# Bagasse Cogeneration – Global Review and Potential

Produzido por Michael Brown, após reuniões com Associados da Cogen-SP, UNICA e Workshop de 31/03/2004, realizado com o apoio da Comgás, UNICA, CPFL, Dalkia e FIESP/CIESP

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WADE
WORLD ALLIANCE FOR DECENTRALIZED ENERGY

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| | |
|---|---|
| BNDES | Brazilian Infrastructure Development Bank |
| CCGT | Combined Cycle Gas Turbine |
| CDM | Clean Development Mechanism |
| $CO_2$ | Carbon dioxide |
| DE | Decentralised Energy |
| DG | Distributed Generation |
| ERC | Electricity Regulatory Commission (India) |
| FAO | United Nations Food and Agriculture Organisation |
| GHG | Greenhouse Gas (es) |
| Ha | Hectare (1 hectare = 2.47 acres) |
| HEP | Hydro-Electric Power |
| IPP | Independent Power Producer (s) |
| MNES | Indian Ministry of Non-Conventional Energy Sources |
| MWe / GWe | Megawatt / Gigawatt of electricity capacity |
| MWh / GWh / TWh | Megawatt-hour / Gigawatt-hour / Terawatt-hour of production |
| $NO_x$ | Nitrogen oxides |
| O&M | Operation and Maintenance |
| OECD | Organisation for Economic Cooperation and Development |
| PV | Photovoltaic |
| R$ | Brazilian Real (currency) |
| RE | Renewable Energy |
| SEB | State Electricity Board (s) (India) |
| $SO_2$ | Sulphur dioxide |
| T&D | Transmission and Distribution |
| TCD | Tonnes of Cane Crushed per Day |
| TPH | Tonnes per hour |
| UNIDO | United Nations Industrial Development Organization |
| US$ | US Dollar (currency) |
| VR | Vale do Rosario |
| WADE | World Alliance for Decentralized Energy |
| WTO | World Trade Organisation |

# About WADE

WADE is a non-profit research and advocacy organisation that was established in June 2002 to accelerate the worldwide deployment of decentralised energy (DE) systems. WADE is now backed by national cogeneration and DE organisations, DE companies and providers, as well as a range of national governments. In total, WADE's direct and indirect membership support includes over 200 corporations around the world.

DE technologies consist of the following forms of power generation systems that *produce electricity at or close to the point of consumption*:

- High efficiency cogeneration / CHP
- On-site renewable energy systems
- Energy recycling systems, including the use of waste gases, waste heat and pressure drops to generate electricity on-site.

WADE classifies such systems as DE regardless of project size, fuel or technology, or whether the system is on-grid or off-grid.

WADE believes that the wider use of DE holds the key to bringing about the cost-effective modernisation and development of the world's electricity systems. With inefficient central power systems holding a 93% share of the world's electricity generation, and with the DE share at only 7%, WADE's overall mission is to bring about the doubling of this share to 14% by 2012. A more cost-effective, sustainable and robust electricity system will emerge as the share of DE increases.

To ensure that its goal can be achieved, WADE undertakes a growing range of research and other actions on behalf of its supporters and members:

- WADE carries out promotional activities and research to document all aspects of DE, including policy, regulatory, economic and environmental aspects in key countries and regions.
- WADE works to extend the international network of national DE and cogeneration organisations. Current WADE network members represent Europe, the USA, India, China and Brazil.
- WADE provides a forum for DE companies and organisations to convene and communicate.
- WADE jointly produces an industry journal – "Cogeneration and On-Site Power" (published by James and James in association with WADE).

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# Executive Summary

Bagasse cogeneration describes the use of fibrous sugarcane waste – bagasse – to cogenerate heat and electricity at high efficiency in sugar mills.

This report indicates that there is abundant opportunity for the wider use of bagasse-based cogeneration in sugarcane-producing countries and to contribute substantially to high efficiency energy production. Yet this potential remains largely unexploited. The potential for bagasse cogeneration to make a meaningful contribution to the energy balance is especially great in Cuba, Brazil, India, Thailand, Pakistan, Colombia and The Philippines. The potential, in absolute terms, is also very high in China, despite being proportionally small due to the country's massive scale of electricity generation.

**GLOBAL MARKET POTENTIAL**

| | Sugarcane production (tonnes / yr) | Potential for electricity production (GWh / yr) | Bagasse potential as percentage of electricity demand |
|---|---|---|---|
| **Brazil** | 386,232,000 | 38,623 | **11.50** |
| **India** | 290,000,000 | 29,000 | **5.83** |
| **China** | 93,900,000 | 9,390 | **0.72** |
| **Thailand** | 74,071,952 | 7,407 | **8.15** |
| **Pakistan** | 52,055,800 | 5,206 | **8.36** |
| **Mexico** | 45,126,500 | 4,513 | **2.42** |
| **Colombia** | 36,600,000 | 3,660 | **9.19** |
| **Australia** | 36,012,000 | 3,601 | **1.95** |
| **Cuba** | 34,700,000 | 3,470 | **25.93** |
| **USA** | 31,178,130 | 3,118 | **0.09** |
| **Philippines** | 25,835,000 | 2,584 | **6.16** |
| **Other** | 244,581,738 | 24,458 | **0.32** |
| **TOTAL** | **1,350,293,120** | **135,029** | **0.97** |

Why bagasse cogeneration? The benefits include:

- Lower emissions of $CO_2$ and other gases than from conventional fossil-fuel generation
- Near-zero fuel costs (paid in local currency), commercial use of a waste product and increased fuel efficiency leading to an increase in the economic viability of sugar mills
- More secure, diverse, reliable and widespread supply of electricity for local consumers
- Minimal transmission and distribution (T&D) costs, and reduced network losses, as generation is located near important loads
- Greater employment for local populations.

The economic development potential of bagasse cogeneration should not be under-estimated. Most cane producing countries are poor or extremely poor, with high unemployment and low rates of access to electricity supplies. If the measures recommended in this report can be implemented, there is substantial scope for the technology to accelerate social and economic development in some of the world's poorest regions.

In addition, many cane-producing countries are heavy users of coal in the power generation sectors, including India and China. Use of bagasse to generate electricity and heat can have a significant impact on emissions. The application of the Clean Development Mechanism (CDM) of the Kyoto Protocol, giving a monetary value to $CO_2$ emission reduction, could therefore be an important driver for bagasse cogeneration in cane producing countries. Many such countries are also major importers of oil, giving scope for ethanol production from cane to alleviate a high import burden and reduce emissions from oil consumption.

The amount of energy that can be extracted from bagasse is largely dependent on two main criteria: moisture content and the technology used for energy production. The output of electricity from bagasse cogeneration plants is fundamentally dependent on the prevailing electricity market rules – inadequate buyback prices paid to mill owners by the utility company create a substantial disincentive to size cogeneration plants to meet mill heat demand. Conversely, higher rates can incentivise owners to upgrade their energy facilities to enable maximum on-site efficiency. This is the key to enabling the potential for bagasse-based cogeneration to be achieved.

This issue is now starting to be addressed in many countries, including Brazil and parts of India, where the introduction of biomass feed-in tariffs are ensuring that the external benefits of bagasse cogeneration are being recognised by markets. Analysis by WADE Chairman, Tom Casten, indicates that, in India, realisation of the 5,000 MWe potential for bagasse cogeneration could generate large savings in terms of both $CO_2$ (38 million tonnes per year) and infrastructure (US$10.8 billion). The most dramatic finding is that the cost burden to India, to the tune of almost a billion dollars a year, will be significantly reduced by incentivising sugar mills, through a buyback rate of 7 USc / kWh, to maximise the use of cogeneration.

A separate challenge being addressed is unavailability of fuel out of season. This is now being increasingly resolved by enabling boilers to co-fire with other fuels such as wood or coal.

With many cane producers worldwide facing economic difficulty, bagasse cogeneration can bring about a significant boost to the industry by providing an additional, stable revenue stream and so increasing the competitive position of sugar mills. For those countries, notably Brazil, that produce ethanol from sugarcane as a petroleum substitute, greater mill efficiency can reduce ethanol costs and so accelerate the rate of substitution at a time when international oil prices are high.

In order for bagasse cogeneration to achieve the potential outlined in this report, it is important that certain key measures are brought forward. Building on experiences in India, Brazil and elsewhere, WADE recommends that:

1. Planning and regulatory paths are cleared for the development of enhanced cogeneration facilities in sugar mills. This includes ensuring fair and easy access to the grid for both large and small generators as well as guaranteeing that incumbent generators and utilities do not hinder these processes.
2. Financial and tax incentives, in line with other incentives for renewable energy, are provided to boost the initial development of cogeneration facilities in sugar mills. This would allow generators to invest in the necessary equipment and infrastructure to maximise their electricity output whilst making the most effective use of heat and electricity generated onsite. Financial incentives also include the provision, where

possible, of renewable energy feed-in tariffs that reflect the benefits of onsite production and biomass combustion.

3. Where financial and tax incentives are currently unavailable, the CDM should be promoted and developed. The CDM could provide the incentive required for the upgrade or installation of cogeneration equipment in mills in a cost-effective manner whilst facilitating the meeting of Kyoto Protocol commitments by Annex 1 parties.
4. Further research is carried out into bagasse gasification to fully explore its potential, so that the best technologies can continue to be promoted and installed to reap the maximum benefits of bagasse cogeneration.

# 1. Introduction

Cogeneration from sugarcane waste (bagasse) provides one of the best examples of renewable-based cogeneration yet it remains largely unexploited. The advantages of bagasse as a fuel for cogeneration are numerous, ranging from the environmental to the social and economic. Some advantages, such as increased security and diversity of supply or the furthering of aims of sustainable development even apply across these categories.

The sugar industry is a major worldwide industry that currently faces many problems, as sugar prices are extremely volatile, with countries able to produce sugar most cheaply proving to be tough competition for those less able to do so.

The sugar industry is also a large energy user. Most sugar mills already produce their own electricity to meet on-site needs, by burning bagasse or other fuels. This, however, is often not in cogeneration mode since, until very recently, there has been no incentive to produce electricity efficiently due to the unavailability of tariffs for electricity produced by IPPs and sold to the grid. Much of the potential for energy generation has thus, so far, been wasted as there was no requirement for it. With the introduction of biomass feed-in tariffs in countries such as Brazil and parts of India, there are now great opportunities for sugarcane-producing countries to learn from the best practices around the world.

Until now, the potential for bagasse cogeneration has been largely un-quantified. This report was compiled to highlight the advantages and main issues of bagasse cogeneration and the potential it offers for electricity production.

# 2. Overview of Global Sugarcane Processing Industry

Sugarcane is currently grown under a wide range of conditions, in tropical and sub-tropical regions between c. 35°N in Spain to 35°S in South Africa. As water requirements for the crop are 1.2-1.6 m/year, good distribution of rainfall is required if there is no irrigation. Sugarcane harvesting generally occurs every 9-14 months, depending on crop variety.[1]

The three largest sugarcane growers in terms of production are Brazil, India and China, yielding between them more than half of total sugar production. Table 1 and Figure 1 compare production and yield figures for the top 11 sugar-growing countries.

TABLE 1

**MAIN SUGARCANE-PRODUCING COUNTRIES**

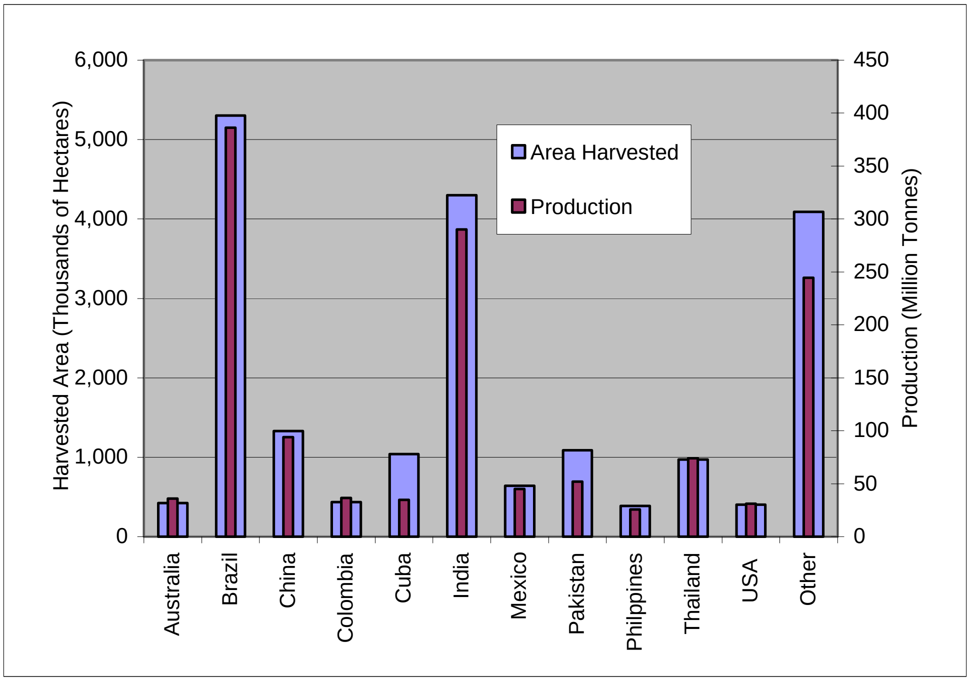
| | Area Harvested (Ha) | Production ranking | Yield (tonnes/ha) | Production (tonnes) |
|---|---|---|---|---|
| **Australia** | 423,000 | 8 | 85.13 | 36,012,000 |
| **Brazil** | 5,303,560 | 1 | 73.83 | 386,232,000 |
| **China** | 1,328,000 | 3 | 70.71 | 93,900,000 |
| **Colombia** | 435,000 | 7 | 84.14 | 36,600,000 |
| **Cuba** | 1,041,200 | 9 | 33.33 | 34,700,000 |
| **India** | 4,300,000 | 2 | 67.44 | 290,000,000 |
| **Mexico** | 639,061 | 6 | 70.61 | 45,126,500 |
| **Pakistan** | 1,086,000 | 5 | 47.93 | 52,055,800 |
| **Philippines** | 385,000 | 11 | 67.10 | 25,835,000 |
| **Thailand** | 970,000 | 4 | 76.36 | 74,071,952 |
| **USA** | 403,390 | 10 | 77.29 | 31,178,130 |
| **Other** | 4,091,132 | | | 244,581,738 |
| **TOTAL** | 20,405,343 | | | 1,350,293,120 |
| **Average** | | | 68.53 | |

SOURCE: FAO DATABASE[2]

[1] Food Market Exchange, at www.foodmarketexchange.com, acc 22 March 2004

[2] FAO, http://faostat.fao.org/faostat/form?collection=Production.Crops.Primary&Domain=Production&servlet=1&hasbulk=&version=ext&language=EN, accessed 22-3-2004. Figures are for 2003.

