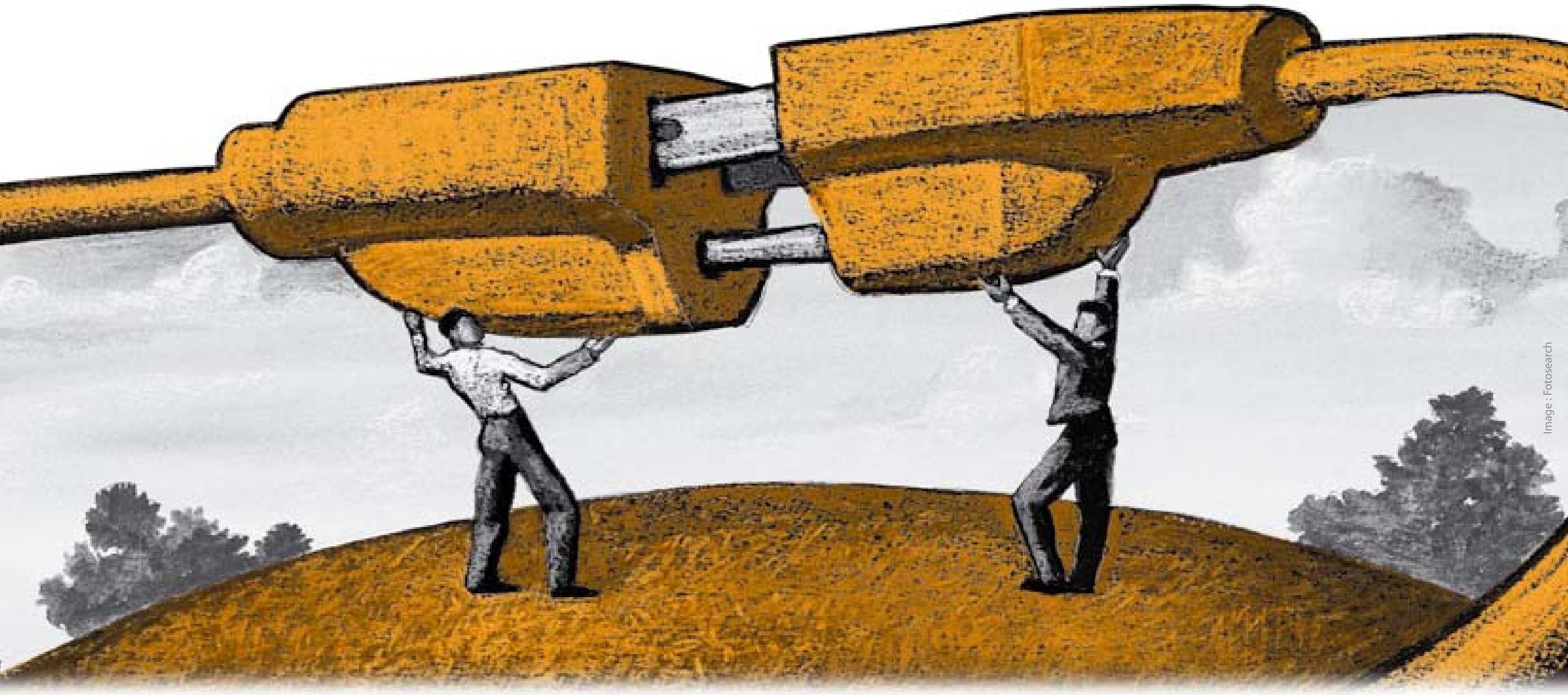

Can sugar provide A SPARK?

Wanted! Greener energy. Is South Africa doing everything in its power to come clean?

By GRANT NORRIS and JAKO VOLSCHENK

The province of KwaZulu-Natal in South Africa has two strong bio-industries, namely sugar and forestry, which produce considerable volumes of residue. What is the potential of these two waste resources to deliver cost-effective, green electricity? This question led to research at the University of Stellenbosch Business School (USB) to determine to what extent these two resources can offer feasible and economically viable sources of electric energy.

