JSESD003: Strategic Energy Management to Reduce Energy Cost and Improve Competitive Position of a Beverage Company: Case Study

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Abstract

This study was aimed at examining energy use in organisations, particularly to determine whether or not there was any energy-saving potential, and ways in which it could be enhanced, given that energy efficiency brings with it economic benefit. The study evaluated energy consumption using a brewery company as a case study. A company audit was undertaken through inspection and observation of equipment status and conditions in relation to energy use. Effort was made to identify potential energy management improvements at the case study company. Some design and decision support tools that could be used to improve the management of energy were suggested, and energy-saving measures for the operation were also recommended. The study found that despite the fluctuating demand on the compressors, possible savings of about 35% could be achieved on the compressor plant section, while a potential saving of 6% was possible for the refrigeration plant. Eliminating the identified air leaks would reduce the air plant energy consumptions by 7%, and elimination of the pressure drops would therefore introduce an energy saving of 5%.

Keywords*:* brewery, consumption, energy, measures, opportunities, saving

Introduction

Market growth, consumer demand, product life cycles and the rate of technical and system changes are all constant and unpredictable in today's corporate climate. As a result, businesses are constantly striving to increase efficiency, save on expenses, and improve management methods to meet customer demands (Hammer & Champy, 1993).

Energy is regarded as merely another commodity among all known costs. Because of its perceived status as a minimal contributor to economic

efficiency, its administration and efficiency play a limited role in public policy. Energy management initiatives are generally discretionary undertakings that are not vital to the immediate profitability or long-term survival of the organisation, according to the National Business Initiative (2014). Their technical character renders them vulnerable to senior management rejection because of their uniqueness, which is viewed as a high risk.

Energy prices are typically regarded as an uncontrollable necessary evil that decreases with respect to local energy pricing. A company could miss out on possible savings, revenue-generating measures, and possibly the strategic position if it does not pay close attention to opportunities at all levels of operations in the value chain. Without even placing a price on carbon emissions, there is a lot of opportunity to enhance energy efficiency and there is a lot of economic benefit, especially in developing nations (Sorrell, 2011). Paying close attention to energy use and prices could make a company more profitable and improve its public image as it demonstrates environmental sensitivity and good corporate responsibility.

Energy management review

Energy management could be defined as the proactive organisation and methodical coordination of energy acquisition, conversion, distribution and use to meet demand while keeping economic and environmental goals in mind (Khalid, 2014; Siemens, 2011). Capehart et al. (2003) define energy management as a strategy for maximising profitability and boosting competitiveness by carefully deploying energy. It is the management of all organisational energy requirements through optimum programmes of procurement, generation and consumption of various types of energies based on the short-term and long-term overall plans of the organisation with due consideration to cost, availability, economic factors and other driving factors, according to the Japan Energy Conservation Centre (2005).

Strategic energy management may save over 20% of total energy use in some nations, which is a substantial amount of money. Depending on the operational operations, significant monetary and energy savings could be realised through energy management as depicted by Fig. 1. Low-cost activities could save 5%-15% in the first year or two, moderate-cost activities could save 15%-30% over the next three to five years, and high-cost activities could save as much as 30% -50% in the long run (Turner & Doty, 2007). The recent sharp increase in energy costs can be mitigated significantly by cost savings achieved via the installation of energy management solutions (Fysikopoulos et al., 2013). By not spending more for energy than is required, the savings can provide a competitive edge or boost profitability.

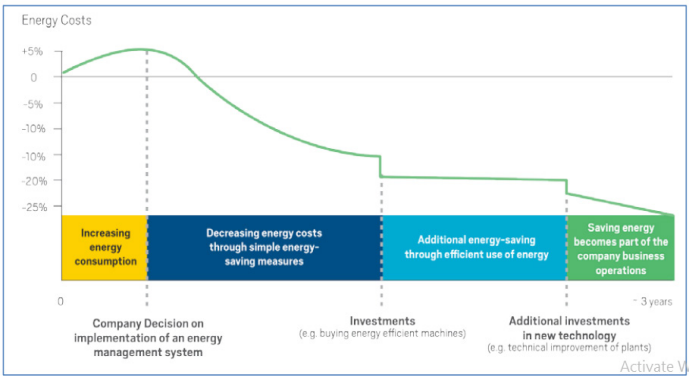


Figure 1: Illustration of energy savings using energy management (Khalid, 2014)

Energy management systems play an important role in preserving energy resources and lowering carbon emissions (Oda et al., 2012). At the national level, energy management aids in the following areas: improving capital savings on power plant construction, reducing energy imports and dependence on other nations for energy, extending the life of local energy resources, and reducing the danger of energy shortages. At the corporate level, energy management would help the company to: become less reliant on a commodity whose price they have no control over, identify and eliminate challenges, thereby increasing productivity, and mitigate potential future problems such as energy scarcity, policies or legislation, and price fluctuations (Fig. 2). Because of its incalculable and endless value, the necessity for energy management cannot be overlooked (Vera et al., 2007).

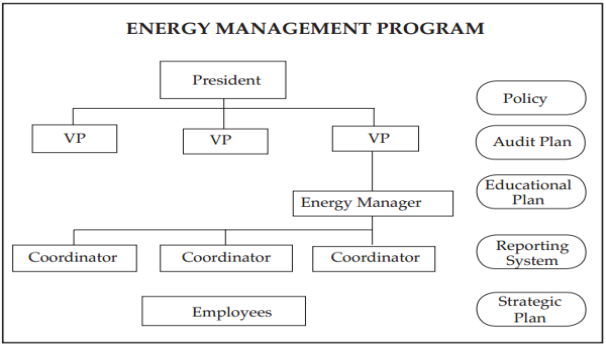


Figure 2: Generic organisational chart for energy management (Oda et al., 2012)

Many studies have found that in order for an energy management programme to be successful, it must have the following elements: top management's undivided commitment, an energy committee to oversee the programme, adequate energy monitoring schemes, well-formulated action plans, accountability for the energy used, and employee participation (Turner & Doty, 2007).

Representatives from various divisions of the organisation, such as administration, marketing and finance, maintenance, operations and any other important department, should serve on the committee for the energy management programme. These should not be permanent, but should be assigned for a set length of time to allow for rotation, which brings in new ideas and also serves as a tactical way of getting rid of non-performers, thus continuously enhancing the committee's efficacy (Turner & Doty, 2007). They should create programme goals and priorities, track performance, design and implement action plans, and keep track of any government activities and other legislation that directly or indirectly affect energy management. They should inform the firm and the community about their progress and the success of energy management programmes, as well as the results.

For successful energy usage, as well as analysis of the entire plant and energy management success, data on all energy-related activities must be gathered and represented in a usable format, allowing for the easy identification of possible areas for improvement in the organisation's activities. In energy management, two types of energy loads must be evaluated. Non-production loads are energy loads which are not reliant on production levels, such as radiation losses and tank heaters. There are also production loads that are proportional to the rate of production. Most businesses just consider the total load, but it is critical to consider the two loads independently. The location of non-production loads should be recognised so that attention can be focused on these regions.

The separation of the two loads also makes it easier to estimate the total energy consumed by various production rates, which is a useful tool because production rates are rarely consistent. After accurately capturing the collected data and identifying the energy usage and utilisation sites, certain critical performance values may then be established. Two of the important ratios are:

$$\textit{specific energy requirement} = \frac{\textit{amount of energy required}}{\textit{unit of product output}}$$

$$\textit{equipment energy efficiency} = \frac{\textit{useful energy}}{\textit{input energy}} \; x\ 100\%$$

The ratios above can be used to derive other important pieces of information and can also be used to compare with other companies.

Some of the basic activities that can be done to identify opportunities would include comparing the energy requirements with other companies (benchmarking) and previous periods, using standards, considering the process or processes of energy exchange, considering recovering waste energy, exploring process modification, as well as improving housekeeping. Traditionally, areas of energy management could entail tariffs analysis and negotiation (where negotiable), electricity demand management and correction of the power factor:

$$power\ factor = \frac{resistive\ power}{resistive\ power + reactive\ power}$$

Scheduling process operations could also be viewed as a viable solution. Improved boiler control, the use of economisers, steam accumulators, condensate recovery, continuous blow down, and blow down recovery are some of the ways in which the organisation can increase boiler efficiency. Inspection, particularly of insulation, leaks and steam traps can be added to this. As a result, a go-maintenance system might be implemented to ensure that equipment runs efficiently.

