

ENERGY CONSERVATION - A MANAGEMENT PERSPECTIVE

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Abstract

The background to the high coal usage at the TSB owned Malelane mill is examined in the context of the SA Sugar Industry energy scenario. Some sugar industry energy conservation techniques are reviewed. Energy conservation involves a double faceted approach: (a) energy saving capital projects and (b) attention to energy-related operating and maintenance practices. The methodologies used to launch and manage the Malelane Energy Conservation Programme are discussed. The impact of the type of technology and time efficiency on energy benchmarking is reviewed. Key energy efficiency indices for energy usage management are listed and the limitations of some energy indices are discussed.

Keywords: energy, conservation

South African sugar industry energy scenario

One of the strategic goals of the SA Sugar Industry is to maintain global competitiveness by being a low cost producer. For coal-burning factories, such as Malelane, the cost of energy impacts significantly on the cost of production so there is a strong incentive to reduce energy consumption.

National and international policies affecting climate change are expected to make greater impact on environmental, political, economic and social issues. In this regard the Kyoto Protocol drafted in 1997 committed industrialised countries to reduce green house gas emissions. It is expected that intermediate emission reduction requirements will be negotiated in the near future and that these will likely affect carbon-intensive developing

countries like South Africa. The SA sugar industry is a small user of fossil fuels, however, the potential for increased co-generation from bagasse is an attractive opportunity to partially reduce reliance on coal-generated electricity. This scenario predicates that co-generation of heat and power will become a strategic commercial issue for the sugar industry in the future.

The SA sugar industry has been aware of the need for energy savings but has not given this high priority due to low or non-existent incentives. The traditional scheme of energy supply in a sugar factory is to burn bagasse to produce enough steam and electrical power for its own consumption. This is shown in Figure 1.

Background to high energy consumption at Malelane mill

Malelane Mill was originally designed along traditional lines but now exports approximately 15% of its bagasse for animal feed and particleboard manufacture. Furthermore, the energy demand has increased due to the need to refine the raw sugar produced by both of the Company's mills, and by the export of power for irrigation of adjacent company-owned cane farms. The operation of the refinery to process stored raw sugar during off-crop, when no bagasse fuel is available, aggravates the use of supplementary fuel. During this period coal is the only fuel. The complexity introduced by these integrated operations is shown in Figure 2.

Coal costs for Malelane Mill for the period 1989 to 1997 are shown in Figure 3. The costs show a steep increase that outstrips the typical 10 % annual price escalation for this commod-

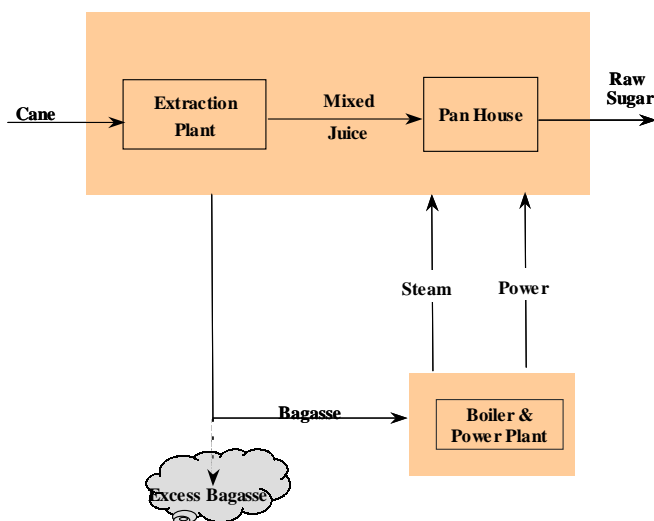


Figure 1. Traditional cane sugar factory.

