data [6]. Zimbabwean coal thermal plants operate at 0.5 kg kWh^{-1}. The coal used in the plants is priced at US$40 ton^{-1}, has a calorific value of 28 MJ kg^{-1} and releases 2.62 kg of CO_2 for every kg burnt [11]. Bagasse is considered to be a cost-less fuel. This might change in future. The project results in carbon dioxide emission savings of 19.74 million tonnes during the lifetime of the power plants. This also results in cost savings of US$126.71 million when using the long-term marginal cost of electricity provided by ZESA, representing a cost of –US$6.42 ton^{-1} of carbon dioxide.

Other possible areas of improvement at both Hippo Valley and Triangle Limited include improvement of load profiles, plant availability, automation requirements and meeting environmental constraints through cleaner production. The use of coal in firm power plants would be minimal due to more efficient burning of bagasse. Coal, which is plentiful at the two local collieries, can be used to supplement bagasse

Table 2
The economic analysis of the project

Lifetime of the power plants, years	25 years	
Discount rate	15%	
Fuel price, US$ per ton	In power plant US$ 40	
Bagasse-sugar trash price	Levelised price is currently $0	
Coal carbon content	Coal used in Hwange Thermal power plants has about 71.5% carbon content	
Long-run marginal cost of electricity	$0.06 kWh^{-1}	
Plants specific assumptions	Baseline	Proposed project alternative
Investment costs, US$ kW_e^{-1} installed		1100
Installed capacity, MW_e		210
Capacity factor		91%
Total energy generation (GWh)		1520 GWh (Biomass) 815 GWh (Coal) 705 GWh
Available power to grid		1320 GWh
Transmission losses		Supply at distribution level 0%
Annual energy supply (GWh)		1320 GWh
Specific fuel consumption (t GWh^{-1})		987 ton bagasse per GWh
Eletricity to the grid produced by		
Coal	100%	705 GWh
Bagasse		615 GWh
Costs	Baseline	Proposed project alternative
Investment (million US$)		
Power plant		242
Sugar mill	5	12
Bagasse handling	3	3
Sugarcane supply	10	10
Subtotal (million US$)	*18*	*265*
Annual fuel costs (Million US$)		Coal cost 13.818 Sugarcane bagasse 0
Annual cost electricity-fuel	79.2	13.818
Net present value (NPV), million US$	*511.96*	*89.32*
Annual O&M costs, million US$	(Included in LRMC)	7.26
NPV (million US$)		*46.93*
Total costs, present day million US$		
Electricity or power plants costs	511.96	378.25
Sugar mill	5	12
Bagasse handling	3	3
Sugarcane supply	10	10
Total, million US$	*529.96*	*403.25*
Power plant emissions (t CO_2 $year^{-1}$)	(From coal) 1,694,616	(From coal) 905,079
Carbon emissions t CO_2 in 25 years	42,365,400	22,626,975

Sources: [1,3,5–9,11].

in the firm power plants. The proven coal reserves in Zimbabwe are 502 million tonnes, which can last 101 years [11]. The use of renewable energy like bagasse will extend the life of this energy reserve, while mitigating net emissions of carbon dioxide in the process.

4.3. Improving bagasse power output in future

Turbine efficiencies in the sugar factories range from 70% to 88% and steam temperatures are normally limited to 525°C [6,12]. In order to improve thermal efficiencies, new co-generation technologies offered by many companies should be considered in order to evaluate economically feasible options that will enable optimal utilization of bagasse. Gasification technology can be used to enhance the use of bagasse in the production of electricity in the long-term future, when the technology has been fully developed. In Brazil it has been estimated that 6000 MW of electricity could be generated in the sugar industry using gasification. Typical sugar and ethanol industries in Brazil generate in the low efficiency cogeneration units of about 14 kWh ton^{-1} of crushed sugarcane (tsc). This can be increased to 120–250 kWh/tsc with conventional but high efficiency turbine cycles and to about 500 kWh/tsc if biomass integrated gasifier steam turbines were used [13]. In the case of Zimbabwe, the potential power capacity in the sugar industry has been estimated to be about 210 MW and about 517–615 GWh of bagasse generated electricity for export to the grid. Gasification technology can raise this export potential to 1692 GWh [3,12].

5. Promoting bagasse cogeneration

Biopower from the sugar industry has a role to play in solving some of the power problems faced by the electricity industry in Zimbabwe. The failure by government through the utility to invest in new power plant capacity indicates that the sector will stagnate for a very long time unless independent power producers are given a role to play. The current economic climate has resulted in a situation whereby the utility is saddled with debts and is making operational losses. The sugar industry offers renewable energy production options, which have proved to be economically feasible in other countries like Mauritius and Reunion. However the right conditions need to be put in place to attract investment in this area. This section discusses the need to change the Electricity Act of Zimbabwe, the status of the Zimbabwe Power Company a subsidiary of ZESA in such a development and the role that the global environment facility and other donors and development agencies can play.