The ISO 50001 energy management standard was created as a framework to meet the needs of energy management systems that enable ongoing energy efficiency and performance improvement (Meffert & McKane, 2009). It is a traditional management standard applicable to both the manufacturing and service industries. It can be used in conjunction with other management systems, particularly those relating to quality and environmental management, such as ISO9001 and ISO 14001 (International Organisation for Standardisation, 2011).

Materials and Methods

This research was based on a beverage company case study. It was carried out to determine the operations and structures of the organisation that affect the management of energy consumed in the firm's output. The study looked at the firm's energy usage to see whether there was any energy-saving potential and how management might help improve the organisation's energy use. The project's major focus was on energy-intensive operations, however, the company's management structure was also examined.

An in-depth examination of the organisation's activities was conducted in order to identify the energy-intensive regions. The products made, the organisational structure, the steps of the brewing process, the frequency of brews and, most importantly, the energy input, losses and product outputs were all determined. The energy consumption data for the energy-intensive step of the brewing process was collected. To obtain further information on energy trends, semi-structured, unstructured, and non-directive methodologies were utilised in addition to organisation flowcharts, data sheets and plant walks.

Case Study

The case study company is in the beverage manufacturing and distribution business, as well as the agricultural industrial area. Its plant makes clear alcoholic drinks and packaged carbonated soft drink cans, among other products. Established in 1898, the company is a big market shareholder, and is listed on the local stock exchange. It was first listed on the stock exchange in 1946. The company is part of a large conglomerates subsidiaries that include a beer processing plant, a non-alcoholic beverage plant, a malting plant, a plastic production plant, and transportation and distribution companies. The case study company aspires to be a fully integrated total beverage company that dominates all segments of the country's cold beverage market. It also intends to increase its worth in real terms on a long-term basis by providing exceptional service to its clients. Procurement, operations, information technology, audit and corporate services are key units in the case study company.

The beverage manufacturing plant is conveniently positioned near additional raw materials, hardware stores for spare parts, and a rail link for easy final product shipping. The configuration of the factory is set up to allow for a one-way flow of products. Materials from the utility department pass via the brew house, where they are packed before being delivered to the warehouse on the opposite side of the factory.

The company has a functional structure, which is defined as a method of classifying individuals based on their specialised abilities and job functions, for which it is well-known (Kulu, 2016). Finance, production and marketing are among the centralised departments, each with its own functional head. The general manager is in charge of the entire organisation, as illustrated in Fig. 3.

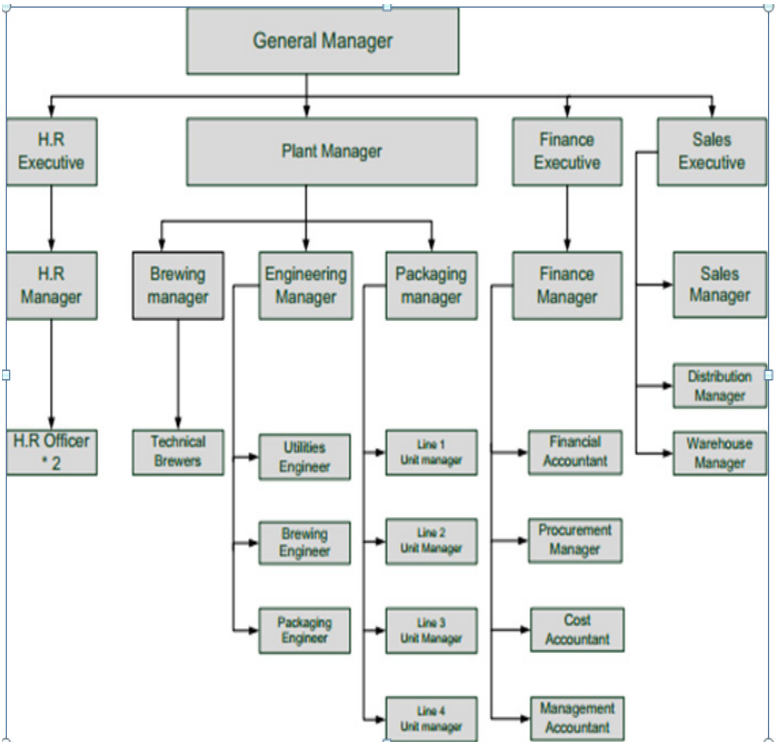


Figure 3: Organisational structure

Other departments at the organisation are human resources; safety, health and environment (SHE); utilities; brewing; quality; packaging; warehouse and distribution; loss control; and information and technology.

The utilities department consumes the bulk of energy input resources, which include coal and electricity. All operations that require energy use one of the two energy sources. In the boilers, coal is utilised as a fuel, while electricity is used mostly in the refrigeration processes throughout the brewing system. The boiler house, water treatment plant, carbon dioxide plant and engine room are the four sections of the department. As a result, the department provides steam, carbon dioxide, cold liquid ammonia and glycol for refrigeration activities, as well as municipal, service and processed water to the plant. All of the equipment that serves the same purpose is gathered in one place. The boiler house houses the boilers, the water treatment plant houses the filters, and the refrigeration plant houses the compressors.

Refrigeration plant: The refrigeration plant is responsible for cooling processes as some brewing processes require low temperatures. The refrigeration process helps to keep the temperature of some equipment and beverages lower than the surroundings (Rayner, n.d.). The applications are mostly in the fermentation process and the cellars. The refrigeration working substances are ammonia, water and glycol. The primary refrigerant is ammonia, with glycol and water being the secondary refrigerants used at the plant. The refrigeration plant is automated, as compressor loading and control systems for refrigerant flow are automatic.

The electric compressors do the external work to enable the refrigeration process. They are the main electricity consumers at the plant. The heat exchangers also merit mentioning as they facilitate heat transfer from the ammonia to glycol which is then delivered to the plant. The ammonia enters the heat exchangers at -5°C and exits at +2°C, and on the other end, glycol enters at +5°C and exits the heat exchanger to the plant at 0°C. Refrigeration is used in wort cooling, fermentation cooling, maturation, filtration and packaging of beer. It is an expensive process in the plant and consumes between 40% and 60% of the total electrical energy plant requirements.

Air generation plant: The air distribution system makes the air dry and doses the air with oil to lubricate the pneumatic equipment.Compressed air is vital for pneumatics in the brewery, it is critical in powering systems in raw material handling , the brew house itself, filtration, bright beer tanks (BBTs), blending, packaging, and storage.

Steam generation plant: The steam generation plant has four coal fired water tube boilers and two stockers running concurrently. It supplies the plant with steam for the several plant processes. The steam working pressure is 10 bars and in those processes that use heat exchangers, the condensate is pumped back to hot wells. The steam plant has a lot of critical equipment without which the steam production process is impossible or ineffective.

The brewing manager is in charge of the brewing division, which includes everything from raw materials to wort production, fermentation and beer storage. As per the production plan, every effort is made to supply the required volumes of beer for packaging at the proper brand splits. The brewing department is divided into three sections: the brew house, fermentation and basement. These contain storage vessels, CIP, filtration and brighter beer tanks. Since the brewing process follows a set of standard procedures in a specific order, the equipment is set up following the operations of the brewing process as shown in Fig. 4.

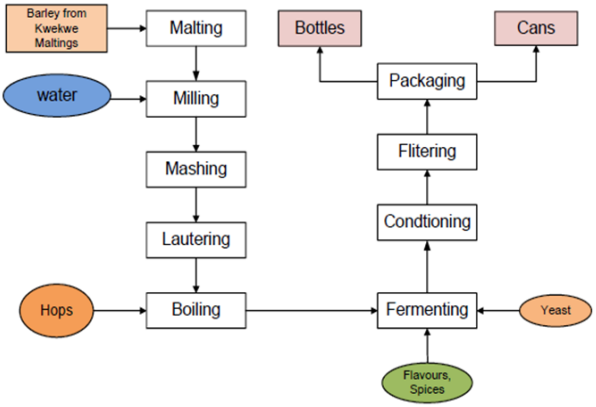


Figure 4: Typical brew process

In the first section of the brewing department, malt is converted to wort through milling, mashing and wort boiling. Wort production is done in the brew house as shown in Fig. 5.