FIGURE 1
**SUGARCANE PRODUCTION BY COUNTRY**




SOURCE: FAO[3]

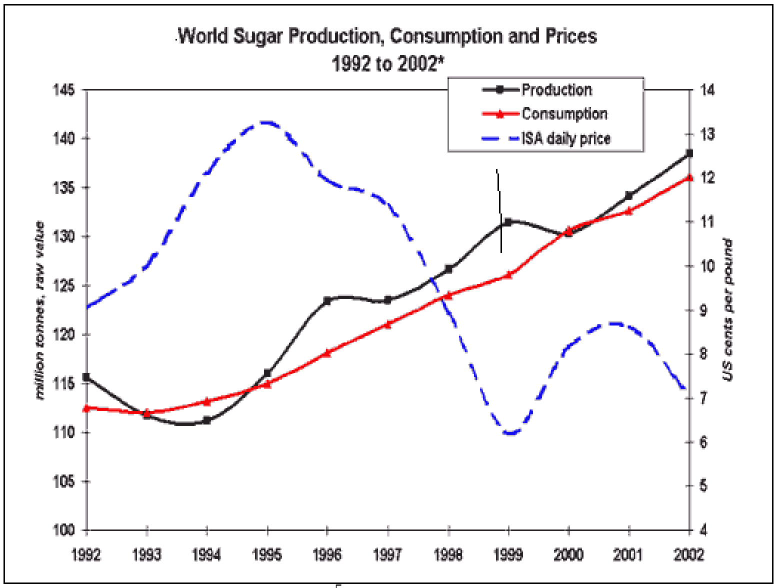
# Price and Production Trends

Historically, sugar prices have been extremely volatile, affected by recurring supply and demand imbalances. In the last forty years or so, prices have overall been relatively low as world production exceeded demand. There have been short price booms such as in the early 1980s, when sugar prices more than quadrupled to 103.4 USc/kg from a long-term average price of 22 USc/kg.[4] Such booms were, however, typically followed by long periods of low prices, with these occasionally dipping below production costs in the main low-cost exporting countries. Figure 2 shows trends in sugar production, consumption and prices between 1992 and 2002.

[3] FAO (see note 2)
[4] Food Market Exchange (see note 1)

FIGURE 2

**SUGAR PRICES 1992-2002**




SOURCE: FOOD MARKET EXCHANGE[5]

The development and increased uptake of artificial sweeteners has been expected to help to reduce price volatility; also, in recent years, growing consumption of sugar by developing countries may have reduced the variability of prices, as markets in these countries are more price-sensitive than their richer counterparts.

# Industry Challenges

Challenges for the sugarcane industry in developing countries include the requirement for the removal of protectionist barriers in the European Union (EU) and USA[6] for sugar and alcohol; in 2003, for this reason, an action was started at the WTO against the EU by a group of countries led by Brazil (see Figure 3).

[5] Food Market Exchange, at www.foodmarketexchange.com/datacenter/product/sugar/detail/dc_pi_sugar_05_04.htm, acc 22 March 2004

[6] UNICA, at http://www.unica.com.br/i_pages/agroindustria_politicas.asp, acc 30 March 2004

Price volatility in sugar markets is a substantial difficulty for many cane-producing countries. This could, however, be reduced by a number of methods that would increase revenues for non-consumable products derived from cane:

1. Promotion of alcohol-fuelled vehicles: Brazil already encourages alcohol as a vehicle fuel, whilst new programmes for alcohol use in France, Mexico, Canada, Sweden, Australia, India, Colombia and China indicate favourable markets for ethanol fuels; the USA could also be a large market in the future.[8] In some countries, vehicle fuels are blended at the pump with bio-fuels such as sugar alcohol.
2. Expansion of bagasse-based cogeneration:[9] As this report makes clear, this could be implemented through increasing the value of electricity exported by sugar mills, or through the Kyoto Protocol's Clean Development Mechanism (CDM), amongst others. For bagasse cogeneration to take off, the value of electricity it generates needs to be increased to ensure that it is worthwhile producing for sale to the grid.

FIGURE 3

**THE WTO DEBATE**

Since 2002, a group of countries led by Brazil has claimed that EU subsidies for sugar exports distort competition conditions in the international market, damaging efficient sugar producers such as Brazil and other developing countries. The main reproaches are:

- Improper export subsidies. The EU claims that subsidised sugar exports are legitimate, as they apply to former colonies in Africa, Caribbean and the Pacific (ACP) under preferential treatment. Brazil, Australia and Thailand claim that the EU has the right to import sugar under preferential treatment, but not to export it. Brazil does not question the preferential tariff given to ACP countries.
- Sugar exports. Brazil claims that the EU is double-subsidising some of its sugar exports, which is prohibited under WTO rules.

SOURCE: USDA[7]

# The Sugar Production Process

The process of sugar production from cane is outlined in Figures 4 and 5, on pages 7 and 8 respectively.

The process is very energy-intensive, requiring inputs of both heat and power at many stages. This is why it is so well suited to the application of cogeneration.

[7] USDA, at http://www.fas.usda.gov/gainfiles/200310/145986300.pdf, acc 30 March 2004
[8] UNICA (see note 6)
[9] UNICA (see note 6)

FIGURE 4

**THE SUGAR PRODUCTION PROCESS**

| Processing raw sugar from sugarcane | |
|---|---|
| **Harvesting** | - |
| **Cleansing and grinding** | - |
| **Juicing** | Extraction of juice from the pulp. The remaining pulp, or "bagasse," is dried and used as fuel. |
| **Clarifying** | Addition of $CO_2$ and lime juice to the liquid sugar, followed by heating. As the $CO_2$ travels through the liquid, it forms calcium carbonate, which precipitates non-sugar debris (fats, gums and wax) from the juice. This precipitate, called "mud", is then separated from the juice by centrifugation. The juice is then filtered to remove any remaining impurities. |
| **Evaporation** | The filtered juice is evaporated in a vacuum, concentrated at a low temperature and the sugar crystallised in vacuum pans. |
| **Crystallisation** | Pulverised sugar is fed into a sterilised vacuum pan, as the liquid evaporates, a thick mass of crystals forms. The crystals are spun-dry in a centrifuge, producing raw, inedible sugar. |

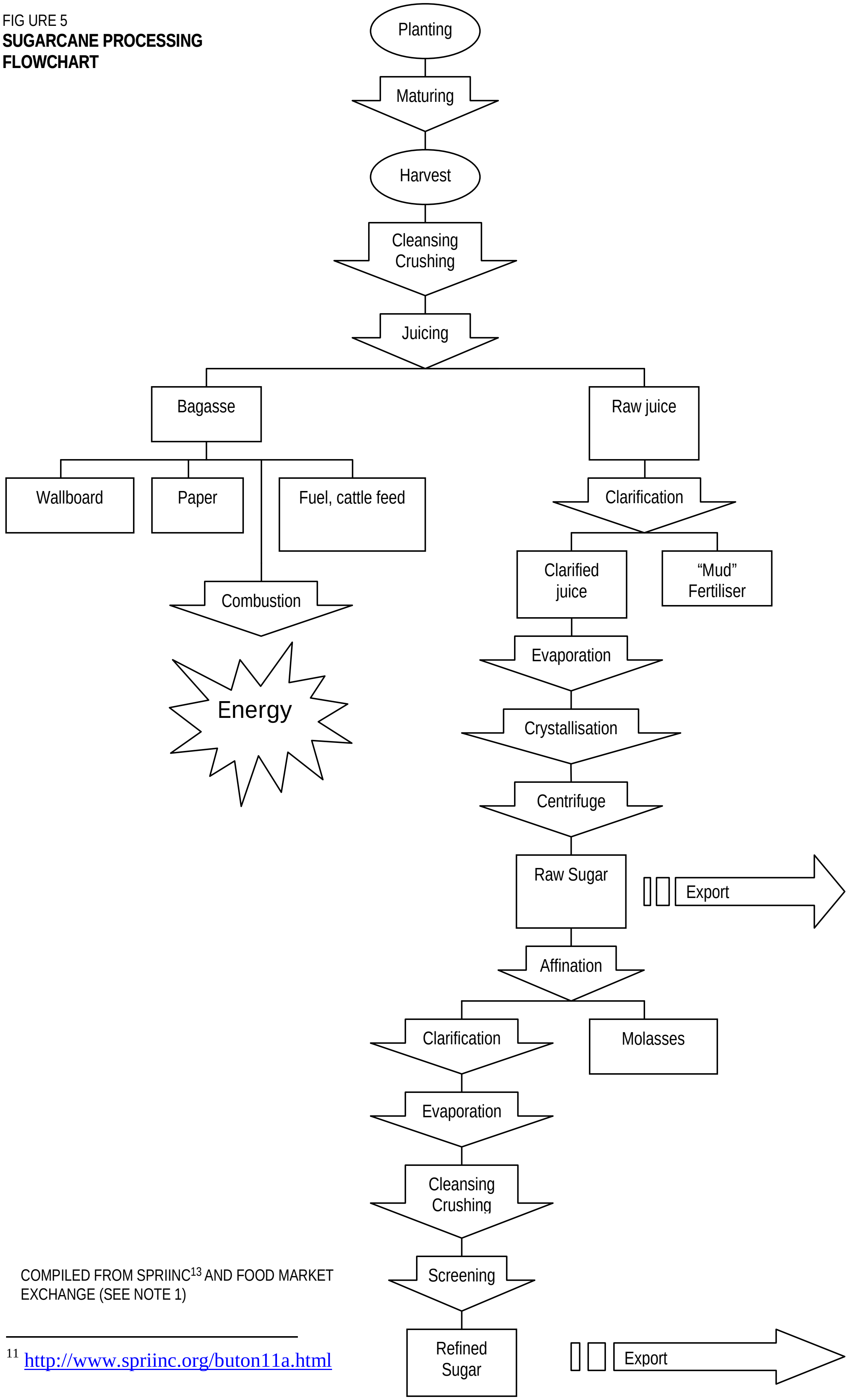
| Refined sugar production | |
|---|---|
| **Affination** | If the refinery is part of the raw sugar production facility, the cane sugar may be washed more heavily in previous steps and the affination step omitted. Affination removes the molasses film from raw sugar with warm, almost saturated, syrup. Crystals are separated from the syrup by centrifugal washing with hot water or a high purity solution of sugar. |
| **Clarification** | The main purpose of this process is to eliminate inorganic impurities present in raw sugar. |
| **Evaporation** | After clarification, the syrup must again be concentrated by multiple-effect evaporators and crystallised by vacuum pans. This is the same sequence used in the raw sugar process. The process of evaporation consists of boiling and crystallisation steps. |
| **Drying and cooling** | The damp sugar from the centrifuges is then treated in a special piece of equipment usually consisting of 2 horizontal drums. In the first drum, the sugar is dried by hot air and in the second, known as the cooler, sugar crystals are dried at ambient temperature. |
| **Screening** | The sugar from the dryer-cooler passes over vibrating screens, which separate out lumps that form when the sugar is sent to a hopper for bagging. |
| **Packaging** | - |

SOURCE: FOOD MARKET EXCHANGE[10]

[10] Food Market Exchange (see note 1)

FIG URE 5

**SUGARCANE PROCESSING FLOWCHART**




COMPILED FROM SPRIINC[13] AND FOOD MARKET EXCHANGE (SEE NOTE 1)

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[11] http://www.spriinc.org/buton11a.html

Sugar mills produce a range of by-products, including bagasse, filter mud and molasses. A typical sugarcane complex with a capacity of 3,000 tonnes crushed per day (TCD) can produce 345 tonnes of refined sugar, 6,000 litres of alcohol, 3 tonnes of yeast, 15 tonnes of potash fertiliser, 25 tonnes of pulp, 15 tonnes of wax, 150 tonnes of press-mud fertiliser[12] and 240MWh of exportable electricity from bagasse.

Bagasse is the fibrous residue of cane stalk obtained after crushing and the extraction of juice. Each tonne of sugarcane can yield 250kg of bagasse.[13] The composition of bagasse varies with variety and maturity of sugarcane as well as with harvesting methods used and efficiency of the sugar mill in processing the sugarcane. The properties of bagasse are outlined in Table 2, below.

