Sweetening the power sector: Current experience and future potential for bagasse CHP around the world

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Abstract

Massive unrealised potential exists worldwide for generating useful heat and power from bagasse. If sugar processing facilities around the world were to install combined heat and power (CHP) capability based on state of the art technology the sector represents a power generating potential equivalent to about 10% of the EU's annual electricity consumption. Realizing that potential would offer plant operators economic benefit as well as provide wider economic opportunity and environmental benefits for the world's cane growing regions. Many regions can already attest to the many benefits arising from their bagasse CHP investments. A minimum, of 3.7GW bagasse CHP capacity is already installed worldwide, and more is being commissioned every day. Several key obstacles do however remain before the full promise of CHP can be realized in the sugar industry. Major challenges include gaining access to the electricity grid, negotiating fair tariffs for power fed to the grid, and securing bank financing for CHP projects. The sugar industry and the power industry will have to work together to overcome these barriers if they are to share the benefits that bagasse CHP offers.

Endulzando el sector energético: la experiencia actual y las perspectivas futuras de la PCCE (CHP) a partir de bagazo alrededor del mundo

A nivel mundial existe un potencial colosal no realizado para generar calor y electricidad de considerable beneficio, a partir del bagazo. Si las fábricas procesadoras de azúcar alrededor del mundo establecieran instalaciones capaces de una producción combinada de calor y electricidad (PCCE) a partir del bagazo y en base a una tecnología de avanzada, el sector representaría un potencial de generación eléctrica equivalente a un 10% del consumo anual de electricidad en la Unión Europea. Si ese potencial se convirtiera en realidad, el resultado podría otorgar a los operadores de las plantas no sólo beneficios económicos sino que además ofrecería oportunidades económicas más amplias y beneficios para el ambiente en las áreas productoras de caña alrededor del mundo. Varias regiones pueden ya dar fe de los muchos beneficios derivados de la inversión en tecnología PCCE con bagazo. Ya han sido construidas un mínimo de instalaciones alrededor del mundo con una capacidad PCCE a partir de bagazo de 3,7GW, y más están siendo puestas en marcha día a día. No obstante, aún quedan ciertos obstáculos claves antes de que el resultado completo de la PCCE en la industria azucarera pueda verse materializado. Entre los desafíos principales se incluyen la obtención del acceso a la red eléctrica, la negociación de tarifas justas para la electricidad suministrada a la red además de lograr la financiación de los bancos para apoyar los proyectos PCCE. Para poder compartir los beneficios derivados de la tecnología PCCE a partir de bagazo, la industria azucarera y la industria de la energía eléctrica tendrán que trabajar juntas para poder sobrellevar las barreras mencionadas.

Versüßung des Energiesektors: Derzeitige Erfahrungen mit und künftiges Potential für Bagasse-CHP in aller Welt

Weltweit existiert ein enormes unrealisiertes Potential für die Erzeugung nützlicher Wärme und Kraft mit Bagasse. Wenn die zuckerverarbeitenden Werke in aller Welt auf dem neuesten Stand der Technik beruhende CHP-Einrichtungen (Combined Heat & Power Production = Kraft-Wärme-Kopplung) installieren würden, hätte der Sektor ein Energieerzeugungspotential, das etwa 10 % des jährlichen Energieverbrauchs der EU decken könnte. Eine Realisierung dieses Potentials würde sowohl den Betreibern der Werke wirtschaftlichen Gewinn bringen, als auch allgemeinere Wirtschafts- und Umweltvorteile für die Zuckerrohr anbauenden Regionen der Welt eröffnen. Viele Regionen können bereits die vielen Vorteile bescheinigen, die ihnen aus ihren Investitionen entstanden sind. Eine weltweite Bagasse-CHP-Kapazität von mindestens 3,7 GW ist bereits installiert, und täglich werden neue Werke in Betrieb genommen. Es gilt jedoch noch mehrere entscheidende Hürden zu überwinden, bevor die Aussichten von CHP in der Zuckerindustrie voll realisiert werden können. Zu den hauptsächlichen Herausforderungen zählen die Gewinnung von Zugang zum Elektrizitätsnetz, die Aushandlung von fairen Tarifen für den ins Netz eingespeisten Strom und die Sicherung der Bankfinanzierung für CHP-Projekte. Die Zuckerindustrie und die Energiewirtschaft werden zur Überwindung dieser Barrieren zusammenarbeiten müssen, wenn sie in den Genuss der Vorteile kommen wollen, die Bagasse-CHP zu bieten hat.

