Sugar Cane Bagasse Energy Cogeneration – Lessons from Mauritius

by

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Paper Presented to the Parliamentarian Forum on Energy Legislation and Sustainable Development, Cape Town, South Africa (5-7 October 2005)

Executive Summary

Sugar cane is a major commercially grown agricultural crop in the vast majority of countries in Africa. It is one of the plants having the highest bioconversion efficiency of capture of sunlight through photosynthesis and is able to fix around 55 tonnes of dry matter per hectare of land under this crop on annually renewable basis. Under current practice, 50% of this dry matter are harvested in the form of cane stalk for sugar recovery with the fibrous fraction therefrom in the form of bagasse meeting, through combustion, energy requirements for the process. Cane production in Mauritius varies between 5.0 to 5.5 million tonnes, 35% of which are produced by around 28,000 small growers. Between 550,000 to 625,000 tonnes of sugar are recovered from the cane.

A number of countries, in particular those devoid of any fossil fuel, have implemented energy conservation and efficiency measures so as to minimise cogenerated energy (steam and electricity) utilised in cane processing and to export excess electricity to the grid. In Mauritius 10 out of 11 factories are exporting electricity to the grid during crop season out of which three are using coal as a complementary fuel to export electricity during the intercrop as well. Such electricity (725 GWh including 318 GWh from bagasse accounts for 40% of the total amount generated. All the power plants are privately owned. This development has been possible through the participation of all the stakeholders (corporate and small planters) with Government providing appropriate policy guidelines, legal framework and incentives.

There is thus potential for replication of this successful experience to other sugar cane producing countries in Africa. The current cane production is around 90 million tonnes. A potential for around 10,000 GWh exists from this annually renewable resource considering the conversion efficiency achieved in Mauritius.

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Background

The sugar cane crop has been occupying a prominent position in the Mauritian economy over the years since its introduction by the Dutch in the seventeenth century. After trials on a number of crops, it has been found to be the best crop suited for the agroclimatic conditions in the island which includes frequent visit of cyclones. Sugar production has increased over time to reach a plateau of around 600 to 650,000 tonnes, export markets and arable land area putting a limit to this production. The sugar industry is a major net foreign exchange earner but its relative contribution in the economy has been declining with the development of the tourism and manufacturing sectors. However, the agro-industrial nature of the sugar cane gave Mauritius an industrial base that enabled the island to become a semi-industrial society. It is recognised by all stakeholders (Government and the industry at large) that a viable sugar industry is essential to continued economic growth and social stability.

2. Mauritius, as a member of the ACP countries, enjoys a ready market for its sugar under the Sugar Protocol of the Lomé Convention. Around 506,000 tonnes (or 90%) of sugar produced are exported under this trade agreement. 7% of the production are sold to the United States and 4% to other markets. 85% of the price is obtained for around 40,000 tonnes of sugar sold under a special preferential sugar agreement as from 1995 with the entry of Portugal into the European Union.

3. The island of Mauritius has an area of 1,860 km^2 and a population of 1.3 million with a per capita income of US$3,710 in 1998. Two distinct groups of growers own the total area under cane. The miller-planters, having a majority share in the milling companies, and large planters hold 65% of the cane area, the individual size varying between 700 to 5,500 hectares and this group produces 60% of total sugar. The other group comprises of around 28,000 independent growers holding plot sizes between 0.1 to 10 hectares. 90% of this group own less than 2 hectares and are part-time farmers. The independent growers and the miller-planters are entitled to 78% of their sugar and the totality of the molasses and filter mud. The millers obtain 22% of the sugar as payment for milling.

The Sugar Sector Action Plan

4. Until the year 1975, sugar production grew steadily to meet rising demands in the guaranteed market which was also associated with rapid price increases. In the subsequent years prices start to fall and the industry profitability and even its viability were threatened. The major cause of this threat was due to Government policies, in particular, the increase in sugar export tax in 1979 coupled with climatic conditions (cyclones, and drought). These developments became a matter of concern and, as a consequence, Government in consultation with the private sector worked out a Sugar Sector Action Plan to restructure the industry targeted at maintaining its viability and at modernising production both at field and factory levels. Industry operations were also

rationalised at a national scale. This plan provided for export duty relief and rationalisation cane milling activities (two small mills out of a total of 21 were closed in1985). These measures impacted positively on profitability of the industry and investments were made to modernise production both at field and factory levels.

