

Bagasse Energy Cogeneration in Zimbabwe: The Technology, Possible Improvements and Setting the Right Environment.

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Abstract- Zimbabwe has suffered electrical power shortages resulting in electrical energy imports rising to between 30% and 50% of total energy needs. Electricity generation capacity has stagnated at around 2000 Megawatts (MW) since 1985, when two thermal units totalling 440 MW were completed at Hwange. The current plan is to increase capacity by installing 600 MW at Hwange at a cost of US \$ 900 million. Raising this level of capital is difficult and over the last 15 years there has been a failure to increase capacity. The article argues that promoting power investment in the sugar industry offers a bridging and realisable alternative for electricity generation in Zimbabwe. Investment in a 35 MW bagasse (moisturised fibre left when sugar has been extracted from sugarcane) system would require a capital of about US\$ 55 million, which is easier to source. It is further argued that creating the right environment will make bagasse power projects economically and financially feasible. There is a need to; set cost-effective purchase prices, ensure independence of tariff setting, encourage process improvements, encourage power investments through incentives, ensure top level government commitment, promote human resources development in the sugar power sector and to promote research and development in bagasse power generation.

## 1. INTRODUCTION

Zimbabwe has experienced a stagnating electrical power capacity of 2 Gigawatts (GW) against a growing demand for electricity [8]. In reality, the effective capacity has tended to be around 1750MW due to plant outages. This has resulted in excessive electrical power imports, power blackouts and load shedding at times. Other factors like forced outages in local generation and external power pool suppliers has also contributed to load shedding and power blackouts. The imports are generally around 650 MW and some of the import contracts are take or pay, which were entered into during times of generator reliability crisis. According to the Confederation of Zimbabwe Industries, power blackouts were costing big companies an average of Z \$1 million (US\$ 50 000) each year for the period up to July 1999 [17]. The scarcity of foreign currency has made it an imperative that load shedding be introduced at times. In some cases unplanned power blackouts have occurred. The scale of

energy disruptions, though planned for at times, has resulted in huge losses to industries. These losses far outweigh the costs of paying the correct price for electricity that covers long-term marginal costs. On the other hand, it is clear, that large-scale investment in electricity generation requires a lot of capital. An extra capacity of 300MW of thermal plant would require around US\$ 450 million in investment capital [2]. This investment level is beyond the capacity of the currently heavily indebted Zimbabwe Electricity Supply Authority (ZESA) and the Government of Zimbabwe at the moment. While micro-scale and localised energy production systems can be considered, it is clear that economic growth through industrialisation would not benefit a lot from such initiatives. One way would be to encourage Independent Power Producers (IPPs) to come to the rescue. They can put in place small and medium scale systems, whose capital requirements are more manageable. It is becoming clear, based on the experience in Mauritius, that co-generation can assist to alleviate the electrical energy crisis in Zimbabwe. It is estimated that the two sugar factories in Zimbabwe, Hippos Valley and Triangle Limited can provide up to 210 MW of firm power generating capacity if the right environment is created [7]. Firm power is the continuous supply of electricity throughout the year, even during the sugar off-crop season. This makes it necessary to store bagasse and to use coal as a supplementary fuel. This would go a long way in reducing the current level of energy imports in Zimbabwe.

Bagasse energy cogeneration in Mauritius has over the last few years demonstrated that the sugar industry has the potential to meet a substantial portion of a nation's energy needs. 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 would need to be set at a level that takes into account long-term marginal cost. This, if put in place, might in the case of the Zimbabwean situation offer an incentive for a direct business arrangement between the sugar companies and the utility ZESA, without a need for a lot of government intervention. It is noted that the current tariffs have been eroded by further devaluation of the Zimbabwean dollar. They are generally set at about US 4.2 cents per kWh [8]. This paper discusses the bagasse power technology, possible improvements and proposes specific policies, policy instruments and laws that would be needed in Zimbabwe in order to attract investment in cogeneration in the sugar industry. The paper addresses the question of ownership and organisational structure of the envisaged new power plants, the role of the governments and the utility and the training needs in order to enable successful technology transfer.

The following section discusses bagasse energy cogeneration in general. A direct application of this technology in Zimbabwe is discussed later in section 3. The section shows that the purchase price offered by ZESA cannot justify investment in extra power plant capacity for the purposes of grid export. It is noted that the sugar companies

can improve their processes and create more power capacity for export to the grid. The companies can only invest in middle range 20 MW plants in the absence of good pricing. Section 4 identifies the need for an independent regulator. The fact that power plants have long life cycles is acknowledged as a hindrance to bagasse power development, yet it offers an opportunity to plan for the future, since most of the plants are more than 20 years old and will need to be replaced soon. The fact that bagasse power in Zimbabwe is a technically feasible option that can contribute more than 5% of national energy needs is noted. Section 5 exposes the weakness of the current tariff setting

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policy and suggests the need for cost recovery tariff levels. Section 6 addresses institutional issues and the need for commitment in the top echelons of government. A minimum plant capacity of 30 MW is suggested [3]. Section 7 suggests the need to separate the power plant from the mill. Private sector investment is proposed as well as equity ownership by workers, millers, and planters and by ZESA. Section 8 proposes a change of the Electricity Act and suggests incentives and power purchase agreement legal issues. Section 9 addresses research and development issues and human resource development needs specific to Zimbabwe. Finally a conclusion is presented, which indicates that addressing the policy issues raised in this paper will make bagasse energy development both technically and economically feasible. The section also indicates the benefits to the environment as a result of using biomass.