TABLE 2
**PROPERTIES OF BAGASSE**

| | |
|---|---|
| Water content | 46-52% |
| Fibre content | 43-52% |
| Soluble solids | 2-6% |
| | |
| Average Density | 150kg/$m^3$ |
| Low-heat value[14] | 1780kcal/kg |
| High-heat value[15] | 4,000kcal/kg |

COMPILED FROM FOOD MARKET EXCHANGE[16], GOLLAKOTA & SOBHANBABU (2002)[17] AND RIBEIRO[18].

In the sugar industry, bagasse is usually combusted in furnaces to produce steam for power generation. It is also used as the raw material for production of paper and as feedstock for cattle. Figure 6 outlines other possible uses of bagasse.

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[12] Food Market Exchange (see note 1)
[13] Pickering, S. (2000). Sugarcane: Offering Australia a Sweet Power Alternative, in Refocus (September-October 2000). Available at http://www.re-focus.net/news_archive/index.html.
[14] Low-Heat Value (gross calorific value) is the maximum energy that can be derived from a fuel. It is the heat evolved when all the products of combustion have cooled to atmospheric temperature and pressure.
[15] High-Heat Value (net calorific value) is the heat evolved when all the products of combustion have cooled so that the water remains in gaseous form.
[16] Food Market Exchange (see note 1)
[17] Gollakota, S.V. & Sobhanbabu, P.R.K. (2002). Accomplishments of the USAID-India's GEP-ABC Component. Proceedings of the 3rd International CHP and Decentralized Energy Symposium & USAID International Conference and Exhibition on Bagasse Cogeneration, October 2002, New Delhi.
[18] Ribeiro, J.E., DEDINI. Optimising Energy Generation and Use in Sugar and Alcohol Plants. Presentation given on 12 February 2004.

The value of bagasse as a fuel depends largely on its calorific value, which in turn is affected by its composition, especially with respect to water content and to the calorific value of the sugarcane crop, which depends mainly on its sucrose content[21]. Every tonne of sugar has an energy potential equivalent to that of 1.2 barrels of petroleum.[22]

FIGURE 6

**OTHER USES OF BAGASSE**

Research is currently being undertaken on further developing and promoting biodegradable plastics made of sugar and bagasse that break down into water and $CO_2$ within six months instead of the hundred years or so required by conventional plastics. As it takes 17kg of cane bagasse and 3kg of sugar to make just 1kg of biodegradable plastic, bagasse-based plastics are currently niche products. However, their chemical resistance, quality and biodegradability are promising despite the higher costs associated with their development.[19] In the near future, environmental requirements may accelerate a wider uptake of cane plastics.

Bagasse could also compete, to some extent, with petrochemicals involved in the manufacture of adhesives, synthetic fibres, herbicides and insecticides as well as substances like ethyl ether, acetic acid, ethyl acetate and diethyl amines.[20] Once again, the main advantage of bagasse in these applications would be its biodegradability.

## Energy Requirements

The sugar and alcohol production process is energy-intensive, requiring both steam and electricity.[23] Historically, sugar mills have been designed to meet their energy requirements by burning bagasse: this was seen as an economic means of producing electricity whilst cheaply disposing of bagasse.[24] However, as there was little potential for the sale of electricity to the grid, efficiency in the process was a hindrance rather than a bonus.

In addition, over the years the energy requirements of sugar mills have increased, both in and out of season. This has mainly been due to the development of downstream units such as distilleries as well as ethanol, chemical, paper, effluent treatment and biogas generation plants. The establishment of settlements around mills, with their related social, educational and commercial activities, has also contributed to increased electricity demand. In countries such as India, this has compelled sugar mills to buy electricity from utilities and use non cane-based fuels to meet energy requirements, particularly out of season. In the case of the least energy-efficient mills, such requirements can be quite high.

About one third of the bagasse produced in a mill can provide enough steam and electricity for the mill's requirements.[25] Table 3 summarises the typical energy requirements cane mills.

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[19] UNICA http://www.unica.com.br/i_pages/pesquisa3.asp, acc 30 March 2004

[20] UNICA (see note 19)

[21] UNICA, at http://www.unica.com.br/i_pages/cana_tecnologia.asp, acc 30 March 2004

[22] UNICA, at http://www.unica.com.br/i_pages/agroindustria_alta.asp, acc 30 March 2004

[23] UNICA, at http://www.unica.com.br/i_pages/pesquisa5.asp, acc 30 March 2004

[24] WADE (2003) Survey of Decentralized Energy in Brazil; Pers. Comm. Sunil Natu (2004).

TABLE 3
**STEAM AND POWER DEMANDS OF A TYPICAL SUGAR MILL, PER TONNE OF CANE CRUSHED**

| Sugar Mill Efficiency | Low-to-High |
|---|---|
| **Steam requirement** | c.500kg (low and high efficiency) |
| **Electricity requirement** | 15kWh (low) to 34.5kWh (high) |

COMPILED FROM ECOINVEST[26], SHIRGAOKAR (2002) [27]

Boilers employed in non-cogeneration sugar mills have historically been rather inefficient, using pressures of only 20-45kg/cm$^2$ with matching backpressure turbine generators. In such mills, steam produced at comparatively higher pressures is passed through steam turbines, generating electrical power for the milling process. Backpressure steam at 1.5kg/cm$^2$ and small quantities of medium-pressure backpressure steam (7kg/cm$^2$) are used for process requirements.

[25] Casten, T (2004). The DG Revolution – A Second Indian Miracle. Available at http://www.localpower.org/pdf/DG%20Revolution%20Tom%20Casten.pdf
[26] Ecoinvest, 2000, at http://www.ecoinv.com/english/Projects/Sugarcane/sugarcane.htm, acc 2 April 2004
[27] Shirgaokar, R.V. (2002) Case Study: Upgraded Bagasse Cogeneration. Proceedings of the 3rd International CHP and Decentralized Energy Symposium & USAID International Conference and Exhibition on Bagasse Cogeneration, October 2002, New Delhi.

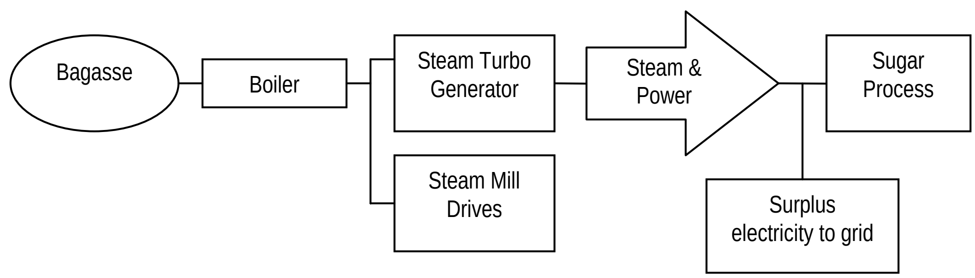
# 3. The Benefits of Bagasse Cogeneration

## Bagasse Cogeneration - A Technical Overview

Bagasse cogeneration was pioneered in Mauritius and Hawaii. By 1926-27, 26% of Mauritius' and 10% of Hawaii's electricity generation was from sugar factories.[28]

The process of bagasse cogeneration is sketched out in Figure 7, below.

FIGURE 7
**THE BAGASSE COGENERATION PROCESS**




The new generation of high-efficiency boilers being installed on grid-connected bagasse cogeneration plants, produce extra-high pressures and temperatures rated at respectively 60-80 $kg/cm^2$ and 490-520°C and above, compared to current settings of around 20 $kg/cm^2$ and 300°C. The rationale for using such boilers is summarised in Table 4.

[28] Report of the First National Forum on Small-Scale Renewable Energy in Belize, 6th July 2001, available at http://www.bun-ca.org/publicaciones/18.pdf, acc 11 March 2004.

TABLE 4
**COMPARISON OF LOW- WITH HIGH-TEMPERATURE AND -PRESSURE BOILERS**

| | Low T and P | High T and P |
|---|---|---|
| **Power Generation (kWh/TC)** | 20-30 | 90-160 |
| **Net Power from Bagasse (kWh/tonne)** | 60 | 370-510 |
| **Heat rate, processing (kcal/kWh)** | 21,000 | 6,000-8,000 |

SOURCE: GOLLAKOTA & SOBHANBABU (2002) [29]

In order to maximise the amount of electricity sold to the grid, it is also important to minimise the process use of steam and power through the use of energy conservation techniques and management as well as energy efficient equipment. In India, such policies have included conversion of mills from steam-driven to electricity-driven, use of steam-saving equipment in boiler houses and energy-efficient pumps and motors.

## The Rationale for Cogeneration from Bagasse

From a financial point of view, bagasse cogeneration is a classic win-win for the sugar industry,[30] as it boasts numerous advantages over traditional generation. Cogeneration of energy from bagasse is attractive as it combines low cost, efficiency and social benefits with the provision of clean, renewable energy.

Bagasse cogeneration, especially in high-temperature and pressure configurations, could play an important role in encouraging much more efficient use of resources and ensuring widespread access to electricity services. Unfortunately, insufficient incentive to supply electricity to the grid because of low or inexistent buyback rates has meant that, until recently, around two thirds of harvested bagasse was wasted.[31] This situation is now set to improve, with the introduction of more effective biomass feed-in tariffs in countries such as Brazil and India.

[29] Gollakota & Sobhanbabu (see note 17)
[30] Ghosh, S. (2002). Bagasse Cogeneration – A Bank's Perspective. Proceedings of the 3rd International CHP and Decentralized Energy Symposium & USAID International Conference and Exhibition on Bagasse Cogeneration, October 2002, New Delhi, p 120.
[31] Casten (see note 25)

## 1. Economic Benefits

Benefits and advantages of bagasse cogeneration include:

a. Increasing the viability of sugar mills
b. Near-zero fuel costs, paid in local currency and valuation of bagasse as a waste product
c. Increased fuel efficiency
d. Increasing diversity and security of electricity supply
e. Location at the point of energy demand, leading to minimal transmission and distribution (T&D) costs.

### a. Increasing the Viability of Sugar Mills

The long-term economic viability of sugar mills has become more vulnerable, mainly due to fiercely competitive domestic and global sugar markets. The inherent energy inefficiency of design and operation as well as the industry's high energy requirements are also factors of growing importance. Appropriate remuneration of electricity from bagasse cogeneration would increase the added value to the alcohol and sugar sectors.[32] This is especially valid as sugar-milling seasons often coincide with peak demand loads. In countries such as Brazil, where peak power can be up to ten times costlier that off-peak power,[33] sugar mills can thus benefit immensely from the opportunity to sell electricity to the grid.

### b. Fuel Costs

The capital costs of bagasse cogeneration plant are the lowest of all renewable forms of power generation, equal to those of biomass gasification projects, whilst generation costs, despite being higher than biomass gasification projects, small hydroelectric (HEP) and photovoltaic (PV), are on par with biomass power and lower than wind.[34] Bagasse cogeneration projects also have short development periods, as the technologies used are proven and well established.

### c. Diversity and Security of Supply

The use of a local fuel source guarantees a certain degree of security of energy supply, improving and increasing the trade balance with imported fuels. Onsite crop use ensures that delivery times

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[32] Ottenheym, R., Cogen SP (2003). Promoting Energy Cogeneration in São Paolo.
[33] WADE (see note 24)
[34] Majumdar, D. (2002). Financing of Bagasse Cogeneration – Issues and Opportunities. Proceedings of the 3rd International CHP and Decentralized Energy Symposium & USAID International Conference and Exhibition on Bagasse Cogeneration, October 2002, New Delhi.

are short and costs are kept low. Out of season, biomass co-firing with green wood or eucalyptus, for instance, is now possible in many cases, being factored into the design of new bagasse cogeneration plants. This enables bagasse cogeneration plants to operate beyond the crushing season for up to 300-330 days / year.

The advantages of bagasse cogeneration in increasing security of power supply issues also include the capacity to generate during the dry season,[35] when, for example, HEP sites are not operational. Sugar mills that produce and export electricity also increase grid stability and reliability as well as decreasing the need for costly capital investments in grid upgrading in these areas.[36] In Brazil, for instance, São Paolo State has already developed all its large economically viable HEP sites, so the promotion of electricity from bagasse cogeneration is seen as a means of avoiding electricity imports from other regions to meet the State's demand.

**d. Location**

As a decentralised mode of electricity generation, bagasse cogeneration reduces T&D losses by supplying electricity near its generation point whilst reducing loads on grid wires.[37] This could be most significant in large countries such as India and Brazil, where average T&D losses account for around 23% and 16% of centrally generated electricity respectively,[38] mainly due to long distances between generation and end-users. Bagasse cogeneration will thus benefit customers who do not have to bear the costs of such high T&D losses.

Integration of cogeneration technologies in the sugar industry, especially in extra-high pressure and temperature configurations, will almost certainly be essential for the long-term growth and economic survival of the sugar industry in many cane producing countries. The ability to meet all of the mill's increased energy needs as well as the promise of additional revenues from the sale of exportable surpluses to utilities or third parties could become key factors in securing the sugar industry's viability.

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[35] de Hollanda, J. & Poole, A., INEE (2001). Sugarcane as an Energy Source in Brazil. Available at http://www.inee.org.br/down_loads%5Cabout/SUGARCANE&ENERGY.pdf, acc 2 April 2004
[36] Ottenheym, R., Cogen SP (2003). Promoting Energy Cogeneration in São Paolo.
[37] Casten (see note 25)
[38] Casten (see note 25)

## 2. Social Benefits

The social benefits of onsite bagasse-fired cogeneration are:

a. Greater employment for local populations

b. More widespread availability of electricity

c. More secure and reliable supply of electricity for existing consumers.