5. Additional policy initiatives were designed by Government in 1988 to bring further improvements in the viability and efficiency of the sugar sector. However, while Mauritius had an assured export quota under the Sugar Protocol, price paid by the EC countries were linked to developments in the EC Common Agricultural Policy. Price decreased to the tune of 2% yearly since 1988 and it was difficult to predict the rate of price declines over the ensuing period. Under these circumstances, the industry was already adjusting to those developments. For example, more emphasis was laid on:

(i) production of speciality sugars which fetches a price premium;

(ii) increase in yields through introduction of improved irrigation techniques, adoption of mechanisation and derocking of lands;

(iii) centralisation of cane milling activities involving consolidation of cane processing in mills with higher capacity;

(iv) research to increase productivity in field operations coupled with introduction of high yielding varieties; and

(v) last, but not least, improved use of by-products such as bagasse and molasses which will help to diversify revenue basket sources and reduce industry's vulnerability to sugar price shocks.

The Sugar Industry Efficiency Act (1988)

6. Further incentives were provided to the industry in 1988 in the Sugar Industry Efficiency Act whose objective was to provide for an efficient and viable sugar industry while seeking to promote agricultural diversification and diversification within sugar. The Act essentially brought about the reduction of the nominal export duty rate and an increase in the exemption limit on the duty. A system of performance linked export duty rebate was introduced wherein incentives were provided for improved sugar recovery, enhanced use of bagasse for electricity production and use of marginal cane lands (interline and inter-cycle rotational land) for the production of crops other than sugar. Amendments to the Income Tax Act provided incentives to produce speciality sugars, save energy in cane processing and use bagasse to produce electricity.

7. Government in partnership with the private sector initiated a bagasse energy development programme to address the Sugar Section Action Plan's agenda on use of by-products in the sugar industry. A high-powered committee on bagasse energy development, chaired by the Minister of Agriculture was set up and it included the Ministers for Energy, Economic Planning and Development, Environment and Land Use,

and Cooperatives and the Financial Secretary. This Committee also guided the work of a Technical Committee chaired by the Financial Secretary, with representation from relevant Government Ministries and agencies, the sugar industry and local research organisations. The setting up of this committee in 1991 also coincided with events in the Gulf area threatening supply of fuel derived from fossil resources.

Energy Status

8. Mauritius has limited renewable energy resources and no known oil, gas or coal reserves. Its main locally available energy resources are hydro power and sugar cane biomass (bagasse and cane tops and leaves). Hydro - power is almost fully exploited with its nine hydro stations including one with 10 MW installed capacity. The other resource, sugar cane bagasse which represents 30% on cane was being generally used inefficiently to meet internal power requirement for cane processing. Hydro power and power exported to the grid from sugar factories amounted to 22% and 13% of power supply to the public grid in the year 1990. The remaining 65% was met from imported fossil fuels (diesel, coal and gas). It was felt that a rapid increase in fossil fuel import could be prevented by a more efficient exploitation of bagasse energy for electricity generation.

Evolution in Energy Demand

9. There had been a sharp increase in energy consumption associated with high levels of economic growth involving the rapid expansion of the export processing zone and the tourism sector. Power demand in the residential sector also increased as indicated by marked rise in sales of household appliances. In the period 1985-1990 annual increases in electricity consumption and maximum demand averaged over 11 and 9.5% respectively. The average economic growth was 6% but the EPZ and tourism sectors were expanding at a much higher rate so much so that the Ministry of Energy had to revise the forecast in energy consumption to 10% for the period 1988 – 1992.

10. In order to meet the increase in demand of electricity, three investment options were available. Firstly, the utility could add 2 units of 24 MW each to its existing 4 units. Secondly, it could invest in a 40-50 MW coal plant. The third option would comprise of bulk purchasing of power from 2 x 22 MW bagasse cum coal plants, to be privately operated by sugar companies at 2 regional sugar factories. This third option would displace public sector investment. This third option was the economically preferred option.

