International Sugar Organization

Cogeneration – Opportunities in the World Sugar Industries

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Abstract

A survey of already installed cogeneration capacity in the sugarcane processing sector as well as existing development plans shows that bagasse-based production of electricity for export to the national grid is fast becoming a major activity of sugar mills. An increasing number of mills in a growing number of countries are already involved or are planning to start in the near future electricity production in excess of captive consumption. A review of the current situation and prospects for cogeneration in 13 countries in Africa, Asia, Latin America and Oceania shows that the scope for efficient, competitive and environmentally friendly electricity production could be sizeable. In technical terms, the amount of energy that can be extracted from bagasse is largely dependent on two main criteria: the amount of processed cane and the technology used for energy production. Crucially, only the use of high-efficiency boilers generating extra high pressures and temperatures allows production in excess of the captive consumption of a mill. The cost of boilers and their installation is relatively high but, as shown by projects in Brazil and Thailand, capital investment costs may be recovered by revenues from electricity exports to the national grid in a period not longer than 5 years. On the other hand, the success of cogeneration by sugarcane mills is fully dependent on the existing legal framework and the prevailing electricity market rules. Firstly, the electricity generation and supply to the national grid has to be allowed for sugarcane mills. Secondly, prices paid to mills by the utility company have to be adequate. Power Purchasing Agreements have to be long-term. The legal framework has to ensure fair and easy access to the grid for sugar mills. To kick-start the process in the sugar industry financial and tax incentives in line with incentives offered for other generators of renewable energy are of great importance. Financial aid from national and international development agencies is particularly important in the time of the global credit crunch, when normal commercial financing is rarely available or too expensive. A separate challenge being addressed is unavailability of bagasse fuel out of season. Electricity distributors and consumers are most interested in an uninterruptible (firm) supply throughout the year. Taking into consideration the high seasonality of sugarcane harvesting and processing, such continuity is hardly achievable if power generation is solely bagasse-based. This inherent bottleneck is now being increasingly resolved by enabling boilers to co-fire fossil fuels in the intra-crop periods. Better utilization of non-bagasse biomass as a renewable fuel may provide a long term solution. The full use of cane trash potential in power generation in future, when the proper technology is finally developed, seems particularly promising.

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Glossary of terms and acronyms

Additionality	a reduction in CO_2 emissions under a CDM project should exceed those emissions that would occur in the absence of the activity
Bagasse	the fibrous residue remaining after sugarcane is crushed to extract the juice
Bar	unit of pressure
Captive consumption	the internal processing energy need of sugar mill/factory
CER	Certified Emission Reduction, the name given to a carbon credit from a CDM project
CDM	Clean Development Mechanism, as defined by article 12 pf of Kyoto Protocol
CHP plant	combined heat and power plant
CO_2	Carbon Dioxide.
Cogeneration	in technical terms, a process of producing both electricity and usable thermal energy from the same fuel; high efficiency boilers will not only provide sugar processing with cheaper heat but can also produce electrical output much higher than the internal processing needs (captive consumption) - the excess can be exported to the national grid if the electricity market regulations and rules allow it
Feed-in tariff	an incentive structure to encourage the adoption of renewable energy, as higher tariffs paid for electricity generated from renewable fuels as against those for electricity generated from fossil fuels
Firm supply	uninterruptible supply throughout the year
GHG	Greenhouse Gas
GWh	gigawatt (1 bln watt) hour, a typical unit to measure electricity production and use
IPP	an Independent Power Producer, an entity, which is not a public utility, but which owns facilities to generate electric power for sale to utilities and end users.
KWh	kilowatt hour, unit of energy, a typical unit to measure electricity production and use
kg/TC	kg for tonne of cane, unit to measure steam consumption in sugar cane processing
MW	one million watts, a typical unit to measure a generator's capacity
MWh	megawatt hour (1,000 KWh), a typical unit to measure electricity production and use

PPA	Power Perchase Agreement, a legal contract between a power generator and distributor/user
UN-FCCC	UN Framework Convention on Climate Change
WADE	World Alliance for Decentralized Energy
watt	unit of power
watt hour	unit of energy

Introduction

In technical terms, cogeneration is a process of producing both electricity and usable thermal energy (heat and/or cooling) at high efficiency and near the point of use. The combined generation of electricity and heat increases the total efficiency by nearly 50% as against separate production of electricity and heat. Cogeneration is a well known process in the sugar industry and it is used in every single sugarcane mill or beet factory. Practically every phase in sugar manufacturing (juice extraction, bagasse/pulp drying, juice purification, evaporation and crystallization) requires heat. The co-product of heat generation is electricity, which is also needed for cane/beet processing. Relatively low-steam-temperature installations generate sufficient electricity to meet the processing need of a plant. However, high efficiency boilers will not only provide sugar processing with cheaper heat but can also produce electrical output much higher than the internal processing needs (captive consumption). The excess can be exported to the national grid if the electricity market regulations and rules allow it. Exports of electricity can make sugar mill/factory cogeneration an attractive and cost-efficient means of cutting production costs, reducing pollution and generating additional revenues for the sector depending on the ratio between the price secured and production cost of electricity generated in the sugar industry. Moreover, in the case of sugarcane processing, electricity and heat are generated from burning bagasse, practically a cost-free fuel for sugarcane mills.

As early as in 2004, the ISO addressed the issue of cogeneration in the context of possible opportunities for the world sugar industry in the field of renewable energy, particularly the Clean Development Mechanism (CDM) of the Kyoto Protocol ("World Sugar and renewable Energy: New Drivers and their Impacts"- MECAS(04)04 of 17 March 2004). Since then, power cogeneration in excess of captive consumption has become a major activity for sugar crop processing industries in different parts of the world on the back of the economic benefits of lowering energy and, hence, production costs while increasing the sector's revenues. The attractiveness of cogeneration has been further enhanced by the growing instability of energy prices and rising internationally concerted efforts to increase the level of renewable energy supply. Although cogeneration is not confined to the cane sector as beet factories can also sell an excess of produced electricity generated from fossil fuels, the focus of the paper is on the cane processing sector, where bagasse is in use for generating excess electricity for the national grid.

The purpose of this paper is to review existing and planned cogeneration capacities in sugar sectors in a number of countries in different parts of the world with a view to accessing potential increases in power generation and additional revenue streams. The cogeneration concept in the sugar crop processing sector is first provided. It takes stock of the fundamentals of cogeneration, economic and environmental drivers, as well as new technologies for bagasse-based cogeneration. The following chapter analyses the current situation, cogeneration potential and legal framework in individual countries. We focus on the industries where cogeneration has already become a major activity (Brazil, Guatemala, India and

Mauritius), but information available in the public domain on developments in 9 other countries in Africa, Asia, Latin America and Oceania is also presented. Because comparable information about cogeneration is not consistently available for a desk study of this type, each country study differs in content and scope. Finally, conclusions on the potential of cogeneration to improve revenue streams, as well as barriers and constrains to further development are drawn.

I. The Cogeneration Concept

As mentioned in the introduction, cogeneration is a process of producing both electricity and usable thermal energy (heat and/or cooling) at high efficiency and near the point of use. According to the World Alliance for Decentralized Energy (WADE), the efficiency of a combined heat and power (CHP) plant is 47% higher than that of a separate power plant and boiler with a similar capacity. Bagasse cogeneration was pioneered in Mauritius and Hawaii. In 1926/27, 26% of Mauritius' and 10% of Hawaii's electricity generation was coming from sugar mills.[1]

The range of technologies available allows the design of cogeneration facilities to meet specific onsite heat and electrical requirements. There is a strong technological platform from which cogeneration can develop. And there are some newer technologies that – although still in their developmental stage – have the potential to further improve the economic and environmental optimality of cogeneration in future. [2]

1. Bagasse cogeneration – technical overview

Sugar crop processing is energy intensive, requiring both steam and electricity. The energy is supplied as bagasse (in the case of the cane processing sector) or fossil fuel (in the case of the beet processing sector) to the power house. The latter typically incorporates a steam boiler and a back-pressure steam turbine. Fuel is burned in the boiler furnace producing live steam, which is supplied to the turbine. The turbine drives an electrical generator and the steam leaving the turbine exhaust flows to the heating equipment for sugar manufacturing.[3]