Introduction

Burning bagasse to simultaneously produce heat useful in sugar processing and electricity for the grid is a highly energy efficient process. The global potential for electricity generation from the combustion of bagasse is enormous. The cane sugar industry and the international electricity generator manufacturing industry share a common interest in promoting bagasse electricity generation to the wider public. Sugar manufacturers can improve the overall efficiency of sugar production, thereby cutting costs; and, also may be able to sell excess electricity to the grid. Electricity generating equipment manufacturers gain experience in working with biomass fuels and increase sales of their products. Since bagasse combined heat and power (CHP) also offers great public benefits it is surprising that

Table 1. Bagasse CHP potential of many of the world's major cane producing regions

Country	Sugarcane production (tonnes / yr)*	year	Total demand 2002 (GWh)**	Potential electricity production (GWh / yr)***	Potential as % of 2002 electricity demand
Angola	282,000	2002	1,587	31	1.97
Argentina	14,750,000	2002-2003	81,650	1,637	2.01
Australia	36,995,000	2002-2003	195,590	4,106	2.1
Benin	45,000	2002	565	5	0.88
Brazil	320,000,000	2002-2003	351,890	35,520	10.09
Burkina Faso	364,000	2002	336	40	12.03
Burundi	191,000	2002	138	21	15.39
Cameroon	1,027,000	2002	3,321	114	3.43
Chad	300,000	2002	89	33	37.25
China	90,107,000	2002-2003	1,456,600	10,002	0.69
Columbia	19,400,000	2002-2003	41,140	2,153	5.23
Congo	500,000	2002	4,740	56	1.17
C te d Ivoire	1,436,000	2002	2,976	159	5.36
Cuba	34,700,000	2004	13,404	3,852	28.74
Dominican Republic	5,070,000	2002-2003	8,910	563	6.32
Ecuador	5,173,000	2002-2003	10,790	574	5.32
Egypt	12,700,000	2002	75,578	1,410	1.87
El Salvador	4,468,000	2002-2003	4,370	496	11.35
Ethiopia	2,672,000	2002	1,998	297	14.84
Gabon	164,000	2002	1,080	18	1.69
Guinea	236,000	2002	795	26	3.29
India	282,000,000	2002-2003	510,090	31,302	6.14
Indonesia	25,530,000	2002-2003	92,380	2,834	3.07
Kenya	3,845,000	2002	4,337	427	9.84
Madagascar	291,000	2002	781	32	4.13
Malawi	2,336,000	2002	1,012	259	25.63
Mali	309,000	2002	651	34	5.27
Mauritius	5,018,000	2002	1,707	557	32.62
Mexico	43,948,000	2002-2003	189,660	4,878	2.57
Morocco	1,418,000	2002	14,236	157	1.11
Mozambique	2,200,000	2002	5,046	244	4.84
Nicaragua	3,431,000	2002-2003	2,320	381	16.42
Nigeria	182,000	2002	18,430	20	0.11
Pakistan	52,056,000	2002-2003	62,960	5,778	9.18
Philippines	24,962,000	2002-2003	42,380	2,771	6.54
R union	1,909,000	2002	1,084	212	19.54
Senegal	845,000	2002	1,615	94	5.81
Sierra Leone	55,000	2002	237	6	2.57
Somalia	191,000	2002	223	21	9.49
South Africa	25,045,000	2002	189,363	2,780	1.47
Sudan	7,200,000	2002	2,400	799	33.3
Swaziland	4,727,000	2002	1,173	525	44.74
Tanzania	1,727,000	2002	2,566	192	7.47
Thailand	74,100,000	2002-2003	95,630	8,225	8.6
Togo	27,000	2002	451	3	0.66
Uganda	2,218,000	2002	1,401	246	17.57
USA	31,178,000	2004	3,659,989	3,461	0.09
Venezuela	6,250,000	2002-2003	80,930	694	0.86
Zambia	2,100,000	2002	5,345	233	4.36
Zimbabwe	5,136,000	2002	11,220	570	5.08
Total	1,160,814,000	2002	7,257,168	128,850	1.78

