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Bagasse Energy Cogeneration Potential in the South African Sugar Industry

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Abstract *– the paper explores the potential energy cogeneration effect of bagasse in the South African sugar industry. At the present moment very few sugar mills are exporting surplus electricity generated to the national grid. There is a need to take advantage of the abundant bagasse that is produced from the sugar industry through more efficient combustion processes to co-generate process steam and electricity for the supply to the grid. The industry also needs to take advantage of available technologies to efficiently generate electricity from bagasse using high pressure steam boilers. Using the current available technology the industry has a potential to produce about 3000 GWh per year and this is about 1.3% of the current generating capacity in South Africa. This translates to a generating capacity of 343 MW. Application of Integrated gasification combined cycle can result in 11000 GWh and this is about 5% of the current generating capacity at Eskom. In terms of MW this is equivalent to a generating capacity of 1255 MW. The other benefit derived from cogeneration is the1.619 kilo tonnes reduction in the use of coal which also translates to 2.84Mt of carbon dioxide. The cogeneration project will also improve the competitiveness of the sugar industry provided a viable price per KWh of electricity is agreed upon.*

Keywords – bagasse, cogeneration, electricity, sugar industry

1. INTRODUCTION

South Africa is currently faced with a serious shortage of electricity resulting in load shedding, which has negatively affected the operations in the domestic, industrial and mining sectors. Load shedding is the last of a number of interventions taken to reduce demand in a system emergency situation. The risk of load shedding will remain high until at least 2013 if immediate actions to alleviate the crisis are not put in place. Specific immediate and long term measures need to be put in place to avoid these power outages. South Africa has seen significant levels of growth in electricity consumption. Eskom has resorted to increasing the amount of electricity imported from Cahora Bassa in Mozambique. The power utility has also come up with demand side management practices set to save 3000 MW by 2012[1]. There are also plants to build more thermal power generating plants. The fight against global warming has intensified efforts and emphasis on the use of renewable and clean energy as an alternative to the more polluting fossil deposits. The study also aims to show the potential reduction on the green house gas emission as a result of the use of bagasse to generate electricity in South Africa. The use of bagasse is both a way to improve the amount of electricity generated in the country and also to reduce the green house gases. The idea is to encourage the adoption of renewable energy sources as alternatives to the conventional fossil fuels that are mainly used for electricity generation.

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2. CURRENT ELECTRICITY GENERATION

Eskom has a total net generating capacity of 38 736 MW from 11 operating coal-fired power stations, and a further 2,300 potentially available from two plants which are currently being re-commissioned [2]. Eskom operates Africa's only nuclear-powered plant at Koeberg near Cape Town and smaller gas/liquid fuel turbine stations, hydroelectric and pumped storage schemes. Eskom generates 95% of the country’s energy demand. Early this year (2008), Eskom had to cut electricity to the country's mining industry after a shortfall of 400 MW, threatened to collapse the country's entire electricity network.

Station	**Type**	**Capacity MW**
Kendal	Coal fired	3840
Majuba	Coal fired	3843
Matimba	Coal fired	3690
Lethabo	Coal fired	3558
Tutuka	Coal fired	3510
Matla	Coal fired	3450
Duvha	Coal fired	3450
Kriel	Coal fired	2850
Arnot	Coal fired	2020
Hendrina	Coal fired	1895
Camden	Coal fired	930
Grootvle	Coal fired	390

Komati	Coal fired	585
Koeberg	Nuclear	1800
15	Gas/liquefied	925
16	Hydro electric	600
17	Pump storage	1400
Total		**38736**

Table 1. Current generating capacities

Table 1 shows the current generating capacities at Eskom's power stations countrywide. With national power producer Eskom reportedly set to face severe supply-demand challenges within the next three years, electricity cogeneration is emerging as a possible means of reducing industrial electricity demand. If the economy grows according to the government proposed 6% this would mean an additional requirement of 1600MW per year. Eskom also has put up projects to increase its generating capacity. The projects involve new power plants and expansion and refurbishment of existing stations to increase power generated. To ensure supply reliability, Eskom plans to generate an additional 22000 MW by 2017 [1]There are also plans to construct more power stations and to increase generating capacity of existing stations in order to meet the projected demand in electricity in the future. Table 2 shows the planned stations to be put in place until 2017

Project	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Camden (return to service)	390	390								780
Grootvlei(return to service		585	585							1170
Komati(return to service)		120	140	320	285					965
Ankerlig(open cycle gas turbines)	589		740							1329
Gourikwa (open cycle gas turbines)	439		296							735
Arnot Upgrade (Coalfired	75	60	60	30						225
Medupi (Coal-Fired)						798	1596	798	1596	4778
Ingula (Pumped storage)						666	666			1332
Bravo (Coal-fired							803	1606	803	3212
Wind Farm (Renewable				100						
Co-generation*			500	1000	1000	1000				3500
IPP (OCGT)				1000						1000
Annual Total	1493	1155	2421	2450	1285	2464	3065	2404	2399	19136