## 2. BAGASSE ENERGY COGENERATION

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 current technology involves sugar milling and extraction using a diffuser line or tandem mills. Sugar cane from the fields comes to the weighbridge for the purposes of payment to the farmer. They are normally paid on the basis of the sucrose content as analysed in the laboratory. The cane comes to the cane-feeder table. The weighing helps in the control and mass balancing to identify loss areas during processing. The feeder table takes big sugarcane bundles and feeds them into the conveyor.

### 2.1 The Diffuser line [13]

The diffuser line normally consists of a conveyer, which carries the sugar cane to the knives. The processing method involves opening up the sugar cane cells to enable the extraction of the sucrose out of the cane. The cane knives cut the cane into small pieces, which can be handled by the shredder. A conveyor takes the cut cane into the shredder. A hammer against a washboard presses the cane, in order to shred it. The cane is checked to find the preparation index

(PI). This checks whether or not the cane has been well prepared. There is always a loss of sucrose during shredding. The Preparation Index should normally be about 91%. This reflects the loss of sugar that goes with the remaining fibrous residue, which is called bagasse. Poor extraction of sugar results, if the cane is not well prepared. On the other hand, over-prepared cane causes flooding and the wash is poor, resulting in poor removal of sucrose. The prepared sugar is always sampled in order to determine its sucrose content. In some cases, the farmer is paid based on this laboratory analysis.

A conveyor delivers the prepared cane to the diffuser, where there is a roller driving the cane at 50-60 meters per hour. Water is poured on to the shredded cane in order to wash the dissolved matter out. The pH is controlled at around 6; otherwise the cane degrades to glucose and fructose. The control is achieved by adding Lime to the diffuser bed. The temperature is controlled at around 80°C. Warm water is normally used and steam is injected into the diffuser as necessary. This temperature level kills bugs that destroy sucrose and enhances the diffusion process. The steam used is the vapour from the second set of the evaporators and it is called vapour two.

The juice from the diffuser has minimal suspended solids and it is supplied to the mixed juice tank. The bagasse acts as a filter; removing suspended solids. There is a counter current in water movement and cane movement. The water washes the many trays containing prepared sugar. This process, whereby water or juice is applied to prepared sugar in order to enhance sugar extraction, is called imbibition. The juice at the end is pumped back to the previous tray. The process is repeated until the juice is pumped to the first tray. The de-watering rollers at the end of the diffuser press out the juice remaining in the cane and they slow down the shredded cane in order to maximise sugar extraction. The bagasse is then ferried to the de-watering mills, which reduce the moisture content of the final output bagasse to around 48%. The pressed juice is pumped back to the last tray of the imbibition process. Juice from the first tray after repeated imbibition is the one taken as mixed juice to the mixed juice tank. The water that is used for imbibition is the condensate from the evaporators. This warm water makes it easier to maintain a temperature of 80 degrees Celsius in the diffuser. The last conveyor can then take the bagasse to the boilers or to the storage facility for future use in boilers, for stock feeds and for other products. The mixed juice undergoes processing to give final sugar products and by-products.

## 2.2 The Use of Tandem Mills [13]

This normally has a number of mills, which operate in tandem. Each mill is made out of three rollers. These are all squeezing mills, which squeeze the sugar cane juice out. Water for imbibition is added so that fibre maintains enough water, which is used to wash the sucrose. In the main it

dilutes the cane. It is a counter current system with cane in one direction and juice collection in the other direction done in a determined number of stages. The extraction of juice is done at the first two mills. The juice is taken to the screens in order to remove fibre and suspended solids. The juice is then pumped to the mixed juice tank. The output of the shredder line is bagasse at the last mill and it has about 50% moisture content. This is used in the same way as the bagasse from the diffuser. Similarly, the juice is processed as indicated earlier in the diffuser line. For energy cogeneration, the main interest is in the usage of the bagasse.