Worldwide, most sugarcane mills have achieved energy self-sufficiency for the manufacturing of sugar and can even generate a small amount of surplus electricity during the peak of the crushing campaign. However, using traditional equipment such as low pressure boilers and counter pressure turbo alternators, the level and reliability of electricity production is not sufficient to change the energy balance and to permit exports to the electric power grid. In typical conditions the steam circuit of the plant is generally balanced, i.e. the steam supply sufficiently meets the plant's own requirements. Typically, the processing of one tonne of cane yields about 250-280 kg of bagasse (with moisture level of 50%), which can generate 500-600 kg of

[1] Bagasse Cogeneration –Global Review and Potential. WADE, June 2004
[2] Guide to Decentralized Energy. WADE, September 2003.
[3] Sugar Technology. Beet and Cane Sugar Manuafacture. Berlin, 1998

steam, close to the 400-600 kg of steam consumed in the processing.[4] On the other hand, the use of more efficient high pressure boilers together with condensing extraction steam turbines can substantially increase the level of exportable electricity. Such gains are possible because there is a degree of flexibility in the way steam is produced and used to power steam turbines in sugar mills. While the steam pressure coming out of the turbines must – because of requirements of the cane processing – be close to 2.5 bar, the incoming pressure can be within a wide range depending on the boiler specifications. The power that can be generated is proportional to the thermal energy, a function of the pressure and temperature in the boiler. Almost without varying the quality of fuel, it is possible to increase the electric power generated by a mill by installing boilers and turbines that operate with steam at higher pressure and temperatures

The table 1 illustrates how the steam boiler parameters directly affect the production of energy surplus in the cane processing industry.

Table 1 Electric power and bagasse surplus in cogeneration system in the sugarcane processing sector.

Cogeneration system parameters	Electric power surplus (kg/tc)	Bagasse surplus (kg/tc)
21 bar, 300°C	10.4	33
42 bar, 400°C	25.4	50
42 bar, 450°C	28.3	48
65 bar, 480°C	57.6	13

assuming that: *a processing of 1 tonne of cane produces 280 kg of bagasse (50% moisture)*
process steam pressure at 2.5 bars
consumption of steam - 500 kg/tc

Source: Sugarcane-Based Bioethanol – Energy for Sustainable Development. BNDES, Rio de Janeiro, November 2008, www.sugarcanebioethanol.org.

Furthermore, reducing steam consumption from 500 to 350 kg/tc increases the surplus power by 24% and with partial use of cane trash (50% of 70 kg/tc) the surplus can be more than doubled. Clearly, optimizing steam utilization for cane processing is a key to increasing the bagasse surplus required for cogeneration.

Cogeneration is not confined to the cane sector, beet factories can also generate an excess of produced electricity generated from fossil fuels. Use of high efficient CHP plants not only allows to reduce the unit cost of heat and energy required for beet processing but also allows to export a substantial part of generated electricity to the national grid. in Germany in 2008 sugar beet factories produced 897.604 MWh, of which 170.672 MWh (or 19% of the total production) were exported to the national grid.[5] The level of cogeneration varies greatly from factory to factory depending on the size and efficiency of the plants power house. In the UK, the British sugar Wissington beet factory produces steam and electricity in an on-site

[4] Sugarcane-Based Bioethanol – Energy for Sustainable Development. BNDES, Rio de Janeiro, November 2008 and V. Seebaluck, Manoel Regis Lima Verde Leal, Frank Rosillo-Calle, P.R.K.Sobhanbabu, Francis X. Johnson. Sugarcane Bagasse Cogeneration as a Renewable Energy Resource for Southern Africa. Presentation to the 3rd International Green Energy Conference. Sweden, June 2007
[5] Communication from Pfeifer & Langen, Germany, April 2009

high quality gas-fired CHP plant, which allows to export 350 thousand MWh of electricity to the grid as well as cover the processing needs of the factory.[6]

2. Cogeneration – economic drivers

Cogeneration and, hence, additional income revenues from electricity sales to the national grid may contribute substantially to the economic viability of the sugar sector. Calculating the potential energy gains from cogeneration in the sugarcane processing industry is not a straightforward exercise due to the fact that the energy value of bagasse is a function of cogeneration system parameters. For illustration purposes, however, one can use a flat coefficient (as that of the Ministry of Mining and Energy of Brazil in National Energy Balance, 2008): 1 tonne of bagasse (50% moisture) = 0.213 tonne of crude oil. Thus, if global production of bagasse is put at 424.186 mln tonnes (see table 2), then potentially the sugarcane processing sector might annually generate the same amount of electricity from bagasse as from burning 90.41mln tonnes (662.4 mln barrels) of crude oil with a market value of USD34.4bln even at today's considerably reduced level of world prices (USD52/barrel).

Table 2 Global potential bagasse availability – 2007 (thousand tonnes, 50% moisture)*

South America	**132,182**	**Asia**	**198,139**
Argentina	7,165	China	40,913
Bolivia	1,223	India	94,834
Brazil	108,228	Indonesia	9,174
Colombia	7,423	Pakistan	14,165
Ecuador	1,614	Philippines	7,000
Peru	2,950	Thailand	23.298
Venezuela	2,282	Vietnam	4,078
Others	1,297	Others	4,677
Central America	**20,749**	**Africa**	**28,076**
Costa Rica	1,215	Egypt	3,810
Cuba	3,890	Ethiopia	1,108
Dominican Republic	1,592	Kenya	1,697
El Salvador	1,825	Mauritius	1,507
Guatemala	7,705	South Africa	7,454
Honduras	1,271	Sudan	2,424
Nicaragua	1,646	Swaziland	2,058
Others	1,605	Zimbabwe	1,139
		Others	6,879
North America	**28,166**	**Oceania**	**16,034**
Mexico	17,669	Australia	15,084
USA	10,497	Others	950
WORLD	**424,186**		

Source: Energy Data Associates, UK, March 2009

* Availability conversion factor from the UN Energy Statistics Yearbook 2004 assuming a yield of 3.26 tonnes of fuel baggase (50% moisture) per tonne of cane sugar produced.

According to the WADE estimates, 11 leading countries had 3.9 GW of installed bagasse-based cogeneration capacity. Using high-pressure steam technologies, the

[6] Communication from British Sugar, UK, April 2009

technical potential is more than 130 TWh (terawatt hour = 10^{12} Wh) annually (as in 2005).

The level of initial investments is high. Thus, in Brazil the cost of an installation of a turbine to generate a surplus 15MW of electricity to the national grid is put at USD12.0 mln[7] while in Thailand the reported cost of an erection of a power house with twice higher capacity was EUR35.5 mln.[8] Nevertheless, with the right set of energy market conditions (further discussed in *Barriers and Constrains* section), capital investment costs may be recovered by revenues from electricity exports to the national grid in a matter of three to five years. Also of importance, bagasse cogeneration projects have short development periods as technologies used are proven and well established.

Cogeneration may also bring additional revenues from the monetisation of Certified Emission Reduction (CER) credits within the terms of the CDM (discussed later). Without a full knowledge of the CER credit pricing structure of each project, the level of the monetisation of carbon assets generated by each project as well as capital costs involved it is not possible to judge additional net-revenues of sugar mills involved in the CDM cogeneration projects. Since 2005 prices of CERs have varied in a wide range between USD3.0 and USD25.0/tCO_2. In the last week of March 2009 IDEAcarbon's weekly survey of market participants suggests forward prices for CERs in emission reduction purchase agreements of €6.50 to €8.50/tCO_2.[9] A reduction in emission due to already approved CDM bagasse cogeneration projects is estimated at 2.41mln tonnes per annum in CO_2 equivalent.

Apart from direct benefits to the sugarcane processing sector, there are also broader economic benefits of bagasse-based cogeneration including:

- More diverse and, hence, secure and reliable supply of electricity to the national grid;
- More widespread supply of electricity, in particular, in rural areas;
- Possibility of increased supply of electricity during the dry season when hydroelectric plants are particularly stretched;
- Lower expenses on fossil fuel imports in the case of fuel net-importing countries and higher earnings from fuel exports in the case of net-exporter.

As noted earlier, cogeneration is not confined to the cane sector, beet factories can also sell an excess of produced electricity generated from fossil fuels. In Germany in 2008 sugar beet factories exported 170,672 MWh to the national grid. Based on the base electricity prices of EUR0.068 per KWh (average for the last quarter of 2008) the sector's annual revenue from electricity exports can be estimated at about EUR11.6 mln. Actual prices can be significantly higher than base as electricity supplied during peak hours can bring up to a 50% premium. In the case of the most efficient power generators in the industry, the revenues from electricity sales can fully cover fuel costs for the factory.

