

## BAGASSE-FUELLED COGENERATION IN KENYA opportunities and implications

### Cogeneration and On-Site Power Production

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Kenya could generate 10% of its electricity needs from cogeneration plants fuelled with bagasse from sugar cane. [Bernard Osawa](#) and [David Yuko](#) examine how this could be achieved, and describe the benefits that such a move would have for cane farmers, local economies, electricity consumers and the environment.

As in most sub-Saharan countries, biomass fuels, used mainly in households, constitute an estimated two-thirds of Kenya's energy mix. Petroleum and grid electricity constitute the remaining third of the total energy used in industrial, commercial and household sectors. Access to grid electricity for households currently stands at a low 15.3% nationally and less than 2% in rural areas. Total installed grid-connected generation capacity is 1230 MW, dominated by hydropower at 56%, while thermal and geothermal contribute 32% and 10% respectively. Consumption of electrical energy is dominated by the industrial sector at 63%, followed by domestic and small-scale industrial at 33%, while consumption by rural electrification customers comprises only 4% of the total demand.

Investment in the power sector has lagged behind growth in demand, with the effect of this situation being felt throughout the Kenyan economy, largely in the form of lost production due to inadequate power supplies. The principal challenges facing the power sector are to:

- ensure provision of reliable, efficient, and cost-effective power supplies
- increase the population's access to electricity as a means for stimulating income and employment growth
- improve the efficiency of power distribution and supply through reductions in technical and non-technical losses and collection of revenues
- strengthen the regulatory framework

Over the last decade, the intensity of commercial energy use has been on the decrease, indicating a decline in economic growth. While the cost of, and accessibility to, energy for industry has been cited as the reason for poor economic performance leading to a low demand for power (786 MW), it is believed that demand is suppressed by the prevailing poor economic conditions, a cyclic situation. Historical average demand growth rate over the past five years has been a low 1.4%.

**Unlike other industries that only consume energy, the sugar industry can generate surplus power over and above its internal requirements**

### COGENERATION AND THE SUGAR INDUSTRY

Potential for cogeneration exists in the sugar industry where steam is raised from bagasse, a waste product of the cane milling process, for power generation and process heat. Unlike other industries that only consume energy, the sugar industry can generate surplus power over and above its internal requirements by burning bagasse to generate process steam and power. However, due to statutory requirements and other limitations on the sale of electricity, sugar factories in Kenya have been unable to exploit energy in bagasse. Excess bagasse is currently treated as waste and incinerated, largely as a process of disposal. Process steam and power are in this case unfortunately treated as a by-product of the disposal exercise.

The current Kenyan government, voted in on a platform of accelerated economic development and infrastructure rehabilitation, has committed itself to, among other initiatives, the rehabilitation of the sugar industry. Power generation through cogeneration is seen as opening up new avenues for revenue creation in the sector. Accordingly, the Ministry of Energy recently permitted sugar companies to generate power for sale to the national grid and to the public in general. Furthermore, various fiscal incentives for investments in regular and non-conventional renewable energy projects have been suggested for inclusion in the national energy policy document. Meanwhile, local utilities are looking at strengthening the transmission grid, which, coincidentally, will allow the sugar companies to feed in their power. Consequently, it has become a viable proposition for sugar companies to raise high-pressure steam in modern, high-efficiency boilers using bagasse to generate heat and power economically to provide surplus power for export to the grid.

Like other sectors in the Kenyan economy, the sugar industry has undergone continuous decline over the past decade. Statistics provided by the Kenya Sugar Board indicate that the best performance in the last decade (1992-2002) was recorded in 1996 when the industry had 131,100 hectares under cane yielding a healthy 90.9 tonnes of cane per hectare and supporting 23,900 plantation jobs in direct wage employment. In contrast, 2002 figures show that the acreage had dropped to 126,800 hectares, while the yield was down to 70.7 tonnes per hectare with the number of plantation jobs down to 2630.

While some of the job losses can be credited to increased mechanization in the farms, the bulk of the reductions are attributable to poor economic performance of the sugar factories and increased competition from cheap imports. The resulting poor sales of sugar from local factories impact negatively on payment to farmers, hence the downward spiral. Additional revenues from power generation, and the improved efficiency accompanying new investment, should help to revamp the industry.