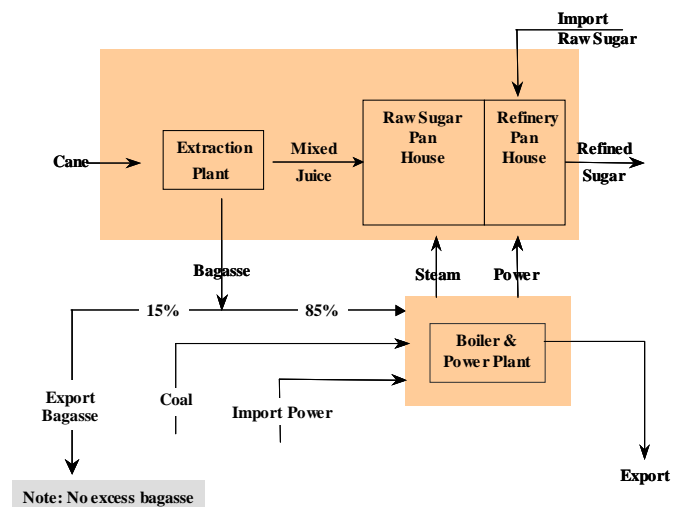


Figure 2. Malelane mill energy related flows.

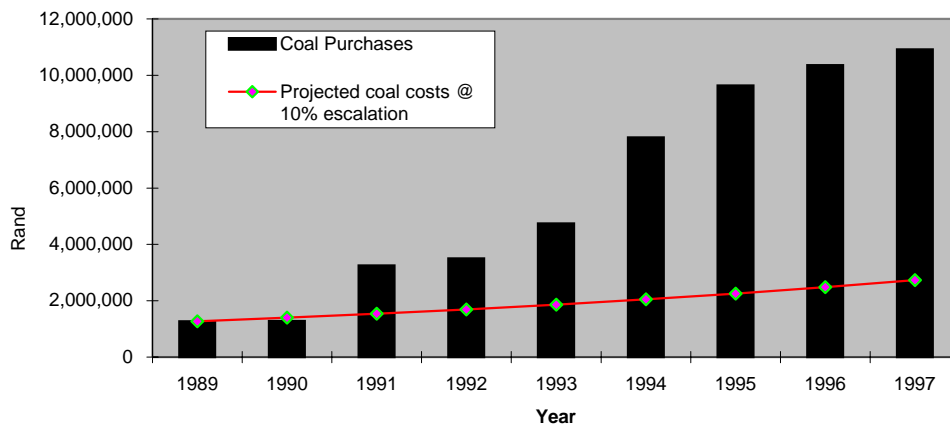


Figure 3. Malelane mill coal cost and coal price evaluation.

Note: Off-Crop Refining Commenced in 1994.

ity. Operational staff have identified several maintenance problems that account for inefficient operation and hence increased energy usage. Notwithstanding this, the escalating trend in costs suggests other underlying causes. This situation prompted management to launch an intensive energy investigation in 1997 to determine the causes of high energy and power consumption.

Review of energy conservation measures at sugar factories

The Malelane Mill has had an energy management programme since 1987. The focus of the programme had been firstly on management commitment and secondly on operational efficiency. With respect to the latter, the following was emphasised: boiler efficiency improvement, bagasse moisture reduction, process steam demand reduction by optimising operating parameters and minimising downtime. Close attention was paid to: imbibition, pan movement water and massecuite exhaustions, i.e. factors under operator control.

Mann (1988) advocated a 'management by objective' approach at the Sezela mill to optimise energy efficiency. He stated that 'significant gains in energy conservation may be made by concentrating on the operator controlled factory activities which have an impact on the overall energy balance'. Included in this group of operator controlled activities are: water added to process, boiler fuel : air ratio and unburned carbon in boiler ash. Another objective to be actively managed was the factory overall time efficiency. Low time efficiencies imply downtime, which in turn implies that the boilers are being fired with supplementary fuel.