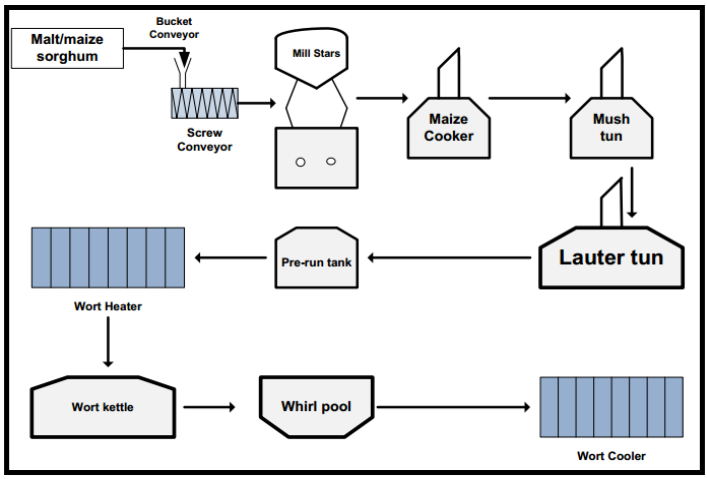


Figure 5: Brew house operations

The malt is then milled in order to increase the contact surface area between the brewing liquor and malt. The milling process is used to ensure a high yield conversion of starches into sugars. Wet milling is used at the plant to improve the extraction efficiency of fermentable sugars from the filtration bed which results in reduced lautering time.

Wort boiling is used to sterilise the malt extract so that contamination is reduced. Hops are also added to balance the sweetness of the malt, contribute to aroma and taste, and help prevent spoilage. The hot wort from the kettle is then introduced into the whirl pool at 96ºC where it is then cooled by cold water from a water chiller. The cooled wort is then oxygenated when it passes through the aerator before yeast is pitched.

Fermentation vessels store the brewed wort during the fermentation process. The excess space in the tank is for accumulation of carbon dioxide, a by-product of the fermentation process. Yeast pitching, the addition of yeast for fermentation, is done soon after the brew is added into the fermentation vessel. The brew is then oxidised to activate the fermentation process. Throughout the fermentation process, gravity levels are monitored constantly so that the stage of fermentation activity can be determined.

The fermented beer is then transferred to the storage vessels by a screw pump which has a side glass that allows the viewing of the beer colour when it is being transferred. The screw pump also has a carbon dioxide injection terminal that carbonates and dusts the fermented beer. The fermented beer is then kept in the storage vessels where it is allowed to lager properly. The laagering process is the development of the flavour of the beer, its aroma and the initial clarification of the beer from its fermentation residues.

The beer maturation process is best done at low temperatures, which sees the beer pass through glycol chilling heat exchangers that maintain the beer below 20°C. Glycol circulatory jackets maintain the chilling effect in the storage vessels. The brewed beer has a high concentration compared to the brand requirements, hence it undergoes dilution from high gravity beer to normal gravity, and with the required volumetric percentage of alcohol. Mull water, which is carbonated and aerated water generated at the utilities water plant, is used to dilute the beer. The mull water is combined with the high gravity beer in proportions that allow alcohol volumetric to match with the final beer brand (normal gravity), and the amount depends on the brand under dilution.

Diluted beer is delivered to bright beer tanks (BBT) for buffer storage through another carbonation vessel. The beer is continuously carbonated in the BBT for at least six hours as it awaits packaging.

The organisation has systems in place to encourage employees to

make informed decisions and drive towards continuous improvement and success. Improvement targets include waste elimination and performance improvement, therefore accurate and timeous information should be readily available, and meetings are held to discuss performances on the scoreboards and proposed corrective actions. The case study will most likely help build a strong plan on how to implement the system and the key players in the management in terms of the processes and the employees.

Energy Audit Results and Analysis

Production

The fluctuations in the production output during the year were in response to demand. The cold winter period was marked by low production due to subdued uptake of the product. Similarly, at the beginning of the year, low production is due to low buying power soon after the festive season. The graph in Fig. 6 shows the monthly production figures in hectolitres (HL) for the period, May 2017 to April 2018, with two peak periods in November/ December and February/March.

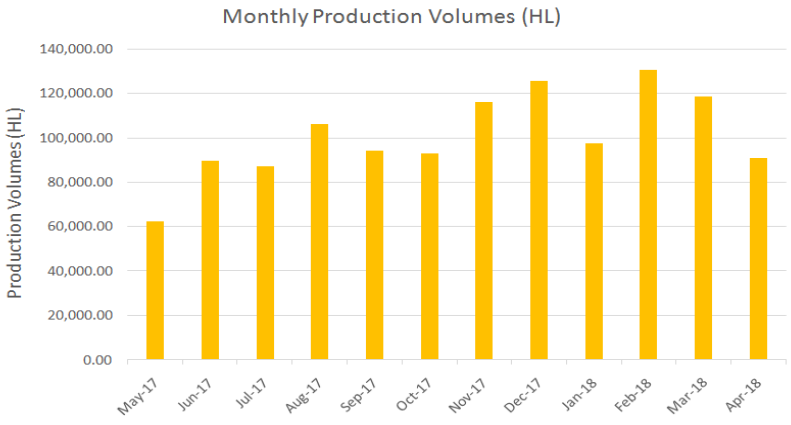


Figure 6: Monthly production for a full financial year

Capacity Utilisation

The maximum production month was considered to be February. Fig. 7 shows the actual daily production levels and the average production levels during this month. The optimum bottle filling capacity of the plant was summarised as:

a) 180HL/hr to pack 750ml bottles = ±5 400HL/day
b) 145HL/hr to pack 375ml bottles = ±4 350HL/day
c) Daily average production for February 2018 =± 4 206HL

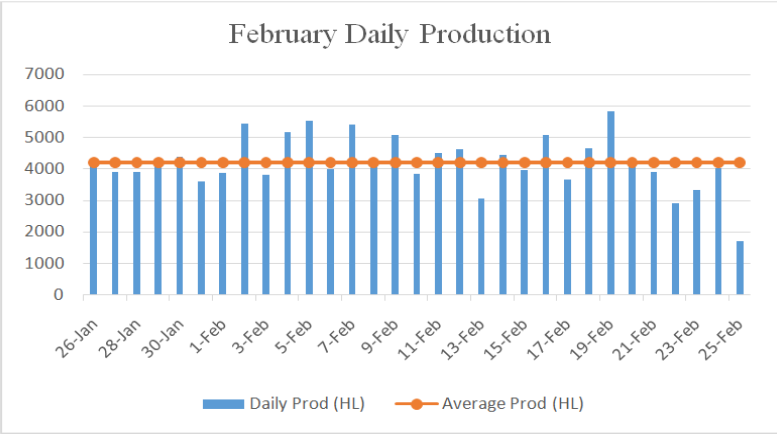


Figure 7: Daily production for February 2018

The plant capacity utilisation was found to be relatively high, ranging between 78% and 98%. This significantly dropped during the other months due to reduced demand for the products.

Energy Consumption by Source

The case study company runs for 24 hours a day throughout the year. The operating environment considered here was for the period May 2017 to April 2018. The energy information was taken from the utilities department's daily, weekly and monthly reports. The two primary energy sources in the plant are electricity and coal, and these are used to power electrical equipment and machines, and for steam generation, respectively (Fig. 8).

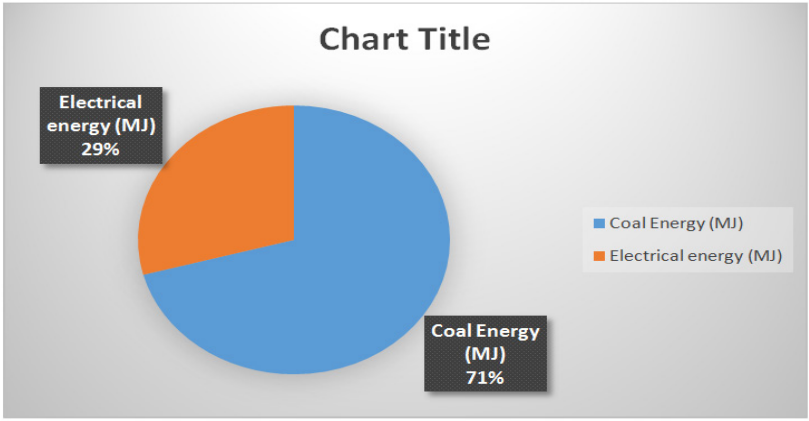


Figure 8: Energy source distribution

Electricity

The firm has a main meter which is used for billing. The other sections of the plant with sub-meters installed are packaging lines, brewing department, refrigeration plant and air plants. Individual pieces of equipment are also sub-metered. Table 1 shows how the various sections have been defined according to the company's records.