In the light of the threatening consequences of global warming, the latent energy locked up in biomass waste is coming under increasing scrutiny by scientists, because the processes of converting bio-material into electricity are much cleaner than those involving fossil fuels. An equally important factor is that biomass is a renewable resource, unlike the earth's diminishing stores of fossil fuels.

The USB study has found that the quantities and energy yields of sugar waste in KwaZulu-Natal make it a viable proposition in seeking to achieve South Africa's medium-term green energy targets. The residue of sugar production, or sugar bagasse, has already been used successfully for electricity generation in other sugar-producing countries.

Burning global issues

Concerns about global warming and climate change are mounting as more and more scientific observations project gloomy scenarios for the earth's future. The industrialised world, with its dependency on fossil fuels, has reached a point where it releases unsafe levels of greenhouse gases (GHG) into the air. These higher concentrations of GHG disturb the naturally controlled radiation of the sun's warmth back into space.

Observers estimate that the global energy supply system alone is responsible for 75% of the damaging human-induced GHG emissions. A solution to the escalating problem, therefore, must start with the energy industry and will require a dramatic turnabout from the current over-reliance on carbon-intensive fuels.

The debate started on the issue of sustainable sources of energy. Back in the 1970s, the oil crisis made the world aware of the threat of depletion of the earth's reserves of oil and coal. This event prompted interest in specifically renewable forms of energy.

More recently, global warming fears have intensified the quest for renewable and clean energy sources as an alternative to fossil deposits. Significant investments and technological advances have since been made in solar, wind, hydropower and biomass industries, which are all driven by renewable and non- or low-carbon-emitting energy sources.

Biomass is vegetation-derived organic material which, in its natural state, stores solar energy through photosynthesis. This energy is later released either through natural decay, or it can be harvested by controlled combustion or chemical processes. Energy from biomass is deemed to be carbon-neutral because the emission of carbon-dioxide is balanced by the absorption thereof during the plant's growth.

The most common biomass production systems, agriculture and forestry, are used directly in the provision of basic societal needs such as food, animal feed, clothing and housing. However, the residues left after primary processing may still contain useful stores of energy. Currently, this potential is largely overlooked and untapped.

The International Energy Agency (IEA) estimates that only 11% of the world's energy needs are served by biomass material, but even this figure is mostly attributed to the primitive uses of biomass in remote rural areas. Only 1.1% of worldwide electricity is produced through more advanced uses of biomass.

Africa is a good example. Biomass energy is mostly relied upon for home needs via simple combustion. Because such processes are inefficient and often culminate in deforestation, they are not sustainable. Parts of Africa have vast biomass resources, but the continent lacks the technology to use it in advanced, sustainable ways for energy generation. As a result, large quantities of biomass waste are merely disposed of by dumping (decomposition emits methane) or burning. This is harmful to the environment, and the available energy potential is wasted.

Obstacles: biomass-to-electricity conversion

- The wide dispersion of biomass resources make them expensive to exploit.
- Intermittent or seasonal availability of resources necessitates forms of energy storage.
- Most renewable energy technologies are relatively new and have yet to reach technical maturity.
- Most renewable energy technologies cannot yet compare cost-wise with conventional fuels.

Where does South Africa stand?

In South Africa, coal (92,8%) and nuclear power (6,7%) provide almost all the electricity consumed. Only small quantities are supplied by biomass, hydro-energy and gas. South Africa has rich high-quality coal deposits which drive a highly efficient power supply network. Because of the key role that low-cost electricity plays in achieving the desired economic growth and social objectives of the country, coal is likely to remain a very attractive source of electricity in the medium-term.

However, the South African government is not putting environmental concerns on the back burner and has committed itself to establishing a renewable energy industry. It has set a medium-term target to push up energy supply from renewable sources (biomass, solar, wind and hydropower) to 10 000 GWh by the year 2013 – about 4% of the projected electricity demand. Government envisages that 6 500 GWh of this energy will come from biomass.