## DEVELOPMENT OF COGENERATION

Experience from Réunion, Mauritius, India, Brazil and Cuba confirms the practical potential for cogeneration in Kenya, where it has hitherto been limited by the technology employed, financial and technical resources availability, and legal and regulatory frameworks. In the case of the success story countries, the development of cogeneration evolved along the well-established stages of own generation, intermittent power, continuous power and firm generation. In Kenya, one sugar factory has the capacity for intermittent power supply, but has been constrained by regulatory barriers. During the electricity crisis of 2000 this factory was able to sell power, but was limited by the capacity of interconnecting transformers linking it to the grid.

It would seem natural for Kenya to avoid the intermediate steps and 'leapfrog' from own generation to firm power supplies by learning from the experiences of Réunion, Mauritius and Brazil. Kenya has the advantage that the crop season lasts an estimated 300 days a year, while the out-of-cane season is usually during the wet season, coinciding with the duration of maximum hydro availability and making firm generation attractive. Annual maintenance could be carried out during this period.

The power and process steam requirements in a sugar plant can be met in one of two ways:

*Conventional cogeneration* deploys a bagasse-fired boiler in conjunction with an extraction-condensing and/or back-pressure steam turbine coupled to an electrical generator, or a double extraction-condensing turbine coupled to an electrical generator. This is the predominant method currently used in Kenya with pressures of 20-25 bar and with resultant efficiencies of less than 10%. System efficiencies of up to 25% can be achieved for steam pressures of 45-66 bar, permitting electricity exports of up to 100 kWh per tonne of cane crushed. Plant performances of 110 kWh (82 bar) per tonne of cane crushed are operational in Réunion, Mauritius, India and Brazil. This means that the process of generating more power from sugar factories for export to the grid is essentially an efficiency upgrade exercise accompanied by a modernization and capacity improvement of sugar mills.

*Integrated gasification cogeneration with combined cycle (IGCC)* uses an external gasifier to produce combustible gases from the bagasse, which are then fired in a modified gas turbine. Hot exhaust gases are passed through a waste heat recovery boiler for generating steam; some of the exhaust gas is used for drying bagasse. Efficiencies achieved in the conversion of biomass to electrical energy can be as high as 37%. The IGCC system is still largely in a stage of commercial infancy, with a few installations in Brazil.

## OPPORTUNITIES FOR COGENERATION

The current total installed cogeneration capacity in the Kenyan sugar industry is 36.5 MW, used exclusively within the industry. Sugar industry statistics show that in 2002 alone Kenya produced an estimated 1.8 million tonnes of bagasse with a gross calorific value of 16,800 TJ, equivalent to 323,000 tonnes of oil worth approximately US\$194 million. In conditions such as have been established in Mauritius, this bagasse could produce 360-600 GWh per year of excess electricity for sale, depending on the technology used. At this rate, cogeneration from bagasse could easily provide 10% of the national electrical energy demand.

To achieve the 10% target economically, sugar factories will need to invest in firm generation through equipment upgrade, with efficiencies high enough to generate economic quantities of power for sale to the national grid. Issues that need to be addressed include:

- modular capacity, high-efficiency boilers to be installed in phases
- ample storage capacity for bagasse to cover autonomy
- factory efficiency optimization
- improved scheduled maintenance
- harvest cane trash as a possible extra boiler fuel (potential additional fuel capacity of up to 20%), which will require substantial investment

To sell their power to the national grid, sugar factories will, in addition, require investments in appropriate upgrade of grid interconnections consisting of power transformers, electrical switchgear and power lines.

With appropriate investment, the bagasse could be used to generate an effective capacity of 135 MWe and 90 MWe at pressures of 82 bar and 60 bar respectively, to power the sugar factories and export up to 550 GWh of electricity to the national grid annually in addition to process steam. This could displace energy currently produced from fossil fuels. At an average consumption of 0.22 tonnes of oil per MWh for thermal plants, bagasse-based cogeneration would save some \$90 million of foreign exchange annually. Additionally, cogeneration would promote the use of indigenous energy source, build local capacity for independent power production, encourage private sector participation in the power sector and create an import of financial benefits to cane farmers.