### a. Employment

Bagasse cogeneration has the potential to boost employment for neighbouring populations, increasing income for farmers. It will also allow operational personnel to develop skills to use local equipment and technologies, improving the local socio-economy.[39]

### b. Availability of Electricity

As sugar mills tend to be located in rural areas, near sugarcane plantations, bagasse cogeneration will prove beneficial to local populations by contributing to expanding access to electricity supplies in areas otherwise distant from the grid. The advent of links to the network will facilitate the collection of electricity payments by electricity boards in rural areas whilst electricity boards will be able to better serve rural consumers through the upgrade of local and rural networks.

### c. Quality of Electricity

The simultaneous increase in reliability and quality of power in the area will enhance quality of life whilst reducing voltage and frequency variation and the associated damages that these cause to network equipment.

As it is a locally sourced fuel, bagasse will increase the reliability of electricity supply by diversifying sources and reducing fossil fuel dependence. This is particularly true of countries heavily dependent on HEP, such as Brazil, where bagasse cogeneration could reduce the risks of electricity shortages in dry years.

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[39] Ribeiro (see note 18)

## 3. Environmental Benefits

As a biomass fuel, bagasse supplies a raw material for the production of natural, clean and renewable energy, enabling its use to further government targets for renewable energy use. In brief, the environmental advantages of bagasse cogeneration are:

a. Low emission of particulates, $SO_2$, $NO_x$ and $CO_2$ compared to coal and other fossil fuels
b. In GHG terms, bagasse combustion emits less than composting.
c. Fuel efficiency.

### a. Emissions

Bagasse combustion is environmentally friendly because it boasts low particulate and $CO_2$ emissions. This is especially true where bagasse cogeneration replaces carbon-intensive fossil fuel generation. For instance, in India and China, bagasse could displace coal, which amongst other problems has very high levels of ash.

### b. Combustion versus composting

In terms of $CO_2$ and other GHG, bagasse cogeneration would add no net emissions: bagasse is viewed as a waste product that needs to be disposed of – either by decomposition (composting) or combustion, both of which would release, as $CO_2$, the carbon contained in bagasse.[40] Besides, if the bagasse were to be composted, it would also release methane, a GHG 27 times more potent than $CO_2$.[41]

These benefits will enable bagasse cogeneration to be a potentially significant player in international carbon credit markets in the future, with sugar industries reaping the social and financial benefits of the added revenues (see sections 7 and 9).

### c. Fuel efficiency

Cogeneration is a highly efficient energy conversion process. The same amount of bagasse will yield more power (heat as well as electricity) in cogeneration mode than in conventional combustion processes that do not recover heat. More efficient fuel use can thus also further countries' sustainable development goals.

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[40] Ribeiro (see note 18)
[41] Casten (see note 25)

# 4. India

## Electricity Production

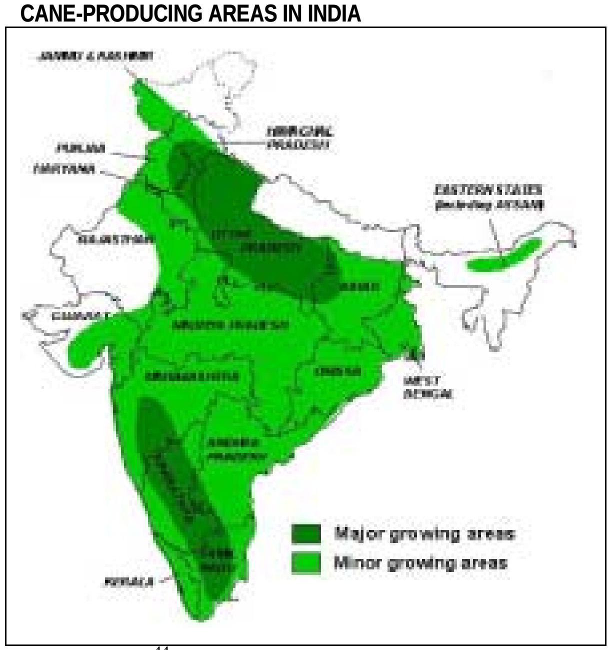
India's total electric generation capacity is 120.3GWe.[42] The current prevailing energy mix, consisting of 65-70% fossil fuel based thermal energy, is expected to remain at this level over the next 10-20 years.

T&D and commercial losses are very large, amounting to around 40% of the total electricity generated centrally. For this reason, 1kWh generated locally can be taken to be roughly equivalent to 1.5-1.8 generated centrally.[43]

## Cane Production

India has just over 500 sugar mills,[45] with nine states (Uttar Pradesh, Bihar, Punjab and Haryana in the northern region; Maharashtra & Gujarat in the western region and Andhra Pradesh, Tamil Nadu and Karnataka in the southern region, Figure 8) holding 95 % of them. Most mills are either privately owned or co-operatives.[46] Figure 9 gives details of the distribution of sugar mills in India.

FIGURE 8
**CANE-PRODUCING AREAS IN INDIA**




SOURCE: USDA[44]

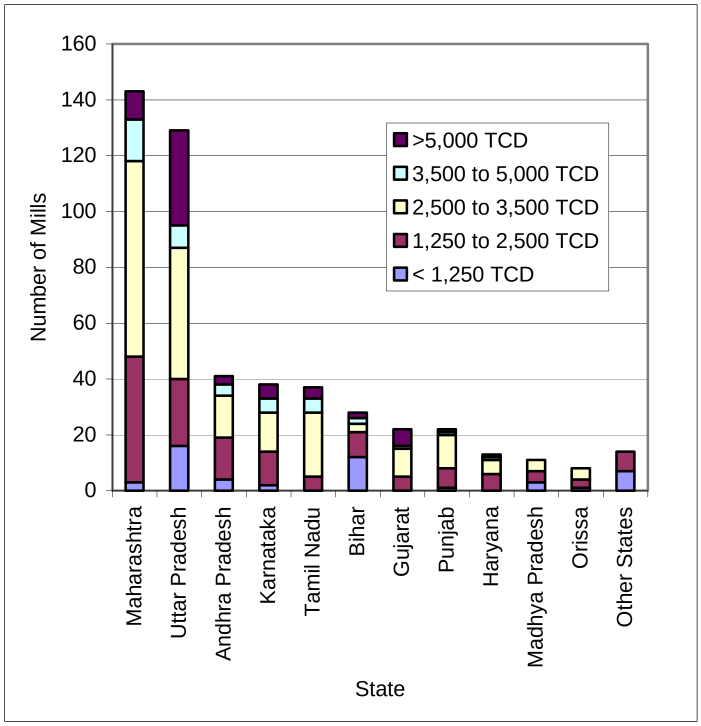
In India, the crushing season lasts 100-250 days per annum depending on the region,

[42] USDOE, http://www.eia.doe.gov/pub/international/iea2002/table64.xls, last accessed 27-May-2004
[43] Casten (see note 25)
[44] USDA, at http://www.usda.gov/oce/waob/jawf/profiles/graphs/ind/indsugc.gif, acc. 19-April-2004
[45] National Federation of Co-operative Sugar Factories Ltd., New Delhi. **Co-operative Sugar**, June 2003.
[46] The Sugar Technologist's Association of India. List of Cane Sugar Factories & Distilleries (2002-2003)

weather, irrigation and cultivation practices as well as cane availability, in itself a function of the prices paid to cane growers.

Sugar mills have capacities ranging from below 1,250 TCD to 10,000 TCD. The Indian Government has now established minimum capacity criteria for new sugar mills standing at 2,500 TCD.

FIGURE 9
**DISTRIBUTION OF SUGAR MILLS IN INDIA**




SOURCE: THE SUGAR TECHNOLOGIST'S ASSOCIATION OF INDIA (2002-03)[47]

## Market Trends

The economic and commercial performance of the Indian sugar industry has generally been poor and subject to wide fluctuation. The complexities of regional, socio-economic and political linkages of the different ownership sectors of sugar mills present severe challenges for survival and growth.

Indian sugar mills are currently self-sufficient in energy, already using bagasse to meet their steam and power requirements. As only 20-30% of all bagasse is used for these purposes, this suggests that the remaining 2/3 of bagasse is currently being "wasted",[48] as it is being incinerated for disposal purposes rather than energy recovery.

Greater sector efficiency, higher quality and integration are challenges for the industry to improve the strength and capacity built in the last seventy years. These aims can be achieved through:

[47] Sugar Technologist's Association of India (see note 46)
[48] Casten (see note 25)

- Substantial improvements in cane development and management including cultivation practices, crop variety and water management to improve yields and recovery without affecting the average fibre content.
- Improvements in both sugar and by-product manufacturing, achieved through operational and energy efficiency improvements, will contribute to making the best use of bagasse.
- Capacity expansion and diversification into cogeneration and alcohol/ethanol production projects in order to maximise the value of sugar whilst adding security to sugar markets through diversification of products.

# Bagasse Cogeneration: Current Status, Future Potential

## Historical Background

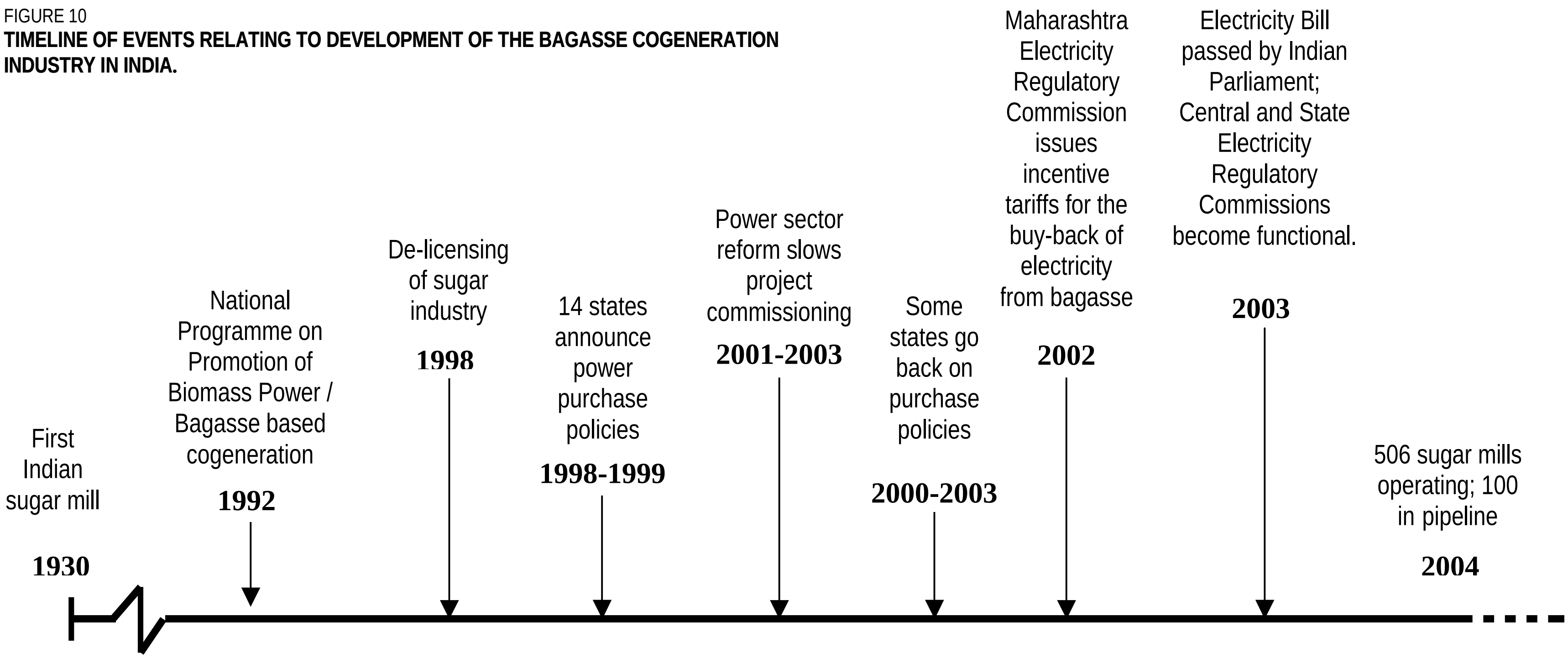
Since the early 1990s, in recognition of the advantages of bagasse cogeneration relative to current regimes of centralised generation in India, several governmental, national and international agencies and financial institutions have been acting to promote and develop cogeneration power projects in Indian sugar mills. In addition to its wider benefits, bagasse cogeneration is seen as a potential means of meeting India's renewable energy targets,[49] set at 10% of total installed grid capacity by 2012.[50] A timeline of the industry's development is given in Figure 9.

In 1994, the Indian Ministry of Non-Conventional Energy Sources (MNES) started the process of helping bagasse cogeneration to take off by urging State Electricity Boards (SEB) to purchase power from local generators at full avoided costs whilst contributing half of grid connection costs. Eligibility criteria cover a wide range of configurations, broadening the Programme's applicability. The implementation of this regime in Maharashtra was particularly advantageous, with a buyback rate of 6.7 USc / kWh. After regulators became convinced that such distributed generation could provide a cost-effective and environmentally friendly solution, this eventually resulted in 710MWe of new capacity being built, planned or contracted.[51] Since then, objectives and policy strategies have been altered to meet changing markets and new challenges whilst governmental, fiscal and financial institutions have developed further incentives. Current incentives are summarised in Table 5.