Table 1: Metered sections

Section	Comprise of
Refrigeration	It has four individually metered compressors • Howden 1 • Howden 2 • Howden 3 • Howden 4
Air plant	It has two individually metered air compressors • ZR400-1 • ZR400-2
Packaging	It has three individually metered lines • Line 1 • Line 3 • Line 6

Utilities Others	• CO_2 Plant • Engine room auxiliaries
Brewing	• Yeast room • brew house • mash filter
Plant others	• Administration • Canteen • Workhouse • Laundry
Boiler and effluent	• Boiler house auxiliaries • Effluent plant

Fig. 9 gives the average monthly consumptions over a full year. The refrigeration plant and the air plant are the major electricity consumption sections, sharing about 40% of the total energy used in the plant. The rest of the sections of the plant consist of activities that are not metered. An estimate14% was attributed to the boiler house and the effluent plant which do not have meters. The packaging lines are also high on the plant's electrical energy consumers.

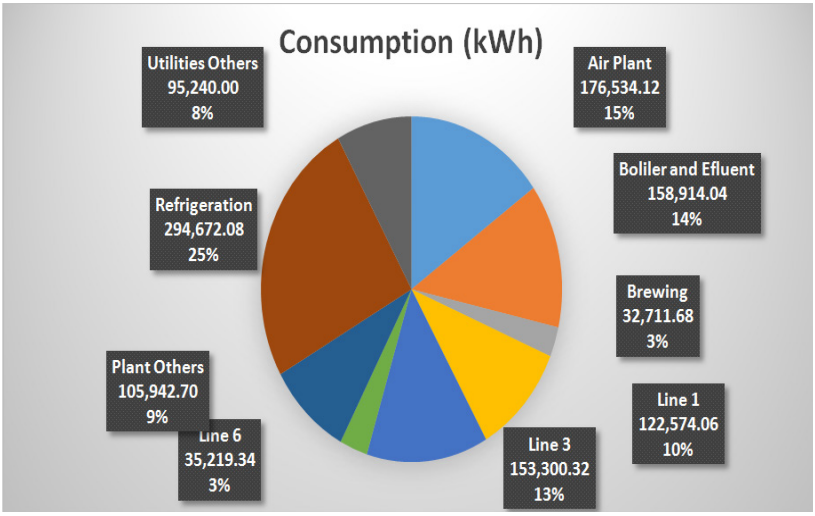


Figure 9: Electrical energy consumption values and distribution

Pareto data analysis was done to identify areas presenting the most opportunities for electrical energy savings. Fig. 10 shows that the refrigeration plant, air plant, boiler and effluent plant, line 3 and line 1 consume 80% of the electricity, and the other sections take up the remaining 20%.Significant energy savings can be achieved by focusing energy saving interventions on the equipment responsible for the most consumption.

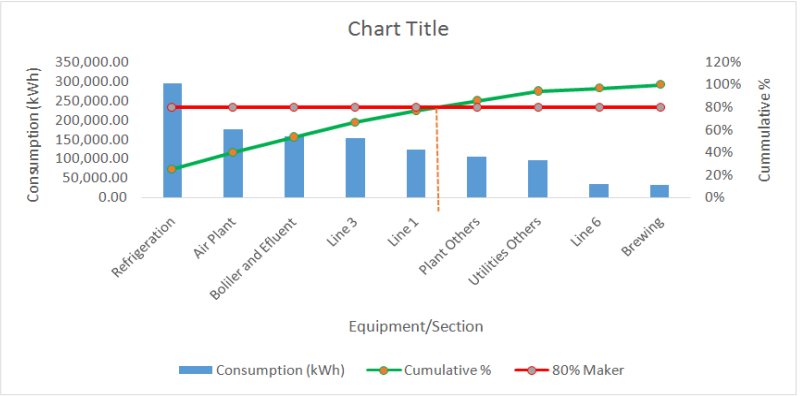


Figure 10: Equipment Pareto chart of electrical consumption per month

Higher yield savings could be achieved by targeting energy management programmes on the equipment on the left of the dotted line. Identification of such energy intensive equipment and sections is important for the programmes.

In Fig. 11, it is evident from the graph that electricity consumption increases with production. However, there are instances where this is not the case, like the energy consumption increase in September despite a decrease in production volume from the month of August. In this case, it would be imperative to do a 'Five Why' analysis to identify, measure, analyse, improve and control the root causes. In this regard, the firm will be in a better position to mitigate the recurrence of such undesirable trends.

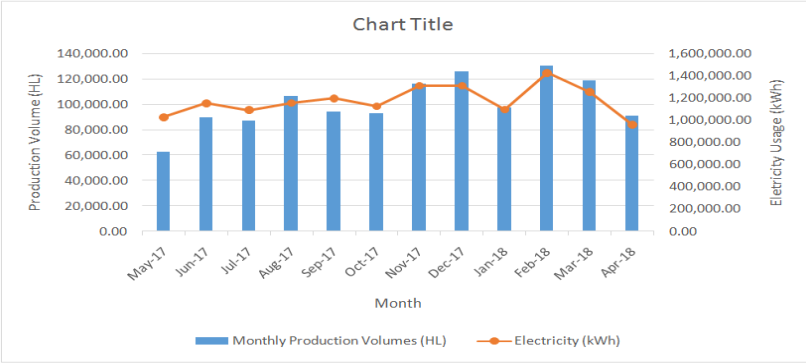


Figure 11: Variation of production and energy consumption

The identification of how the variation of production relates to the plant's energy consumption gives the indication of the specific energy consumption or energy intensity as a key performance indicator.

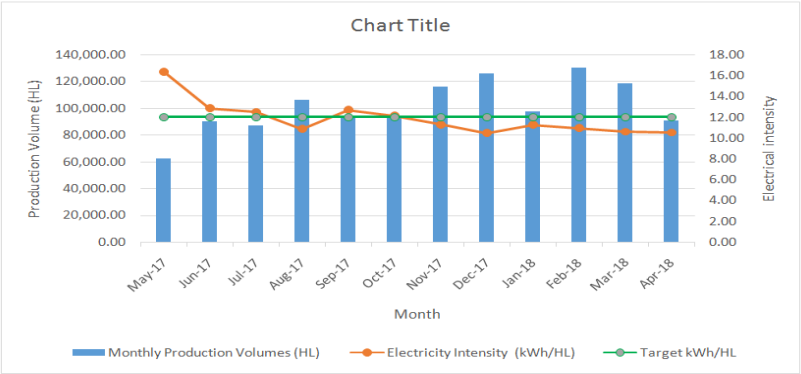


Figure 12: Monthly specific consumption and corresponding production volumes

Fig. 12 shows the production and calculated energy intensity (the ratio of the electrical consumption to the production volume) and the target intensity for the period under study. The plant had mostly been operating within the set limits especially in the later part of the study, with a monthly average of 11.87 kWh/HL. However, there were periods where the specific energy

usage was outside the set target, specifically in June, July, September, October and, notably, the maximum was recorded in May with a 37% deviation from the target. The failure to meet the target in the winter period is actually astounding as the energy usage of one of the major electrical energy consumer, refrigeration, is expected to be lower. It can be noted that the specific electricity consumption targets for 2015 was 11 kWh/HL, but was increased as the value at that time was very difficult to attain and seemed unrealistic. The improved energy usage over later months should encourage the setting of a lower target as there are many opportunities to improve specific electricity consumption in the plant.