* Source: Production of Sugar and Sugar Cane and Potential for CHP in Africa (2002) Sugar Cane Bagasse for Electricity Generation in the African Continent Dr Kassiap Deepchand Mauritius Sugar Authority, Port Louis, Mauritius, 2004 Annual and semi-Annual Report series, GAIN Global Agriculture Information Network, USDA Foreign Agricultural Service and Bagasse CHP, Global Review and Potential, World Alliance for Decentralized Energy, June 2004

**USA Energy Information Administration, International Energy Statistics http://www.eia.doe.gov/emeu/international/electric.html

*** Calculated based on generalization that 1tonne cane proces1/3 tonne bagasse and 3 kg bagasse will generate 1kWh .

developing bagasse projects has not proven easier than it has. Benefits to the public arising from bagasse CHP investment may include local employment, spin-off development and decreased pollution and being less at the mercy of international commodity prices.

But how great is exactly the global potential for bagasse CHP? How can the two industries work together to realize the potential and convince the wider community of the enormous benefits that will arise from investment in bagasse CHP? These are among the questions that this article hopes to shed some light on.

Why bagasse CHP?

Bagasse CHP is particularly appealing for several reasons:

• The fact that bagasse is a renewable resource makes it attractive from an environmental perspective: bagasse is carbon neutral and has low SO_2, NO_x and particulate emissions compared to coal and other fossil fuels. Also because both heat and power are generated simultaneously the process is more efficient than separate generation of process heat and electricity.
• The short pay-back of bagasse projects make the option of particular interest from a cost saving perspective.[1] Near-zero fuel costs combined with product diversification (assuming markets exist for the power) make bagasse CHP appealing to mill operators.
• Sugarcane is widely grown in the tropics and the potential for bagasse CHP is largest in some of the world's poorest countries. Bagasse CHP is a great win-win development opportunity.
• Onsite power generation using bagasse leads to greater employment in the local community.
• Bagasse CHP provides power of a higher quality and reliability for the mills that produce it as well as other grid customers.

The wider benefits of onsite power also arise from developing bagasse projects:

• A more diverse generating mix means a more secure and reliable electricity supply. Dependence on imported energy commodities can be reduced. Diversity also helps build contingency, being handy, for example, in periods of drought in area heavily dependent on hydro power.
• Generation located closer to where it is used (closer to the load, in electricity industry jargon) reduces the need for electrical grid upgrades which can result in considerable savings for utilities, governments and any other organization involved in financing grid expansion projects.
• Assuming it displaces the need to purchase power from a central plant that burns fossil fuel, onsite power results in reduced emissions and a cleaner environment.

Unrealized potential

The theoretical potential for electricity generation from bagasse can be calculated based on cane sugar production data. On average, processing one tonne of sugarcane will result in a third of a tonne of bagasse waste. Of course when a CHP system is installed the bagasse is no longer a waste; rather it is a valuable fuel resource. A third of a kWh of electricity can usually be generated for each kilogram of bagasse burned. The fiber content of the cane, which can vary between 11 and 20 % will affect calorific value of the bagasse derived from it; higher fiber cane means bagasse with more electricity generating potential. Table 1 summarizes the potential for bagasse electricity generation for many of the world's cane growing nations. Based on 2002 cane production data and data on how much power was consumed in each nation in 2002 we can see that bagasse could be used to supply anywhere between 0.68% (in the case of China) to almost 45% (in Swaziland) of total electricity demand. This is assuming static energy intensity and sugarcane production. Worthy of note are the many African cane producing countries that could meet a considerable portion of current energy demand via bagasse CHP.