### 2.3 Electricity Generation from Bagasse

The bagasse percentage cane can vary from 23% to 37%. In the average it is around 30%. This depends on the fibre percentage cane, which normally ranges from 12 to 19%. The rest of the bagasse is made up of trapped dissolved matter, trash and water. The moisture content is also a large determinant of the bagasse percentage cane, since it constitutes about 45 to 55 % of the bagasse, soon after processing. The 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 19 250 KJ/kg. The net calorific value of bagasse with a moisture content of 50% is 7620 KJ/kg. 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

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, storing bagasse takes a lot of space, hence the need to use boilers that burn as much of it as possible. The boilers generally range from 35 to 150 tonnes of steam per hour, at pressures varying from 15 to 82 bars and temperatures ranging from 300 to 525 degrees Celsius. The turbo-alternators that are used for electricity generation can be up to 35 MW. The possible capacity is increasing with the development of new technology in the area. The high-pressure steam from the boilers is used in the turbo-alternators to produce electricity. It can also be used by the shredders, de-watering mills, drying-off mills, steam-feed

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pumps, for sugar processes (after pressure reduction) and by an ethanol plant. The usage areas vary and depend on the set up of the sugar factory. The factory processes use the low-pressure steam that is exhausted from the high-pressure steam processes. All these processes can be improved upon, resulting in less usage of steam and more electrical energy production. The amount of steam used per tonne of crashed cane, depends on how modern the plant is and whether or not the plant has steam or electrically driven critical machinery. Generally a ballpark figure of 50-60 per cent steam on cane is used, which is about 450 to 600 kg of steam per tonne of cane. A reduction of this consumption level will reduce the need to redirect live steam to sugar processes. In the beetroot sugar industry, 300 kg of steam are used per tonne of beetroot. There is room for the

improvement of this figure in the sugar cane industry [2, 4, 10, 12, 14].

### 3. BAGASSE ENERGY COGENERATION IN ZIMBABWE

Zimbabwe has two sugar factories in an area known as the Lowveld. These are Triangle Sugar Limited [16] and Hippo Valley estates. The two factories produce electricity from bagasse and meet most of their electricity requirements.

#### 3.1 Cogeneration at the Hippo Valley Estates Plant

The Hippo Valley Estates processes an average of 2.2 million tonnes of sugar cane a year, producing an equivalency of about 260 000 tonnes of raw sugar. On average, the plant crushes 10 500 tonnes of cane per day over period of 9 to 10 months every year [9, 10, 11]. The Hippo Valley Estates sugar plant is made up of two diffuser lines, which can process about 450 to 500 tonnes of cane per hour. Using a bagasse percentage cane average of 30%, which normally obtains at the company, about 660 000 tonnes of bagasse are produced every year. The moisture content averages 48%, reflecting the good dewatering characteristics of the diffuser lines. On average, a tonne of dry bagasse with 48% moisture produces 2 tonnes of steam, provided the exhaust gas temperature is around 150 degrees Celsius. The steam produced per tonne of bagasse goes down with a rise in exhaust gas temperature. The final molasses produced by the company is sold. The company has 5 turbo-alternator sets that have been in use for over twenty years now. A new turbo-alternator rated at 20 MW has been installed [11]. The company has been involved in discussions with the local utility, Zimbabwe Electricity Supply Authority (ZESA), for a long time on electricity pricing. There were disagreements on the pricing of power, but an agreement was reached at the end of 2001, to have a trial period for electricity exports for six months. A power purchase agreement has been signed and the interconnecting interface was being constructed with the hope to start electricity exports in July 2002.

There are a total of six boilers, three rated at 45 tonnes of steam per hour, two at 68 tonnes of steam per hour and finally one rated at 100 tonnes of steam per hour. The factory operates at 55% (550 kg steam per tonne of cane) steam on cane. The total installed capacity is now 46MW and the turbo-alternator sets are as follows: a 3.5MW back-pressure set, 5MW pass-out set, 7.5MW fully condensing set, 2MW fully condensing set, 8MW back-pressure set and a 20MW back-pressure set, which is the latest installation. The first five turbo-alternator sets are quite old, over 20 years, and therefore not as efficient as the new one. Normally, the whole estate requires about 14.5 MW of power. Moreover, the old turbines are not run at full power because of stability problems and old age considerations. The condensing turbine has its condensate directly forwarded to the boiler

water feed. Exhaust steam from the pass-out and backpressure turbines combines with the exhaust coming from the prime mover turbines and is sent for process heating in Kestners (initial effect evaporators), evaporators and clear juice heaters. The low-pressure process steam at Hippo valley comprises of approximately: 116 tonnes per hour from power turbines, 70 tonnes per hour from prime movers, 54 tonnes per hour from the pressure reducing station. The average steam requirement per day is 5 775 tonnes. The power plant has an extra capacity, which can enable it to export electricity at specified times [10].

It has been shown through evaluation that live steam usage for process heating can possibly be reduced in the Hippo Valley plant from 23% down to about 16% of the total amount generated, saving nearly Z\$ 25 million (US\$ 500 000), which can result in an increment in the company profits annually [10]. The use exhaust steam is insufficient for old process heating equipment and it is unavoidable to tap some of the live steam for this purpose. Because of its state it has to be first de-superheated and reduced in pressure to achieve a similar quality as that of the exhaust steam. This process is unfavourable since live steam is expensive to generate compared to exhaust steam. Moreover the de-superheating process requires special valves, which besides being a capital cost also need to be maintained in operation at a cost. In a good operation using existing technology about 16% of the live steam generated must be directed towards process heating. However the current redirection of about 23% of the live steam at Hippo Valley suggests that major process improvements need to be made. The principal solution is therefore to optimally utilise the low-pressure steam to avoid or minimise the high quantity of live steam being directed for process heating. This shows that improving sugar processing is important in the drive towards enabling sugar companies to export electricity to the national grid. These types of process improvements need to be supported at both the company and government level. The best available technology in this area can involve no de-superheating at all, resulting in more savings.