The energy saving programme implemented at Noodsberg (Webb & Koster, 1991) over several years reduced coal consumption by 35 000 tons per annum (90% reduction). Noodsberg Mill is similar to Malelane in that it refines its own as well as imported sugar. In the absence of reliable steam % cane figures, Noodsberg's management relied on a theoretical heat and mass balance to assess the effectiveness of energy-saving plant modifications. The focus of the mass balance was to assess the global effect of the plant modifications rather than to perform a theoretical calculation on each unit operation.

The Al Khaleej Refinery in Dubai was faced with a situation of good performance in sugar recovery and quality but not in steam consumption. Their action steps to improve energy efficiency involved using Pinch Technology to identify energy savings, reviewing of day to day process operations and setting of benchmarks for key performance indicators. The starting point for good process performance and energy efficiency is reliable simulation of heat and mass balances for different scenarios at the design stage. (Ghurair & Singh, 1999).

The Hulett's central sugar refinery in Durban, which generates steam and part of its power requirement from coal, adopted a similar approach with regard to its energy conservation strategy. The Company made use of 'outside consultants who examined the energy balance and applied, amongst others, the principals of pinch technology'. (Hoekstra & Tayfield, 1998).

British Sugar was faced with rising fuel prices in the 1960's and late 1970s (Twaite *et al*, 1986). Energy reduction was achieved by a combination of experience and intuition on the one hand and significant capital expenditure on the other. Systematic process integration analysis proved beneficial in identifying energy saving measures in boiler plant and in ensuring thermodynamically sound designs.

Energy conservation programme at Malelane

The common thread running through the above case studies is the need for a systematic approach in carrying through an energy saving programme. Energy conservation involves a double faceted approach, viz. energy-saving capital projects and continuous attention to existing operating and maintenance practices that impact on energy. Malelane Mill re-launched its energy conservation programme in 1997. This programme started with a planning phase in which the scope, time frame and role players involved in the energy study were defined. The energy conservation methodology steps are depicted in Figure 4.

The following discussion covers some of the main components of the energy conservation programme.

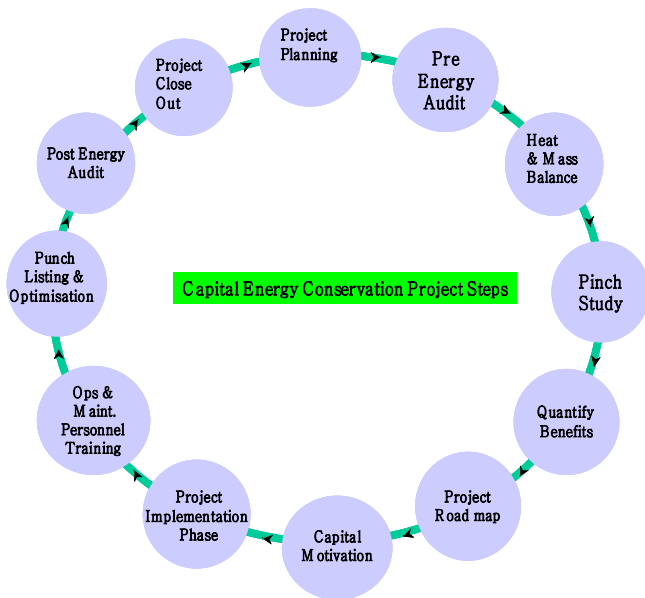


Figure 4. Energy conservation methodology steps.

Heat and mass balance

The establishment of the correct energy balance is of paramount importance to start optimising energy costs. The heat and mass balance model of Malelane mill served as the basis for establishing a status quo performance level. The model provides all sugar stream, steam and water flows under steady operating conditions based on actual plant season to date data extracted from factory records. Where no data was available actual measurements have been taken when steady operating conditions prevailed in the plant. In some instances it was necessary to use original equipment manufacturers' design data e.g. specific steam consumption of turbines and turbine efficiencies. Heat transfer figures for dirty evaporators (i.e. end of cycle conditions) were used for evaporators to introduce

some conservatism into the model. Three simulations (start, mid and end of milling season) were run to ensure the impact of varying cane quality was taken into consideration.