5.1. Deregulation of the electricity industry

The Electricity Act of Zimbabwe 1985 brought together the operations of the Central African Power Corporation, which managed power generation and transmission from Kariba for Zimbabwe and Zambia, Electricity Supply Commission responsible for coal-fired generation at Hwange and Munyati and for the distribution of power throughout Zimbabwe and the electricity undertakings of the cities of Harare, Bulawayo and Mutare into the Zimbabwe Electricity Supply Authority (ZESA), a vertically integrated monopoly, responsible for generation, transmission, distribution and supply of electricity [1]. The reason for that was to streamline administration of the electricity sector, achieve economies of scale and tariff rationalization. However the growth of the industry expected from this initiative did not take place. Private investment in the power sector was only allowed through the consent of the Minister and there was no favorable legal or regulatory framework for it. The new Electricity Act was gazetted on 28 March 2002 [14]. This provides for the restructuring of ZESA into companies responsible for generating, transmitting, distributing and supplying power in the country. The Zimbabwe Electricity Regulatory commission is created with the responsibility to create, promote and preserve an efficient electricity industry and market. There is a concern that the major decisions of the commission still require the approval of the Minister under the Act. Better decisions would be made if the ultimate accountability were to parliament. This would ensure; rationalization of the tariffs to cover the full costs; greater autonomy and flexibility of the regulatory commission; the creation of appropriate incentives and legal instruments for IPPs, for example tax holidays where necessary; better methods of promoting bagasse and other renewable power; attraction of technical partners, foreign and domestic investors and technology transfer; and better identification of training and research needs of the bagasse power sector.

The transformation process in the electricity industry was started with the formation of the Zimbabwe Power Company (ZPC) in 1996, as a wholly owned subsidiary of ZESA. Its purpose is to make power investments in new power generation projects and related electricity trading. It aims to develop joint ventures with investors that have the necessary technical and management experience. It is an ideal shareholder in bagasse power development together with all other stakeholders in the sugar industry. However due to lack of independence from the mother company, decision-making processes in the company are very long and this is not attractive for the sugar industry. The tariff negotiations are also done directly with ZESA rendering ZPC a non-pricing decision making branch of the utility. The purchase price of electricity between ZESA and Hippo Valley Estates is agreed on every year, and takes into account the electricity pool price from the other generators supplying the grid in future [7]. However, it has been found to be difficult to set the rules in the absence of a legal regulatory framework. Otherwise rules change as soon as the management in the utility company is changed.

5.2. Development assistance and financing for bagasse power

The global environment facility (GEF) can assist bagasse power development in Zimbabwe if it re-engages development agencies. GEF is a vehicle for sustainable development, which resulted from the Earth Summit in Rio de Janeiro in 1992, governed by a 32-member council of both donor and recipient countries. UNDP, UNEP and the World Bank Group implement the projects. Forty-one renewable energy projects were approved, with grants of US$480 million and total costs exceeding US$2.5 billion, between 1991 and 1999 falling in the two categories of Barrier removal and Cost reduction projects. A number of lessons have been learned from these projects. In Mauritius, the project financed efficiency investments in the sugar mills, to provide surplus power for export to the grid. The project promoted an institutional and regulatory framework for private power generation in the country and thus created greater dialogue and partnership between the private and public sectors. Even though the objective of constructing a bagasse and coal fired power plant was not achieved, there was an indirect influence on private investment in the bagasse-fired electricity generation industry. CBTV embarked on and completed a bagasse power plant on its own. This served to show that the construction of demonstration power plants is not always necessary. What is critical is to set the right environment that can attract IPPs to invest in bagasse power generation. Similarly GEF can catalyze bagasse projects in Zimbabwe by supporting efficiency in the sugar processes and assisting to rationalize the electricity tariffs so that they provide a good return on investment [15].

The problem with GEF projects is that the private sector has found their development process to be slow and inaccessible. The projects generally take two years to prepare from initial concept to final approval and the implementation process is normally planned over several more years. This is not competitive enough for the private sector where decisions and implementation activities take far shorter times. The International Finance Corporation (IFC), the private sector affiliate of the World Bank has come in with GEF projects to address these concerns. GEF has also evolved new approaches to private sector involvement. These include non-grant (contingent) financing, financial guarantee mechanisms, support for investment feasibility studies, increased dialogue with the private sector, effective communication of GEF procedures and requirements and long-term partnerships. The sugar companies in Zimbabwe can use these new approaches as well as IFC financed projects. The implementing agencies have the challenges of incorporating these approaches. The World Bank Group has already established Fuel for Thought: Environmental Strategy for the Energy Sector, to address these new approaches, with GEF being requested to finance 20% of the total contributions as grants. The challenge in future is to remove the need for such GEF grants. In the meantime, GEF has extended implementing agencies to include regional development banks like the Asian Development Bank and European Bank for Reconstruction and Development [15]. The Zimbabwean sugar companies can approach the African Development Bank to facilitate GEF assistance for bagasse power development.