[7] Plinio Nastari. What Can be learned from the Brazilian sugar/ethanol/cogeneration story? Presentation to the ISO/Assiut University International Seminar, Luxor, Egypt, March 2008
[8] COGEN 3, Information Sheet, November 2004
[9] CarbonPositive http://www.carbonpositive.net/viewing, 2nd April 2009

3. Cogeneration: environment and CDM

Cogeneration in beet sugar sector has no direct environmental benefits due to the use of the fossil fuels.[10]

In the cane processing sector the situation is very different. Bagasse-based energy is totally renewable and does not involve mining, extraction and long-distance transportation expenses of fossil fuel. It is regarded as a clean fuel with respect to the environment. As a biomass, bagasse supplies raw material for the production of natural, clean and renewable energy, reducing needs for and use of fossil fuels. Bagasse is a waste product that needs to be disposed of in two ways – either by combustion or decomposition (composting). Both of them would release, as CO_2 , the carbon contained in bagasse. Very little fly ash and almost no sulphur are produced during the combustion process. In other words, the environmental advantages of bagasse cogeneration are lower emission of particles, CO_2 and other green house gases (GHGs) compared to carbon-intensive fossil fuels, as well as lower emission as against that during composting. Besides, if the bagasse was to be composted, it would also release methane, a GHG which is 27 times more potent than CO_2. [11]

If the surplus energy is supplied to the national grid it would substitute fossil fuel burned in conventional thermoelectric plants. The reduction of emissions is estimated to be about 0.55 tonnes of CO_2 equivalent per tonne of used bagasse. [12] Such reductions in greenhouse gas emissions qualify for carbon credits if they constitute “additionality” (the reduction should exceed those emissions that would occur in the absence of the activity), and could be used for obtaining CER credits within the terms of the CDM established by the Kyoto Protocol.[13]

There are presently about 70 CDM bagasse cogeneration projects registered with the UN Framework Convention on Climate Change (UN-FCCC). There are 28 registered projects in India, 26 in Brazil, 3 in Thailand, 2 in El Salvador, 2 in Honduras, 1 in Ecuador and 1 in the Philippines.[14] The extent of emission reduction and associated carbon credits differ substantially across the projects depending on the size and efficiency of power plants, captive consumption of sugar mills, amount of replaced electricity generated by thermoelectric plants, etc.

4. New technologies for bagasse-based cogeneration

To conclude the discussion of the concept of cogeneration in the sugar industry it is worth noting the enormous potential for further technological development in this

[10] However, it may be argued that the use of more efficient and, hence, less polluting power plants in sugar beet processing is also beneficial for environment
[11] Bagasse Cogeneration –Global Review and Potential. WADE, June 2004
[12] Sugarcane-Based Bioethanol – Energy for Sustainable Development. BNDES, Rio de Janeiro, November 2008
[13] For more details see MECAS(04)04
[14] Compiled from http://cdm.unfccc,int/Projects/projsearch.htnl

field. The surplus power generation in the cane processing industry can be increased further by the use of more efficient energy conversion systems, such as gas turbines fuelled by gas produced by thermo-chemical conversion of biomass, biomass gasification integrated with gas turbines (BIG-GT), and the recovery of part of the sugarcane trash, that is burned or wasted otherwise. to supplement the bagasse fuel.

In gas turbines the exhaust is used to raise steam in the heat recovery system by a) heating process needs in a cogeneration system for injecting back into the gas turbine to raise power output and efficiency in a steam-injected gas turbine cycle (STIG) or b) expanding through a steam turbine to boost power output and efficiency in a gas turbine/steam turbine combine cycle (GTCC).[15] Gas turbines are characterized by lower unit capital cost and are considerably more efficient that comparable sized steam turbines.

The basic concept of BIG-GT technology involves pre-treatment of biomass, followed by gasification, cooling and cleaning of the gas, and its combustion in a turbine. Gasification enables to implement the use of gas turbine and achieve considerably higher temperatures, reducing thermodynamic losses and maximizing performances.[16] The technology, however, is not yet fully developed for industrial use.

The use of the sugarcane trash after green harvesting is another way to increase further the surplus power generation. A large amount of residues as dry and green leaves, as well as tops left on the field is one of the major characteristics of green harvesting. Trash blanketing is necessary step in order to protect the soil against erosion, to decrease water evaporation and maintain biological activity in the soil. Studies show, however, that these needs are covered by about 50% of cane trash while the rest can be collected and used for cogeneration. The surplus power generation can be raised from the present level of 50 to 60 kWh/TC to 100-120kWh/TC with existing technology, or to 250-300kWh/TC with BIG-GT system.[17] Of importance, there are costs involved in gathering and transporting cane trash to a mill. According to some estimates, they can be as high as USD6/tonne.[18]

5. Barriers and constraints

Beside the size of the cane crop and, hence, the amount of available bagasse as well as limits imposed by installed technology, the output of electricity cogeneration by sugarcane mills is dependent on the existing legal framework and the prevailing electricity market rules. The monopolistic behaviour of electricity companies and the rigidity of regulatory frameworks virtually block Independent Power Producers (IPP)[19] from being connected to the grid and selling their available surpluses.

[15] V. Seebaluck and others. Sugarcane Bagasse Cogeneration as a Renewable Energy Resource for Southern Africa. June 2007
[16] Sugarcane-Based Bioethanol – Energy for Sustainable Development. BNDES, Rio de Janeiro, November 2008
[17] Biomass power generation, UNDP and CTC, Brazil, 2005
[18] Plinio Nastary. March 2008
[19] The Independent Power Producer (IPP) is an entity, which is not a public utility, but which owns facilities to generate electric power for sale to utilities and end users.

Therefore to start with, the IPP generation and supply to the national grid has to be allowed.

As previously discussed, the level of initial investments required to start cogeneration is high and can be justified only when there are legal long-term commitments of electricity distributors to purchase bagasse-based electricity from sugarcane mills. Therefore, a legal contract in the form of a Power Purchase Agreement (PPA) between the IPPs and electricity companies is a crucial element of the legal framework required. PPAs also play a key role in the financing of electricity generating assets. Under the terms of a PPA, the IPP typically assumes the risks and responsibilities of ownership when it purchases, operates, and maintains the turnkey facility. The IPP secures funding for the project, maintains and monitors the energy production, and sells the electricity to the host at a contractual price for the term of the contract. The term commonly ranges between 5 to 25 years.

Another important issue, which may disallow cogeneration is pricing in the electricity market. To make cogeneration commercially viable, millers' production costs including capital costs have to be covered. Ideally, offered prices have to include the provision of renewable energy feed-in tariffs (an incentive structure to encourage the adoption of renewable energy).

A separate challenge being addressed is unavailability of fuel out of season. Electricity distributors and consumers are most interested in an uninterruptible (firm) supply throughout all year. Taking into consideration the high seasonality of sugarcane harvesting and processing, such continuity is hardly achievable if power generation is solely bagasse-based, even when part of the bagasse is stored for power generation during the intra-crop periods. It has also to be taken into consideration that over the years the out of season energy requirements of sugar mills have increased. This has been due to the development of downstream units such as packing, chemical, paper, effluent treatment and biogas generation plants. The establishment of settlements around mills, with their social, educational and commercial activities, have also contributed to increased electricity demand. Of importance, in a number of cane producing countries the intra-crop periods may coincide with wet seasons and abundant hydroelectric energy supply that may mitigate the problem of seasonality in cogeneration.

This inherent bottleneck is now being increasingly resolved by enabling boilers to co-fire fossil fuels in the intra-crop periods. Better utilization of non-bagasse biomass as a renewable fuel may provide a long term solution here. The full use of cane trash potential in power generation in future, when the proper technology is finally developed, seems particularly promising.

II. Country Studies

To better understand the drivers, constraints and potential of cogeneration in the sugar industry, this part of the paper scrutinises in detail the situation in those countries where cogeneration capacities are already in active use and the produced excess is exported to the national grid. We have also reviewed the situation in several other countries where cogeneration has started emerging. In the table below we have summarized available information on the current status of cogeneration and reported expansion plans for near future in 13 countries in Africa, Asia and Latin America analysed in this paper. It has to be noted that there is an understandable lack of homogeneity in the market regulations and conditions for bagasse-based cogeneration due to differences in national energy balances as well as potentials of the sugarcane industry. The sugar sector in each reviewed country has its own set of barriers and constrains.