Linking Bagasse Energy with Sugar Production

11. This project of bagasse energy development was a logical extension of Sugar Sector Action Plan wherein Government and the private sector participated in the restructuration process of the sugar industry given that enhanced use of by-products, including bagasse for electricity production was a key objective in the plan. Furthermore, the active participation of the private sector with Government in formulating all the

policy measures coupled with appropriate enactments enumerated brought about an improved business environment for the sugar sector. In 1990, the industry presented a programme of investment of the order of US$130 million for sugar factory rehabilitation and modernisation, irrigation and diversification. Of this amount, around US$27 million was meant for bagasse saving and handling operations, expansion of the industry's capacity to generate electricity and pollution abatement.

Objectives of Bagasse Energy Development

12. Government formulated a bagasse energy development programme in partnership with the private sector over a 6-month period in 1991 on the basis of the recommendations of the High Powered Committee on Bagasse Energy[1]. The programme had two main objectives:

(i) to optimise the use of bagasse for electricity generation and export to the grid. Over the 5-year period to expand electricity generation using bagasse from 70 GWh and 120 GWh, that is a 22 MW bagasse-and coal;

(ii) to investigate into uses of other fractions of the sugar cane biomass (cane tops, leaves and dry trash) for electricity generation which would further add to amount of electricity export to the grid with the concurrent reduced dependance of fossil fuel.

This programme aimed at maintaining the long-term viability of the sector, increasing investment in rehabilitation and modernisation and rationalising the industry operations on a national scale. It was meant to ensure the continued viability of the sugar sector and sustainability of production to meet industry's commitment under the preferential sugar market.

13. The national objective was to develop other sectors of the economy – EPZ and tourism which are energy intensive activities. As a consequence energy demand was to increase. Inefficient use of bagasse implied import of fossil fuels. Alternatively efficient use of bagasse for energy export to the grid will bring additional revenue to the industry. At the same time, the industry will save on the investment on boilers and turbo alternators which represents almost 50% of the investment of the sugar factory.

14. The project required investment to the tune of US$80 million (1991 prices) in:

(i) erection and commissioning bagasse cum coal fired power plants at 2 sugar factories;

(ii) modernisation of sugar factories to improve the efficiency of bagasse use in sugar cane processing;

(iii) bagasse transport from cluster of sugar factories to a regional sugar factory located power plant; and

(iv) investments in transmission lines from sugar factories to the national grid.

15. The investments were geared towards promoting regional bagasse/coal fixed power plants. The coal as a complementary fuel would ensure power export to the grid year round in that bagasse supply is limited to the crop period normally 5-6 months duration. The regional location of power plants was the preferred option in that bagasse costs are minimised, the sugar factory benefits from the advantages of co-generation. The activities of a number of large sugar estates in the main cane growing areas are diversified with positive impacts on the social stability of the sugar sector.

Institutional Set up and Project Strategies

16. In the implementation of the project, a regulatory framework was set up to promote private sector investments in power production and sugar factory modernisation and to encourage an efficient market in bagasse. The key elements of this framework were energy pricing and contracting, involving electricity, bagasse and coal. The institutional implementation arrangements addressed the integration of policies and programmes for bagasse energy development with the Government's overall energy production strategy. It also included project management, coordination, monitoring and evaluation. An ad-hoc technical committee was set up (in lieu of the regulatory framework) at the Ministry of Energy to carry out the above activities and it comprised of representatives from the Mauritius Sugar Authority, the Ministries of Finance, Economic Planning and Development. A BEDP coordination was established at the Mauritius Sugar Authority to assist the Management Committee in the tasks of planning and monitoring the implementation of the BEDP and its project components.

17. All the parties, relevant Government Ministries and agencies, the Utility, the private sugar industry stakeholders fully participated in the project right from inception through all stages right from project conception and to implementation through constant interaction and participation. The other specific strategies used by the project management to guarantee achievement of project objects were mainly through incentives provided in enactments by Government which were devised all along the various stages of the project.

Implementation of Bagasse Energy Projects

18. The project stages were as follows:

(i) Government policy defining clearly the bagasse energy option as a means to promote a renewable energy resource available locally.

(ii) Sugar industry to evaluate its energy requirement and optimisation of same through proper investments in measures for energy conservation and use.

(iii) Public utility to spell out its energy demand based on reliable forecast in order to establish its base load requirement over time.

