**Is investment in a sugar cane bagasse dewatering mill economically justifiable for cogeneration?**

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In light of the Kyoto Protocol to reduce green house emissions, the Australian government has made a commitment to "increase the contribution of renewable energy sources in Australia's electricity mix by 9,500 GWh per year by 2010" [1]. A substantial penalty ($A40/MWh) will be applied to non-complying electricity producers. Depressed crystal sugar commodity prices and the federal green power legislation, are acting together to move Australian sugar millers towards increased co-generation and electricity export. One significant opportunity to increase the value of power exported is to increase the calorific value of the bagasse by mechanical dewatering prior to combustion. Dewatering is defined here as the removal of water from bagasse to levels below 50% moisture (wet basis). The focus of this analysis is to determine how moisture content affects exportable power and, thus, determine whether mechanical dewatering is economically justifiable in the Australian context.

**Analysis**

A standard Australian sugar factory could be considered to be one that processes 2,000,000 tonnes of cane with a fibre fraction of 14.5% (wet basis), over a period of 22 weeks, at an operating rate of 600 tonnes of cane per hour, and with a plant availability just under 90%. This averages to a dry fibre rate of approximately 85 tonnes per hour. Across the season, 580,000 tonnes of bagasse would be produced. Such a factory would consume approximately 30 GWh electrical energy annually, with an additional energy loading of 300 tonnes/hour steam (around 50% on cane by mass) to meet sugar crystal processing requirements. The electricity produced by cogeneration is predominantly used in the factory but a small excess (1–4 MW) would be sold on the state electricity grid, typically at less than $A18/MWh, offering little inducement for greater effort to export to the grid [2].

The spent sugar cane fibre, bagasse, is essentially a ligno-cellulose waste product which is delivered to the power plant either fresh, directly from the milling train via buffer storage, or by reclamation from a stockpile. The moisture content of fresh bagasse usually varies from 44 to 54% due to changes in milling train operation or the cane supply. Variations in the moisture content of stockpiled bagasse may be larger. The lower the moisture content, the higher the calorific value of the bagasse as a fuel [$\boldsymbol{h = 19600 - 196(M + A - 0.01MA)}$, where $\boldsymbol{h}$ is gross calorific value kJ/kg wet basis, $\boldsymbol{M}$ is moisture percent wet basis, $\boldsymbol{A}$ is ash percent dry basis]. The commercial value of bagasse may be estimated from the value of substitute fuels required in the event of a fibre short fall due to poor growing conditions, high mill final moisture levels, or a decline in power plant efficiency. To replace one tonne of bagasse (at 50% moisture) on an equal energy basis would require $A8 of woodchip or $A21 of black coal (Mackay region prices).

For the standard factory above, the effect of bagasse moisture content on gross power output during the harvest crushing season (in-season) has been modelled using HYSYS.Process [3], for two boiler plant configurations: (1) high pressure boiler, thermal efficiency 72%, steam pressure 66 bara, steam temperature 540 C, factory demand 45% steam on cane (by mass); and, (2) low pressure boiler, thermal efficiency 60%, steam pressure 18 bara, steam temperature 260 C, factory demand 52% steam on cane. The marginal change in gross export power with moisture reduction through mechanical dewatering is determined from the energy modelling, thus:

?? High pressure boiler: $(P - P_{ref}) = -0.02\ (M^2 - M_{ref}^{\ 2}) + 0.9\ (M - M_{ref})$

?? Low pressure boiler: $(P - P_{ref}) = -0.01\ (M^2 - M_{ref}^{\ 2}) + 0.3\ (M - M_{ref})$

where $\boldsymbol{P}$ is export power in MW; $\boldsymbol{M}$ is percent moisture (wet basis); and, the subscript *ref* indicates the base or reference case. The high pressure system is noted to have a significant gross power advantage over the low pressure system, and will (therefore) be the subject of the economic analysis.

The in-season analysis has been extended to off-season analysis on the basis that the change in gross export power with change in bagasse moisture, is similar within and outside the crushing season.

Liquid is expressed from sugar cane fibre by a rolling process; therefore, the most obvious method for dewatering bagasse is to apply the mill rolling principle. Two operational scenarios are considered: (a) in-season where all bagasse is dewatered and burned within the harvest season setting the maximum fibre rate for dewatering (all fibre dewatered once only); and, (b) off-season where half of the bagasse is assumed to be stockpiled for off-season reclamation, dewatering and power export. Two hardware options are considered: (1) modification of the existing final mill by adding additional rolls and chutes ($A2.2m for in/off-season operation); and, (2) a new stand-alone milling unit customised for moisture reduction and installed as a dedicated part of the system conveying bagasse to the boiler plant ($A4.4m for in-season only operation, and $A3.4m for off-season only operation – lower cost due to split in bagasse stream to boiler and stockpile).

The economic evaluation of the hardware and the operational scenarios has been completed assuming:

?? costs are limited to those additional to existing milling train capital and maintenance costs;
?? costs include estimates for the opportunity cost of power consumed during dewatering, additional conveying, safety issues and effluent handling;
?? capital life of 20 years at 11% discount rate;
?? nominal exported “green power” value of $A50/MWh;
?? both hardware options achieve a moisture reduction of 5% from 50% to 45% (wet basis); and
?? total costs have been calculated per tonne of dry fibre being processed, assuming fixed plant size.

For the high pressure boiler, the modification of existing final mill hardware (option 1) is economically viable for both in-season and out-of-season operations. For a 5% reduction in bagasse moisture the increase in export power net revenue is $A1.3/t (dry fibre) in-season, and $A0.7/t off-season. The payback periods are 5.5 and 9.9 years respectively. The new stand-alone dewatering mill (option 2) is not viable on its own merit for in-season operation (-$A0.1/t return), and is marginally viable for out of season operation ($A0.3/t return).

Stockpiling costs associated with dozing, loading and trucking/conveying have not been included in this analysis. These logistics costs amount to approximately $A15–20/t (dry fibre) for stockpiles of 100,000 tonnes (dry fibre). If these costs are attributed fully to off-season dewatering operations then both hardware options show negative returns for off-season operation. Off-season operation must be considered in the light of seasonal peaks in the wholesale electricity market, the capital investment decision to convert from low pressure to high pressure boiler plant, and other capital decisions relating to the reduction in plant steam requirements.

**Conclusions**

Dewatering bagasse prior to burning substantially increases its energy value as a fuel and, hence, the electrical power available for export. The economic analysis has shown that dewatering bagasse can be conducted in a commercially viable manner for the high pressure boiler case, in-season by modifying existing final mill hardware to include a dewatering roll set. Out of season operation is not justifiable on its own merit and must be considered in conjunction with other commercial decisions.

**References**

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