In fact actual potential may be much higher. Conventional CHP plants installed tend not to employ flue gas or steam drying of bagasse. Burning bagasse that has been dried can increase the power output of a plant from an approximate industry average of 120kWh / t of cane to 150kWh / t of cane.[2] Advanced technology sugar plants can reach even more impressive efficiencies. Gasifying the bagasse and using cane trash can bring the output up to 300kWh / t cane.[3]

A quick calculation based on total cane production in the Table 1. multiplied by an upper limit of 300kWh generated per tonne of cane processed in state-of the art facilities shows that based on current annual cane yields existing potential for bagasse generation is 348 TWh per year, more than 10% of the European Union's total electricity demand in 2002. (1,160,814,000 tonnes per year x 300kWh per tonne = 348 TWh per year and total demand in the EU in 2002 was 2986TWh[4]). Even with CHP technology more typical of today's existing plants which produce around 120kWh/t more than 139 TWh annually is not an unrealistic aim. It is clear that fully developing bagasse potential could displace the need for, vast amounts of coal fired plant (or other technology). Because bagasse CHP is carbon neutral major environmental benefits would certainly rise from its wider adoption.

One thing is certain, regardless of the assumptions one makes in calculating the potential contribution bagasse can make to the electricity portfolio in cane growing regions, the scope for improvement is enormous.

Existing capacity

More difficult to find but equally as revealing, are data on actual installed bagasse CHP capacities in different sugarcane growing nations. Besides general unavailability of data, uncertainties which plague clear understanding are numerous. Do the statistics available have capacity factors built in? Are they only applicable for the duration of the cane growing season or are they averaged over the whole year? Do they include plants that are co-fired with other fuels? Nevertheless figures that are available can offer some interesting insights.

Table 2. shows a selection of nations for which data on existing bagasse capacity were found. The data is incomplete and is certainly an underestimation of the total installed global capacity; first because data for only a handful of countries was found and second because new plants are being commissioned all the time.

The table shows that there is an imperfect correlation between the importance of a nation as a cane sugar producer and the extent to which bagasse has been recognized as the important resource it is. The second and third biggest cane producing nations for example,

Table 2. Current realization of bagasse CHP potential in contributing to overall electricity generating capacity in a selection of cane growing regions

Country	Total power demand 2002 (GWh)*	Total generation capacity 2002 (MW)*	Potential bagasse generation based on 2002 cane production (GWh/year)**	Minimum 2004 Installed Bagasse Capacity (MW)***	Approximate Percent of total capacity (MW) that is bagasse 2004	Approximate Percent of total 2002 power demand (GWh) that could be met with bagasse	Approximate Percent of potential bagasse capacity(MW) realized 2004
Australia	195,590	45,312	4,106	30	0.1	2.1	3.6
Belize	110	52	128	19	36.5	116.1	72.4
Brazil	351,890	76,242	35,520	1,658	2.2	10.1	22.7
China	1,456,600	338,310	10,002	800	0.2	0.7	38.9
India	510,090	120,318	32,190	450	0.4	6.3	7
Kenya	4,337	1,165	427	37	3.1	9.8	41.6
Mauritius	1,707	500	557	242	48.4	32.6	100
Nicaragua	2,320	643	488	15	2.3	21.1	19.1
Reunion	1,084	435	212	110	25.3	19.5	100
Thailand	95,630	23,169	8,225	430	1.9	8.6	25.4
Vietnam	32,060	8,300	1,537	65	0.8	4.8	20.6
Total	2,651,418	614,446	93,392	3,791	0.6	3.5	18.9

Sources:

* USA Energy Information Administration, International Energy Statistics http://www.eia.doe.gov/emeu/international/electric.html

** Calculated based on generalization that 1tonne cane proces1/3 tonne bagasse and 3 kg bagasse will generate 1kWh .

*** Information compiled by the World Alliance for Decentralized Energy.

India and China, vary by almost a factor of four in terms of the proportion of approximate bagasse potential that each nation has realized. Australia, among the top 10 cane growing countries of the world, has 30 MW of bagasse capacity installed out of a total potential of more than 950MW. Thailand on the other hand seems to be slightly ahead with 430MW installed, albeit out of more than 1900MW potential (in both cases estimates are based on 2002 cane production figures). Among the large cane producing nations Australia again trails in terms of approximate proportion of potential, having realized only about 3.6% of its overall potential. Although China has already realized an above average 38.9% of its total bagasse fuelled generating potential, in absolute terms there is still enormous room for growth, exceeding 2350MW (again based on 2002 cane production figures).