Given the relatively long-term operation for which power projects are designed, more efficient units are attractive options

## COST IMPLICATIONS

For cogeneration plants, the investment costs vary with net export capacity, from \$1.4 million/MW at the lower pressures, through \$1.8 million/MW mid-range to \$3.1 million/MW at the top end. This compares with \$1.1 million/MW for heavy fuel plants, \$2.25 million/MW for geothermal and \$2.5 million/MW for hydro power plants. Thermal power plants have significant fuel costs that are passed directly to the consumers under current tariffs.

Except for disparities arising from management performance, three out of the existing six factories in Kenya have identical capacities of 125 tonnes of cane per hour (TCH), while a fourth with similar capacity currently operates at 70% of the rated capacity. These four factories are in the league of 3000 tonnes of cane per day (TCD) and have a planned expansion to 5000 TCD. A fifth factory operates at its full rated capacity of 350 TCH, producing more than half of the country's sugar. The sixth, with a similar capacity as the other four, is currently under receivership with little signs of being re-opened. Consequent analysis hereinafter - see Table 1 - is therefore based on 5000 TCD capacity and can be adjusted for other volumes. Current operational performance and the installed capacities will be limiting factors to cogeneration as the cane crushing process is the source of fuel.

Component	Possible plant options		
Boiler pressure (bar)	45	60	82
Recommended plant capacity (tonnes of cane per day)	5000	5000	5000
Boiler capacity (tonnes of steam per hour)	140	140	140
Bagasse feed rate (tonnes per hour)	58	62	70
Turbine capacity (MW)	25	30	50
Daily power generation, gross (MWh)	420	550	820
Equivalent capacity (MW)	18	24	40
Daily export power, net (MWh)	260	330	550
Equivalent export capacity (MW)	12.5	14	24
Total capital investment (\$ million)	18	25	75
Estimated local component (\$ million)	4	5	12
Estimated annual revenue from electricity (\$ million)	4	5	8.3
Simple payback period (years)	4.5	5	8.8

This means that a 10% bagasse cogeneration contribution to the grid can be achieved by investing in efficiency upgrades at the five operational sugar factories in Kenya. The total investment costs will vary according to boiler pressures and efficiencies selected, and the power plant configurations at different factories. These costs would typically range between \$120 million at 60 bar and \$230 million at 80 bar, delivering an estimated 480 GWh with simple payback periods of 6-7 years and 8-9 years respectively. The cost figures compare reasonably with recent investment performances for geothermal and hydro plants. Corresponding estimated annual revenues from sale of electricity is \$20-36 million in addition to savings from current net electricity imports into the sugar factories.

Higher operating pressures offer better efficiencies, and therefore better resource utilization. However, they also entail higher capital costs and more sophisticated levels of technology. Given the relatively long-term

operation for which power projects are designed, typically 25-30 years, the more efficient units are attractive over these periods. Like other renewable energy technologies, biomass cogeneration lends itself to modular implementation, allowing large projects to be broken down into smaller units that can be implemented in phases. Apart from being easier to finance, these modules reduce the impact of additional capacities on the grid system, enabling power sector planners to match demand with supply.

Of the total capital costs of putting up sugar factories, on the order of 60% is attributable to the cost of the cogeneration power plant. Given that a number of the factories are planning capacity expansions, with most in need of a large degree of reinvestment to replace obsolete plant, cogeneration provides an ideal platform for the upgrade. In this case, the power plants should be designed to take expanded capacity in future. At present, all the factories are net importers of power, either due to inadequate capacity or, in the case of one factory, inadequate arrangements for generation when the factory is under maintenance. In the cogeneration scenario, the factories consume an estimated 30% of the power generated by the plant in exchange for bagasse fuel, effectively saving on their energy bill.

## IMPACTS OF COGENERATION

Based on 2002 figures, annual bagasse production is estimated at 1.76 million tonnes, equivalent to 323,000 tonnes of oil worth some \$194 million at current fuel prices. Investment in bagasse cogeneration could be used to generate steam and electricity to power the sugar factories and export up to 550 GWh of electricity to the national grid, displacing energy currently produced from fossil fuels. At the average consumption of 0.22 tonnes of oil per MWh, this translates to an annual saving of \$90 million of foreign exchange.