### 3.2 Cogeneration at the Triangle Limited Plant

The Triangle Sugar Limited factory is able to crush about 2.5 million tonnes of sugar cane per year, producing a maximum of 290 000 tonnes of raw sugar. The plant runs for 9 to 10 months every year [7, 8, 9, 12, 13]. It also produces most of its power requirements, from burning the bagasse. At an average percentage cane of 31%, the company produces about 775 000 tonnes of bagasse. The average moisture content of the bagasse is about 50%. The tandem mill line contributes most of the moisture. The calorific value of bagasse increases with reduction in moisture content. Temporary storage of bagasse for about 5 hours reduces 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% [12]. The company tries to store the

bagasse temporarily, whenever possible in order to reduce its moisture content. Bagasse accounts for roughly 88% to 90% of energy requirements at the Triangle Sugar Factory. There is a diffuser line rated at a maximum capacity of 300 tonnes of cane per hour and a 66 inch tandem mill shredder line, rated at a maximum of 200 tonnes of cane per hour. 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.

Triangle uses four boilers for its processes. The six oldest  
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boilers are no longer used continuously and serve as a back up system. Boiler number 10 produces about 150 tonne of steam per hour at 3100 KPA. It can super heat to 400°C and it is a water jacket boiler. Boilers 7, 8, and 9 are also water jacket boilers. Boiler number 9 is rated at 3 100 KPA, superheats to 400°C and produces 120 tonnes of steam per hour. Boiler number 8 is rated at 45-tonnes/hour steam and boiler 7 is also rated at 45 tonnes/hour of steam [12]. These boilers mainly use condensed water, which is evaporated from the sugar cane. Water from other sources is used for topping up and when starting up the factory operations after a shut down. The recycled water is almost adequate for steam generation and imbibition. The live steam is used to run the generators, to run the drying mills for dewatering, to drive the 66-inch shredder line mill, to supply the factory letdown station, to supply the ethanol plant letdown station and at the boiler feed water pumps. Exhaust steam from the generators is used for evaporation at the evaporator stations, for general process heating and for heating at the ethanol plant. Triangle Limited uses between 450 - 600 kg of steam per ton of cane in the sugar processes. This figure goes up depending on the thermal efficiency of the process operations, when white sugar is the final product and when the level of usage of steam at the ethanol distillery is high.

The plant can produce up to 35.5 MW during the harvesting season and about 5 MW out of season. The current maximum generating capacity is 140 GWh, which is about 44 kWh per tonne of cane [7]. This is a very low figure, when compared to Reunion Island power plants, which can export 110 kWh per tonne of cane, after meeting the requirements of sugar processes. Some of the old alternators are rarely used. Generally, the plant operates at a lower than maximum capacity output of 21 MW, which is just enough to meet domestic consumption needs [12]. Electricity is used at the plant and it is not sold to the local utility, ZESA, because the purchase price offered is considered by the company to be low. The plant has the capacity to produce more electricity and export some of it to the utility. The sugar plant operates about 9 months a year, using bagasse for power generation. Coal and stored bagasse is used during the off-crop period, which averages three months per year. During this time and at any time that it is necessary to do so, power is also imported from the ZESA grid. There are six turbines coupled to alternators at Triangle Limited. Five of them are



backpressure turbines, which exhaust steam at 150 kPa and the sixth one is a condensing turbine, which exhausts at below atmospheric pressure. The plant and the local community mostly use electricity generated here.

#### 4. THE POTENTIAL FOR IMPROVING BAGASSE POWER GENERATION IN ZIMBABWE

Bagasse energy cogeneration in Zimbabwe as shown in the last section is faced by a number of problems. The main problem is that there is no agreement between the utility company and the potential independent power producers (IPP) on the pricing structure. There is no independent facilitator to bridge the gap between the two. Another inhibiting factor to investment in new technology in the sugar industry is the long life cycle of existing electricity generation plants. This limits investment in state-of-the-art cogeneration technology in the short-term, if not medium-term. Hippo Valley has just installed a 20MW turbo alternator, which enables it to export Power to the National Grid. ZESA on the other hand would prefer a continuous supply throughout the year (firm power) as opposed to intermittent power injection to the grid. However the supply to the grid from the sugar companies can only be intermittent at the moment. Triangle is not exporting power at all due to the poor prices offered. It can export power to the grid when the right pricing structure is in place and if it replaces a part of the old power plant.