Meanwhile smaller economies have proven that realizing bagasse potential is not only a theoretical possibility but also a lucrative and efficient practice. The Indian Ocean island of Mauritius has been coasting at 242MW bagasse capacity since at least 2002, comfortably proving that almost half of the island's demand for electricity can be economically met using bagasse. Belize, having realized 72.4% of its overall bagasse potential leads the Caribbean nations, already meeting about 36.5% of its domestic electricity requirements through bagasse.

The above discussion highlights the promise yet to be realized as well as examples of where significant progress has already been made. But how can remaining markets be developed and why has progress towards meeting further potential been so slow? Cooperation between the two major industries involved in bagasse is called for in order to take things forward.

Sugar sector role

Sugar mill owners and other individuals and organizations are probably the most influential players in driving investment in bagasse CHP. Of course in the sugar industry sugar products are the core business but the benefits of also producing an additional commodity for sale, electricity, are becoming increasingly well known to sugar industry leaders. Drivers in the sugar industry for CHP are varied and include:

- Turning what for many mills is a waste that can be expensive to dispose of into a valuable by-product that can be sold.
- Eliminating fuel costs for boilers by replacing fossil fuel with near-zero cost sugarcane waste.
- Economic diversification schemes for sugar companies via expanding into the power sector.
- Endeavoring to capture financing earmarked for climate change abatement and environmental financing: funds that sugar product manufacturers would not otherwise have access to.
- The desire to be perceived by the community as doing "the right thing".

The April 2005 WTO ruling that EU provides illegal subsidies to its sugar producers could be a driver for the sugar industry as a whole in the developing world and thus also an additional driver for bagasse CHP.

For example, a EU commissioned "accelerated strategic plan" for the sugar industry, in order to dampen the effects of the WTO ruling on those countries that had preferential treatment and guaranteed access to high prices in the European market, has called for, among other things, diversification in the sugar industry in including an increased focus on bagasse CHP.[5] The ruling should increase the revenue derived for the sugar industry in the cane growing nations expected to benefit from the decision including Australia, Brazil and Thailand.[6] A spinoff result may be increased negotiating power domestically for sugar producers.

Seeing as a typical sugar mill has onsite load of between 10 and 30kWh/t of cane processed, investing in a CHP plant could result in anywhere between 110 and 290kWh for export to the grid for every tonne of cane processed.

Because cane sugar factories range in scale from plants of about 1000t cane/day capacity, more typical in countries like India and China, up to 40,000t cane/day capacity plants, which exist in Brazil and Thailand,[7] there is also considerable variability in the scope for electricity production and sales from plant to plant. Assuming a plant with a 6,000t cane/day operation, even after onsite needs are met, some 660MWh- 1,740MWh could be generated for sale to the grid every day. Again assuming a typical 0.067 US$/kWh (the average industrial retail price for electricity for OECD countries between 1994 and 2000[8]) a plant is looking at:

0.067 US$/kWh x 1,740,000kWh = 1165.80 US$ a day of additional revenue in addition to displaced electricity costs.

Of course in many countries mills are unable to sell power to the grid at all, and IPP contracts and even if they are the 0.067 may be an overly generous price. Still this quick analysis provides an approximate estimate as to the additional revenue potential that investing in onsite bagasse CHP can offer. In some circumstances such an economic incentive may be sufficiently attractive in itself to go ahead with a project.

Many existing plants that would be ideal candidates for a bagasse CHP facility are currently operating at sub-optimum level in terms of cane processing. Because sugar is the core business of plant managers there is already an enormous incentive in place to make investments in plant upgrades to improve sugar yield from the cane. Going forward industry players must ensure that the opportunity presented by plant upgrades for core process improvement for installing CHP capacity at the same time is not wasted.

A coordinated effort by cane growers and processors is needed to engage local governments and utilities in developing bagasse potential. Clear grid connection procedures as well as tariffs that are fair for all involved must be negotiated. It must be made clear how energy from bagasse can benefit the wider community and local economy.