(iv) Memorandum of understanding between utility and sugar company;

(v) Conduct of feasibility study.

(vi) Signing of formal Power Purchase Agreement (PPA) between utility and the private investor.

(vii) Raising of funds for investment in power plant using PPA as the bank guarantee.

(viii) Conduct of a detailed design of project.

(ix) Carry out a tendering exercise for supply of items of equipment.

(x) Evaluate the tenders.

(xi) Award of contract.

(xii) Erect and Commission the power plants.

(xiii) Operate the plants

Constraints to Bagasse Energy Development

19. In spite of all the above measures, it was observed that investments in bagasse saving in the satellite factories were slow. Only 40% of the total amount (US $15 million) of the Sugar Energy Development Plan Loan were disbursed and the rest (US$9 million) was cancelled. In addition investment in the bagasse cum coal plant was not forthcoming. A number of factors was identified which has influenced this state of affairs[2].

Price of Bagasse

20. The progress in the implementation of the power plant at Union St Aubin (USA) sugar factory was slow due, inter alia, to the fact that the plant had to rely on a huge amount of bagasse from the satellite factories. These factories were pricing their bagasse on the price of coal and at the condensation mode of operation. Under these conditions, the efficiency of conversion of steam into electricity is higher compared to that of a condensing-extraction mode of operation which is the usual industrial set up for energy cogeneration in the sugar industry. This price had a negative impact on the financial viability of the project. This issue was resolved through consolidation of cane milling activities whereby the totality of cane was processed in lesser and lesser number of sugar

factories whose cane crushing capacity was increased. The centralised mill invested in the power plants.

Funding and the fiscal framework

21. The energy projects require a relatively huge investment cost that made it not attractive. Hence Government introduced several enactments which allowed investors to raise tax free debentures for the generation of electricity from bagasse and the modernization of sugar factory; to enable them in cases of segregated activities, growing companies to offset losses incurred by millers in respect to the capital expenditure in energy production from bagasse and in the revamp of sugar factories. Furthermore, the performance- linked rebate on export duty was extended to producers of firm electricity who saved and used their own bagasse and also to millers selling bagasse to continuous power stations. A proportion of capital expenditure incurred in the installation of efficient equipment used to enhance bagasse saving and energy generation therefrom was entitled to a refund of export duty payable.

22. Two distinct companies undertake cane growing and cane milling and in most cases the majority shareholder of the milling company is the growing company. Hence the milling company undertaking a cogeneration project is allowed to transfer in any income year any unrelieved loss to the growing company. Moreover, accumulated unrelieved losses attributable to investment, initial and annual allowances in respect of qualified plant and machinery acquired after the effectiveness of the SIE Act 1988 could be transferred to a related planter. Production of electricity from bagasse is one of eligible plant and machinery.

23. Any amount of bagasse used for purposes other than manufacture of sugar is priced at Rs100 (or US$3.7) per tonne and this money is credited by the CEB mainly to a bagasse transfer price fund. The distribution of the proceeds from that fund was modified wherein millers or sugar factory based power companies exporting electricity to the CEB became entitled to benefit from the Fund. This Fund had previously been accruing to growers only.

24. In 1994, the export duty was abolished and concurrently the sugar companies had, as per a Memorandum of Agreement with Government, to segregate growing and milling activities and set up public milling companies. A Sugar Investment Trust (SIT) was created and 20% of the equity shares in the milling companies were sold to planters and workers. Two directors on the Board of the Milling Company would be from the SIT.

25. In 1995, provisions in the new Income Tax Act which were in favour of bagasse energy were retained and, in addition, tax on milling companies was brought down to 15%. The foreign exchange control was removed. All these fiscal measures created investment friendly environment and the decision to invest was left to individual operators.

Centralization of Cane Milling Activities

26. Consolidation of cane milling activities through centralization is one of the means of reducing cost of production. 19 sugar factories were in operation in 1993 and their cane crushing capacity ranged between 55 to 250 TCH.

27. In 1997, Government came up with a Blue Print on Centralization of Cane Milling Activities (Ministry of Agriculture and Natural Resources, 1997) . This Blue Print, besides setting guidelines and conditions to be adhered to in any request and implementation of such closures, emphasizes the need to link such closures with energy generation from bagasse. Eight requests for closures were approved subsequent to the publication of this Blue Print and were generally in conformity with the provisions of this document, where bagasse energy generation, inter alia, occupied a prominent position.