##### 4.1 Improvement by Investing in New Technologies

It is further noted that a lot can still be done by the utilities in order to improve the competitiveness of their operations. These improvements save energy, making it possible to export higher volumes of electricity to the grid. The power plant at Belle Vue in Mauritius consisting of two boilers of 140 tons of steam per hour each, at a pressure of 82 bars and a temperature of 525 degrees Celsius has been able to drive two turbo-alternators of 35 MW capacity each [14]. This is at a plant with a crushing capacity of 310 tonnes of cane per hour, well below the capacity of each of the sugar plants in Zimbabwe. This shows that process, equipment and efficiency improvements at a plant like Triangle Limited, with a crushing capacity of 500 tonnes of cane per hour and Hippo Valley with a similar capacity, can produce about 105 MW of electricity each, using three 140 ton steam per hour boilers and three 35 MW turbo-alternators [7]. The plants would use less coal since their factory processes operate for 9 to 10 months, using bagasse from more than 2.2 million tonnes of sugar cane. Some of the bagasse saved through efficiency improvements can be stored and used during the off-crop season. In comparison, the Belle Vue plant operates sugar processing for 7 months and crashes a total of 900 000 tonnes of sugar cane [3].

There should be a policy that supports maximum power rating possible for investment in alternators for electricity generation. A higher rate of return is ensured for alternator

capacities exceeding 30 MW. At Union St Aubin Sugar Factory in Mauritius, it was found out that a firm power plant project would have a reasonable rate of return on investment when its capacity was in the range of 30 MW, instead of the 22 MW installed. The proposed power projects are for six 35 MW turbo-alternators require an investment of about US\$ 150 million to US\$200 million at each plant. This is much lower than the US\$900 million to US\$1.2 billion needed for the next power sector capacity expansion project that ZESA plans to implement by the year 2005 [7, 8, 9]. The bagasse plants would generate 210 MW compared to 600 MW for the thermal power plants. However, its advantages would be that less capital has to be sourced, the private sector could fully fund the project and the investment per unit output would be lower. Investment in a new diffuser line at Triangle Limited would be necessary. The improvement process can entail phasing out all the ten boilers existing at the plant and embarking on a high-level investment programme. 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. High-pressure boilers offer a very high amount of energy output per unit mass of sugar cane. The two factories at Reunion Island produce firm power using boilers, operating at around 82 bars, and export electricity to the grid at a rate of about 110 kWh per tonne of cane [3]. Triangle Limited and Hippo Valley have not been able to export any electricity at all recently. It is also noted that each plant in Reunion processes around 900 000 tonnes of cane per year, compared to Triangle's 2.5 million tonnes per year and Hippo Valley's 2.2 million tonnes per year. On average, the Zimbabwean plants produce 32-44 kWh per tonne of sugar cane crushed [3, 11].

Cogeneration technologies offer higher efficiencies. Improving their efficiency will result in benefit to the environments by reducing the amount of emissions for a

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given energy output. Power generation from primary fuels can achieve 15-55% efficiency. However sugar factories can use sugar processes as a sink to generate electricity at around 75% energy efficiency. Turbine efficiencies range from 70-88% and steam temperatures are normally limited to 525

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C [9]. These are the inherent advantages of cogeneration that exist in all sugarcane processing industries. Full-scale cogeneration at the sugar factories in Zimbabwe will improve energy efficiency towards the higher values and hence benefit the environment. There is room to consider new cogeneration technologies offered by many companies in order to evaluate economically feasible options that will enable optimal utilisation of bagasse. The objective should be to lower plant costs, ensure higher rate efficiencies, improving process energy balance and maximising power plant efficiency simultaneously. This would entail investment

in the modernisation of boilers and alternators. Gasification technology can be used to enhance the use of bagasse in the production of electricity in 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 about 14 kWh per tonne 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 [1]. In the case of Zimbabwe, the potential power capacity in the sugar industry has been estimated to be about 210 MW and about 517 GWh of bagasse generated electricity for export to the grid, using the Reunion example. Gasification technology can raise this export potential from 517 GWh to at least 1692 GWh [7.8].

Vacuum filters are currently used to separate juice from the mud underflow of the clarifier. Bagacillo (fine bagasse particles) is used as a filter and this causes pollution and contaminates the juice. The process is cumbersome, occupies a large working area and leaves a significant amount of sugar in the filter cake. The decanter centrifuge for solid-liquid separation is very effective in separating solids from sugar bearing liquid, without using bagacillo and with low sugar loss in the cake. The technology requires small space, saves power and is a neat/clean operation. Bagacillo can then be used as boiler fuel. The Low Pressure Extraction System brings down operating pressure by about 10% of that required in conventional sugarcane juice extraction systems and saves electric/motive power by about 40% in addition to lower maintenance costs. Such savings translate into electricity that can be directly exported to the grid. These are some of the experimental technologies, which can be tried in Zimbabwe also [8].