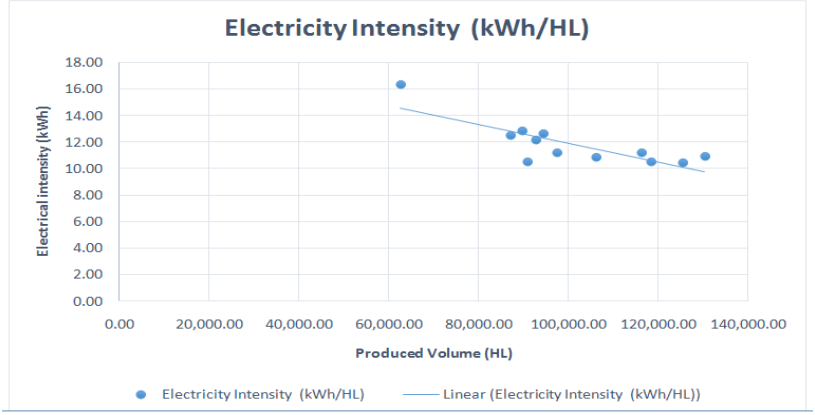


Figure 13: Specific energy requirements against monthly production volumes

Fig. 13 shows that the specific electrical energy requirements decreases with an increase in production. This explains the high specific electrical requirement for the month of May as it recorded the lowest production and highest specific electrical energy consumption. This is a winter seasonal trend. While it might seem logical to produce a lot of product within the same period and shut down the plant for some periods, it may not help energy usage as plant start-up draws a lot of energy until normal operation is attained.

The plant monthly electrical maximum demand profile for the study period is shown in Fig. 14.

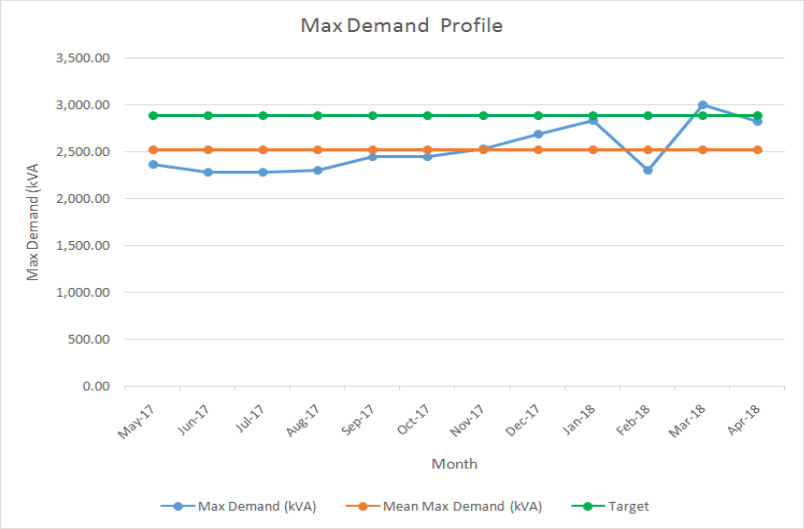


Figure 14: Monthly maximum demand profile

The profile is fluctuating constantly and the values are well below the target value except for March. Power correction, even distribution of load shedding and other maximum demand management programmes, can lower the maximum power usage, thereby lowering the electricity power bill as well.

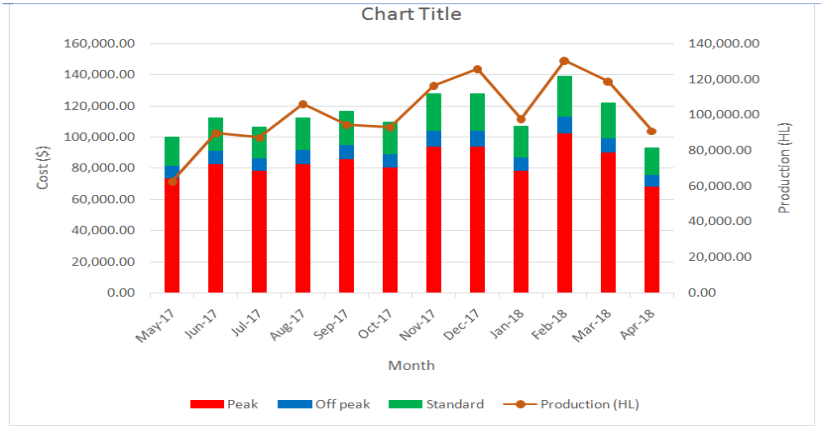


Figure 33: Monthly electrical energy cost

Figure 15: Monthly electrical energy cost

The energy usage of the plant during the study period assumed that the rate of energy use is constant throughout the month. Fig. 15 gives the costs for the different billing periods (indicating peak, standard and off-peak costs) and the total monthly energy cost without indicating maximum energy demand.

It was evident that the peak period contributed the highest costs although it had the least number of hours per week. In this regard, it was favourable to do most energy intensive activities during the off-peak period and standard period where charges are significantly lower than during the on-peak period. This can be achieved by shedding during the on-peak period or rescheduling some activities from the peak period to the less cost-intensive billing periods.

However, it is imperative to strategically schedule these activities such that the production process's ability to meet the demand is maintained. The constant energy consumption assumption used in the calculations may give results deviating in any direction from the estimated values.

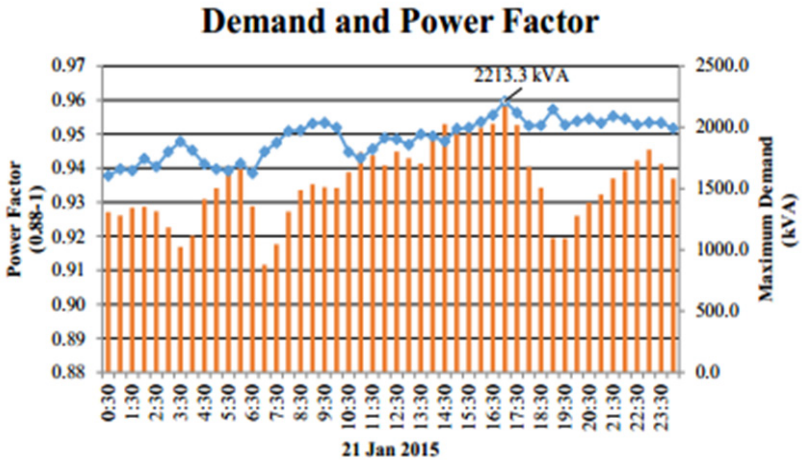


Figure 16*: *Day demand profile

A typical day demand profile of the plant is shown in Fig. 16, where the information recorded by a data logger on 21 January (a weekday) showing demand in 30-minute intervals is shown along with the power factor. The graph shows that on the day, the company did not utilise the off-peak

hours and also did little to minimise usage during the peak period, with the maximum demand of 2213.3kVA recorded in the on-peak period. Low demand was recorded during off-peak period. To avoid excessive electrical bills, a demand management programme must be implemented in order to improve these situations, and to also not shift the problem to other activities like production demands or labour costs.

The ratio of the electrical energy cost to the production volume yields the results of the cost per volume. This parameter shows the impact of electrical investment on production. Fig. 17 shows how the monthly electrical cost intensified over the period of study.

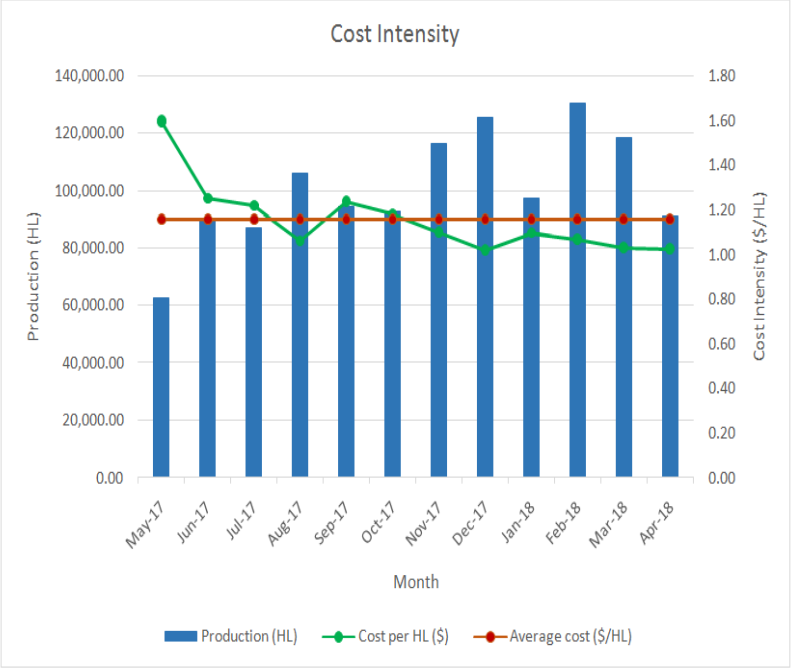


Figure 17: Monthly electrical energy cost intensity

The average cost for the study period was US$1.16 per hectolitre of the product produced. Because of the assumption made in the tariffs calculations, the graph is similar to that of the electrical energy intensity.