Pinch analysis

The heat and mass balance model was then subjected to a systematic thermodynamic study, by performing a Pinch Analysis, in order to identify and evaluate opportunities for energy conservation. The data extracted from the heat and mass balance model were used in the Pinch Analysis to determine the grand composite curve from which energy recovery opportunities could be identified. These were then subjected to operating, flexibility and sensitivity constraints to determine the optimum evaporator design and vapour-bleeding scheme.

Project road map

The next phase subjected these scenarios to economic plant operability, availability and flexibility analyses.

Capital costs versus energy savings trade-offs were comprehensively explored to yield the optimum investment strategy to save energy. 'Quick win' energy saving projects based on the Mill's investment criteria were identified and prioritised for short-term implementation.

Post energy audit

Each project's performance is individually assessed against the original design specifications. In addition the integrated effect of the various energy projects is assessed by re-running the heat and mass balance inclusive of the implemented conservation measures as well as the current cane quality and process performance parameters.

The post audit assessment of coal usage and OTE is shown in Figure 5. The marked decrease in coal usage and the increase in OTE are evident.

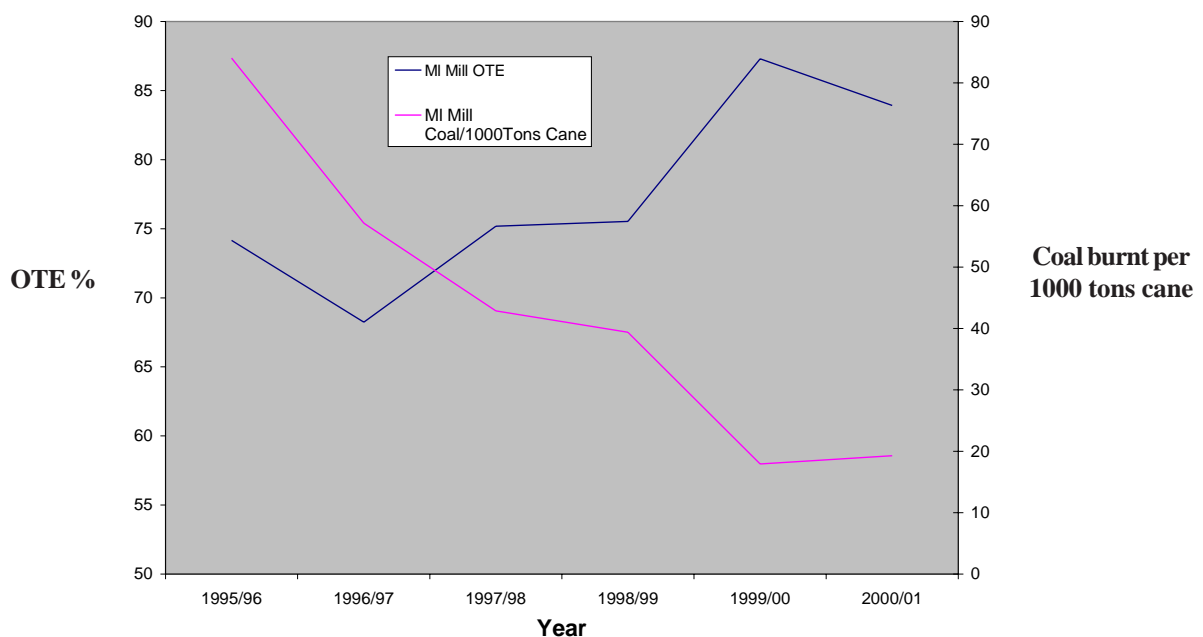


Figure 5. Malelane OTE vs coal consumption - six year trend.

Continuous energy management

In addition to the energy conservation projects, day to day maintenance and operations philosophy form key components of a factory's energy conservation programme. The backbone to continuous energy saving methodology is an energy management information system based on reliable key energy data. The critical data must measure the energy sensitive processes. There are two levels of information required, viz. for plant personnel where all energy sensitive streams are continuously monitored and for management where only key energy indices are monitored.