#### 4.2 Bagasse Electricity for the Grid is Technically Feasible in Zimbabwe

Hippo Valley and Triangle Estate have a unique advantage when compared to other sugar industries in that they can operate for 9 to 10 months every year, while some sugar factories rarely operate beyond 7 months. The use of coal in firm power plants would be minimal. It is estimated that more than 5% of Zimbabwe's electricity supply can be from the sugar industry, if all the sugar power plants are converted to firm power plants, which export power to the grid throughout the year. Both Hippo Valley and Triangle Estates have enough cane crushing capacity to match the bagasse requirements of a large power plant. The current plans are for intermittent power export to the grid when good prices are offered. Such type of power import is not very efficient for the utility. There is a need to consider moving toward continuous power supply to the grid during the crop season by using coal whenever bagasse runs out. The most mutually beneficial solution would be to go for firm power supply, that is ensuring

power supply throughout the year, including the off-crop season. Coal, which is plentiful at the two local collieries, can be used to supplement bagasse in the firm power plants. The main challenge is that the utility company requires the Independent Power Producer (IPP) to provide power at the required levels and with a high level of reliability. On the other hand, the IPP wants an assurance from the utility that the pricing policy is good enough to enable it to meet its long-term marginal costs and make a reasonable profit. This requires that a detailed long-term contract be put in place in order to meet the interests and requirements of both parties. A power purchase agreement is critical in order to encourage investment in the power sector as well as to ensure the security of the independent power producer. From the Mauritius experience, intermittent power production is very inefficient and should generally be discouraged in favour of continuous and ultimately firm power production. The long-term strategy on grid export of bagasse energy should therefore focus towards firm power production and 20 to 30 year power purchase agreement contracts [3].

#### 5. SETTING ELECTRICITY TARIFFS THAT ATTRACT INVESTMENT IN THE POWER SECTOR

There needs to be pricing policy agreement between the sugar industry and ZESA if any power plant developments in this sector are to take place. Investments in bagasse energy development in other countries indicate reasonable payback in bagasse cogeneration plants at a price of 5 to 7 US cents per unit [5, 6]. In Zimbabwe it would be difficult to offer such prices given the current government controls and economic reality. Also the fuel cost structure is different and coal is available locally. However, there is a possibility to set the price at a level that can attract investors into the power sector, taking into account the true local cost structure. There may be a need for an independent regulator to step in and decide on clean energy pricing [5]. While it is realised that a competitive market works well when there is excess capacity, which is not the case in the Zimbabwean power sector, an independent regulator and ZESA, working within government set policies, can help to create the desired excess capacity and ensure that the prices are not beyond the consumers' paying capacity.

A top-level technical committee on energy investment would enable swift and equitable facilitation of a power purchase agreement. Currently this is the main hindrance to investment in bagasse power. The situation is worsened by the fact that government effectively controls the tariff structure. A policy on a tariff structure that covers the long range marginal cost and guidelines on power purchase agreements need to be put in place urgently. This alone could attract independent investors into the power sector. The purchase price for bagasse-generated electricity could also be set as a percentage of the electricity tariffs of the utility. If the set price does not cover the cost of investment in new bagasse power projects, the government should

consider paying a premium price for the clean energy generated using bagasse, while at the same time offering import duty exemptions for investment in energy saving technologies in the sugar industry. Electricity subsidies should be avoided. Where necessary, subsidies can only be considered on the basis of detailed research. Load limiters can be considered for low-income groups. The participation of various stakeholders in tariff setting should be clearly limited to consultations by the regulator and big companies and commercial concerns should not be allowed to influence

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tariffs in their favour.

#### 6. STRENGTHENING INSTITUTIONS THAT FACILITATE BAGASSE ENERGY INVESTMENT

A high level of participation by government can ensure the success of bagasse cogeneration projects. In the case of Mauritius, the setting up of a High Powered Committee, chaired by the Minister of Agriculture and consisting of Minister of Energy, Minister of Finance and Minister of Economic Planning and Development marked the beginning of successful policies and programmes in bagasse electricity development. Top officials in the ministries, the Joint Economic Council, the Mauritius Chamber of Agriculture and the World Bank, supported this Committee. Policy and projects for bagasse energy development were henceforth successfully developed [2,3]. Zimbabwe can learn from such institutions how best it can tackle bagasse energy development. It is also noted that such a top level Committee would need to link up to investors through technocrats. The breakthrough in the Mauritius case was the setting up of the Technical Committee in 1995 under the Ministry of Public Utilities. This is chaired by the Secretary for Energy and is comprised of top officials from the Mauritius Sugar Authority, The Central Utility Company, and Ministry of Finance and from the Ministry of Economic Planning and Development. The Committee's main purpose is to avoid delays in the implementation of bagasse energy projects [3]. This kind of a committee enhances the facilitative role of government in contractual agreements and in expediting of project approval. A similar institutional arrangement should be set up in Zimbabwe. The secretary for Mines and Energy ministry could head such a technical committee in Zimbabwe and it would include representation from the Zimbabwe Sugar Association, ZESA and other officials of the relevant ministries. One important role of the technical committee would be the facilitation of power purchase agreements.