[49] Majumdar (see note 34)
[50] Gollakota & Sobhanbabu (see note 17)
[51] Casten (see note 25)

FIGURE 10

**TIMELINE OF EVENTS RELATING TO DEVELOPMENT OF THE BAGASSE COGENERATION INDUSTRY IN INDIA.**




| 1930 | | 2004 |
|---|---|---|
| 29 | Number of Mills | 506 |
| 1,176 | Cultivated Area (Thousand Hectares) | 4,500 |
| 36 | Cane Production (Million Tonnes) | 295 |
| 1.3 | Cane crushed (Million Tonnes) | 1.35 |
| 110 | Season (Number of Days) | 180 |
| 0.12 | Sugar Production (Million Tonnes) | 13.2 |
| 8.96 | Average % of Cane Recovered | 9.95 |

COMPILED FROM NATIONAL FEDERATION OF CO-OPERATIVE SUGAR FACTORIES LTD (2003)[1], PERS.COMM, SUNIL NATU (2004), MERC

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[52] Co-operative Sugar (see note 45)
[53] www.mercindia.com

TABLE 5

**INCENTIVES FOR BAGASSE COGENERATION FROM INDIAN GOVERNMENTAL, FISCAL & FINANCIAL INSTITUTIONS**

| Incentive: | Description: |
|---|---|
| **National Programme on Promotion of Biomass Power / Bagasse-based Cogeneration** | Capital Subsidy for CHP projects in co-operative/public sector sugar mills, through Joint Venture (JV) or IPP mode, equivalent to 3,500,000-4,500,000 Indian Rupees (c. US$ 77,000 – 100,000) / MW of exportable surplus, depending upon level of pressure / temperature configuration. |
| | Interest Subsidy for commercial biomass power / CHP projects through leading financial institutions, at 2-3 % or 1-3% depending on biomass category and level of pressure / temperature configuration. |
| | Financial assistance under National Biomass Resource Assessment Programme, up to 90% of the cost. |
| | Financial support to research projects proposed by industry – laboratory / academic institution consortia. |
| **Accelerated Depreciation** | 100% depreciation in the first year can be claimed for the following power generation equipment:<br>1. Fluidised Bed Boilers<br>2. Back pressure, pass-out, controlled extraction, extraction and condensing turbines for power generation with boilers<br>3. High efficiency boilers<br>4. Waste heat recovery equipment |
| **Income Tax Holiday** | Five year tax holiday with 30% exemption |
| **Customs Duty** | 20% duty levy for New and Renewable Sources of Energy power projects of less than 50MWe capacity (under Project Import Category). This covers machinery and equipment component parts required for generation of electric power. |
| **Central Excise Duty** | Exempted for renewable energy devices, including raw materials, components and assemblies. |
| **Central Sales Tax** | Exempted for renewable energy devices, including raw materials, components and assemblies. |
| **General Sales Tax** | Exemption is available in certain States. |

COMPILED FROM PERS.COMM. SUNIL NATU (2004)

The adoption by SEB of such promotional programmes has triggered the uptake of bagasse cogeneration projects. Indeed, since the first SEB implemented this policy, 87 new bagasse projects have been developed or started, adding almost 1% to total Indian generation capacity.[54]

[54] Casten (see note 25)

## Potential for Bagasse Cogeneration in India:

Projections for India's potential for bagasse cogeneration range from 3.5GW[55]-5.2GW[56] (2002 projection) to at least 5GW (2004 projection). This potential is expected to be tapped by 2012, resulting in annual savings of $923 million / year whilst reducing annual $CO_2$ emissions by 38.7 million tonnes.[57]

TABLE 6
**STATE-BY-STATE POTENTIAL FOR BAGASSE COGENERATION IN INDIA**

| State | Potential (MW) | Commissioned exportable capacity, as of 31 December 2003 (MW) |
|---|---|---|
| Maharashtra | 1,250 | 21.0 |
| Uttar Pradesh | 1,250 | 75.0 |
| Tamil Nadu | 500 | 105.0 |
| Karnataka | 500 | 125.0 |
| Andhra Pradesh | 300 | 49.3 |
| Bihar | 300 | Nil |
| Gujarat | 250 | Nil |
| Punjab | 150 | Nil |
| Other | 500 | Nil |
| **Total** | **5,000** | **375.9 (7.5%)** |

SOURCE: MNES, NEW DELHI

Table 6 illustrates the potential, State by State, for producing exportable surpluses from sugar mill cogeneration. Figures are based on current mill numbers, capacities, efficiencies and cane availability as well as future prospects in terms of modernisation for optimisation of export potential. The potential is to be achieved mainly through improvements in energy efficiency and adoption of extra-high pressure (>60 kg/cm$^2$) and temperature configurations. Despite adding to the mills' demand for steam and power, the corresponding increase in power output would in itself so big as to make this worthwhile from a financial stance. More potential could also be achieved by always considering co-firing with other available fuels as an option, as this would enable mills to continue exporting power out of season.[58]

In addition to those mentioned in Table 6, 38 projects with equivalent exportable surplus capacity of 335.17 MW are currently at various stages of implementation.

[55] Majumdar (see note 34)
[56] Shiralkar, S.V. (2002). CHP and Decentralized Energy in India – Benefits and Challenges. Proceedings of the 3rd International CHP and Decentralized Energy Symposium & USAID International Conference and Exhibition on Bagasse Cogeneration, October 2002, New Delhi.
[57] Casten (see note 25)
[58] Casten (see note 25)

Figure 11 gives the cost of generation for a typical project, based on a set of givens and assumptions outlined in the left-hand column.

FIGURE 11
**THEORETICAL PROJECT EXAMPLE - INDIA**

There are several models for sugar mill cogeneration projects, with outputs varying most with crushing capacity and technologies used.

The project mill has the following features:

- 2,500TCD capacity
- 67kg/cm$^2$ pressure, 495°C temperature extraction-condensing turbine, operating both in and out of season.
- Boiler capacity: 80 TPH
- Installed total generating capacity for cogeneration: 18MWe
- Generation capacity: 15MW, 10MW of which are exportable in season (180 days) and 15MW out of season (120 days).
- Capacity utilisation: 85%.
- Total power exports: 73.44MWh per year, shared equally between the crushing and non-crushing seasons.

Exchange rate taken: 1 Indian Rupee = US$ 0.022, given to the nearest dollar.

| | **COST US$** |
|---|---|
| Capital cost<br>(cost / MW installed capacity) | 119,403<br>(6,634) |
| Cost of generation | |
| • 70% debt (interest rate 16%) | 13,378 |
| • 30% equity (interest rate 12%) | 4,290 |
| • Depreciation (5.28% of capital cost) | 6,302 |
| • O & M cost<br>(% of capital cost) | 4,179<br>(3.5%) |
| • Admin overheads<br>(% of capital cost) | 907<br>(0.75%) |
| • Interest on working capital<br>- 3% spares @ 15%<br>- 3 months debtors @ 15% | <br>531<br>2,145 |
| • Loading of fuel cost for cogeneration, in season<br>• (MT of bagasse @ US$8.85 / MT) | 1,504<br>374 |
| • Off-season fuel cost<br>• (MT of procured bagasse / equivalent biomass or coal @ US$14.37 / MT) | 16,208<br>2,492 |
| • Total | 49,442 |
| **Cost of generation (US$ / kWh)** | **0.067** |

SOURCE: COGEN INDIA, PERS. COMM. SUNIL NATU

The potential for bagasse cogeneration in Indian sugar mills is therefore great, with expanded use providing increasing economic value and returns from higher efficiency in generation, distribution and equipment use. Energy audits, careful implementation, maintaining efforts for energy conservation and above all, building capacity and culture for the purpose, will go a long way to achieve these goals.

# 5. Brazil

Brazil has a population of 170 million people, mostly concentrated along the southeast coast. By 2002, approximately 95% of homes had access to electricity services, but in remote areas of Brazil for which connection to the national grid is uneconomic, rural communities rely on decentralised renewable energy projects for electrification. Electricity consumption is concentrated in the industrialised southern coastal regions.[59]

## Electricity Production

Brazil's generating capacity is currently around 74GWe, 95% of which is generated centrally by HEP.[61] Vast distances separate the HEP schemes from end-users and, consequently, T&D system losses are amongst the highest in the world at an average of 16%.[62] Table 7 gives a breakdown of losses in the Brazilian T&D system.

TABLE 7
**GRID LOSSES IN BRAZIL**

| | Consumption | Losses |
|---|---|---|
| Off-grid Systems | 2% | 29.6% |
| **Grid systems** | | |
| North | 19% | 14.9% |
| North East | | 19.3% |
| South-East / Central | 79% | 16.0% |
| South | | 11.9% |
| **Average** | | **16.0%** |

COMPILED FROM BNDES AND USAID[60]

In order to meet electricity demand during prolonged periods of low rainfall, large surpluses of water were traditionally maintained in hydropower reservoirs.[63] However, with demand for electricity forecast to rise by 3% per annum until 2020,[64] the Brazilian government is striving to provide new security to the electricity sector whilst delivering greater access to rural populations. Over-reliance on HEP was an underlying factor behind the 2001 electricity crisis, as low rainfall led to low storage levels in reservoirs.

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[59] WADE (see note 24)
[60] USAID Programs: the Leader With Associates (LWA) Program and the Brazil Clean Energy and Energy Efficiency Program (BCEEP), U. S. Agency for International Development; and WINROCK International.
[61] UNICA (see note 23)
[62] WADE (see note 24)
[63] UK Trade and Investment (2002). Power Market in Brazil: Overview. Available at http://www.tradepartners.gov.uk/energy/brazil/profile/overview.shtml, last accessed 17 May 2004.
[64] WADE (see note 24)

Cogeneration currently represents around 3% of total electricity generation. Of this, biomass accounts for two thirds with coal and gas making up the remainder. Most biomass cogeneration is based on bagasse use in sugar mills.

## Cane Production

In Brazil, cane is produced on only 1% of the land suitable for farming.[66] It is grown in both the south-central and north-northeast regions, allowing for two harvest periods and a continuous production. Figure 12 illustrates the main sugar-growing areas of Brazil. Depending on planting time, sugarcane takes between twelve and eighteen months to mature, but a plantation can then be harvested up to five times on condition that significant investments are made at each cycle to maintain productivity.[67]

FIGURE 12
**MAIN SUGAR-PRODUCING AREAS IN BRAZIL**


SOURCE: USDA[65]

Brazil's sugarcane industry employs a total of 1 million people.[68] São Paulo State alone employs about 400,000 in its plantations and mills, representing 40% of the State's rural employment[69] for the combined production of sugar, ethanol, energy and electricity associated with sugarcane.[70]

Currently, 80% of harvesting is manual but mechanisation is advancing, especially in São Paulo State, where this now reaches 25%.[71] For manual harvesting, the cane trash is burnt prior to harvest, as this makes safer and more productive for cane cutters. This method, however, leaves little scope for energy production from bagasse.

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[65] USDA http://www.usda.gov/oce/waob/jawf/profiles/graphs/brz/brzsugc.gif Acc. 19-April-2004
[66] UNICA (see note 22)
[67] UNICA (see note 22)
[68] UNICA http://www.unica.com.br/i_pages/cana_corte.asp, acc 30 March 2004
[69] UNICA http://www.unica.com.br/i_pages/sociedade_desenvolv1.asp, acc 30 March 2004
[70] UNICA (see note 69)
[71] UNICA (see note 68)

## Market Trends

Brazil is the world's largest sugar producer and exporter,[72] with half of its production going to a host of countries led by Russia and Nigeria.[73] Sugar exports contributed US$1.2 billion to the trade balance in the year 2000. São Paulo State, on its own, produces 60% of all Brazilian sugar and accounts for 70% of national exports.[74] Brazil is able to remain competitive in international markets due its use of advanced technology and management methods that enable it to have the world's lowest production costs. Besides, the leveraging of exports by the devalued Real with respect to the U.S. dollar has also maintained its position in the competitive international market.[75]

With its high population and a long tradition of high per capita sugar consumption (52kg compared to a world average of just 22kg[76]), Brazil has a high domestic annual consumption, which, in spite of macroeconomic problems, is inelastic.[77]

Around 55% of Brazilian sugarcane is converted into alcohol for fuel.[78] As alcohol and sugar prices rise and fall in relation to each other, the conversion to alcohol rises or falls according to the optimal balance for revenue maximisation. Alcohol content in domestic gasoline is high and is set by the government. Since June 2003, this has been 25%.[79]

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72 UNICA http://www.unica.com.br/i_pages/acucar_tecnologia.asp, acc 30 March 2004
73 Food Market Exchange http://www.foodmarketexchange.com/datacenter/product/sugar/detail/dc_pi_sugar_05_03.htm, acc 22 March 2004
74 UNICA (see note 72)
75 USDA (see note 7)
76 UNICA (see note 72)
77 USDA (see note 7)
78 UNICA (see note 22)
79 USDA (see note 7)

# Bagasse Cogeneration: Current Status, Future Potential

## Historical Background

The development of bagasse cogeneration was initially prompted by the 1970s oil crises, when Brazil was highly dependent upon petroleum. Sugar mills were then encouraged to generate electricity for their own consumption.