The kWh price

28. Issues related to the kWh price and the Power Purchase Agreement were addressed by a Technical Committee was at the Ministry of Energy. In the price setting mechanism, the Committee worked on the basis of the cost of diesel plant of 22 MW capacity proposed by the CEB to arrive at the avoided cost for the firm power plant. The World Bank provided support to the Committee to work out the principles and the guidelines. This Committee determined the avoided costs and recommended the kWh price for coal and bagasse.

Evolution of Project Implementation

29. The activities related to project implementation were undertaken as planned but there was a delay in its date of completion. It was mainly due to the fact that the investors to finance the Union St Aubin plant decided not to go ahead with their project. At the initial stage, an in-house feasibility was carried which indicated that a 22 MW plant would be economically justified and its cost would be US$23 million. Subsequently the services of a design firm was hired using the investor's own fund. The firm presented a design and its cost was twice that of the initial proposal (about US$51 million or US$2318 per kW installed). This was on the high side for a steam power plant. The consulting firm was requested to improve the viability of the plant and , in 1994 it came with a proposal for a 30 MW capacity plant at a cost of US$59 million. This was equivalent to US$1967 per kW installed. In 1995 the design firm recommended re-designing major components such as the boiler and the turboalternator, to take account of future capacity of the factory and improvements in the thermodynamic cycle of the plant. This new design brought about 30% increase in cost of the previous 30 MW plant design. Under these circumstances, the overseas bank, which was interested in funding the foreign exchange, decided not to fund the project. The promoters of the project decided not to go ahead with the project.

30. Almost immediately after, another company in the North of the island drawing itself on the experience and studies undertaken at Union St Aubin started negociations for

the erection of a 70 MW (2 units of 35 MW each) for firm power export to the grid. After successful negociations for a power purchase agreement with the utility and funds from foreign banks, the company, Centrale Thermique de Belle Vue (CTBV) erected and commissioned the power plant in April 2000. This plant required an investment of US$90 million.

31. The other component of the project related to improvements in mill efficiency thereby to produce surplus bagasse that could be provided to the planned power plant. At the time when the loan was negotiated foreign exchange was a constraint but subsequently Government lifted exchange control thus decreasing the need for World Bank funds right from the start of implementation. At the request of Government, the World Bank cancelled US$9 million of the US$15 million.

Bagasse Energy Projects

32. Table 1 shows the status of the energy projects and it includes technical details on the 10 bagasse-based power plants. The 3 “firm” power plants operate year round using bagasse during crop season and coal during the off-crop period. The so-called “continuous” power plants operate on bagasse during the crop season only.

Table 1: Bagasse based Power Plants in Mauritius up to year 2000

Factory	Tonnes cane per hour	Power	Start Date	Units from Bagasse (GWh)	Units from Coal (GWh)	Total Units from Bagasse & Coal (GWh)
FUEL	270	F	Oct 1998	60	115	175
Deep River Beau Champ	270	F	April 1998	50	60	110
Belle Vue	210	F	April 2000	105	220	325
Médine	190	C	1980	20	-	20
Mon Tresor Mon Desert	105	C	July 1998	14	-	14
Union St Aubin	150	C	July 1997	16	-	16
Riche en Eau	130	C	July 1998	17	-	17
Savannah	135	C	July 1998	20	-	20
Mon Loisir	165	C	July 1998	20	-	20
Mon Desert Alma	170	C	Nov 1997	18	-	18
Total		3 F 7C		340 GWh 215 GWh F 125 GWh C	395 GWh	735 GWh

F = Firm or Bagasse during crop and Coal during intercrop
C = Continuous or Bagasse during crop season only

Progress on Bagasse Energy Evolution

33. Bagasse energy development projects successfully attained the key objectives, which were to set up an investment plan, the institutional framework and the policies to encourage private investment in bagasse/coal power plants. As at the year 2000, the bagasse cum coal power plants accounted for 240 MW installed or more than 50% of the total (425 MW). An additional firm power plant project (2- 41.5 MW) is currently being erected in the south. This plant located next to a sugar factory with an hourly cane crushing capacity of 350 tonnes (1.2 million tonnes cane) will export 136 GWh of electricity from bagasse and 200 GWh from coal. Depending on evolution of baseload over the next decade, another 30 MW plant will come on line.