Some of the key energy performance parameters, which are monitored at Malelane Mill are shown in Appendix 1. The relevant benchmarks have been sourced from the design data for Malelane Mill as well as from SA sugar industry norms. In the absence of reported data, benchmarks for Malelane Mill has been sourced from historical records.

Factors affecting energy benchmarking with other factories

Effect of type of technology on energy usage

A commonly used overall efficiency figure for steam usage in a cane sugar factory is steam % cane. According to Albert-Thenet (1991), 'It is a meaningful index when comparing factories milling cane of similar quality and having similar processes, however, it should be used with caution when comparing factories in different regions, where quality may be different and where processes may include by-product factories or co-generation of electricity'. For example: Wunsch (1998) expresses the opinion that a cane raw sugar factory can be modelled to achieve a steam on cane figure of 27% (compared to currently achievable steam on cane of 50-60%) by adopting technology from the beet industry. In this regard the use of higher pressure input steam to the first effect, the use of falling film evaporators as fourth and fifth effects and the use of continuous pans for crystallisation work allows vapour bleeding to be practised such that vapour losses to the final effect condenser are minimised. Wunsch argues that his design will create an excess of 45% bagasse, which can then be available for by-product use and/or for co-generation.

Kinoshita (1999) recommends the use of Net Power Generation/Cane Fibre Rate (kWh/ton fibre) for assessing the performance of a raw sugar factory energy consumption in a standardised manner. The advantage of this measure is that since the energy efficiency index is defined in energy terms, all fuels (bagasse, sugarcane residues and fossil fuels) imported or exported by the factory are viewed as equivalent units of electricity. The bagasse equivalent is used to compensate for imported fuel. Steam used by peripheral operations like refineries and by-product plants is credited back to the raw sugar generation facility on the basis of the equivalent power produced by utilising the diverted steam in a condensing turbine generator. This measure is specific to a raw sugar factory. Its application for benchmarking Malelane Mill is complicated by the fact that data for other South African factories is not readily available for comparison.

Impact of overall time efficiency on energy usage

Overall Time Efficiency (OTE) is a measure of the actual cane processing time as a percentage of gross available time. Plant stoppages due to poor cane supply, breakdowns or scheduled downtime for maintenance have a 'double-barrel' negative impact on the energy consumption of a sugar factory. Stoppages mean that the bagasse supply from the cane extraction plant is interrupted and as soon as bagasse stockpiles are depleted, supplementary fuel must be burned to keep generating power and steam for process needs. In addition, whilst the plant is not crushing cane and therefore not producing cane juice, water is substituted for juice in the evaporators and pans. This means that steam is being used but no cane is being processed, resulting in an inflated steam % cane figure.

Boiler efficiency

Boiler efficiency can be measured either by the direct or indirect method. The indirect method measures the losses around a boiler and is an instantaneous measure of boiler efficiency. It is an accepted method used by boiler manufacturers to assess boiler performance. The limitation of this technique is that it is a snapshot of boiler performance. The method is usually reserved for measurement when the boiler is burning coal. Catch sampling of coal and ash may introduce errors into the measurement. The measurement of excess combustion air is also a problem.

The direct method assesses boiler efficiency by relating energy in steam output as a percentage of energy in fuel and boiler feed water. The limitation of this technique is that it requires accurate massing of fuel, boiler feed water, steam and blow down losses. This method is more suited to efficiency reporting over longer periods for which bagasse and coal massing can be more accurately determined.

Another factor which affects energy efficiency is the quality of cane being processed. Sugar factories have limited control over this aspect. Higher fibre % cane will make more bagasse available for combustion whilst higher ash and higher moisture reduce the calorific value of bagasse.