**Efficient cogeneration plants create on average 3.5-5.2 jobs per GWh directly**

With an optimistic job creation target of 500,000 jobs annually set by the current government, development of cogeneration in the sugar industry could provide numerous opportunities. Industry statistics show that efficient cogeneration plants create on average 3.5-5.2 jobs per GWh directly. Thus for a total capacity of 500 GWh, some 2000 jobs could be created directly from the sugar industry alone through cogeneration. Most of these jobs would, however, be created upstream in sugar plantations.

Current annual turnover of the industry is estimated at \$160 million, of which \$100 million is due to independent sugar farmers, otherwise referred to as 'out growers'. Historically, only half of this amount is normally paid while the rest has always been carried over as arrears due to cash flow concerns within the factories. Investment in cogeneration would bring the desperately needed benefit of additional revenues to pay off the farmers for their cane. Improved plant efficiency, coupled with planned production expansion to meet international competition, would increase industry turnover by 20-40%. Secondary benefits and corresponding impacts would spread to other sectors, but the biggest beneficiary would be the small-scale out grower, thus directly addressing wealth creation targets.

Sugar farmers currently frustrated by poor prices and late payments could be motivated to put more land under cane. With improved factory efficiencies and healthier performance arising from better cash flows and more reliable steam and power, higher cane output from the farmers is anticipated. Ultimately, cogeneration capacity would be limited by land available for cane, and by efficient agricultural production, account being taken of the need to balance food production against commercial sugar cane plantation.

Apart from substituting fossil fuels, cogeneration provides an opportunity for the reduction of greenhouse gas emissions, while strengthening the infrastructure base in relation to electricity supply. With carbon financing currently at \$5-8 per tonne of carbon dioxide, additional revenues can be accessed to finance the development of the sector, once clear baselines have been established. This would substantially reduce borrowing to finance the development of these projects, with a resultant decrease on the national external debt.

## POLICY ISSUES

Any efforts to develop cogeneration in Kenya will have to begin with a look at the performance of the sugar industry and electricity sector in totality. In a situation where all the sugar factories are largely owned by the government, it will be essential to develop policies that facilitate the accelerated development of these sectors through the involvement of the private sector. Key issues that policy needs to address include:

- clear bagasse development policy, recognizing bagasse as a resource and facilitating development of bagasse-based projects
- stimulation of investment by offering tax breaks and other incentives for investment in firm generation plant and efficiency improvement initiatives; incentives should lower front-end barriers to project development

- restructuring the national sugar authority to enhance management, development and investment into the sugar sector and to promote cogeneration and efficiency
- enactment of clear fiscal incentives for cogeneration to encourage investment
- creating suitable and attractive regimes for independent power producer involvement, including pricing and grid feed-in laws for cogen electricity
- provision of support to indigenous local private sector participation in the energy sector to ensure sustainability
- the setting of realistic but challenging targets for increased cogeneration contribution to the electrical energy supply mix
- development of a national pool of multi-disciplinary competence to develop, design and oversee local implementation of cogeneration projects
- involvement of local and international financing groups to provide finance for investment in the sugar sector, especially for cogeneration projects

Developing and implementing coherent and consistent policies that cover these areas will ensure comprehensive and efficient development of cogeneration and the sugar sector, and facilitate the implementation of projects through private sector involvement.

## LOOKING FORWARD

Cogeneration provides a clear potential for diversification of the sugar industry into energy-related activities such as power generation and ethanol production, and should be accorded high priority. Sugar factories in Kenya have been unable to meet the national demand for sugar at competitive prices at a time when other Common Market for East and Southern Africa (COMESA) countries are desperate to sell cheaper sugar to the local market. By giving requisite attention and support to cogeneration, the sugar industry can bridge the production gap, thus making sugar farming more attractive.

Furthermore, given more than 100,000 small-scale cane growers currently producing about 88% of Kenya's sugar cane, the implications for rural livelihood enhancement of this diversification could be very significant.

While cogeneration matches other power generation options in terms of investment costs, it provides an indigenous source of electrical energy for the nation, saves on foreign exchange, is a tool for employment and wealth creation and an agent for abatement of environmental degradation.

Left on its own, the sugar industry does not have the resources and capacity to realize the full potential of cogeneration. Clearly, the biggest hurdles are policy barriers and attitudes on the part of developers and financiers. A combination of players is required make a 10% contribution by cogeneration a reality.

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