Table 3 Bagasse-based cogeneration, current status and potential in selected countries

	Number of mills		Cogeneration capacity MW		Expansion plans for the total cogeneration capacity MW
	Total (in 2007/08)	Connected to the grid	Total	For export	
Brazil	**370**	**48**	**3,081**	**509**	**15,000 (by 2015)**
Guatemala	**14**	**9**	**497+**	**289++**	**585 (by 2011)**
India	**492**	**107 (a)**	**2,200**	**1,400**	**3,000 (a)** **10,500 (by 2015)**
Mauritius	**10**	**10**	**240 (b)**	**467.9 GWh (c)**	**n/a**
Australia	27	n/a	392 *850GWh (d)*	*370GWh (d)*	n/a
Colombia	12	-	-	-	266 (by 2011) (e)
El Salvador	7	2	n/a	n/a	n/a
Kenya	6	1	32	25	n/a
Nicaragua	4	2	n/a	23 MWh (f)	n/a
The Philippines	28	1	21	n/a	n/a
South Africa	17	-	-	-	400MW (by 2013)
Thailand	50	2	n/a	n/a	n/a
Uganda	2	2	20 (g)	13-14 (g)	n/a
TOTAL			***6,483***		***26,751***

(a) 38 mills are in the process of establishing cogen facilities.
(b) including around 140 MW from coal-based generation.
(c) actual exports in 2007.
(d) actual production and exports.
(e) 8 mills with the total installed capacity of 266 MW, of which 155MW may be destined for exports.
(f) monthly exports during the 2008 campaign.
(g) Kakira Sugar Works (KSW) only.
\+ including around 200 MW from bunker-based generation.
++ including around 129 MW from coal-based generation.

1. Brazil

Overview and potential for cogeneration

Until the late 1990s before sugar mills were allowed to export electricity to the national grid, the costly removal of excess bagasse at the mills prompted the industry to use plants equipped with low, mostly 21-bar, pressure boilers in order to incinerate surplus bagasse. The possibility of exporting surplus energy to the grid has created a revolution in the industry. Installed capacity increased from about 100

MW in 2000[20] to 3,081 MW in 2008 with another 460MW under construction or awaiting regulatory authorization to operate. In the first 5 years of the current decade the supply of electricity generated by the sugarcane processing sector to the grid grew at an annual rate of 67%.[21] Table 3 shows that in 2007/08 509MW of actually installed capacity were used for exporting electricity to the national grid by 48 of 370 sugarcane mills. Of importance, due to the seasonal character of cane processing mainly during the dry season (May to November in the case of the all-important Centre-South) the peak of the surplus energy exports coincides with the periods when most of Brazil's hydro-power generating capacity is under stress from lower water availability.

Table 3 Surplus power capacity in sugarcane mills in 2007/08

States	Number of mills connected	Installed surplus power capacity during crushing season (MW)
Goiás	3	52
Mato Grosso	2	16
Minas Gerais	5	32
Paraná	3	92
São Paulo	20	228
Centre-South	**33**	**420**
Alagoas	7	40
Bahia	1	4
Paraíba	1	9
Parnambuco	4	34
Rio Grande do Norte	2	2
North-NorthEast	**15**	**89**
BRAZIL	**48**	**509**

Source: Plinio Nastari. What can be learned from the Brazilian sugar/ethanol/cogeneration story? Presentation to the ISO/Assiut University International Seminar, Luxor, Egypt, March 2008

As estimated by the industry specialists, sugarcane mills accounts for the generation of 8.357GWh, approximately 2% of the Brazil's total electricity production. Moreover, the projected growth in generating capacity of the sugarcane processing sector is substantial. By 2015 it could reach 15GW,[22] an equivalent of 15% of the current total annual power generation in Brazil.

For those mills which are already exploiting a new market niche of cogeneration, the export of electricity to the national grid has a very positive economic impact. It is creating an additional income from the same agricultural produce. This serves as a credit abated from the feedstock cost used for sugar and ethanol production. At the current electricity tariffs of BRL150-160 per MWh (or USD66.5 to 71.1 per MWh) determined upon a price discovery system based on public auctions (discussed in more details in the following section), revenues from cogeneration account for approximately 15% of the total revenues accrued from sugar and ethanol sales. Even though the level of initial investment is high, cogeneration is clearly profitable.

[20] Power Struggle. The future contribution of the cane sector to Brazil's electricity supply. Rabobank, 2007.
[21] Sugarcane Based Bioethanol – Energy for Sustainable Development. Coordination BNDES. Rio de Janeiro, November 2008, www.sugarcanebioethanol.org.
[22] Sugarcane Based Bioethanol – Energy for Sustainable Development. Coordination BNDES. Rio de Janeiro, November 2008, www.sugarcanebioethanol.org

As calculated by Datagro, in order to generate 15MW of surplus energy from processing 1 mln tonnes of cane a miller will need to invest USD12.0 mln. Sales of 75000 MWh during an average crushing campaign of 5000 hours would bring USD4.89 mln. When the direct cost (12% of the total revenue) is deducted, an annual net income may be as high as USD4.3 mln. Therefore after less than 4 years of operation, investment may be covered. Then, revenues from electricity sales become the additional income of a mill.[23]

Cogeneration – legal framework

Until 1997 the utilities industry was strongly regulated and dominated by public power utility companies. It was not possible for sugar mills to export energy to the grid.

Since the late 1990s generators and distributors have access to the national transmission network, for which they pay a tariff established by the government's electricity sector regulator, Agência Nacional de Energia Elétrica (ANEEL). Meanwhile, matching supply and demand takes place under the supervision of the Operador Nacional do Sistema Elétrica (ONS), which is tasked with ensuring that buyers and sellers of electricity are able to establish secure, long-term agreements. A special system known as the Ambiente de Contratação Regulada (ACR) functions as an auction ensuring that demand is met by adequate supplies. Distributors are required to project their future energy demands, which are passed to the government's Empresa de Pequisa de Energia (EPE), a division of the Ministry of Mining and Energy. The EPE in turn calculates the required increase in generation capacity necessary to meet future demand. Via the ACR distributors are required to contract 100% of the projected requirement with generators.

Prices are established through reverse auction, for which investors in generation projects submit a bid for the price of energy associated with their project. These bids are ranked and projects are selected according the their ranking untill the required demand is matched by project capacity. Deals established via the ACR last from five years to 15 years in cases where the generator already established production capacity. In cases where the deal has been established prior to the construction of generation capacity, such deal lasts a minimum of 15 years and a maximum of 30 years in the case of hydroelectric projects[24] from the date at which the new facility begins to generate electricity. According to ANEEL 72% of electricity consumption is currently channelled through the ACR.[25]

There is an alternative mechanism, the Ambiente de Contratação Livre (ACL) which permits generators and so-called "free consumers" (typically industrial users) to enter into bilateral contractual agreements. The duration of these agreements is

[23] Plinio Nastari. What can be learned from the Brazilian sugar/ethanol/cogeneration story? Presentation to the ISO/Assiut University International Seminar, Luxor, Egypt, March 2008

[24] In 2006 hydroelectric plants were responsible for 76% of the national supply of electrical power (Balanço Energético Nacional, 2007).

[25] Power Struggle. The future contribution of the cane sector to Brazil's electricity supply. Rabobank, 2007.

much more flexible than in the ACR system. Free consumers account for 19% of electricity consumption.

In addition to the unit price of electricity established via the auction system, an extra price incentive or a feed-in tarriff has been created by the government especially for bagasse based cogeneration to encourage electricity production during the dry season. This bonus is known as the Custo Econômico de Curto Prazo (CEC). In 2005, the value of the CEC stood at BRL22.9 per MWh, representing a significant premium to the established price of BRL 127 per MWh. However, in the following year the EPE reduced the CEC to BRL3.2 per MWh.[26]

In 2008 a serious obstacle, which had previously discouraged mills from offering electricity to the market, was removed. Uncertainty as to who would pay for the costly transmission lines needed to carry power from mills to the grid and for upgrading existing links has ended. A new formula whereby the cost of getting the electricity to distributors is shared between mills and transmission companies were agreed.[27]

2. Guatemala[28]

Overview and potential for cogeneration

Bagassed-based cogeneration has become a major activity of the sugarcane processing sector in Guatemala. Unlike Brazil, the sector is supplying energy to the national grid throughout all year. Annually about 40% of electricity is generated using fossil fuels.