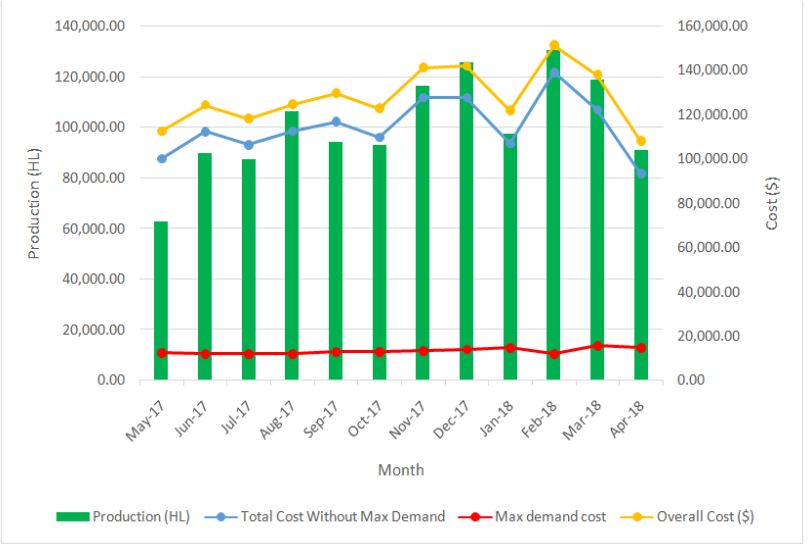


Figure 18: Overall monthly electricity costs

The values shown in Fig. 18 do not include VAT, which is charged at 15%, and the rural electrification charge.

Table 2 below shows the estimated electricity costs for the entire year. Pareto diagram, Fig. 19, shows electricity consumption periods and their contribution to the electricity costs. The peak period contributes to 66% of the bill, with the standard period contributing the other portion to reach the 80% mark.

Table 2: The year's electricity cost

	Peak	**Off Peak**	**Standard**	**Max demand**	**Total**
Usage (kWh)	7,807,583.56	2,680,289.33	3,613,427.10	30,240.40	
Cost per Unit	0.13	0.04	0.07	5.24	
Cost (US$)	1,014,985.86	107,211.57	252,939.90	158,459.70	1,533,597.03

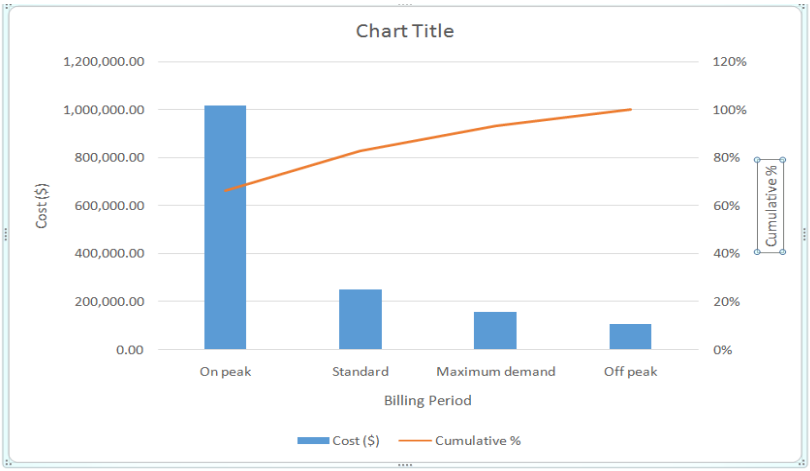


Figure 19: Billing period Pareto diagram

The organisation should, therefore, schedule its electricity management operations during these periods. The best course of action is to offset some electricity-requiring activities to the off-peak periods, reducing demand during these peak periods. The production processes should be scheduled in such a way that the peak plant demand coincides with the off-peak periods and the low demand activities coincide with the peak period.

Coal

Coal is used as the fuel in the boilers to heat water to produce steam which is used for heating processes within the plant. The brew house is the steam generation plant's major customer. The steam is generated by the four boilers, with one or two boilers operating depending on the plant's demand. A front-end loader shovels coal, which is then weighed to determine its weight. The coal is then placed in coal bunkers. The total coal added to the bunkers is then used to determine the coal consumption. The coal usage recorded on a day is not the actual used, but the coal added to the bunkers on the day. The company also only records the overall coal usage and does not determine the coal usage of individual boilers.

Fig. 20 shows a graph of the monthly coal usage and the corresponding production volumes.

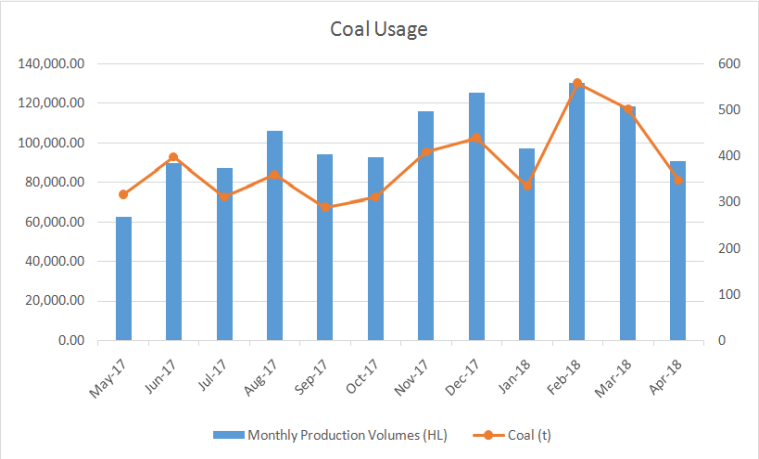


Figure 20: Coal usage over the production period

The average coal usage per month is 382 tonnes, with the maximum coal usage recorded as 558 tons and the minimum usage recorded as 288 tonnes. The usage is mostly dependent on the plant production volumes.

The graph of the relationship between the coal usage and the production volume is shown in the Fig. 21.

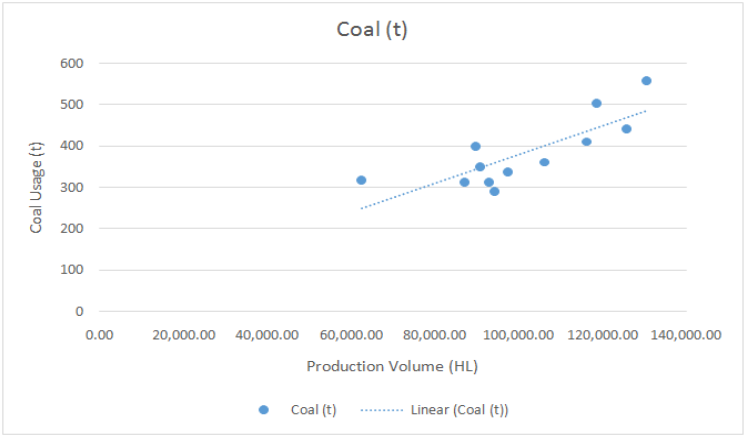


Figure 21: Coal usage relationship with production volume

It can be reasonably concluded that there is a linear relationship between production and the coal usage.

The monthly coal usage intensity profile is given in Fig. 22. The fluctuating profile indicates that there are factors that constantly change how coal is being utilised within the plant. The points above the targets indicate areas where the coal usage has been out of the tolerable usage rate. This indicates that a lot of wastage has occurred, especially in May. Production volumes and plant procedures and equipment should be assessed and optimised to improve the coal usage within the plant.