Potential in KwaZulu-Natal

The study focused on KwaZulu-Natal with its large sugar and forestry industries which generate substantial quantities of waste. Sugar bagasse is the fibrous waste left after the milling of sugar cane. Wood waste comprises the off-cuts, sawdust, chips and bark left after the processing of logs. Limited amounts of these byproducts have found secondary uses in the pulp and paper, and the board production industries. Of interest for this study, therefore, was the unused part which also needs to be disposed of in an environmentally acceptable and cost-effective manner.

Experience worldwide confirms that biomass has gained acceptance as a source of energy. The Nordic countries are leaders in using wood waste. In the USA, biomass power has become a $15 billion industry. Other countries promoting biomass energy projects include China, Nepal, India, Australia and Mauritius. Sugar bagasse plays an important role in many of these countries.

The important question in this study was whether it would be possible to convert the two renewable energy sources found in KwaZulu-Natal into electricity in an economically viable way. ►

Conversion technologies

Several conversion technologies exist to process energy from biomass. This study examined only direct combustion. Other technologies include those that convert biomass to liquid fuels (like methanol and ethanol), combustible gases, and compacted high-energy solids. Direct combustion, however, is the most widely used and technologically mature process. Fuel is fired in a boiler to produce high-pressure steam, which drives a steam turbine. The turbine in turn drives an electric generator. The process is similar to that used in fossil-fuel plants.

Sources of bio-waste

Sugar bagasse: There are 12 sugar mills in KwaZulu-Natal. Electricity has been produced from bagasse by some of these mills for many years, but almost exclusively for their own consumption. The low price offered for electricity sold to the national grid has discouraged the mills from expanding electricity generation into larger-scale supply projects.

The average annual mass of sugar bagasse, produced over a period of ten years, is 5 411 kilo tons.

Sawmill waste: For the purpose of the analysis, only the sawmill waste of the forestry industry was considered. There are even larger volumes of waste produced in the forest operations, but these locations are more spread out and, since it is costly to collect and transport the waste to a central location, this component was not seriously considered for the study. There are 77 sawmills in KwaZulu-Natal. Together they supply about 18.5% of the national sawn-timber production. The waste generated by sawmills usually far exceeds the waste supplied to the pulp and paper, and board industries. The excess waste is costly to dispose of and some mills have invested in plants to convert the waste into energy for in-house power. These have also not expanded into larger scale supply systems.

The average annual mass of sawmill waste is estimated at 416 kilo tons.

Energy potential: Based on regular conversion factors as well as on published data from the national Department of Minerals and Energy (DME) on the two biomass types in KwaZulu-Natal (see top box), calculations were done to determine the annual electricity capacities of the two resources (see box below).

These analyses show that sugar bagasse has by far the highest electricity generation potential, namely 2 637 GWh per year versus the 300 GWh per year of sawmill waste. A similar analysis on the forest waste component of the forest industry revealed that the total capacity potential of biomass waste from this industry may be close to 1 000 GWh per year. The forest waste component was excluded from the financial viability analysis owing to the costly transport factor.

The low price offered for electricity sold to the national grid has discouraged the mills from expanding electricity generation …

Biomass energy conversion assumptions

Gross calorific value (GCV) – stated in Megajoules per ton (MJ/ton)	The total energy released during a combustion process by a specific fuel type
Net calorific value (NCV) – stated in Megajoules per ton (MJ/ton)	NCV is the GCV minus the latent heat of the water formed by the combustion process (loss of energy). The difference between GCV and NCV is higher for biomass than for other fuels, and increases with moisture content. **7 017 MJ/ton** was used for sugar bagasse **10 368 MJ/ton** was used for sawmill waste
Energy content in Megajoules	Tonnage of biomass multiplied by the NCV
Energy conversion	**1 KWh = 3.6 MJ** (standard energy conversion factor)
Energy efficiency conversion rate (fuel content to power)	25% (based on international experience)
Annual capacity factor	This represents the proportion of hours in a year that a power plant can produce electricity at its rated capacity. Based on similar international experiences **a factor of 57%** was used. This translates to ± 5 000 hours per year.