The cogeneration programme started in Guatemala in 1994, when the first PPAs contract were sign between the biggest private electricity distributor (Empresa Electrica de Guatemala - EEGSA) and 6 sugar mills, with a total amount of 160.4 MW during the crushing season and 128.7 MW available during the intra-crop season. To guarantee firm supply of electricity operating the full year round, the sugar mills have to operate the same steam boilers, with two different types of fuel, sugarcane bagasse and bunker fuel. The flex-fuel technology boilers were designed by a local engineering firm. At the very beginning, there was high consumption of fuel oil while boilers' efficiency was very low, near 38.01 KWh/TC, but the efficiency has gradually improved and at present is as high as 72.6- 86.8 KWh/TC. Since the mid-1990s the use of bunker fuel has reduced from 2.1 mln barrels per year, to 350 thousand barrels (as in 2007). Most sugar mills use high pressure flex-fuel steam boilers. In 2007 the sector had capacity to generate 296.8 MW of electricity during the harvest season and 200.3 MW during the intra-crop period.

[26] Ibid
[27] P. Knight. Cogeneration may be the next big story for the Brazilian sugar industry. F.O. Licht International Sugar and Sweetener Report, 14th March 2008
[28] The contents of this section is based on information provided by ASAZGUA, Guatemals's Association of Sugar Industry, April 2009

From 2006, 9 out of the total 14 sugar mills have been exporting electricity to the national grid.

Table 4 Guatemala: Captive consumption and exports to the national grid by sugar mills (in GWh)

Captive consumption

	Pantaleón	Concepción	Santa Ana	Madre Tierra	Magdalena	La Unión	Tulula	San Diego	Trinidad	Total
2001	45.41	25.13	33.83	18.73	38.56	33.52	SD			195.17
2002	60.08	31.23	34.60	19.97	45.32	36.59	3.44			231.23
2003	61.23	31.52	33.13	22.02	56.05	44.50	12.10			260.55
2004	87.57	34.73	43.58	26.59	68.20	51.41	10.76			322.84
2005	99.94	38.90	36.85	29.19	77.08	59.14	10.32	2.84	3.96	358.21
2006*	68.73	23.30	32.24	23.47	75.19	40.96	SD	7.10	12.92	283.92

Exports to the grid

	Pantaleón	Concepción	Santa Ana	Madre Tierra	Magdalena	La Unión	Tulula	San Diego	Trinidad	Total
2001	125.33	136.79	98.22	67.13	52.40	90.83	6.02			576.72
2002	150.64	119.71	116.71	55.01	51.61	106.96	20.47			621.12
2003	144.30	107.72	110.52	43.88	64.51	123.22	21.88			616.04
2004	167.08	98.09	100.90	50.71	72.62	116.64	23.29			629.33
2005	193.53	105.50	99.74	63.59	87.83	129.60	25.58	0.70		706.06
2006*	185.70	102.90	99.30	70.14	158.23	117.49	35.76	1.81	15.85	787.17
2007**	58.18	30.74	36.77	25.82	56.56	39.91	13.52	0.61	9.61	271.72

* for the first 10 months of 2006
** sales till 27th February 2007

Cogeneration – legal framework

Until 1990 the utilities industry was strongly regulated and no sugar mills or IPPs from other sectors were allowed to export energy to the grid. As mentioned earlier, in 1994 the first PPAs were signed between an electricity distributor and 6 sugar mills. The mills started cogeneration in 1995.

According to the industry, apart from allowing sugar mills like IPPs to supply electricity the national grid, no incentives have been provided by the government for bagasse-based cogeneration. The sugar sector follows general regulations established for the electricity market in Guatemala. The purchases are regulated by the terms and conditions of the long term PPA with EEGSA. The current PPA will expire in 2014. The agreement fixes a base price for KWh with an indexation depending on prices for bunker fuel. The base price is established by the Administrador del Mercado Mayorista, (AMM) taking into account minimum offered prices from all the power generating units and the required demand. Prices vary depending on hours when electricity is delivered and are higher during the peak hours and lower during the rest of the day.

3. India

Overview and potential for cogeneration

Until the 1970s, sugar mills were using only low pressure boilers. With the growing demand for electrical power and widening gap in the demand and supply of power, sugar mills in the mid 1990s incorporated high pressure boilers and high efficient turbines to generate additional power for supply to the grid. Sugar factories started using 45 bar boilers, while the cogeneration units are currently using 67 to 105 bar boilers.

Since the beginning of the 1990s, power cogeneration has become a major activity of India's sugar industry. About one third of operating sugar mills (145 out of total of 492 in 2007) has installed or are in the process of establishing cogen facilities. [29] The current capacity to co-generate and export surplus power to the national grid in 107 mills is estimated by the industry at around 2,200 MW but will increase to 3,000 MW when new cogen units are assembled in about 40 mills.[30] The full potential of the sector is projected at over 10,500 MW including 3,500 MW for internal consumption and 7,000 MW for export to the national grid. In tables 5 and 6 potentials for cogeneration by the sugar industry in different states are summarised.

Table 5 India: potential for cogeneration in the sugar industry by individual states

State	Number of mills	Total cogeneration	Captive use	Exportable electricity
		MW		
Bihar	9	189	59	130
Uttar Pradesh	133	3350	1135	2215
Uttrakhand	10	243	72	117
Punjab	16	312	99	214
Haryana	14	215	85	130
M.P. Rajastan, Chattisgarh	9	148	48	100
Gujarat	17	386	120	266
Maharashtra	165	3066	1080	1986
Karnataka	47	957	292	656
Andhra Pradesh	38	718	228	490
T.N. & Pondicherry	37	776	245	531
Others	7	140	37	103
TOTAL	**499**	**10500**	**3500**	**7000**

Source: S.L. Jain. "India – a sustainable exporter or back to the cycle?", presentation to the 17th ISO Seminar, November 2008.

[29] S.L. Jain. "India – a sustainable exporter or back to the cycle?", presentation to the 17th ISO Seminar, November 2008.
[30] Communication from the Indian Sugar Mills Association (ISMA), 24th February 2009.

Table 6
India: installed and planned cogen units (as on 12th January 2008)

State	Number of units	Total cogeneration	Proposals under implementation	
		MW	Number of units	MW
Bihar	2	23.00		
Uttar Pradesh	41	947.8	16	306.8
Punjab	3	41.0		
Maharashtra	8	166.50	13	250.00
Karnataka	19	418.00	8	192.00
Andhra Pradesh	11	148.95	2	46.00
Tamil Nadu	23	503.86	1	46.00
TOTAL	**107**	**2249.44**	**40**	**817.80**
Exports to the grid	107	1400.00	40	500.00

Source: Communication from ISMA of 25th March 2009

The United States Agency for International Development (USAID) contributed immensely to kick-starting cogeneration of power by sugar mills. In 1994 the USAID jointly with ISMA organized a 3-day seminar-cum-workshop on various options for cogeneration of power based on the configuration of sugar plant and machinery. The experience of sugar mills in Hawaii and Reunion was also presented as case studies in this workshop. This was followed by ISMA delegation's visit to Hawaii in 1995. This provided an opportunity of visiting some of the sugar mills, gaining first hand information on cogeneration of power by sugar units.

The private sector sugar mills in the southern states of Tamil Nadu, Karnataka and Andhra Pradesh took initiative and put up cogeneration plants. The sugar sector in Uttar Pradesh joined later in the year 2000. It has now emerged as the State with an installed capacity for export of 1000 MW power to the grid.

Cogeneration – legal framework[31]

Cogeneration of power, sale, and interstate transmission by large IPPs including sugar mills is allowed by regulations of the National Electricity Policy 1991 under the provisions of the Electricity Act. The sugar industry is freed from licensing both for establishment of new units as well as expansion in existing units.

In 1993 the Ministry of Non-conventional Energy Sources constituted a Task Force to assess the potential for cogeneration in the sugar industry. The Task Force assessed the potential for additional cogeneration of power for supplying to the grid at 3500 MW. The Ministry had announced guidelines requiring individual States to fix electricity prices for bagasse-based cogeneration. These were to include escalating feed-in tariff, payment guaranties by the State Electricity Board (SEB)

[31] The contents if this section is based on information provided by ISMA.

under PPAs, as well as guarantees that SEBs would bear the cost of grid-connection.[32]

The Ministry of Non-Conventional Energy Sources also facilitated setting up of cogeneration plants by giving an interest subsidy to the extent of 2 percentage points on institutional loans. Indian Renewable Energy Development Authority (IREDA) is the nodal agency for disbursement of interest subsidy to cogeneration projects besides being a funding agency.