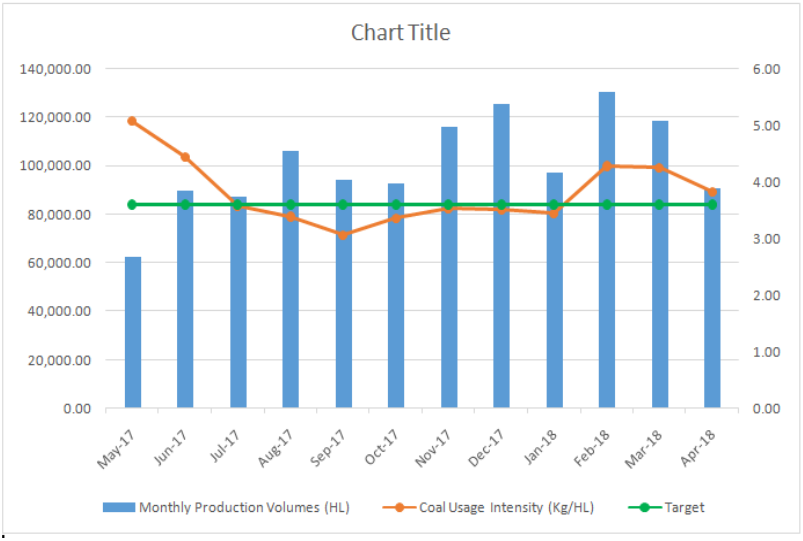


Figure 22: Monthly coal usage intensities

The constant failure to meet the target should prompt a 'Five Why' analysis in order to improve the coal usage efficiency within the plant. Inefficiencies in the steam generation plant and steam system can also result in pollution, with carbon footprint a main environmental concern. The inefficiencies, as a result, might not only cause increased investment in the purchase of the coal, but may also result in the accumulation of penalty fines from the Environmental Management Agency (EMA).

Coal in the country is a relatively cheap commodity, and there are vast coal deposits. The coal costs the company US$24 per tonne to purchase and deliver to the plant. Fig. 23 shows the monthly coal costs and the corresponding production volumes. The coal costs are significantly lower compared to the

electricity costs. This may prompt the organisation not to pay due attention to the efficiencies and issues related to coal usage from a financial view point. Considering the organisations environmental responsibility, it is important to improve efficiencies in the steam generation plant in order to reduce the plant's emissions that will affect local communities and cause climate change. It is also important that the plant uses coal to generate steam in order to reduce financial costs and achieve environmental sustainability during the production process. In that respect, the steam system should therefore be in proper conditions for use, and the steam usage should be managed properly in the respective departments.

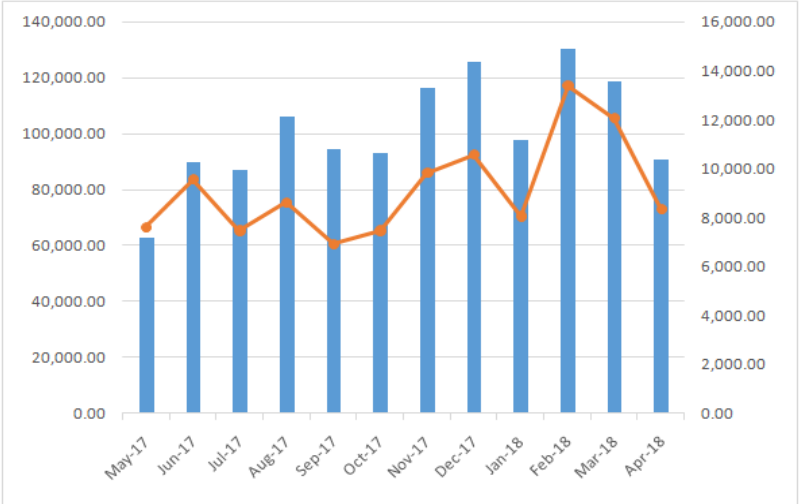


Figure 23: Coal monthly costs

a) Average coal cost = US$9,164/month
b) Lowest coal cost = US$6,927/month
c) Highest coal cost =US$13,394/month

For the study period, the monthly coal cost intensity ranged from US$0.07/ hectolitre to US$0.12/hectolitre, with an average of US$0.09/hectolitre. The steam generated is used in the heating and cleaning processes in the plant. Heating, which is done in the plant, accounts for over 70% of the energy through the use of steam. The brewery batch production process results in a fluctuating steam demand profile throughout the day. The steam-consuming

departments in the plant are divided into six sections. The steam usage data by various sections for the study period (May 2017 to April 2018) was collected from the monthly reports. Table 3 shows the usage for the sections, the intensity, target intensity, target consumption and the estimated steam losses. The steam losses were calculated assuming that the plant should operate on the target consumption values, therefore the loss was the deviation from the expected steam usage. The high losses emanate from leaks, poor insulation and inappropriate valves in the plant. Communication between the utilities and the brew house is poor, resulting in inefficient use of steam. The huge losses represent a huge thermal energy savings opportunity.

Table 3: Study period steam consumptions and losses

Section	Usage (tons)	Intensity (kg/HL)	Target (kg/HL)	Target consumption (kg)	Steam losses (kg)
Wort kettle	12,613.60	10.41	8.00	9,695,380.25	2,918,219.75
Water plant	512.79	0.42	0.40	484,769.01	28,020.99
Packaging	28,334.21	23.38	17.00	20,602,683.04	7,731,526.96
Hot water	4,301.84	3.55	2.00	2,423,845.06	1,877,994.94
D-Plant	189.63	0.16	0.10	121,192.25	68,437.75
Brewing	24,736.25	20.41	16.00	19,390,760.51	5,345,489.49
Total	70,688.32			52,718,630.12	7,969,689.88

The boiler efficiency calculations were done for data collected between 9 April and 12 April, as shown in Table 4. The assumption in calculations is that the boiler is running 24 hours a day and that the coal feed rate is constant, and the steam usage throughout the day is constant. The feed water temperature and the steam temperature are also assumed to be fixed.

Table 4: Boiler efficiency

Parameter	9 April	10 April	11 April	12 April	Average
Steam flowrate (kg/hr)	4,416.67	4,854.17	3,312.50	4,708.33	4,322.92
Coal flowrate (kg/hr)	490.83	700	714.17	706.67	652.92
Coal calorific value (kJ/kg)	26,890	26,890	26,890	26,890	26,890
Feed water temperature (°C)	80	80	80	80	80

Operating pressure (bars)	9	9	9	9	9
Steam enthalpy (kJ/kg)	2,778.10	2,778.10	2,778.10	2,778.10	2,778.10
Feed water Enthalpy (kJ/kg)	334.88	334.88	334.88	334.88	334.88
Heat output	10,790,888	11,859,797	8,093,166	11,503,494	10,561,836
Heat input	13,198,419	18,823,000	19,204,031	19,002,356	17,556,952
Efficiency	82%	63%	42%	61%	62%

Over the period of the study, the boiler recoded a lowest efficiency of 42% and highest efficiency of 82%. The average over the period was 62%. The average inlet temperature to the boiler was assumed to be 25°C and the flue gas temperature recorded in experiments was between 213°C and 259°C, so the average measurement of 236°C was used for calculations. The percentage of CO_2 which was measured from the plant averages between 4% and 12%. The dry flue gas heat losses were between 11.1% and 31.2%. There are significant heat losses due to carbon which is not burnt during the combustion of the coal. The average carbon content for analysis done on ash samples from the plant was 26% and the ash content was estimated to be about 15%. The calorific value of the coal used was 26.89MJ/kg. The heat loss due to unburnt carbon was 4.9%.

There was lack of other equipment and measurements to ascertain to what extent the other factors can affect the boiler efficiency. However, the other losses that can be affecting the efficiency of the boiler include:

a) Loss due to the hydrogen in coal
b) Loss due to coal moisture
c) Loss due to air moisture
d) Loss due to carbon monoxide (incomplete combustion)
e) Loss due to the boiler surface radiation, convection and other unaccounted

Assuming a contribution of 5% of other unaccounted losses, boiler efficiency was found to be 58.9%.

Energy Saving Opportunities

The study mostly focused on the highlights made by the Pareto analysis as these presented more saving opportunities than others. However, other sections like steam management were also considered due to their position in improving the company's environmental goals. Electricity has been identified as the main cost-intensive source of energy. The refrigeration plant, air plant, boiler and effluent plant, Plant 1 and Plant 2 were the main electrical energy consumers.