Table 2. Proposed power plants expansion

2. THE SUGAR INDUSTRY AND BAGASSE IN SOUTH AFRICA

The South African sugar industry is one of the world's leading cost competitive producers of high quality sugar, producing an average of 2.5 million tons of sugar per annum. It is an industry which combines the agricultural activities of growing sugarcane with the industrial factory production of raw and refined sugar and makes a significant contribution to the national economy. This partnership between growers and millers forms the basis of the industry's structure in South Africa. [3]. The sugar cane is supplied to 14 mills in South Africa were it is processed to sugar and also resulting in the production of bagasse. Bagasse is the fibrous biomass remaining after sugarcane stalks are crushed to extract the juice [4]. This waste product can be used to produce significant quantities of surplus electricity. Some of the sugar cane milling plants are undertaking cogeneration of electricity from bagasse but mainly for their own consumption and a small amount is exported to the national grid. Table 3 shows the sugar production levels for South Africa for the past 8 seasons

	Sugar cane production (tonnes)
1999/2000	21 223 098
2000/2001	23 876 162
2001/2002	21 156 537

2002/2003	23 012 554
2003/2004	20 418 933
2005/2006	19 094 760
2006/2007	21 052 266
2007/2008	19 724 000
Average per season	21 194 789

Table 3: Harvested sugar cane in South Africa

Companies like Tongaat Hullets are already making use of this bagasse for cogeneration of electricity. The plants utilise the existing boilers and back pressure turbo-alternator capacity. The mills derive their process steam requirements from turbine exhaust and direct steam make up via pressure reducing valves. Diverting more steam through the turbines creates surplus electricity [5]. Given this background the paper presents the potential energy cogeneration potential in the South African industry. This is in line with the efforts to improve the electricity supply situation in South Africa.

2.1 CURRENT USE OF BAGASSE IN SOUTH AFRICA SUGAR INDUSTRY

In South Africa coal constitutes about 92.8% of electricity generated in South Africa, 6.7% is from nuclear energy whilst the remainder is from biomass, hydro energy and gas [6]. According to Tongaat Hullets Sugar Company every 100 tonnes of sugarcane harvested and milled produce 10 tons of sugar and 28 tonnes of bagasse. [5]. The mills then use portion of the bagasse in a low efficiency steam cycle to produce the electricity and steam for their own use. Excess bagasse is then used to produce electricity for export. Tongaat Hullets own bagasse power generating facilities at Maidstone, Amatikulu and Flexiton mills. The boiler plant consists of standard thermal cycle steam boilers with turbo alternators operating in back pressure mode. The exhaust steam is then used for processing of sugar. The installed capacity for the Tongaat generating plant is 72MW. The plant export 8.5 Mw to the national grid and this is 12% of the installed capacity at the plant. The bagasse cogeneration technology that is widely in use in the South African sugar industry is the direct combustion. In direct combustion fuel is fired into boilers to produce high pressure steam which drives a team turbine. And the turbine in turn drives the electric generator. The process is the same as the one used for conventional fossil fuels like coal. In the direct combustion turbine system power generation efficiency increases with increase in temperature and pressure meaning that large scale power plants have to set up large scale expensive heat resistant facilities in order to achieve high power generation. The power output in the South African industry per tonne of sugar cane crushed is approximately 30 KWh.[r} This gives a high room for improvement in terms of generating efficiency for the sugar industry in South Africa . This can be achieved through the application of more efficient cogeneration technologies that are now available. The integrated gasification combined cycle (IGCC) can also be applied to the sugar industry in order to increase its power generating efficiency. The IGCC technology employs more than one thermodynamic cycle. The result is high generating efficiency as compared to direct combustion effects. The IGCC technology can achieve up to 250- 500KWh/ tonne of sugar cane crushed [7] [8]

2.2 THE CALORIFIC VALUE OF BAGASSE

The gross calorific value (GCV) of dry bagasse has a mean value of 19605 KJ/kg. The gross calorific value (GCV) of wet bagasse is based on the composition of wet bagasse. Water has no calorific value and it also absorbs heat being vaporized during combustion. The combustion reactions of bagasse as a fuel are as given in Table 4. The net calorific value of bagasse, with around 48% moisture content is about 7670 KJ/kg. [8].

Constituent	Mass (%)	Oxygen Required (kg)	Product	Mass of Product (kg)
Carbon	22.5	0.6	CO2	0.825
Hydrogen	3	0.24	Water	0.27
Nitrogen	-	-	Nitrogen	2.01
Oxygen	23	-	-	-
Water	50	-	Water	0.5
Ash	1.5	-	Ash	0.015

Table 4: Combustion reactions for bagasse

3.0 THE BAGASSE COGENERATION POTENTIAL IN SOUTH AFRICA

The South African sugar industry crushes an average of 21 194 789 tonnes of sugar cane per year. This amount of sugarcane in turn generate 5 934 543 tonnes of bagasse. The energy conversion factor for the current power plants is 0.25[6].The energy conversion efficiency in Mauritius is 0.27. The energy conversion factor achievable from IGCC energy conversion factor for the current power plants is 0.25[6].The energy conversion efficiency in Mauritius is 0.27. The energy conversion factor achievable from IGCC assuming that it produces 500KWh/ tonne [7][8]of sugar cane is 0.92. The energy to power conversion is based on the standard energy conversion factor:

IKWh =3.6MJ. Table 3.0 shows the calculated potential cogeneration of the bagasse that is produced in South Africa under three different technologies, that is the present technology in South Africa, The best available technology from Mauritius and best available technology using IGCC.