Key success factors

As the conservation programme progressed, some learning points that emerged were:

- The aims of the energy saving investigations must be well defined to ensure that the results truly provide the data needed for evaluation of energy savings potential.
- The energy savings project must be championed by a senior company manager who has the practical and theoretical background in energy management techniques to ensure that management commitment is visible and focussed.
- Experts should be used for the preliminary planning stage of the project, especially where in-house expertise is lacking. Expert knowledge and experience is required in the fields of measurement of energy streams, plant design, energy conservation techniques and process operation. In-house personnel may become 'factory' blind and fail to:

- identify and correct excessive energy usage;
- recognise opportunities and implement measures to recover energy from waste streams.
- A lack of adequate instrumentation to check energy consumption may conceal that part of the plant has a high energy consumption level. The accuracy of measurements is all-important to ensure that a reliable evaluation of energy savings can be made. When undertaking an audit it is important not to collect measurements just because there are measuring instruments available. Instead it must be pre-determined what information is required and which measurements can provide this information.
- Poor maintenance either due to a lack of spares or a lack of a functional preventative maintenance plan has a significant impact on energy usage.
- Production demands may be so pressing that there is no time to shut down production to carry out scheduled maintenance.
- Housekeeping measures must be addressed, e.g. poor insulation, leaking steam traps, leaking compressed air piping, leaking condensate and steam piping and valves.
- Use of a more expensive fuel to accommodate maintenance needs. Changing to a cheaper fuel does not reduce the amount of energy generated but reduces the total fuel bill.
- The energy conservation project is not over after implementation. Project follow up and training of operating and maintenance staff are equally important to ensure continuous success of the energy saving measures.
- Pre-training for a successful commissioning and post training for optimisation are key requirements for new projects.
- Start with quick win, high payback projects to create a climate of success. It is then much easier to motivate major capital investment projects.

Conclusion

The Malelane Mill experience has been that a systematic project management approach supported by a reliable energy management information system is the key ingredient for a successful energy conservation programme.

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APPENDIX 1

Key energy performance parameters monitored at Malelane mill.

Parameter	Benchmark Data	Comment
Extraction Department		
Ton cane per hour	375	Measure of throughput rate.
Capacity index	90	Measure of capacity utilisation.
Overall Time Efficiency (OTE)	85	Measure of downtime.
Fibre % cane	14.8	Measure of fibre available as fuel.
Ash % cane	1.60	Measure of sand that ends up in bagasse.
Ash % bagasse	3.5	Affects the calorific value of bagasse.
Bagasse moisture %	51	Affects the calorific value of bagasse
Extraction %	97.8	Measure of sucrose extracted from cane.
Imbibition % Fibre	362	Measure of water added to extraction process.
Filter Wash Index	103	Measure of water added to filter plant. Not applicable with mud return to the diffusers.
Raw Sugar Pan House		
Total massecuite as m ³ per ton brix in mixed juice	1.9	Measure of recycling in the pan house. Recycling increases steam demand.
Movement water used in raw sugar pans % massecuite	10	Measure of water added to pan boiling process.
Refinery		
Melt brix %	65	Measure of water added to the refinery.
Thick liquor brix %	72	Measure of additional water load to the refinery pans.
Refinery pan boiling yield as crystal % per strike	60	Measure of recycling in the refinery pan house. Impacts on steam demand.
Steam Generation		
Softened water used as % of boiler feed water	2	Measure of cold water that has to be heated for use as boiler feed water.
Boiler efficiency % (Direct Method)	75	Measure of combustion efficiency of a boiler.
Season average HP steam % cane	60	Measure of overall factory steam usage (includes the effect of downtime i.e. low OTE).
Let down steam % HP steam	7.5	Measure of HP steam bypassing the turbines.
Tons coal per 1000 tons cane	12	Measure of supplementary fuel consumption.
Snapshot Hourly Parameters		
	Benchmark Data	Comment
Boiler efficiency % (Indirect method – coal firing only)	83	Benchmark based on manufacturer design specification.
HP steam % cane for steady conditions	57	Benchmark based on heat and mass balance model Equates to design figure.