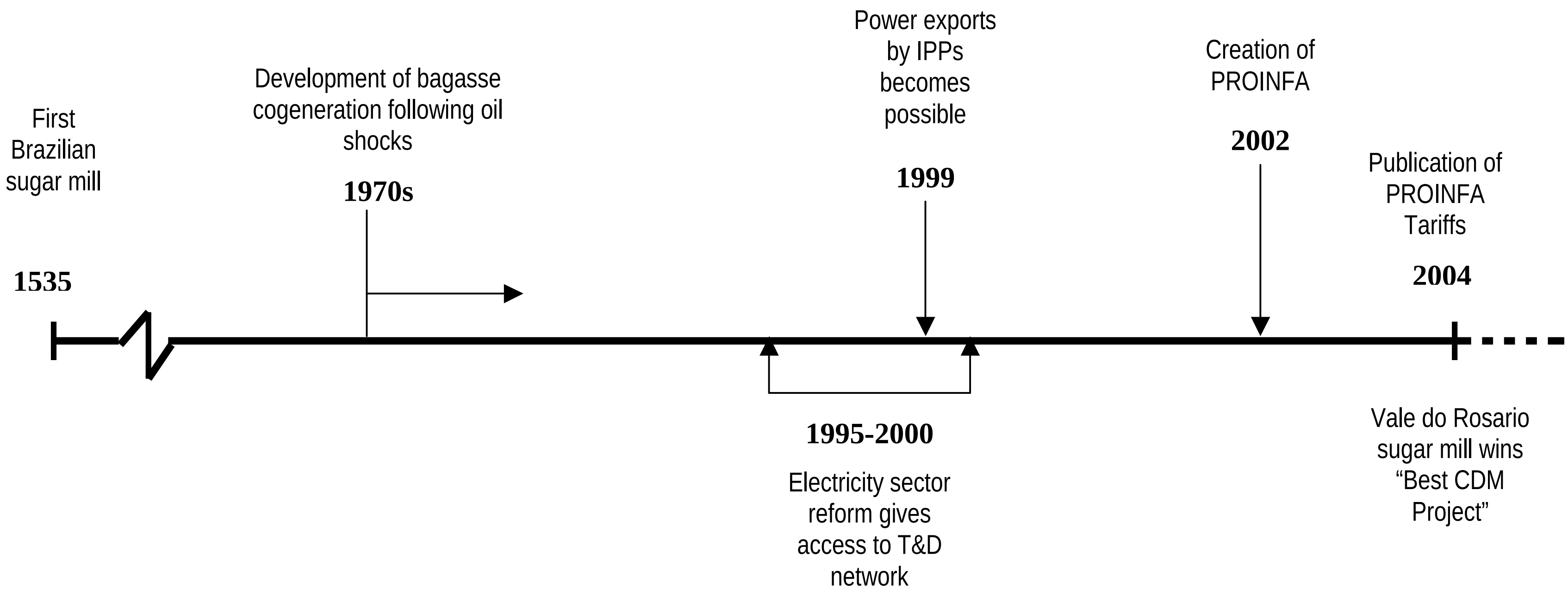
As, until July 1999, power exports from mills were not possible, the industry developed low pressure, low efficiency 2-100MWe units for self-supply only[80] to ensure that excess bagasse could not accumulate and become a disposal problem. Almost all sugar mills and alcohol distilleries in Brazil employed small bagasse-fired steam turbine systems – supplied with steam at 21kg/cm$^2$ – to provide just enough steam and electricity to meet onsite factory needs.[81] Most of these units date from about 20 years ago.[82]

Figure 13 summarises a time-line of the main events affecting the development of bagasse cogeneration in Brazil.

[80] WADE (see note 24)
[81] Ecoinvest (see note 26)
[82] WADE (see note 24)

FIGURE 13

**TIMELINE OF EVENTS RELATING TO DEVELOPMENT OF THE BAGASSE COGENERATION INDUSTRY IN BRAZIL**




COMPILED FROM WADE (2003), UK TRADE AND INVESTMENT (2002)[81]

[83] UK Trade and Investment (see note 63)

Most of Brazil's biomass cogeneration is in São Paulo State, where 40 sugar mills use 1.2-1.5GW of capacity for auto-consumption and 158 MW for sale to the grid.[85] A further 1.3GW are to be installed in 2004 in São Paulo State alone.[86] In total, the Brazilian cane industry has a potential equal to 12GW,[87] of which 6GW in São Paulo State,[88] which can be exploited cost-effectively through the use of higher-pressure boilers, conservation practices and, in the longer term, through the development of new gasifying technologies. Figure 14 analyses a case study for the Cresciumal Sugar Mill, showing the increased generation capacity potentially achieved through some of the measures stated above.

FIGURE 14

**CASE STUDY: CRESCIUMAL SUGAR MILL, BRAZIL**

Increasing focus on production of steam for condensing.

Decreasing drive and process steam.

Increasing power consumption, steam pressure, boiler efficiency, steam temperature, total steam production.

Increasing total surplus power.

| System | | |
|---|---|---|
| OLD SYSTEM | Bagasse power production | 4.5MW |
| | Consumed | 3.5MW |
| | **Surplus** | **1MW** |
| | TOTAL bagasse production | 82t/ha |
| | Bagasse used | 76t/ha |
| | Excess bagasse/surplus | 6t/ha |
| NEW SYSTEM – NEAR FUTURE | Bagasse power production | 30MW |
| | Consumed | 5MW |
| | **Surplus** | **25MW** |
| | TOTAL bagasse production | 88t/ha |
| | Bagasse used | 82t/ha |
| | Excess bagasse/surplus | 6t/ha |
| NEW SYSTEM – MEDIUM-TERM | Bagasse power production | 36MW |
| | Consumed | 6MW |
| | **Surplus** | **30MW** |
| | TOTAL bagasse production | 98t/ha |
| | Bagasse used | 92t/ha |
| | Excess bagasse/surplus | 6t/ha |

COMPILED FROM RIBEIRO[84]

In the current Brazilian energy policy climate, surplus electricity can be sold to electricity distributors[89] – this is, in fact, promoted by various government incentive programmes, described further in section eight. One of these, PROINFA, provides a feed-in tariff for renewable generation including bagasse cogeneration (see Table 12). The release of these tariffs, set at R$93.77-169.08 (US$32.17-58.00) per MWh, could give the impetus required to kick-start the development of efficient bagasse cogeneration in Brazil, greatly enhancing the prospects of the sugarcane industry.

Bagasse cogeneration is being strongly promoted in Brazil for reasons other than simply avoiding $CO_2$ emissions. Brazil's reliance on hydropower so far has meant that in certain areas – São Paolo State, for instance – all large economically viable HEP sites are already developed[90] and

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[84] Ribeiro (see note 18)
[85] UNICA, http://www.unica.com.br/i_pages/cana_produtos.asp, acc 30 March 2004
[86] Pers. Comm. CogenSP (2004)
[87] UNICA, http://www.unica.com.br/i_pages/cana_produtos.asp, acc 30 March 2004
[88] Ottenheym (see note 32)
[89] UNICA (see note 21)
[90] Ottenheym (see note 32)

neighbouring producer regions currently have to supply to make up the deficit. This is not an ideal situation for supply, as it increases distances to end-users and thus grid losses, as well as the need for investment in T&D networks. If, however, local cogeneration – for instance from bagasse – were to provide new capacity, this would help to avoid heavy new investment in the grid and so reduce network costs.[91]

Bagasse cogeneration is being further encouraged through projects qualifying for the Kyoto Protocol's Clean Development Mechanism (CDM).[92] Indeed, 11 sugar/alcohol mills are developing agreements under the CDM. Some of these are outlined in section Nine. However, with the advent of the PROINFA feed-in tariffs and other policy incentives, producers may find that there are fewer advantages arising from CDM opportunities. Proposals under the CDM may therefore decrease in the future.

[91] Ottenheym (see note 32)
[92] UNICA, http://www.unica.com.br/i_pages/artigos_palavra.asp, acc 30 March 2004

# 6. Other Countries – A Summary

## Australia

Australia has 37 sugar mills, of which all bar one are in Queensland or near its border. The mills crush over 40 million tonnes of cane each year, producing 6 million tonnes of raw sugar of which 80% are exported.[93]

Bagasse combustion has long been a part of the Australian sugar industry but, until recently, output was only consumed as waste heat. Rocky Point sugar mill was Australia's first bagasse cogeneration project. It generates up to 180GWh per year of electricity from bagasse,[94] providing an annual supply of electricity to more than 10,000 homes, steam and electricity to the nearby Beenleigh Rum Distillery whilst reducing GHG emissions by up to 155,000 tonnes. As cane crushing is a seasonal event, Rocky Point sugar mill is configured to co-fire with green waste and wood waste to ensure year-round operation.

Since bagasse cogeneration can add significant value to sugar production, electricity sales can potentially match or even surpass revenues from Australian sugar sales.[95] Bagasse cogeneration can also reduce the capital costs of future sugar mill expansions by pushing for greater economies of scale. Both these arguments suggest that bagasse cogeneration offers a viable and realistic mechanism by which to ensure the long-term economic sustainability of the sugar industry, not only in Australia but also worldwide.

Australia has not ratified the Kyoto Protocol but does have renewable energy (RE) targets for which bagasse cogeneration can qualify. Indeed, bagasse cogeneration has the potential to deliver

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[93] Pickering, S. (2000). Sugarcane: Offering Australia a Sweet Power Alternative, in Refocus (September-October 2000). Available at http://www.re-focus.net/news_archive/index.html.
[94] Sims, R.E.H. (2002) Bagasse and Green Waste Cogen Plant; Rocky Point Sugar Mill, Australia. **Cogeneration and Onsite Power Production, 3**(1), Jan-Feb 2002, pp39-42.
[95] Pickering (see note 93)

a large share of the 2% increment in RE required to meet Australia's target of 12.5% electricity from RE by 2010.[96]

## Belize

Belize produces just over 1 million tonnes of sugarcane per year[97]. Belize Sugar Industries are pursuing bagasse cogeneration for its potential for expansion of the sugar industry, recognising the advantages of bagasse cogeneration and including in these the efficient disposal of excess bagasse in an environmentally friendly manner. In Belize, it is estimated that a cogeneration plant sited next to a sugar factory can provide steam and electricity to the plant whilst exporting up to 18-20MW of electricity to the national grid in season (December to June).[98]

## Eastern and Southern Africa[99]

Countries of eastern and southern Africa have a very large potential for producing electricity from bagasse, due to long crushing seasons (8-9 months instead of a typical 6-7 months). The highest potential is in Sudan, which could produce over 40% of its electricity from bagasse cogeneration.

Many eastern and southern African countries would benefit greatly from bagasse cogeneration due to their low electrification rates – especially in rural areas – and their dependence upon HEP. The use of bagasse cogeneration could help to save HEP resources by providing a cheap means of generating electricity during a substantial part of the year, so that there would be less strain on HEP during periods of low rainfall. This point particularly applies to Kenya, where sugarcane plantations are situated in a different climatic zone to the country's HEP plants, making it less likely that both will be affected by drought simultaneously. Bagasse cogeneration would also provide electricity at a stable price compared to fossil fuel-based generation that is dependent on foreign exchange rates and world oil price fluctuations.

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[96] Pickering (see note 93)
[97] FAO (see note 2)
[98] First National Forum on Small-Scale Renewable Energy in Belize (see note 28)
[99] AFEPREN (2003). AFEPREN Occasional Paper 21: Opportunities for Cogeneration in a Reforming African Power Sector. Available at http://www.afrepren.org/Pubs/Occasional_Papers/pdfs/op21.PDF , last accessed 1 June 2004.

Sale of electricity to the grid is already possible in Zimbabwe, Zambia, Tanzania and Kenya. However, there are certain problems with bagasse cogeneration that could stunt its development in eastern and southern African countries:

- Bagasse cogeneration can be expensive compared to HEP schemes already in place (6USc / kWh compared to 3USc / kWh) and compared to cheap electricity from the Southern African Power Pool. Therefore, electricity boards may be unwilling to set feed-in tariffs to the higher level required by sugar mills.
- Poor management of some sugar mills has caused the sugar industry to run into difficulties; some sugar mills – especially in Kenya and Tanzania – have been closed down as a result of this, limiting the scope for bagasse cogeneration in these countries.
- As in many other countries, sugar mills often require refurbishment and upgrading to ensure that they are energy-efficient so that they can profit from electricity generation. Low sugar prices in world markets mean that sugar mills often have little money to invest in such schemes.

# Jamaica

Jamaica produces around 2.5 million tonnes of sugarcane per year.[100] The All-Island Jamaica Cane Farmers Association is calling for factories to produce their own electricity in order to lower the cost of sugar and of the electricity they consume as well as increasing revenues by selling electricity to the grid. It is estimated that each factory could produce around 40MW of electricity.[101]

# Mauritius

Mauritius produces just under 5 million tonnes of sugarcane each year.[102] Bagasse cogeneration was partly pioneered in Mauritius and, by 1926-27, 26% of Mauritius' electricity generation was in sugar factories.[103] Bagasse cogeneration is an ideal source of energy for Mauritius, as the

[100] FAO (see note 2)
[101] James-King, E. (2004). Fuel Bill Still Too High. Jamaica Gleaner, 22February 2004. Available at http://www.jamaica-gleaner.com/gleaner/20040222/news/news1.html
[102] FAO (see note 2)
[103] First National Forum on Small-Scale Renewable Energy in Belize (see note 28)

country has no indigenous oil, natural gas or coal deposits and currently needs to import 75% of its primary energy requirements.[104]

The Mauritian government has recently asserted that the country wants to further develop local energy sources, including biomass, to keep increasing demands for petroleum imports under control.[105] Bagasse cogeneration projects co-firing with coal are being developed to ensure year-round operation. Incentives for the further development of bagasse cogeneration have previously included:

- Performance-linked rebates for surplus bagasse production and power from bagasse cogeneration
- Tax exemptions
- Incentive tariffs for bagasse-cogenerated power.