Table 3: Evolution of Cogeneration (1988-2000)

Year	Cogeneration			Total		Bagasse %		Bagasse + Coal
	Bagasse		Coal					
	IC	GWh	GWh	IC	GWh	IC	GWh	%Total
1995	43	84	41	332	1047	13.0	8,0	11,9
1996	43	119	-	332	1151	13.0	10,3	10,3
1997	53	125	23	370	1252	14.3	10,0	11,8
1998	90	225	62	397	1365	22.7	14,2	18,7
1999	90	184	155	425	1424	21.2	12,9	23,8
2000	160	274	327	478	1527	33.5	17,0	39,4
2001	246	300	411	660	1657	37.3	18,1	42,9
2002	242	299	447	656	1715	36.9	17,4	43,5
2003	242	296	433	729	1840	37.0	16,1	39,6
2004	242	318	407	725	1923	37.0	16,5	37,7

34. It can be seen from Table 3 that in the year 1995, 84 GWh of electricity was exported from bagasse. This was achieved through investment mostly by private sugar mills using cogeneration technology with their own private fund. By the year 2004, cogenerated energy increased significantly with investment in more efficieny bagasse-to-electricity processes and in a greater number of units so much so that the electricity exported to the grid from bagasse increased to 318 GWh from the 242 MW (or 37%) firm installed capacity.

Factors Inducing Bagasse Energy Development

35. The sugar industry future is at stake. In the local context, the cost of production is increasing and in the international scene, sugar prices are decreasing due to trade liberalisation and commitments at the WTO. These factors will impact negatively on the industry if measures are not taken to mitigate these effects. Factory modernisation,

centralisation and exploitation of the by-products for more value added products are measures that will ensure long-term viability of the industry.

36. Bagasse energy projects are linked with sugar factory modernisation in that boilers, turbo alternators and other energy efficient equipment represent a major proportion (up to 50%) of the cost of a sugar factory. Investing in an energy project ensures that this part of the investment (useful life of 25 years) crucial to sugar processing, is financed independently of sugar activities. In addition, the sale electricity adds to the revenue of sugar companies. Furthermore, linking energy projects to centralisation brings about reduction in cost of production. In 1985, 21 sugar factories were in operation and the number has decreased to 14 in year 2000. 10 of these factories export energy to the grid and only 3 of them are firm power plants. It has been projected that by year 2008, only 6 sugar factories will be in operation through the process of centralisation and each one of them will be equipped with a firm power plant such plants are generally more efficient in energy cogeneration and export to the grid.

Replication Opportunities and Sustainability of Bagasse Energy

37. With the successful demonstration of the bagasse energy projects in Mauritius, opportunities are now offered to other cane sugar producing countries to replicate or adapt such projects that Mauritius is well positioned to share its experience given the wide range of technical options available. These options include continuous power plants, seven in number, using boilers operating at pressures between 24-31 bars to generate steam fed to condensing-extraction turboalternators in a variety of set-up taking into consideration energy requirement of sugar cane processing and existing infrastructure, the efficiency of energy use and energy generation in the most financially beneficial manner. In addition, there is a wide range of firm power plants (3 in number) based on boilers generating steam at pressures of 44 bars and 83 bars and equipped with matching condensing-extraction turboalternators. All these plants are located within an area of around 1,850 km^2 and are thus easily accessible.

38. The average kWh/tonne cane processed in 1988 was 13 and even after implementation of the projects up to the year 2000, the value has reached 60 kWh per tonne of cane. This is well below the 125 kWh/tonne cane obtained at CTBV which is equipped with a 2x35 MW power plant operating at around 82 bars.

39. With further centralization of cane milling activities, improvement in exhaust steam in cane processing, upgrading the efficiency of the power plants with the adoption of operating pressures of 82 bars and use of cane field residues as supplementary fuel[3], it can be safely said that 800 GWh of electricity can be exported to the grid from sugarcane biomass. This is more than twice the current amount. There is a significant potential for additional power generation and export to the grid if current R and D efforts on biomass gasifier/gas turbine combined cycle become a commercial reality[4].