In 2003, the Ministry of Consumer Affairs, Food & Public Distribution created a scheme for funding of cogeneration plants from the Sugar Development Fund (SDF) at a preferential rate of interest.

Also in 2003, the Central Electricity Act was amended. The Act consolidated the laws relating to generation, transmission, distribution, trading, rationalization of tariffs, promotion of efficiency and environmentally benign policies. The Act also permit open access for sale of power. The amended Act lays emphasis on incremental power generation from renewable energy sources through preferential tariffs.

The Act provide for restructuring of SEBs and constitution of State Electricity Regulatory Commissions (SERCs) to determine the tariff for generation of power, transmission, etc. SERCs are guided by the National Electricity Policy of the Central Government under the provisions of the Electricity Act.

The National Electricity Policy 2006 announced tariff guidelines to be followed by SERCs. It provides for an Availability Based Tariff (ABT). Any deviations from the committed supply under this arrangement shall be subject to an U.I. tariff (unexpected inter change) depending on grid frequency. Currently the U.I. tariff ranges from Rs.4/- to Rs.9/- per unit with an average of about Rs.6/50 per unit. In respect of non conventional sources of energy including cogeneration of power, the policy stipulates that the appropriate commission shall fix a minimum percentage of renewable power to be purchased taking into account the availability of such resources in the region. Uttar Pradesh, Tamil Nadu, Andhra Pradesh Karnataka and Maharashtra have notified compulsory purchase of 5% renewable energy. The purchase of renewable energy is made at tariff rates based on long term agreements between cogeneration units and SERCs as against the bidding process recommended in the tariff guidelines announced in 2006. The price offered by the SERCs varies from INR3.0 to INR3.15 per unit.

There are compulsory purchases (5% of the total energy to come from renewable sources) at low prices established by the SERCs in Uttar Pradesh, Tamil Nadu, Andhra Pradesh Karnataka and Maharashtra. The purchase of renewable energy is made based on long term agreements between cogeneration units and SERCs. The cogeneration units who had no other option, except for sale of power to the SERC initially, had signed the agreements with the SERCs. The price offered by the SERCs varies from INR3.0 to INR3.15 per unit.

[32] Bagasse Cogeneration – Global Review and Potential. WADE, June 2004

Apart from low tariff offered by the State regulatory commissions, even the payments have not been made regularly in time. Several cogeneration units falling under this category approached the Central Electricity Regulatory Commission (CERC), a quasi judicial authority constituted as per the amended Electricity Act for relief.

4. Mauritius

Overview and potential for cogeneration

Energy produced from bagasse has for decades been used in Mauritius to run the sugar mills which are self sufficient in energy requirements. Any surplus electricity is exported to the national grid as per terms negotiated with the national electricity providing company. Over time improved technologies to maximise energy output from bagasse have been inducted and the choice of a bagasse/coal based co-gen plant operating at specific pressure levels made after a careful analysis of options to maximise energy output and return. The model is to have a co-gen plant in tandem with the sugar mill with the mill exporting bagasse and receiving energy for its power requirements. A stand alone power plant is beneficial to the millers as they do not have to take the added risk of funding capital investment in new boilers and generators from sugar revenue streams. The bagasse pricing agreements is sometimes a key factor impacting the viability of the cogeneration facility. Cogenerator investors have also a choice of a smaller scale unit using 100%biomass as fuel – thereby maximising potential carbon credits – or adopting a large scale unit maximazing electricity output using fossil fuels in the offseason.

During the 1990s, Mauritius, an island with no domestic fossil fuels and limited resources for hydroelectric power generation (in 2007 hydro electrics contributed 7.2 ktoe or Kilotonnes of Oil Equivalent, out of the total output of 246 ktoe[33]), took a proactive stand on bagasse-based cogeneration to address the future challenges in the sugar industry. As a result exports of bagasse-based electricity to the national grid had nearly tripled between 1996 and 2005 and increased further in 2005 and 2007.

Table 7 Mauritius: bagasse-based exports of electricity to grid (GWh)

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
119.0	124.6	194.3	188.5	278.5	296.5	299.1	296.1	317.9	301.6	445.7	467.9

Source: 1997-2005 - Outline of energy Policy 2007-2025, Government of Mauritius, April 2007
2006-2007 - Economic and Social Indicators on Energy Water statistics, Central Statistics Office, June 2008

In 2007 there were 10 sugar mills with crushing capacities ranging from 100 to 350 tonnes of cane per hour, all of which generated electricity. Three of the sugar mill power plants operate throughout the year using coal during the intra-harvest periods. The advantages of bagasse cum coal source base increases stability of

[33] Energy and Water Statistics -2007, Central Statistical Office of the Republic of Mauritius

electricity supply by sugar mill power plant – due to specifics of island climate subject to severe tropical cyclones, cane and, hence, bagasse production varies greatly from year to year sometimes by more than 20%. Currently the total installed capacity in the sugar industry is around 240MW (including around 140 MW from coal-based generation).[34] Out of 17 boilers installed, 6 units are high pressure/high temperature (44 bars and 440^{o} C) including one generating steam with pressure of 82 bars at 525^{o} C. An average of 60kWh per tonne of cane is generated for sale to the public grid. The total estimated potential of the sugar mills' power plants is estimated at about 750 GWh per year based on a process steam requirements of 450kg/tonne of cane and electrical energy requirement of 30kWh/tonne of cane. In addition, cogeneration of the total sugarcane biomass including tops and leaves) can further increase electricity generation potential by 350 GWh per year based on an 50% collection of the cane trash from the fields.[35] The government has already authorized further expansions of the Sugar Independent Power Producers (IPP).

Table 8 Timetable for Sugar IPPs

2007	CTSav 1 & 2 will be commissioned as scheduled with 74MW off crop and 63.5 MW crop season
2008	A third and new Unit for CTSav to come online in mid-2008 and export 15MW of power to CEB[36]
Late 2009	Fuel to add a new plant of between 20MW (crop) to 22 MW (intercrop) while keeping the existing 27MW plant. Deep River Beau Champ to close down by then
Late 2011	Subject to demand, the power plant in the Medine sugar mill to come on line with 15MW (crop) to 21 MW (intercrop)

Source: Outline of energy Policy 2007-2025, Government of Mauritius, April 2007

According to the Multi Annual Adaptation Strategy (2006), bagasse–based generation is targeted to grow by 300 mln kWh (300 GWh) by 2015. The key features of the Strategy is the commissioning of five 42MW/82 bar and one 35MW/82 bar bagases/coal power plants.

Cogeneration – legal framework[37]

During the past two decades Mauritius has elaborated a comprehensive legal framework for energy cogeneration in the sugar sector.

a) The Sugar Industry Efficiency Act (1988)

The Act provided some fiscal incentives for promoting more efficient use of cane bagasse. the Acr introduced performance-linked rebate on export duty payable by millers for bagasse save and sold for firm electrical power generation. Milllers were also exempted

[34] V. Seebaluck, Manoel Regis Lima Verde Leal, Frank Rosillo-Calle, P.R.K.Sobhanbabu, Francis X. Johnson. Sugarcane Bagasse Cogeneration as a Renewable Energy Resource for Southern Africa. Presentation to the 3rd International Green Energy Conference. Sweden, June 2007
[35] Ibid.
[36] The Central Electricity Board (CEB) is a parastatal body, the sole agency for transmission, distribution and marketing of electricity in Mauritius.
[37] The contents of this section is mainly based on information provided in V. Seebaluck and others. Sugarcane Bagasse Cogeneration as a Renewable Energy Resource for Southern Africa.

from the payment of income tax for 75% of the proceeds from sale of bagasse for the purposes of power generating. 60% of the proceeds from the sale of power generated by the industry to the national grid were also exempted from the income tax paid by sugar millers. To discourage an inefficient power generating, the price of intermittent power was frozen at a level of USD0.006/kWh.

c) Bagasse Energy Development Programme (1991)

The Bagasse Energy Development Programme (BEDP) was set up by the government with the assistance of the World Bank. The implementation was aimed at displacing the heavy investments on fossil fuel plants, to reduce the country's dependence on petroleum product imports and to minimize foreign exchange use, to diversify the country's energy base, to improve the viability of the sugar industry through modernization and rehabilitation, and, finally, to contribute in the mitigating of the enhanced greenhouse effect by replacing fossil fuels and reducing CO_2 emission. The BEDP developed the concept of satellite mills supplying excess bagasse to the neighbouring power plant and recommended to erect two firm power plants (60 bars pressure) annexed to the sugar mills. Bagasse was to be burnt during the crushing season and any stored surplus was to be used during the intercrop season, while power plant would also burn coal in the period between the crops allowing optimum use of the boiler house. A Sugar Energy Development Loan (SEDP) amounting to USD15 mln was established by the Government to facilitate the implementation of the BEDP. The loan was mainly destined to projects pertaining to enhance bagasse savings in the cluster of sugar mills. An additional grant of USD3.3 mln was made available from the Global Environment Facility Fund of the World Bank to conduct projects and studies in relation to the BEDP. according to industry experts, only 40% of the SEDP loan was used due to a slow progress in construction of the firm power plant, which would have to rely largely to the supply of bagasse from satellite mills. It was also found that the firm power plant project would have a reasonable rate of return on investment if the capacity would have been in the range of 30MW instead of 22 MW and subsequently the cogeneration plant could not get an agreement with the CEB with regards to the kWh price indexation.