3.0 RESULTS

The results of the potential energy calculations show that South Africa has the potential to produce in excess of 3000 GWh per year using the current technology. This is shown clearly in Table 5.

Technology	**Annual tonnage bagasse kilo tons**	**Average NCV of bagasse MJ/ton**	**Potential energy 1000MJ**	**Conversion to power equivalent MWh**	**Power generation potential MWh**
Direct combustion (current technology)	5 935	7 670	45 517 948	12 643 874	3 160 969
Best available technology from Mauritius	5 935	7 670	45 517 948	12 643 874	3 512 187
Best available technology	5935	7 670	45 517 948	12 643 874	11 632 364

Table 5. Results of cogeneration using different technologies

This is shown in table 4 below. This is about 1.36% of the current generating capacity. There is no significant increase as a result of using the technology available from Mauritius. The use of the best available cogeneration technology can generate 11 632 GWh and this is approximately 5% of the current generating capacity. Thus bagasse cogeneration can significantly increase the power generated in South Africa if applied. The current electricity generation in South Africa consumes 119 113 000 tonnes of coal per year to produce 232 443 GWh electricity per year and in the process emitting 208.9 Mt of carbon dioxide. [1]. The use of bagasse can substitute 1 619 kilo tonnes of coal and in the

A huge amount of capital is obviously required to reap the benefits of the cogeneration potential of bagasse. There is need for capital to set up new cogeneration plants and to expand on the existing ones. The current sugar plants require conversion to accommodate condensing turbines and this requires significant capital injection. The success of the project also depends on a viable unit price for the sale of electricity generated from cogeneration. The cost of electricity from cogeneration will be more expensive than that from conventional fossil fuels Electricity from cogeneration would invariably be more expensive than the average Eskom charge tariff, since much of Eskom's infrastructure is already fully depreciated, while opera-ting costs are lower. Cogeneration would also involve more capital expenditure per unit since plants would produce smaller amounts of electricity than coal-fired power stations. [10]. Electricity costs in cogeneration mode range from \$0.04 to \$0.09/kWh., that is about R0.3 to R0.68 in terms of South African rand. Electricity cost from new gasification plants is around \$0.10-\$0.13/kWh, which is R0.75 to R0.98 but with significant reduction potential in the future [12]

3.4 Expected benefits of Cogeneration in South Africa

The abundant energy from bagasse can help compliment the present generating capacities of coal plants in South Africa, there by helping meet the local power demands

Electricity from bagasse is renewable. The substitution of coal a fossil fuel with bagasse will save the non renewable coal deposits

There is significant reduction in the emission of green house gases specially carbon dioxide when bagasse is used instead of coal. The use of biomass is said to green house gas neutral that is only releasing the gases the plant absorbed. [6].

Bagasse energy projects enhance sugar factory modernisation because boilers, turbo alternators and other energy efficient equipment are the major contributors (Up to 50 %) of the cost of a sugar factory. Therefore investing in energy projects means that this part of the investment crucial to sugar processing will be financed independently of sugar activities.

The cogeneration activities will increase the competitiveness of the sugar industry, including the cane growers. This is due to more revenue from the sale of electricity. Decreasing sugar prices on the international market due to trade liberalisation and commitments at WTO means that the industry should exploit the by products for long term viability. [11]

3.5 Challenges to bagasse cogeneration in South Africa

The determination of a viable price per unit of electricity generated from cogeneration. A higher price than that for electricity from coal is imperative in order to lure investors in the project.

Conversion technologies for renewable energy can not compare in terms of cost with conventional fuels at the moment.

The seasonal availability of bagasse means that there is need for storage of the energy source or alternative fuel source when the bagasse is out of season

Dealing with technical issues with regard to protection systems when exporting to the grid, these include lightning and cane fires in the Natal areas

There is need for allocation of bagasse to other uses like animal feed. So not all bagasse can be directed to cogeneration

4.0 Conclusion

The potential for electricity cogeneration in South Africa is very high. There is only need to for enough capital to source appropriate technology for the energy conversion of. bio energy to electricity. A viable price unit per unit of electricity generated from cogeneration has to be expeditiously agreed upon in order to encourage the private companies to invest in this project. There is also need to carry out a detailed feasibity study and a reliable cost estimate for the bagasse power plants before the projects are embarked on .bagasse cogeneration is there to reduce the power problems being faced in South Africa if taken seriously. The country should borrow experience from Brazil, Mauritius, and Australia where cogeneration has been embraced and benefits being enjoyed

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