There should be streamlined policies that ensure maximum benefits to Zimbabwe's sugar industry from International Emission Trading (IET), the Clean Development Mechanism (CDM) and Joint Implementation (JI) in the Kyoto Protocol [18]. Support from the World Bank, the Global Environmental Facility (GEF) and other related financiers can also be targeted. One of the main challenges in the development of

bagasse-based power is the provision of low interest loans and soft loans in order to enhance the viability of new investment projects. There is a need for the government to make some arrangements to offset bad debts incurred by such investment. While some countries like Zimbabwe and South Africa, might find economies in the production of electricity from coal, mitigation of carbon dioxide emission would be a strong factor in favour of bagasse-based cogeneration. Furthermore, coal resources are finite and cannot ensure sustainable development in the long-term. Setting a base for bagasse energy development would offer a sustainable energy source. Burning coal also emits sulphur oxides, which cause further deterioration in the environment. The mechanisms described above can be used to offset some of the costs incurred when investing in bagasse power plants. Besides the use of bagasse and coal in sugar-related power plants, the use of cane field residues as supplementary boiler fuel is another area open to more exploration, experimentation and research [3].

#### 7. WIDENING EQUITY STRUCTURE IN THE BAGASSE POWER SECTOR

There should be a policy that encourages the utility company ZESA to form joint ventures with the sugar industries. This will improve the level of trust between the companies. The government should set clear policies and laws, which can attract investment in the power sector. Furthermore, there should be a process to encourage the setting up of power plants as separate entities from the sugar plants. These should be encouraged to provide continuous or firm power to the grid. It seems from experiences in Mauritius, that there is an argument for creating the Power Plant as a separate entity from the sugar plant [2, 3, 6, 14,15]. This enhances transparency of the operations and can stimulate more efficient production methods by the two separate, but dependent entities. A critical area would be the need to monitor the price of bagasse, so that it does not render the power plant non-viable. The sugar companies also tend to prioritise investment in field operations, like mechanisation, irrigation systems and the laying of infrastructure in order to improve cane production. This gives further argument to the need to spin off power plants. Probably continuous or firm power plants can be set up as separate venture companies, where the sugar factory can have total or partial equity. These ideas can be coupled with the policy to encourage equity participation by workers, millers, and planters and by the utility in the power company. The small scale farmers can also be encouraged to take part in the sugar industry as growers and shareholders in the power plants. This will ensure better commitment by key stakeholders.

#### 8. LEGAL FRAMEWORK AND INVESTMENT INCENTIVES

A policy should be put in place, which ensures that there is no government interference in electrical energy policy

implementation. It is noted that the Parliament of Zimbabwe has passed a new electricity act. This has not been implemented yet and it proposes the setting up of a Regulator for the power sector. However the main weakness of the new law is that the Regulator is accountable to the Minister and thus has no "real" autonomy. The regulator should be granted greater autonomy and flexibility. It is highly probable that ZESA will continue to be curtailed in its bid to charge attractive tariffs that can attract investment into the power sector. ZESA should be granted the full responsibility for electricity energy policy implementation.

The profits or at least a large percentage of profits made from selling electricity to the grid should be exempted from taxation, under company tax laws. Company tax payable by planters, millers and by the power companies, can be reduced in order to encourage them to expand their production. Equipment imported by the sugar power sector for grid exported electricity generation and equipment imported in order to improve sugar and power plant process efficiency for the purposes of exporting more power to the grid should be exempted from import duties [5]. The necessary legal provisions need to be put in place. Bonus payments and/or duty refunds in non-power sector imports can be put in place for companies that export specified levels of power to the national grid.

If any project were to take off in Zimbabwe, it would depend on the power purchase agreement. The agreement should span the design life of the power plant, which is normally 20 to 30 years. The agreement should set the minimum level of Giga Watt-hours to be purchased or supplied, specify the contract period, give extension options, indicate required targets for the on-crop and off-crop season, set price levels and related indices, consider bagasse pricing and set all other standard contractual requirements. Aspects like mode

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of payment, energy trade in reverse direction after a shutdown or breakdown, metering, dispute resolution, bonuses and penalties applicable need to be considered. It is necessary to quantify the clean energy proportion and the fossil fuel generated energy proportion in order to quantify environmental benefits of using bagasse. Exchange rate fluctuations need to be factored in. Time should be allocated for power plant maintenance. A contract for the exchange of steam and electricity for bagasse can be drawn up between the miller and the power plant, when they operate separately [3,5].

#### 9. PROMOTION OF BAGASSE ENERGY RESEARCH AND DEVELOPMENT AND HUMAN RESOURCE DEVELOPMENT

There should be a policy on manpower development in the sugar and bagasse power plant industries. There is a need to strengthen the sugar technology courses in boiler making, welding, boiler management, alternator operations, electrical

technology, maintenance and fitting, laboratory techniques and process technology offered at the Masvingo and Bulawayo Technical colleges, Harare Polytechnic and at other technical institutions in Zimbabwe. There would be a need to develop some specialisation in sugar technology at university level. Undergraduate students research projects can be sponsored by the government and by the sugar industry in order to address specific problems. Some M. Sc. Student research projects can be sponsored to conduct research in the sugar industry. Master of philosophy research courses can be similarly sponsored. These can be extended to doctoral studies in the area of sugar processing improvements, efficient bagasse energy generation, thermo fluids, gasification and other related technologies in the industry. There should be a government research policy on methods for improving sugar processing, high efficiency turbine cycles and gasification technology in the sugar industry, involving ZESA, the sugar industry, Scientific Industrial Research and development Centre (SIRDC) and the University of Zimbabwe.