Following the experience acquired, three major issues were addressed to facilitate the implementation of the BEDP:

- funding and fiscal framework,
- centralization in the sugar sector, and
- energy pricing.

On the *funding and fiscal framework*, tax-free debentures for financing bagasse-based cogeneration were raised and further incentives were given to enable the industry to offset capital expenditures incurred in energy production from bagasse. The performance-linked rebate on export duty was extended to firm power producers who managed to generate more of their own excess bagasse. Part of the capital expenditure incurred in the installation of efficient equipment used to enhance bagasse saving for cogeneration was also entitled to export duty refund.

Centralization is an ongoing process in Mauritius' sugar sector. Centralization is widely seen as essential if it is to survive in the new market environment following the EU sugar reform (discussed further under *Multi Annual Adaptation Strategy*) .[38]

Following the earlier discussed constraint pertaining to the energy price indexation in the Power Purchase Agreement (PPA) between the IPPs and the CEB, the Ministry of Energy conducted a study on principals and guidelines in the energy pricing. The price was determined based mainly on the type of electricity provided (intermittent, continuous/seasonal or firm), investment in equipment and changes brought to existing plants. For the continuous power producers, 44% of the kWH price is indexed to changes in oil prices and the remaining 56% is fixed. The electricity price for the firm power plants varies according to the plant set-up and is mainly indexed to the price of coal, inflation and exchange rate fluctuations.

d) Multi Annual Adaptation Strategy (2006-2015)

A 10-year reform strategy aims at making the industry more efficient and more flexible as well as building capacity to produce refined sugar, ethanol and electricity. A key element of the reform is to centralize production at four sugar mills from ten sites in 2006. The plan envisages that by 2015, sugar IPP will export about 1,700 GWh of electricity with about 600 GWh coming from optimal burning of bagasse in modern power plants. In addition, high biomass supply, including cane trash is expected to reduce the use of coal. Optimization of the use of bagasse is expected to be achieved as follows: all sugar mills will be coupled with firm power plants operating with state of the art technology; mills will be geared towards maximizing energy savings; wherever possible, cane field residues would be used as fuel; all the power plants would have to adhere to the environment norms applicable to them. Of importance, bagasse-based cogeneration is expected also to create Emission Reduction Credits, which might typically amount to USD15-25 per tonne of carbon offset by substituting fossil fuel.

5. Other countries

Apart from the discussed countries where bagasse-based cogeneration has already become a main activity of the sugarcane processing industry, we also have reviewed information available in the public domain on a number of countries where cogeneration has started emerging.

Australia[39]

In Queensland in the year ending June 2008, the sugar industry generated approximately 850 GWh, with just under 370 GWh exported. The total installed electricity generating capacity of the industry is currently 392 MW with the largest facility in the industry located at CSR's Pioneer Mill in the Burdekin, rated at a

[38] For more details see "EU Sugar Reform –Ramification for Preferential exporters (MECAS(08)18)" ISO, London, October 2008
[39] The contents if this section is solely based on information provided by CANEGROWERS, Australia

capacity of 66 MW. Rocky Point Mill with a capacity of 30MW was the country's first bagasse cogeneration project. As early as in 2002 it generated 180GWh, providing an annual supply of electricity to more than 10 thousand homes, as well as steam and electricity to the nearby Beenleigh Rum Distillery.[40] Other larger facilities include CSR's Invicta Mill (49.5 MW) and Isis Mill (32.5 MW) y Point Mill (30 MW). In New South Wales there is an additional 80MW of installed capacity, which has only recently come online.

The Federal Government formalised its election commitment to a 20% renewable energy target by releasing a discussion paper on the redesign of the Mandatory Renewable Energy Target (MRET), and subsequent amendments to the existing MRET legislation in December 2008.

The amended legislation will extend the existing scheme from 2010 to 2035, ramping up a target of 45,000 GWh between 2010 and 2020, maintaining the target between 2020 and 2025, and phasing down between 2025 and 2030, with the Scheme terminating at 2030. All sugar mills will continue to be eligible with existing baselines carried through to the end of the Scheme. Solar hot water systems will continue to be eligible under the Scheme, but limited to 10 years of renewable energy certificates (RECs).

Release of amended legislation has provided validation that the Federal Government values the potential and participation of the sugar industry in the renewable energy sector. Redesign of the MRET scheme, as characterised in the initial discussion paper would not have included sugar mills, on the basis that sugar mills integrate new co-generation capacity into their existing factories rather than build specific stand-alone plants. An extensive workshop between ASMC (the Australian Sugar Milling Council, a voluntary organisation, established in 1987 to represent Australian raw sugar mill owners), sugar milling companies and the Federal Government highlighted not only sugar industry potential, but many of the vital lessons learned by the sugar industry during the current MRET scheme, supported by an extensive industry submission. The sugar industry is well positioned to maximise opportunities arising from the redesigned scheme, commencing in 2010.

ASMC will continue to provide an interface between the industry and Federal Government on remaining design issues, and champion further renewable opportunities. Issues to be resolved in 2009 include the treatment of electricity intensive trade exposed industries and the penalty price decided by the scheme. The renewable energy expansion capacity of the industry will largely be determined by the penalty price.

Colombia[41]

In 2008 the government passed the Law 1215 which regulates the cogeneration of electrical power in the industries where the combined generation of electricity and heat is an integral part of their production cycles. The Law 1215 allows independent

[40] Bagasse Cogeneration –Global Review and Potential. WADE, June 2004

[41] The contents if this section is solely based on information provided by the Colombia's Sugarcane Industry Association ASOCAÑA in March 2009

power producers (including sugar mills) to sell the excess of electricity to the distributing companies. The proceeds from the sales to the national grid will be subject to a 20% tax. Currently the Regulatory Committee for Energy and Gas (CREG) is preparing the necessary regulation, which will determine technical requirements to be met by independent power producers.

Currently, the sugar industry is preparing a number of cogeneration projects to be implemented in the coming three years with a total amount of investment at USD325 mln. For the time being 8 projects have been already designed. When finished sugar mills will have boilers with the total installed capacity of 266 MW, of which 155 MW will be in excess of the internal processing needs of the sugar mills.

El Salvador

In the public domain, there is information on two bagasse-based cogeneration projects in the country: in El Angel Mill and in Central Izalco. Increasing capacity of new generators allows mills to eliminate the consumption from the grid and also to deliver surplus energy to the national grid. Thus, in El Angel Mill after the complition of stage 2 in 2004 generation capacity would increase to 27.6 MW, after the third stage planned for 2008, capacity whoud increase to 34MW.[42]

Kenya

The industry has a number of cogeneration projects at various stages ranging from feasibility assessments to commissioning. Thus, a cogeneration unit with capacity to export 25MW out of the total capacity 32.5 MW will be commissioned in Mumias Mill in the first half of 2009.[43] The mill operates for 300 days a year with 2 days of maintenance each month. The annual closure for maintanence is for 3 weeks during a typically rainy season, when there is plenty of hydroelectric power since dams are full. The project includes an installation of a high pressure (87 bars, 525^{o}C) steam boiler.

Feasibility studies have been conducted at Nzoia, South Nyanza, and Chemelil mills.