Potential for Replication in the African Continent

40. The success achieved on bagasse energy cogeneration in Mauritius can be replicated in almost all of the cane sugar producing countries in the African continent. Sharing of experiences and opportunities for training can be offered given the variety of power plants in terms of capacities, operating pressures and degrees of sophistication linked with plant efficiency.

41. Table 4 gives the statistics production of sugar[5] and cane in countries in the African continent. The potential amount of electricity that can be exported to the grid using two commercially proven technologies (steam pressures of 44 and 82 bars respectively) have also been worked out on the basis of results obtained in Mauritius. It must be outright highlighted that such plants require a minimum cane crushing capacity of 200 to 300 tonnes cane per hour and many of the African countries have cane production well below these capacities. However, it has been observed that the cane sugar industry in a number of these countries are being rehabilitated and modernised and there is merit in coupling these plants with a cogeneration facility. All the cane sugar factories in Mauritius and Réunion have successfully integrated sugar and electricity production. The total potential in the countries in Africa is around 9,600 GWh on the basis of present cane production and only Mauritius and Réunion are exploiting in a significant manner the sugar cane bagasse for energy[6].

Table 4: Production of Sugar and Sugar Cane and Potential for Cogeneration in Africa (2002)

African Countries	Sugar (x 10^3t)	Sugar Cane[a] (x 10^3t)	Cogeneration Potential (GWh)	
			@ 44 bars[b]	@ 82 bars [c]
Angola	31	282	20	31
Benin	5	45	3	5
Burkina Faso	40	364	25	40
Burundi	21	191	13	21
Cameroun	113	1,027	72	113
Chad	33	300	21	33
Congo	55	500	35	55
Côte d'Ivoire	158	1,436	101	158
Egypt	1,397	12,700	889	1,397
Ethiopia	294	2,672	187	294
Gabon	18	164	11	18
Guinea	26	236	17	26
Kenya	423	3,845	269	423
Madagascar	32	291	20	32
Malawi	257	2,336	164	257
Mali	34	309	22	34
Mauritius	552	5,018	351	552
Morocco	156	1,418	99	156
Mozambique	242	2,200	154	242
Nigeria	20	182	13	20
Réunion	210	1,909	134	210
Senegal	93	845	59	93
Sierra Leone	6	55	4	6
Somalia	21	191	13	21
South Africa	2,755	25,045	1,753	2,755
Sudan	792	7,200	504	792
Swaziland	520	4,727	331	520
Tanzania	190	1,727	121	190
Togo	3	27	2	3
Uganda	244	2,218	155	244
Zaire	75	682	48	75
Zambia	231	2,100	147	231
Zimbabwe	565	5,136	360	565
Total	9,612	87,378	6,117	9,612

(a) Estimated at sugar recovered % cane of 11%
(b) Based on 70 kWh/tonne cane
(c) Based on 110 kWh/tonne cane

42. Implementation of cogeneration will bring additional revenue to the sugar cane industry which is facing threats of price and quota reduction in the preferential markets in

the context of trade liberalisation. Besides, cogeneration is a climate friendly technology that can attract GEF funding as well as financing schemes such as Activities Implemented Jointly and the Prototype Carbon Fund. Most of the cane producing countries in the African continent could benefit from such funding or schemes.

43. The on-going power sector reforms in the region have enhanced the prospects of cogeneration in the continent. However the cogeneration industry has to face a number of policy and institutional challenges in a reformed power sector. The national utility generally operates in a monopolistic situation in that generation, transmission and distribution are undertaken as one bundle of activities. In the reform, it has been envisaged that Independent Power Producers can also undertake generation but the issue of open access to the grid has to be properly addressed in power purchase agreements.

44. The kWh price of cogenerated electricity is around 6-7 US cents and in many cases this price is not competitive with that of hydroelectricity which is priced at around 3 US cents/kWh. Furthermore bagasse energy cogeneration is only possible during the cane harvest season which lasts between 6-9 months and there is need for a complementary fuel such as coal for 3-6 months.