Some authors argue that GEF funds play a role currently unfulfilled by other means. Unlike traditional bilateral assistance projects, which provide sales for donor country firms, GEF provides models and capacities for sustained market growth in recipient countries and promote commercial markets. They overcome the barrier to renewable energy development due to reluctance by countries to borrow from development banks

Table 3
Taking care of risks at CTBV

Type of risk and description	The way it was covered
Commercial risks in construction, like cost overrun, late completion and faulty design	Engineering and Procurement contract with Duke Engineering and Services, a subsidiary of Duke Energy Inc. (USA), which is a reputable company
Commercial operational and maintenance risks. Ensure correct operations and repairs	CTBV Management with the technical partner taking most of the responsibility
Commercial risks regarding sales of electricity. If Bagasse power is not considered as base load, power produced can be wasted	Power purchase agreement with Central Electricity Board guaranteed by government. Take or pay contract for first 325 GWh and indexation of kWh price to reflect production costs
Commercial risks related to the supply of bagasse, coal and water	Contract signed with coal supply company. Product exchange contract signed with sugar mill. Water supply and back-up agreements signed.
Political risks related to changes in law, changes in incentives and currency limits	Change in law clause included in the agreement with government. Concession agreement and guaranteed access to foreign currency ensured.

Source: [6].

by providing incentives and assist to over come private investment barriers like uneven competition from conventional fuels, unproven markets, financing risks and high transaction costs. A need for capacity building among donors and recipients has been identified to ensure that funds are channeled to good projects, allow recipients more informed choices and overcome political constraints. The most critical factor is sustaining the markets and setting full cost-recovery prices for renewables. Private sector participation to speed the projects will work best within this overall framework that is the development of sustainable markets and viable returns [15]. GEF can play an important role in bagasse power development in Zimbabwe by addressing the areas above.

Project support can also be possible through the clean development mechanism (CDM), whereby developed countries can buy certified emission reductions from the bagasse power development project in Zimbabwe [16]. Electricity is currently imported into Zimbabwe at US\$0.03 kWh^{-1}. At this price, bagasse power development projects proposed earlier would have an incremental net present value cost of US\$129.27 million, representing a carbon cost of US\$6.55 ton^{-1} of carbon dioxide. This would be the basis upon which trade for emission reductions can be conducted to make the projects economically viable.

Commercial banks have been able to finance economically viable renewable projects. In Mauritius, banks led by Sumitomo Bank financed CBTV, which was built at a cost of about US\$80 million. These included Barclays Bank and Bank of Scotland and they financed the loan portion of the project, using no-recourse and limited recourse types of financing. The project proceeded on the basis of a power purchase contract. The risks were limited and reduced by signing well-designed and appropriate contracts. These are summarized in Table 3 [6]. Putting in place similar laws and contractual agreements would attract some investment in bagasse power development in Zimbabwe.

6. Conclusion

Bagasse power development has the advantages that it is environmentally friendly, uses renewable energy and it encourages the use of sugar trash in future. Leaving sugar trash to rot and provide compost manure has some environmental problems in that it releases methane gas, which is a greenhouse gas that contributes to global warming. Sugar factories in future have to co-generate heat for sugar processing and power for normal usage in a factory and for sale if they are to remain viable in light of falling sugar prices at the world market. It is noted that cogeneration for export to the grid in the sugar industry will help to save investment costs by the national utility while enabling the modernization and rehabilitation of the sugar industry in Zimbabwe. This can result in large foreign currency savings of about US$39.6 million, based on expected electricity export to the grid at current import prices. It has also been demonstrated that bagasse power prices are competitive if pricing is at the level of the long-term marginal costs of ZESA. The legal and regulatory framework has to be made more favorable to private sector participation by de-linking political decisions from commercial considerations within the Electricity Act. This requires the legislation of the independence of the regulatory commission. The current economic and political conditions in Zimbabwe are a barrier to the proposed projects. However an economic analysis shows that investment in bagasse power development is technically and economically feasible. The Zimbabwean government has to re-engage the development agencies and the donors to make the projects realizable, once the transient political and economic setbacks are overcome and good governance is re-established.

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