Power sector role

Organizations and individuals from the power sector will have to play an increasing role if all the bagasse potential around the world is to be realized. The issue of grid connection and compensation tariffs is probably the single biggest obstacle to larger scale CHP investment. All over the world potential CHP facilities of any scale face barriers in connecting their system to the local grid for the purpose of feeding power back into the grid. Even where such practice is permitted the utility will not always pay a fair price for the power it receives. Indeed in many areas nothing at all will be paid for the power. This is one main challenge that power sector players and sugar sector players must work cooperatively to overcome.

Even within the power sector there is great scope for working cooperatively to overcome common barriers. Companies coming together in joint working groups, facilitated by organizations such as the World Alliance for Decentralized Energy or Cogen SP (Brazil) is one example of how barriers may be effectively removed. Some of the major manufacturers of electricity generating equipment involved in the bagasse CHP industry include Peter Brotherhood, Siemens, and Thermax. Such companies will already have considerable experience dealing with utilities and will possess the technical knowledge needed to convince utility representatives that connecting CHP plants is safe and technically feasible. Having the support of the sugar industry will nevertheless be vital if such projects are to go ahead and become an important fixture of the power capacity in cane growing regions.

Power sector planners recognizing the grid relief benefits to bagasse projects will be a key factor in creating investment interest in bagasse. Computer modelling excercises have shown that investing in decentralized energy technologies such as bagasse CHP as opposed to central plant can result in reduced capital costs for electricity infrastructure in the order of 35% to meet the same future demand.[9] The economy of decentralized energy is largely a result of reduced need for Transmission and Distribution (T&D) infrastructure spending.

Because of its renewable and resource-efficient nature political support for CHP should be easier to garner in the future. Many cane growing regions, notably India and China are heavily dependent on coal for their electricity needs and demand for power is steadily increasing. In any regions that are being squeezed by increasing demand for energy on one side and increasing energy imports on the other, there is no reason why policy makers should not make investment in CHP at sugar plants a priority.

Opportunities for financing at a national level as well as international foreign investment will also be greater for bagasse CHP for the same reasons. Bagasse projects are already garnering some interest under the Kyoto protocol's Clean Development Mechanism and several methodologies have been approved by or are being considered by the CDM Executive Board.[10] Methodology AM0015 deals exclusively with Bagasse Generation.

Next steps

Various actions will be necessary in order to ensure that the range of benefits of bagasse CHP are brought to fruition. Chief among them are:

- Steps must be taken to ensure fair and expedient access to the grid for sugar mills generating onsite power. Various examples exist of how the creation of feed-in-tariffs have spurred bagasse CHP investment. The PROFINA program in Brazil has proven beneficial for cane growers wanting to create their own power and the feed-in tariffs in Maharashtra state (India) are an important driver in the bagasse CHP investment currently planned.
- It must be ensured that tax incentives and rebates are created for bagasse CHP as they are for other renewable energy sources.

Reducing the upfront capital burden for potential investors could go a long way in making bagasse CHP more palatable.

• Lending institutions must recognize bagasse CHP as the sound investment that it is and set lending rates accordingly.

• The potential for bagasse CHP as projects under the Kyoto protocol's Clean Development Mechanism must be taken advantage of.

• Research into ways of making bagasse CHP plants more efficient must be ongoing and strongly supported by the governments in cane growing regions. Innovative technologies must be incorporated into new and existing cane bagasse CHP facilities.

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Endnotes

1 For several reasons the significant investment opportunities of bagasse are currently being overlooked, including the fact that power is not core business for sugar sector and that market structures do not allow power from independent power producers to be rewarded for the value they provide.

2 Personal communication with Dr. Boris Morgenroth, IPRO Industrial Projects GmbH

3 Personal communication with Dr. Boris Morgenroth, IPRO Industrial Projects GmbH

4 International Energy Agency, World Energy Outlook 2004

5 Sugar Industry News, June 1st 2005, http://sugartech.co.za/news/index.php

6 EU subsidised sugar exports ruled illegal . Oxfam/WWF Press Release - 4 August 2004

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8 USEnergy Information Administration, International Electricity Price Statistics http://www.eia.doe.gov/emeu/international/elecprih.html

9 http://www.localpower.org/resources

10 http://cdm.unfccc.int/methodologies/PAmethodologies

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