The responses to such incentives have been increased energy and resource efficiency, including enhancing the calorific value of bagasse to maximise its energy density.[106]

# Nicaragua

Nicaragua produces around 3.25 million tonnes of sugarcane per year.[107] One of its mills, the San Antonio sugar mill, was converted to a 15MW sugarcane and eucalyptus wood co-firing unit in 2000. Observed social, environmental and economic benefits include a tripling of employment compared to previously, when the mill was fuel oil fired. $CO_2$ and acidifying emissions have also dropped by a factor of 30. Bagasse cogeneration projects are expected to increase electricity availability in Nicaragua, where in 2001 only 48% of the population were grid-connected with 60% of electricity generated from petroleum products (mainly imported oil).[108]

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[104] Bhalla, N. (2004). Mauritius Aims to Develop Renewable Energy Sources. Reuters News Service, 23 April 2004.
[105] Bhalla (see note 104)
[106] Deepchand, K. (2001). Bagasse-Based Cogeneration in Mauritius – A Model for Eastern and Southern Africa, available at http://www.afrepren.org/, last accessed 28 April 2004.
[107] FAO (see note 2)
[108] Best, G. (2001) The Energy Function of Sugar Mills: Case Study in Nicaragua. In SD Dimensions, Sustainable Development Department of the FAO, March 2001. Available at http://www.fao.org/sd/2001/EN0302a_en.htm , last accessed 21 April 2004

# 7. Global Market Potential

According to analysis undertaken by WADE, summarised in Table 8, the bagasse cogeneration can make substantial contributions to national power generation in several countries, including Brazil, India, Thailand, Cuba, Pakistan, Colombia and the Philippines. In all these countries, bagasse cogeneration could contribute over 5% of total electricity demand, reaching almost 26% in Cuba. The potential in China, in absolute terms, is also very good, but this is somewhat lost in the proportionally massive level of electricity generation, which is second only to that of the USA.

TABLE 8
**GLOBAL MARKET POTENTIAL**

| | Sugarcane production (tonnes / year) | Potential for electricity production (GWh) | Present National electricity demand (TWh) | Bagasse cogeneration potential as percentage of electricity demand |
|---|---|---|---|---|
| **Assuming that:** | | 1 tonne cane produces 100kWh of electricity | Figures from 2001 | |
| **Brazil** | 386,232,000 | 38,623 | 335.90 | **11.50** |
| **India** | 290,000,000 | 29,000 | 497.20 | **5.83** |
| **China** | 93,900,000 | 9,390 | 1,312.00 | **0.72** |
| **Thailand** | 74,071,952 | 7,407 | 90.91 | **8.15** |
| **Pakistan** | 52,055,800 | 5,206 | 62.27 | **8.36** |
| **Mexico** | 45,126,500 | 4,513 | 186.70 | **2.42** |
| **Colombia** | 36,600,000 | 3,660 | 39.81 | **9.19** |
| **Australia** | 36,012,000 | 3,601 | 184.40 | **1.95** |
| **Cuba** | 34,700,000 | 3,470 | 13.38 | **25.93** |
| **USA** | 31,178,130 | 3,118 | 3,602.00 | **0.09** |
| **Philippines** | 25,835,000 | 2,584 | 42.04 | **6.16** |
| | | | | |
| **Other** | 244,581,738 | 24,458 | 7,563.39 | **0.32** |
| | | | | |
| **TOTAL** | **1,350,293,120** | **135,029** | **13,930.00** | **0.97** |

COMPILED FROM: CIA (2003)[109], FAO[110], SILVESTRIN (2004)[111]

[109] CIA World Factbook (2003), available at http://www.cia.gov/cia/publications/factbook/, last accessed 18 May 2004.
[110] FAO (see note 2)
[111] Pers. Comm. Silvestrin, C.R., CogenSP (2004)

The figure obtained for world bagasse potential, as a percentage of total electricity production may – like China's – appear small, but is highly significant in terms of the current market share of renewable energy, representing 135TWh of electricity that may otherwise be generated by fossil fuels. This is roughly equivalent to the total annual electricity demand of Sweden[112] or around one third of the total worldwide output of wind power projected for 2012.

If projects and incentives like those offered by Brazil, parts of India and Mauritius, amongst others, were to be replicated in all sugarcane producing countries, the scope for efficient, competitive and environmentally friendly electricity production could be sizeable. In regions of Eastern and Southern Africa, for instance, the 16 million tonnes of bagasse left behind annually after sugar processing could potentially generate up to 5.5TWh of electricity if modern cogeneration technologies were employed.[113] This corresponds to more than half of the total combined electricity generation of Kenya, Tanzania and Uganda. [114]

Being the world's largest sugarcane producer, Brazil has an opportunity to exploit its large potential for bagasse cogeneration. With electricity consumption in Brazil projected to grow by 3% yearly between 2000 and 2030, there is ample scope for renewable sources such as biomass to play an increasingly important role, even if large part of demand growth is met by HEP, gas cogeneration and CCGT. This will be especially true if sugar mills deliver their full potential, believed to be up to ten times their current electricity production in some cases. Indeed, the development and implementation of high-pressure and temperature systems and the maximisation of energy efficiency could lead to the development of around 10GWe of cogeneration in Brazilian sugar mills alone. This would be a large proportion of the identified potential of 11-17GWe by 2010.[115]

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[112] DOE, http://www.eia.doe.gov/pub/international/iealf/table62.xls, last accessed 28 May 2004. Figures for 2002.
[113] Deepchand (see note 106)
[114] DOE (see note 109)
[115] WADE (see note 24)

# The Benefits Quantified - Analysis of the Indian Sugarcane Sector

Tom Casten, the Chairman of WADE, has analysed the potential benefits of bagasse cogeneration in India in his paper, "The DG Revolution – A Second Indian Miracle".[116] The paper is derived from modelling a situation whereby bagasse cogeneration displaces coal-fired central generation. The results of the modelling, displayed in Tables 9, 10 and 11, show that bagasse cogeneration in sugar mills could generate large savings, in terms of both $CO_2$ (38 million tonnes per year) and infrastructure (US$10.8 billion) if full potential is achieved.

But the most dramatic finding is that the cost burden to India, to the tune of almost a billion dollars a year, will be significantly reduced by incentivising sugar mills, through a buyback rate of 7 USc / kWh, to maximise the use of cogeneration.

This analysis also proposes a further advantage of bagasse cogeneration, stating that added revenues from sale of electricity to the grid will aid the growth of the sugar-ethanol vehicle fuel market. Extra revenues can lower the net cost of producing ethanol from molasses and second cane pressings, potentially leading to some mills finding it economic to manufacture only ethanol to compete with conventional petroleum-based motor fuels.

[116] Casten (see note 25)

TABLE 9

**BAGASSE RECYCLING IN INDIA**

| Item | Unit of Measurement | Current Contracted Bagasse Generation | Potential Bagasse Generation |
|---|---|---|---|
| Generating capacity | Megawatts | 710 | 5,000 |
| Full load equivalent operation | Percent of year | 68% | |
| Delivered useful power / year | Gigawatt-hours | 4,229 | 29,784 |
| **Equivalent Need for Central Generation, Transmission and Distribution** | | | |
| Losses from central stations | Percent of generation | 23% | |
| Avoided central capacity | Megawatts | 922 | 6,494 |
| Avoided central generation | Gigawatt-hours/year | 5,492 | 38,681 |
| Avoided generator capacity | US$ per kW | $1000 | |
| Total avoided central capacity | US$ millions | ($922) | ($6,494) |
| Avoided T&D cost | US$ per kW | $750 | |
| Avoided T&D with local generation | Percent T&D avoided | 90% | |
| Total avoided T&D | US$ millions | ($622) | ($4,383) |
| Total avoided capital | US$ millions | ($1,544) | ($10,877) |
| **Capital Amortisation** | | | |
| Allowed utility rate of return | Percent | 12% | |
| Time to amortise investments | Years | 25 | |
| Annual capital charge if central | US$ millions | ($197) | ($1,387) |
| Avoided capital amortisation | US Cents per delivered kWh | 4.7 | |
| **Avoided Fuel** | | | |
| Central generation fuel @ 33% efficiency | MMBTU millions | 56.8 | 399.9 |
| Central fuel cost | US$ per MMBTU | $4.00 | |
| Total central fuel cost/year | US$ millions | $225 | $1600 |
| Central fuel/delivered kWh | US Cents per delivered kWh | 5.4 | |
| **Total Avoided Cost** | | | |
| Avoided central power / separate heat generation costs | US Cents per delivered kWh | 10.1 | |

SOURCE: CASTEN (2004)[117]

[117] Casten (see note 25)

TABLE 10
**COMPARATIVE ECONOMICS OF CENTRAL VS LOCAL POWER**

| | | Contracted Bagasse Generation | Potential Bagasse Generation |
|---|---|---|---|
| Total cost of central power | US Cents per delivered kWh | 10.1 | |
| Paid to sugar factories | US Cents per kWh | 7.0 | |
| Societal savings per kWh | US Cents per kWh | 3.1 | |
| Cost per year for central power | US$ millions | $427 | $3,008 |
| Payments/year to sugar factories | US$ millions | $296 | $2,085 |
| **Annual savings to Indian society** | **US$ millions** | **$131** | **$923** |
| **Savings as % of central power** | **Percent** | **31%** | |

SOURCE: CASTEN (2004)[118]

In terms of emissions, bagasse emits negligible amounts of $NO_x$, $SO_2$ and ash compared to coal, the fuel most widely used in India. $CO_2$ will be released from the carbon stored in bagasse regardless of how it is disposed of. Additionally, composting bagasse rather than burning it would yield $CO_2$ and methane, whose greenhouse factor is 27 times more potent.

TABLE 11
**EMISSION SAVINGS FROM RECYCLING BAGASSE**

| | | Contracted Bagasse Generation | Potential Bagasse Generation |
|---|---|---|---|
| Avoided CO2 per MWh | Metric tones | 1.0 | |
| **Total avoided CO2** | Million Metric Tonnes/Year | 5.5 | 38.7 |
| Avoided SO2 per MWh | Pounds per MWh | 12.7 | 13.7 |
| **Total avoided SO2** | Metric tonnes/year | 31,705 | 240,874 |
| Avoided NOx per MWh | Pounds per MWh | 4.7 | |
| **Total avoided NOx** | Metric tonnes/year | 11,733 | 82,636 |

SOURCE: CASTEN (2004) [119]

[118] Casten (see note 25)
[119] Casten (see note 25)

# 8. Electricity Market Regulatory Issues

## Brazil

The Brazilian power grid is a vast interconnected system linking the southern, southeastern and central states that account for 98% of the electrical market. In these areas, the transmission network – to which access is now available for a fee – is regulated as a natural monopoly. Several small isolated systems supply electricity in the north of the country.[120]

### Short History:

A summary of events affecting bagasse cogeneration in the Brazilian electricity sector is given in figure 13, on page 31. Since the 1950s, when private foreign-owned utilities cut investments in power generation, forcing the Government to develop mass electricity supply, Brazil has successfully implemented central power planning on a very large scale.

Between 1995 and 2000, the electricity sector went through a comprehensive process of institutional and regulatory change that introduced free competition in the generation market, enabling the participation of new actors with a more open policy for access to transmission and distribution networks.[121] This, in theory, allowed IPPs to sell electricity to the grid. This is the key issue that determines the commercial viability of the expansion of bagasse cogeneration.

By the end of the 1990s, however, the electricity sector was under increasing strain, as lack of investment in new capacity coupled with increasing energy demand had led to a situation where there was little reserve margin between peak consumption and production capacity.[122] By 2001, low rainfall had depleted reservoirs, causing a near-collapse in the electricity system.

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[120] WADE (see note 24)
[121] UK Trade and Investment (see note 63)
[122] Ecoinvest (see note 26)

As a consequence of this, the regulatory framework considered DE more favourably than in the past, but many decisions are still taken based on the false understanding that central power is the optimal solution. Despite official policy to strengthen the opportunity for IPPs, many utilities and policy-makers still see HEP as the best route for expansion. Not all fully understand the advantages of the relative economics of DE and central power.[123]

## Incentives for Bagasse Cogeneration

Despite constraints in other areas, discussed below, there are growing opportunities for Brazilian IPPs – including bagasse cogenerators – to sell the electricity they generate, enabling even remote producers to access promotional mechanisms. Brazilian IPPs are legally permitted to sell electricity to:

- Licensed electricity supply companies or network operators
- Large consumers who have free choice of electricity suppliers
- Consumers of cogenerated electricity
- Consumer co-operatives (provided permission is granted by the local power utility).

Most incentives applying to bagasse cogeneration exist in the form of schemes for the promotion of electricity from biomass. Table 12, below, summarises the available incentives, PROINFA being of crucial importance because it provides incentives for the sale of electricity to the grid.