Nicaragua

The San Antonio sugar mill installed a 15 MW sugarcane and eucalyptus wood firing power plant in 2000.[44] The second cogeneration project was started in 2002 in Monte Rosa Mill. Currently two 20MW extraction turbo generators and one 16.5 MW condensing turbo generator are in operation. In 2008 during the crushing campaign up to 23 MWh a month were exported to the grid.[45]

[42] UNFCC Monitoring report on Project Ref No 1061, 20th July 2007
[43] Communication from Kenya Sugar Authorities, April 2009
[44] Bagasse Cogeneration –Global Review and Potential. WADE, June 2004
[45] 3rd Monitoring Report. Monte Rosa Bagasse Cogeneration Project, UNFCCC, 24th September 2008,

The Philippines

In March 2009 the First Farmers Holding Corp. (FFHC) commissioned a 21 MW bagasse-based cogeneration plant, reportedly the plant has been gradualy supplying power to the National Grid Corp. of the Philippines.[46] FFHC is a cooperative-based agro-industrial company with its own integrated sugar mill and refinery. The project has been registered and approved as a CDM project.

South Africa

The sugar industry has reiterated its readiness to contribute to the bolstering of the country's faltering electricity generation capacity. According to Tongaat Hulett, one of the leading sugar producing company in South Africa, the country's 14 sugar mills can contribute a combined total of 400 MW to the national electricity grid by 2013, with some mills going on line as early as 2010.[47]

Thailand

At the beginning of the decade the Mitr Phol Sugar group started developing modern bagasse cogeneration plamts with 67 bar (510^{o}C) steam cycle. Two identical 41 MW extraction-condensing steam turbo-generators were inctalled in UFIC and Dan Chang mills. The power plants started their operation in 2004.[48] ater capacity of each power plant was increased to 52.4 MW and curently each plant is able to export on a firm basis throughout a year 37-39MW[49] to the Electricity Generating Authority of Thailand (EGAT) based on a long term contract. Both plants are planning to use cane trash as supplementary fuel to compensate for any shortfalls in sugar cane output. the total investment cost of two projects was EUR71 mln, excluding civil works, building foundations and financing costs. The expected pay back period is about 5 years.[50]

Uganda

Uganda provides an example of successful cogeneration in the sugar industry of Southern Africa. Currently, in Kakira Sugar Works (KSW), the country's biggest sugar producer, out of the total installed capacity of a new TDPS turbine (20 MW) 65% (from 13 to 14 MW) is exported to the national grid on a continuous basis except for 36 hrs per month when the mill is not in operation due to a regular maintenance. Then during an annual shut down the mill does not export power at all for about 5 weeks. The plant was commissioned in December 2007.[51]

KSW proposed the Ministry of Energy and Mineral Development (MEMD) to supply an excess of the bagasse-based generated electricity as early as 1998, but the decision was deferred. Only in 2003 MEMD and the Uganda Electricity Transmission

[46] Kingsman News Summary, 16th March 2009
[47] The South Africa Sugar Journal. November 2008
[48] Renewable COGEN Asia, 2009, http://www.rcogenasia.com/sugar.html
[49] Communications from the Office of the Cane and Sugar Board, Thailand. April 2009
[50] CPGEN3, Information Sheet, November 2004
[51] Communication from KSW, March 2009

Company Ltd. (UECTL) agreed to accept grid supply of 6MW for only peak hours (6 hours a day) at a low tariff of Uganda Shilling (UGX) 4.9/kWh (1000 UGX=USD0.578). To off-set capacity under-utilization and low tariff, KSW has received a GEF[52] Grant of USD3.3 mln and an East African Development Bank (EADB) loan of USD8.6 mln under the World Bank/MEMD Energy for Rural Transformation Project. In 2004 KSW offered MEMD up to 12 MW on 24 hours a day basis but only in N0ovember 2007 did MEMD and UETCL agree to buy 12 MW from the mill on 24 hours a day basis at a tariff of UGX6.15/kWh only (1000 UGX=USD0.5450) as against UGX8.00/kWh requested by KSW and UGX30.00/kWh paid for diesel based electricity.

The KSW has applied for the CDM registration of the project and expects the UN-FCCC approval shortly.

Kinyara Sugar Works, another sugar producer in Uganda, has implemented smaller cogeneration project with an excess capacity of 5MW to export electricity to the national grid.

Conclusions

A survey of already installed cogeneration capacity in the sugarcane processing sector as well as existing development plans shows that bagasse-based production of electricity for export to the national grid is fast becoming a major activity of sugarcane mills. An increasing number of mills in a growing number of countries are already involved or are planning to start in the near future electricity production in excess of captive consumption. Indeed, if in 2004 in Brazil there were 40 sugar mills supplying electricity to the national grid, by 2008 their number was as high as 48. Similarly, in India commissioned exportable capacity grew from 375.3 MW at the end of 2003 to 1,800MW in 2008. Some impressive developments have been also monitored in Guatemala, Mauritius, Uganda. Nevertheless, as estimated by industry experts, no more than 15% of the global market potential has been effectively realised. A possibility of bringing an additional, stable revenue stream leading to an increased competitiveness of the sector is particularly important taking into account the amplified volatility of the world sugar market and, hence, export earning of the sector. Of importance, bagasse cogeneration projects have short development periods as technologies used are proven and well established.

[52] The Global Environment Facility (GEF) is a global partnership among 178 countries, international institutions, non-governmental organizations (NGOs), and the private sector to address global environmental issues while supporting national sustainable development initiatives. It provides grants for projects related to six focal areas: biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. The GEF is also the designated financial mechanism for a number of multilateral environmental agreements (MEAs) or conventions; as such the GEF assists countries in meeting their obligations under the conventions that they have signed and ratified.

From the sugarcane processing sector's perspective, there are three main benefits of bagasse-based cogeneration:

- Very low or no fuel costs and increased energy efficiency leading to decreasing production costs and better economic viability of the sugarcane processing sector;
- Diversification of revenue streams; and
- Possibility of the application of the CDM of the Kyoto Protocol resulting in a monetary value of reduction in CO_2 emission.

In broader terms, bagasse-based cogeneration also allows:

- More diverse and, hence, secure and reliable supply of electricity to the national grid;
- More widespread supply of electricity, in particular, in rural areas;
- Possibility of increased supply of electricity during the dry season when hydroelectric plants are particularly stretched;
- Lower emission of CO_2 and other gases than from conventional fossil-fuel generation;
- Lower expenses on fossil fuel imports in the case of fuel net-importing countries and higher earnings from fuel exports in the case of net-exporter.

In technical terms, the amount of energy that can be extracted from bagasse is largely dependent on two main criteria: the amount of processed cane and the technology used for energy production. Crucially, only the use of high-efficiency boilers generating extra high pressures and temperatures (60-80 bar and 490-520^{o}C, respectively, and above) allows to produce electricity in excess of captive consumption of a mill. The cost of boilers and their installation is relatively high but, as shown by projects in Brazil and Thailand, capital investment costs may be covered by revenues from electricity exports to the national grid in a matter of three to five years.

Despite the potential benefits of cogeneration to a sugar mill, there remain barriers in many cane producing countries to realising its full potential. These barriers include government policy with respect to renewable energy and how policy is translated into the regulatory setting for IPPs – policy has to be clearly defined to enable both the sugar industry and public utility companies negotiate PPAs. A lack of adequate fiscal incentives represent another potential barrier. Finally, local energy balances are of paramount importance in dictating the underlying economic fundamentals of bagasse cogeneration. In countries such as Brazil, India or Mauritius, a clearly defined government policy on the use of bagasse for electricity generation was instrumental in the successful development of their bagasse-based cogeneration activity. To kick-start the process in the sugar industry financial and tax incentives in line with incentives offered for other generators of renewable energy are of great importance. This support is particularly important at the initial stages when the necessary equipment has to be purchased and proper infrastructure has to be developed. Financial aid from national and international development agencies is particularly important in the time of the global credit crunch, when normal commercial financing is hardly available or too expensive.

A separate challenge being addressed is unavailability of fuel out of season. Electricity distributors and consumers are most interested in an uninterruptible (firm) supply throughout all year. Taking into consideration the high seasonality of sugarcane harvesting and processing, such continuity is hardly achievable if power generation is solely bagasse-based. This inherent bottleneck is now being increasingly resolved by enabling boilers to co-fire fossil fuels in the intra-crop periods. Better utilization of non-bagasse biomass as a renewable fuel may provide a long term solution here. The full use of cane trash potential in power generation in future, when the proper technology is finally developed, seems particularly promising.

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