There would be a special need for the sugar companies to offer professional development courses for the existing artisans, technicians, technologists, trainee engineers and engineers. These can be in the form of short courses and attachment programmes. The attachments can be done to the state-of-the-art bagasse power plants in Mauritius, Reunion, India and any other selected countries. Attachments to ZESA Thermal Power Stations would also provide insight and hands-on experience on very large boiler, turbine and alternator systems. This would also help to create a working arrangement with ZESA and to appreciate the utility's workings and requirements. The sugar industry in Zimbabwe offers high salaries and good conditions of service. They have been able to retain good manpower, besides being located in the hot and remote Lowveld of Zimbabwe. They offer cheap accommodation, free utilities, educational support for children and recreational facilities. The companies have good engineering traineeship programmes and are among the very few companies that continue to support university students financially and to promote vocational training of their staff. They have therefore continued to attract the best graduates from Zimbabwean and South African Universities. The manpower requirements of firm plants in Mauritius varied from about 0.5 people per MW for the most sophisticated firm power plant to 1.5 people per MW for the least sophisticated one [3,14]. It is estimated that if the investment in bagasse power sector is to take place in Zimbabwe using sophisticated firm power technology, about 105 people of various grades would need to be employed.

## 10. CONCLUSION

Sugar factories in future have to co-generate heat (steam) for sugar processing and power (electricity) for normal usage in a factory and beyond. The Mauritius case shows the need



for clearly defined government policy, plans and policies for the sugar industry that emphasise cogeneration, laws that promote the policies and plans, creation of deliberate incentives like energy pricing. It is noted that cogeneration for export to the grid in the sugar industry will help to save investment costs by the national utility, will allow for the modernisation and rehabilitation of the sugar industry in Zimbabwe. In addition it can result in large foreign currency savings by substituting imported electricity. Efforts towards exporting electricity to the grid in the sugar industry in Zimbabwe cannot be divorced from the need to improve sugar processes. This can be done by carrying out energy management audits, cleaner production audits and improving the factory processes based on the findings of these audits. Modernisation, rehabilitation and constant improvement of sugar factories can result in massive energy savings, ever improving efficiencies and more energy exports to the grid, bringing in more revenues and profits.

The need to replace power plant at both sugar factories in the near future should provide a window of opportunity to explore that avenue. The plants need to raise their power production rates from 32-44 kWh to close to 250 kWh per tonne of cane crushed. The possibility of gasification to raise this rate to close to 500 kWh per tonne of cane should be explored in the long term as part of research and development initiatives. This way more than 1692 GWh could be exported to the grid every year, bringing in more than US\$ 46.53 million as revenue at current power purchase prices [9]. This would also represent foreign currency savings due to substitution of imported electricity. The reality on the ground is that 3 firm power plants and 7 continuous power plants in Mauritius have been able to generate 216 MW from a maximum of 6 million tonnes of cane [3], while in Zimbabwe the power plants using about 4.7 million tonnes of cane can only generate about 40 MW. They have the potential to generate at least 210 MW of electricity if modern firm power plants are put in place [7].

The benefits in bagasse-based cogeneration in Zimbabwe can be justified in terms of avoided tonnages of coal, avoided net emissions of carbon dioxide, avoided coal ash, bagasse ash used for soil fertilisation and other additional benefits when gasification is introduced. Using modern firm power plants, bagasse energy projects would avoid the use of 293 750 tonnes of coal a year, the emission of 885 000 tonnes of carbon dioxide and 47 000 tonnes of coal ash [9]. However, the overriding factor will be the economic feasibility of investing in such power plants. The level of, the power purchase price, government subsidisation if necessary, donor support and the other factors discussed in this paper are very serious determining factors in the success of bagasse energy cogeneration in Zimbabwe. On the other hand, the sugar companies need to play a proactive role. If sugar prices continue to fall, their survival and viability will depend on diversification into by products like electricity.

It is imperative that the Government of Zimbabwe, ZESA and the sugar companies vigorously pursue bagasse power plant projects as a team and that they ensure their success. Zimbabwean consumers, particularly commerce and industry are prepared to pay full cost tariffs in order to ensure reliable and stable power supplies. The other advantage of co-

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generators as small to medium-scale IPPs is that they supply power at the distribution level and hence there are no transmission losses. This is a major advantage to the utility as the purchaser since power is fed at the load centre. ZESA can use this argument to create an incentive to promote cogeneration in the sugar and other industries. While this paper has presented cogeneration issues in the sugar industry, it is noted that similar issues would need to be considered for cogeneration in the wood industry using wood waste and plant biomass, for processing factories that use oil or coal to fire large-scale boilers to meet process steam requirements and for other thermal power plants that have the potential to raise steam for industrial purposes. These areas are candidates for potential study in the future.

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