TABLE 12
**INCENTIVES FOR THE DEVELOPMENT OF BAGASSE COGENERATION IN BRAZIL.**

| | |
|---|---|
| **"Program for Incentive of Alternative Electric Energy Sources" (PROINFA)** | PROINFA was created in April 2002 to increase the share of wind, biomass and small-scale hydropower systems in the Brazilian energy generation mix from Autonomous Independent Producers (PIA)[124].<br>The first phase of PROINFA aims to integrate 3.3GWe of capacity through contracts between Eletrobrás (the State electricity company) and PIA lasting up to 15 years. The second phase will guarantee that, after the initial 20-year period, these technologies will supply 10% of annual electricity demand, accounting for at least 15% of market growth.<br>The feed-in tariffs under PROINFA, made public in March 2004, are currently set at R$93.77-169.08 (US$32.17-58.00) per MWh for biomass generation. This corresponds to approximately 80% of the national end-user average tariffs. |
| **Energy Reallocation Mechanism (ERM)** | ERM is the financial mechanism by which the risks of HEP are shared amongst the participants of the central dispatching system. Developing grid-connected generation from wind, biomass and qualified cogeneration allows for the mitigation of such risks. |
| **Global Reversion Reserve** | This is a resource managed by Eletrobrás, aimed at promoting wind, solar, biomass, thermal and small hydro projects. |

COMPILED FROM WADE (2003)[125], UNIDO (2003)[126], FALCAO (2002)[127], GALDINO & LIMA (2001)[128] AND TRENCH ET AL (2004)[129]

[123] WADE (see note 24)
[124] Under Brazilian Law, PIA are companies in which stock control does not belong to any generation, transmission or distribution utility.
[125] WADE (see note 24)

Also, as the Brazilian natural gas infrastructure is not yet fully developed, many areas are still without a competitively priced supply. In areas where this is the case, bagasse cogeneration can provide a cost-effective source of electricity and perhaps even heat to industrial and commercial users.

### Barriers and Constraints to Development

While the regulatory environment for bagasse cogeneration appears to be improving, there remain some key issues that should be addressed if the full potential is to be achieved. These are:

- Detailed rules for interconnection apply only to central power, whilst interconnection arrangements for on-site systems in general remain to be clearly defined.
- Utilities often apply old system rules that do not permit ‘inside-the-fence’ generators to run in parallel with the grid.[130] Open access to the electricity system is thus only facilitated for central power. This is likely to predominantly affect the smallest sugar mills that have less weight than larger players such as the Vale do Rosario sugar mill, described in chapter 9.
- Requirements for connection protection and measurement are still strict, causing difficulties and added expense that affect small IPPs in particular.[131]

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126 UNIDO (2003) “CDM Investor Guide, Brazil”, p. 108. (Vienna, Austria 2003).
127 Falcão, R.L. (2002). Proceedings of the Second International Seminar on Cane and Energy, 29 August 2002. Available at www.inee.org.br/down_loads%5Ceventos/Apresentação%20Seminário%20Cana%20e%20Energia_Versão%20Renata3.ppt
128 Galdino, M.A. & Lima, J.H.G. (2001) “PRODEEM – O Programa Nacional de Eletrificação Rural Baseado em Energia Solar Fotovoltaica”.
129 Trench, Rossi e Watanabe (2004). PROINFA Finally Unleashed: Opportunities for Alternative Sources of Energy. Legal alert, 19 April 2004.
130 WADE (see note 24)
131 WADE (see note 24)

# India

## Short history

A summary of events affecting bagasse cogeneration in the Indian electricity sector is given in Figure 10, on page 22. In 1994, the Ministry of Non-Conventional Energy Sources issued guidelines requiring States to fix prices for the purchase of electricity from, amongst others, sugarcane bagasse cogeneration. These were to include periods of low-cost financing, arrangements for third-party sale and limited wheeling,[132] escalated feed-in tariffs, payment guarantees by State Electricity Boards (SEB) and guarantees that SEB would bear the costs of grid-connection.

Thus, up to 2000, 14 States adopted and adhered to electricity purchase policies, which helped to promote and develop the bagasse cogeneration sector. However, between 2000 and 2003, the impacts of power sector reform in India led most States to retire the policies they had previously announced for the purchase of bagasse-generated electricity. This consequently slowed the anticipated development of bagasse cogeneration capacity.

In 2003, a new Electricity Bill was passed in Parliament and the Central and State Electricity Regulatory Commissions (ERC) became functional, triggering new regulatory processes for the purchase of bagasse power in a number of States. The Electricity Bill will, in a sense, aid bagasse cogeneration by granting easy and fair access to the grid, calling for a mandatory provision of at least 10% of renewable power in the electricity system and empowering regulatory commissions to decide on feed-in tariffs for electricity generated from renewable sources.

The Maharashtra Electricity Regulatory Commission (MERC)[133] led the way in 2002 by issuing its incentive tariffs at highly attractive rates, after a time-consuming and comprehensive regulatory process.

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[132] A process by which cogenerators are able to sell electricity directly to other customers
[133] Maharashtra Electricity Regulatory Commission , at www.mercindia.com

## Incentives for Bagasse Cogeneration

State Electricity Boards set their own feed-in tariffs for electricity from biomass sources. MERC was the first to release its tariffs to be implemented by the Maharashtra SEB. These now stand at 3.05 rupees (6.7 US cents) / kWh for the first year of commissioning, with a 2% escalation in each subsequent year. This policy has, so far, proved very positive and conducive to the development of renewable energy projects such as bagasse cogeneration.

## Barriers and Constraints to Development

These are as follows:

- SEBs are still reluctant to buy power from biomass projects, despite the good example set by MERC with its regulatory process and the provision of the Electricity Act. Many States and SEBs remain unaware of the opportunity for DE.
- In many States, there is neither the assurance that electricity can be sold to the grid nor, in fact, any guarantee of timely payment for electricity generated by non-utilities.
- Compensation for failure to supply or fluctuation in grid supply by SEBs is, more often than not, unavailable. This provides little incentive for forward planning of demand and production among non-utility electricity generators.

The ERCs in states other than Maharashtra now need to be encouraged to propose feed-in tariffs. Similarly, regulatory processes in other States need to be initiated and strengthened in order to produce favourable policies comparable to those applying in the State of Maharashtra, as encouraged by institutions such as Cogen India.

## WADE Recommendations

In order for bagasse cogeneration to achieve the potential outlined in section 7, it is important that certain key measures are brought forward. Building on experiences in India, Brazil and elsewhere, WADE recommends that:

1. Planning and regulatory paths are cleared for the development of enhanced cogeneration facilities in sugar mills. This includes ensuring fair and easy access to the grid for both large and small generators as well as guaranteeing that incumbent generators and utilities do not hinder these processes.
2. Financial and tax incentives, in line with other incentives for renewable energy, are provided to boost the initial development of cogeneration facilities in sugar mills. This would allow generators to invest in the necessary equipment and infrastructure to maximise their electricity output whilst making the most effective use of heat and electricity generated onsite. Financial incentives also include the provision, where possible, of renewable energy feed-in tariffs that reflect the benefits of onsite production and biomass combustion.
3. Where financial and tax incentives are currently unavailable, the CDM should be promoted and developed. The CDM could provide the incentive required for the upgrade or installation of cogeneration equipment in mills in a cost-effective manner whilst facilitating the meeting of Kyoto Protocol commitments by Annex 1 parties.
4. Further research is carried out into bagasse gasification to fully explore its potential, so that the best technologies can continue to be promoted and installed to reap the maximum benefits of bagasse cogeneration.

# 9. CDM Opportunities

The Clean Development Mechanism (CDM) is a process by which OECD Annex 1 countries can implement greenhouse gas (GHG) mitigation in non-Annex 1 countries to meet part of their Kyoto Protocol emissions reduction commitments. Potential CDM Projects go through a variety of stages, namely Design, Validation / Registration, Monitoring, Verification / Certification and Issuance.[134]

The multiple environmental and social benefits offered by bagasse cogeneration projects, described in section 3, would suggest that such projects could be strong contenders to qualify as CDM opportunities. Table 14 identifies the potential global savings offered by bagasse cogeneration in terms of reducing $CO_2$ emissions. Note that the basis of comparison is highly conservative, with a power generation comparison with gas-fired CCGT (in many countries, including India and China the fuel used is coal). The savings identified, of 40.2 million tonnes of $CO_2$ per year, equate to almost 20% of the total emissions required to be made by European signatories to the Kyoto Protocol by 2008-2012. Given our conservative assumptions, this share is in reality likely to be closer to 25-30%.

TABLE 13

**$C0_2$ SAVING OF BAGASSE COGENERATION COMPARED TO GAS-FIRED CCGT**

| Technology | Gas CCGT | Bagasse Cogeneration |
|---|---|---|
| Gross Efficiency | 55% | |
| Network Losses | 12% | |
| Emissions ($gCO_2$ / kWh Delivered) | 372 | 0 |
| | | |
| Total Worldwide Bagasse Potential for Electricity Generation (TWh) | | |
| 135 | | |
| Total Worldwide Exportable Electricity from Sugar Mills (TWh), based on 20% self-use | | |
| 108 | | |
| Total $CO_2$ Emissions Avoided by Bagasse Cogeneration (tonnes / year) | | |
| 40.2 million | | |

[134] UNFCCC, http://cdm.unfccc.int/pac/index.html

# India

India is currently thought of as the country with the most CDM potential. As a developing country, India offers excellent potential for GHG emission reductions through the promotion of energy efficiency and renewable energy, improvements in fossil fuel based generation and the use of cleaner technologies in industries dealing with such services as air-conditioning and refrigeration.

In spite of the huge potential and focused promotional efforts, achievements in the field of bagasse cogeneration have so far been minimal, primarily due to complex socio-economic policy issues creating barriers as well as reluctance to invest in what can seem a risky venture. In such a climate, CDM could prove an effective tool to mobilise resources internationally.

A reasonable and achievable potential for emission trade by the year 2010 is expected to be around 9.75 million tonnes of $CO_2$ per year, based on the assumption that bagasse cogeneration plants would operate for 250 days each year, generating 2GW of exportable surplus electricity in SEB grids whilst the current balance of fossil fuel generation remains at 70%. At an average emission trade price of US$5 per tonne of $CO_2$, this equates to revenues of US$50 million per year.

A potential CDM project in India is the Balrampur Chini Mills in Haidergarh. This is one of the UK-based Agrinergy's potential CDM opportunities. This bagasse cogeneration unit, likely to be operational in 2005, is expected to gain carbon credits by reducing greenhouse gas emissions by 85,000 tonnes per year. [135]

[135] Point Carbon (2004) "Agrinergy planning CDM projects", 20 January 2004. Available at http://www.pointcarbon.com/article.php?articleID=3111&categoryID=147

# Brazil

The Brazilian sugar industry can also benefit greatly from the CDM. So far, in Brazil, 11 sugar and alcohol mills are currently developing agreements under the CDM.

Brazil, like India, is not required to reduce emissions as part of the Kyoto Protocol agreement. In effect, as it stands, Brazil has one of the least carbon intensive energy sectors in the world due to its high reliance on hydropower and, increasingly, bio-fuels.

While Brazil's emission baseline is consequently very low, the country could, however, benefit from foreign investments that the CDM would generate. Furthermore, the increased development of biomass cogeneration would benefit sugar and ethanol production, the latter providing a viable substitute for fossil fuels for vehicles. Figure 15 summarises one of the most important CDM projects based on bagasse cogeneration in Brazil.

FIGURE 15
**CDM CASE STUDY – BRAZIL**

**Vale Do Rosario, Brazil – Econergy Brazil (approved CDM Project)**

Founded in 1964, Vale Do Rosario (VR) is a private company with 104 shareholders, most of whom are farmers and sugarcane producers. The region had previously focused only on coffee production, but as this had become unprofitable, VR was established in addition to the coffee industry to provide economic stability to the region.

Vale de Rosario raised the project equity with debt financing being covered by the Brazilian Infrastructure Development Bank (BNDES). VR has aimed to industrialise sugarcane processing whilst maintaining the regional land maintenance and rural traditions of the area. The mill was thus developed like a country factory, independent of worker towns or other dependencies typically found in large, modern agricultural farms.

The VR bagasse cogeneration project aims to increase the surplus electricity sold to the grid by expanding VR's electric power generation capacity, thus operating more rationally under current electric power sector circumstances that recognise the role of Independent Power Producers (IPPs).

As the largest Brazilian sugar mill energy exporter, VR is expected to generate annual savings amounting to 650,000 tonnes of $CO_2$ over the 2001-2008 period. The credits obtained from these emissions reductions will be attributed to the Swedish International Environmental Investment Programme of the Swedish Energy Agency

In 2004, Vale do Rosario was awarded the Best CDM Project by a panel of experts at the Carbon Market Insights conference.

**Other Brazilian CDM Projects include:**

- Santa Elisa Bagasse Cogeneration
- Corona Bagasse Cogeneration Project
- Equipav, Bagasse Cogeneration Project
- Nova America, Bagasse Cogeneration Project
- Alta Mogiana Bagasse Cogeneration Project
- Moema Bagasse Cogeneration Project
- Cantaduva Sugarcane Mill Expansion Project

COMPILED FROM ECONERGY BRAZIL & CIA ACUCAREIRA VALE DO ROSARIO (2003)[136], POINT CARBON (2004)[137], PLANETARK[138], THE WINROCK FOUNDATION[139] AND UNCTAD[140].

[136] Econergy Brazil & Cia Acucareira Vale do Rosario (2003). Vale do Rosario Bagasse cogeneration: A GHG Emission Reductions Project Activity in Brazil; CDM Project Design Document. Available at http://www.pointcarbon.com/wimages/FS_408387121.pdf

[137] Point Carbon (22.4.04), Brazilian Sugar Bagasse Wins "Best CDM Project" available at http://www.pointcarbon.com/article.php?articleID=3549&categoryID=147

[138] Blackburn, P., Reuters (2001). Brazil sugar mill plugs into powerful future. In Planet Ark, available at http://www.planetark.com/dailynewsstory.cfm/newsid/13531/newsDate/3-Dec-2001/story.htm

[139] http://www.winrock.org/REEP/PDF_Pubs/icen95.pdf

[140] http://r0.unctad.org/ghg/sitecurrent/download_c/pdf/Catanduva%20Sugarcane%20Mill%20Project.pdf

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