45. Another issue likely to pose significant challenges to cogeneration development is the deterioration in the management of the sugar industry, which has led to its near collapse in many countries and led to closure of a number of sugar factories. This implies that if a sugar factory is not able to produce sugar, its primary output, it is unlikely to be a good cogenerator.

46. Unless there is an integrated policy of cogeneration linking sugar and electricity exports to the grid as a significant source of income to the industry, it is unlikely that cogeneration can be realised. In addition, most of the sugar factories need to be completely overhauled and modernised and these activities have to link with energy cogeneration, which will enhance the financial viability of the facilities. The Mauritian sugar industry had to face similar situation and sharing of experience gathered on these issues will prove beneficial to the cane sugar industries in the region.

Lessons leant and Recommendations

47. The main lesson learnt from the BEDP is that development of bagasse based electricity generation in Mauritius required a stronger linkage between developments in the sugar industry and those in the power sector, as well as a greater emphasis on multipurpose benefits of baseload power from bagasse/coal plants.

48. Government’s strong support clearly defining its policy with respect to bagasse energy development is critical to the successful achievements of set objectives of substituting bagasse for imported fossil fuels.

49. Conditions must be created to as to enable all the stakeholders to participate fully in the whole process as well as transparent flow of information among them. In this case

the World Bank played a key role in providing the necessary support in areas in which the local stakeholders had little or no experience and acted as a honest broker between the stakeholders.

50. Prior to start of a bagasse power plant, it is of utmost importance that a detailed feasibility including a reliable cost estimate for a bagasse coal plant and an agreement on a financing plan from the private entrepreneur are made available. This would avoid delays in project implementation.

51. At the project conception stage, it was envisaged that the bagasse power plants would be located on a regionwise basis whereby that plant would use its own bagasse and that obtained from a cluster of sugar factories. This concept was abandoned in favour of a new approach with centralisation of milling activities through consolidation of operations in most efficient plants for the dual production of sugar and electricity.

52. The bagasse coal power development has multipurpose benefits in that it is associated with environmental advantages, offers a diversified alternative and secure source of power from locally available and renewable resource when compared to imported fuel oil and finally brings additional revenue to the cane sugar industry.

Concluding Remarks

53. The sugar cane plant is an agricultural crop that is known to have a high bioconversion efficiency of capture of sunlight as a result of which a high amount of atmospheric carbon is fixed into biomass. The main interest until recently was to recover only sugar from this biomass. It can now be considered as a major renewable energy resource in cane sugar producing countries. The majority of the countries in the African continent are endowed with agroclimatic conditions that are conducive to sugar cane production and, with proper investment and management of this resource, high yields are potentially obtainable.

54. Amongst other energy carriers, electricity from the fibrous fraction of cane known as bagasse is the one which has been shown to be commercially viable in island states like Mauritius and Réunion which are devoid of any fossil fuel. In the African continent, around 10,000 GWh of electricity is potentially exportable to the grid on the basis of current amount of cane production and using state-of-the-art technology for conversion of bagasse into electricity. Power sector reforms in the African countries should take on board this option of cogeneration through inclusion of independent power producers to undertake power generation. Opportunities for replication of the success achieved in some countries to others in the region should be looked into.

55. The sugar cane bagasse cogeneration technology is environment friendly and it can attract funds from international agencies like the GEF, the Prototype Carbon Fund and Activities Implemented Jointly under the Kyoto Protocol. Exploitation of sugar cane bagasse as an annually renewable energy resource carries a high priority in the context of

global warming and this option, successfully implemented in Mauritius, should be given serious consideration in other cane sugar producing countries in the African continent.

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Filename:	deepchand_bagasse
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Template:	C:\WINNT\Application Data\Microsoft\Templates\Normal.dot
Title:	Energy from Sugar Cane Bagasse on a Commercially Sustainable Basis
Subject:	
Author:	M.S.A
Keywords:	
Comments:	
Creation Date:	18/10/2005 4:05:00 PM
Change Number:	2
Last Saved On:	18/10/2005 4:05:00 PM
Last Saved By:	Reviewer
Total Editing Time:	0 Minutes
Last Printed On:	18/04/2006 3:53:00 PM
As of Last Complete Printing	
Number of Pages:	17
Number of Words:	6,710 (approx.)
Number of Characters:	34,960 (approx.)