Biomass type	Annual tonnage Kilo tons	Average NCV MJ/ton	Potential energy 1 000 MJ	Conversion to power equivalent MWh	Power generation potential MWh
Sugar bagasse	5 411	7 017	37 969 039	10 546 955	2 636 739
Sawmill waste	416	10 368	4 313 088	1 198 080	299 520

Making the sums

To study the economic viability of setting up new biomass power plants, certain assumptions had to be made.

The income generation potential was critical. The current price paid for delivering power to the national grid is very low. In 2004 the price of coal-fired electricity in South Africa was about 10 cents per KWh. This comparatively low price (in world terms) results from the abundance of high-quality coal in South Africa and the already paid-off capital investment. This tariff is not a fair basis for a viability analysis. Instead, the long-run marginal cost of coal-fired electricity (LRMC) of 25.26 cents per KWh – based on the DME's calculation for setting up a new coal-fired power station – was used as a fair price. It was further assumed that no taxes would be paid.

To finance the capital investment it was assumed that debt could be arranged through municipal bonds at 6.5% interest over a project life of 20 years.

A summary of the economic viability analysis is shown in the table below. The full investigation considered a range of options for each biomass type (different types of plants, technologies and capacities). Only the most viable bagasse option and sawmill-waste option are presented here. The costs were calculated on a per KWh basis to make a direct comparison between the options clearer.

As may be seen in the analysis, sugar bagasse is economically viable, but sawmill waste not. Under the analysis assumptions, bagasse promises a small positive return of 3.53c per KWh, while sawmill waste shows a small negative return of -5.39c per KWh.

The investigation proceeded to examine the resource availability by studying the variance in supply over a ten-year period. Even under worst-case scenario conditions, the financial return on sugar bagasse electricity remained marginally positive.

The study also considered the effect of income generated by earning carbon emission reduction credits (ERC). Because of uncertainties in determining the income potential and in claiming credits, the impact of ERC is not shown in the analysis (table). By using a conservative figure of only 3.64 c/KWh, carbon credit income can already make a substantial difference to the viability of a biomass project.

Cost factor	Unit	Sugar bagasse	Sawmill waste	Calculation
Operations and maintenance cost (O&M)	c/KWh	7.39	20.13	A
Capital cost	c/KWh	14.34	10.52	B
Total cost	c/KWh	21.73	30.65	C = A+B
Projected revenue (LRMC)	c/KWh	25.26	25.26	D
Net income	c/KWh	3.53	-5.39	E = D-C

Sugar gets the green light

The study gives the green light to electricity from sugar bagasse. But the profit margins seem to be modest. The decision to invest in sugar bagasse power plants will need more motivation, in the form of a national commitment to green the country, than pure entrepreneurial considerations will lend.

However, future prospects may be better. As the world's concern about carbon emissions increases and the large industrialised countries are forced to buy carbon credits in order to achieve their emission reduction targets, carbon credits may become a more attractive source of income. Moreover, biomass conversion technology is steadily advancing, and will over time become cheaper and more cost-effective to run.

The 2 637 GWh power potential of the KwaZulu-Natal sugar bagasse residues represents 26% of the national electricity output target of 10 000 GWh of renewable energy set by government for 2013; and 41% of the 6 500 GWh targeted for biomass resources. The answer is that ***no single*** renewable resource is likely to achieve all of that. It will require a number of smaller projects to contribute incrementally to the target – and here sugar bagasse can add its spark. ■

This research was presented to the USB for a Master's in Development Finance (MDevF) by GRANT NORRIS (pictured) in December 2005. The study titled *Biomass waste-to-electricity: KwaZulu-Natal as a case study* was conducted under the supervision of JAKO VOLSCHENK and attained a distinction. Norris has since been co-opted in an advisory capacity to assist with the financial assessment of biofuel projects in KwaZulu-Natal.