Recommendations

The energy savings opportunities were identified through optimisation of energy purchase and the reduction of energy consumption. More work would involve identifying areas to reduce consumption and how the energy should be used. The refrigeration plant accounts for the greatest portion of electricity at the plant, with the compressors consuming 25% of the total electricity. The primary refrigerant is ammonia, while glycol and water are the secondary refrigerant. This is because ammonia cannot be used in some operations due to fear of contamination, and also the high cost of pumping ammonia through the entire system is prohibitive. Findings and possible savings in the refrigeration plant are to be pursued.

The plant compressors and pumps operated at full loads despite the fluctuating demands on the refrigeration plant owing to fluctuating temperature requirement. The fermenting vessel is clearly the one with the largest cooling load, and since the load is not continuous and varies substantially during the 14 to16days fermentation period, there is need for a means to vary the loads on the compressors and the pumps in order to save energy during the low demand periods at the plant. This calls for the use of VSD to control the compressors and the pumps during these low demand periods. According to Nasir (2014) the savings per reduction in frequency can reach about 88% when the compressor runs at 25Hz. Assuming an average frequency of 43Hz to cater for the fluctuating demand on the compressors, possible savings of about 35% can be realised. This presents a possible potential energy saving of 1,237,622.75 kWh which translates to a possible saving of US$123,762.28 per annum.

The refrigeration process is heavily dependent on the condensing temperature. The optimum condensing temperature is a factor of ambient temperature, relative humidity, compressor performance curves and characteristic curves of the condenser system. The condenser temperature is not monitored and regulated to cater for these crucial factors. This results in energy losses and there arises the need to incorporate a control system to

regulate condenser temperature based on the mentioned contributing factors. de Villiers (1992) indicated that the system can coup savings between 5%-10%, with other literature claiming potential savings of up to 29% depending on the fluctuations in the mentioned factors. Assuming pessimistic potential savings of 6% as compared to the claimed potential savings, the company can coup energy savings of 212,163.90 kWh per year. The savings can translate to potential savings of US$21,216.39.

The CO_2 plant refrigeration temperature requirements are significantly lower than those of the other plant processes. CO_2 liquefies at very low temperatures. The low temperature demands of the CO_2 plant make it very necessary and economical that the requirements of the CO_2 plant are catered for by a separate refrigeration plant. This enables the rest of the refrigeration plant to operate at higher temperature and thus save energy.

The bulk of the refrigeration load was for the fermentation vessels where the beer is fermented over 14-16 days. The loads were fluctuating and discontinuous. The refrigeration plant therefore had the most electrical saving potential, as its rescheduling from on-peak periods to off-peak periods does not affect other company expenses like workers' overnight allowances. While it is impossible to completely avoid the on-peak periods, there is need to optimise the schedule to make coincidence of refrigeration activities, especially for the fermentation vessels with the on-peak period at the least possible periods.

The plant had two 400 kW rated ZR400 Atlas compressors with air delivery of 62.1m^3/min to cater for all the plant's compressed air needs. The compressors operated at 6.7 bars against the 6 bars required. The difference is to cater for the leakages that are in the system. Normally, one compressor would be online and the other would be a standby generator. The compressed air was then transmitted to the compressed air consumers throughout the plant for pneumatic systems in packaging, brewing and in the utilities department. An air leak audit was done and the points that leaked were identified. The points were numbered and the acoustics of the leaks and the compressed gas lost was measured in m^3/hr.

Eliminating the identified air leaks would reduce the air plant consumptions by 7%. The company can save an average of 148,288.66 kWh per year which can convert to savings of US$14,828.87.

The compressor is operating at 6.7 bars, 0.7 bars more than the required. This was mainly to compensate for the pressure drops due to the leaks. If the compressors are made to operate at their required pressure, that would present a very significant amount of savings. According to the Compressed Gas Air Institution (2012), for every 2 psig=0.138 bars of pressure reduction,

there is an opportunity to reduce electricity consumption by 1%. Eliminating the pressure drops will therefore introduce an energy saving of 5%. This is equivalent to reduction of consumption of 105,920.47 kWh per year and a saving of about US$10,592.05 Kwh.

The plant compressors run at a constant speed despite the load demands of the plant. The brew process as a batch process involves a great deal of fluctuation in demand of resources. The fluctuations in demand of air in the plant are not catered for and the compressors run at their full capacity regardless of low demand when other customers of air do not need it. The ZR400, 400 kW compressors used are also very large compared to the air demands of the plant. To cater for the overdesign of the compressors and the constantly changing demands for air in the plant at any instant, the use of variable speed drives is a very critical addition to the compressor system. According to Atlas Copco (2017), the use of VSD can make savings of up to 35% of the electricity consumption. The variable nature of the load, coupled with the compressors' over design, can actually present even higher saving potential with the use of the VSD. The stipulated potential savings by Atlas Copco (2017) of 35% present a potential decrease in energy consumption by 741,443.29 kWh, which translate to monetary savings of US$74,144.33.

At the moment, there are four packaging lines in use, namely, line 1, line 3, line 5 and line 6. The lines have different production capacities, electrical energy consumption capacities, and pack different types of products in the plant. Line 6 in particular is for packing canned products. Monthly production volumes of the three months were extracted from history and the total for each line determined, and so was the total consumption for the study period. The intensities were determined and are shown in Fig. 24.

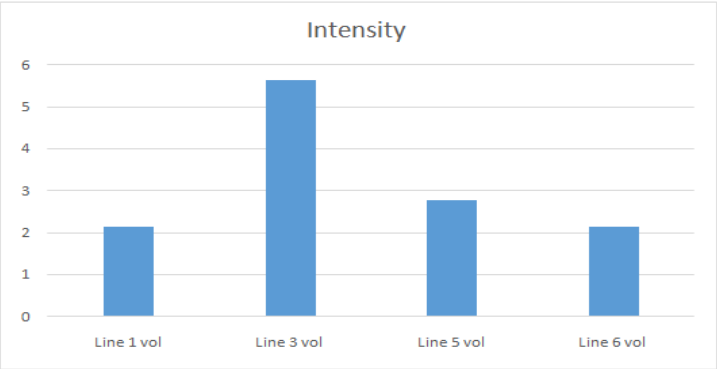


Figure 24: Line intensities

It can be seen that line 6 and line 1 are the less energy consuming lines per hectolitre, hence most production should be done on these lines to minimise the overall electrical energy usage per hectolitre. However, the other lines should be used only to cover for the demand, as the favourable lines cannot meet demands both in terms of volumes and the product mix. The potential savings from this initiative is difficult to quantify due to the ever-changing demands.

During the plant audit, it was observed that some packaging motors were running for about two hours without actual packaging of the product (idle). To identify the losses due to the idling of the motors, the motor currents, voltage and power factor were noted from the name plates of the motors and the power demand calculated. It is impossible to completely eliminate the idling losses, but if simple housekeeping commitment, communication and proper planning of the packaging operations is done, there is a significant amount of energy that can be saved by the switching off of the motors or proper timing of the start-up of the packaging lines. The lines have a total of at least 75 motors. If proper attention to limit the idling period is reduced by 60% and the plant operates 27 days a month factoring in plant potential shutdowns (the plant has been running continuously throughout the year), there are potential savings. These translate to energy savings of 3% on the packaging lines, and annual cost savings of US$11,430.72. These savings can only be achieved by educating the operators on the need to take the energy losses due to idling of the machine seriously. This is a particularly important saving opportunity as it does not require any capital, and its benefits are immediate.

Conclusion

The case study firm's production sales volume has been increasing while the bottom line has been declining since 2012. This study sought to investigate the potential energy savings that could be realised if strategic energy management was to be taken on board at the firm, with the mandate to reduce the energy cost of the organisation through strategic energy management. Effort was made to identify the potential energy management improvements at the case study company. Some design and decision support tools that could be used to improve the management of energy were suggested, as well as recommended energy-saving measures for the operation. Despite the fluctuating demand on the compressors, a possible savings of about 35%, could be achieved on the compressors plant section, while a potential savings of 6% was possible for refrigeration plant. Eliminating the identified air leaks would reduce the air plant energy consumptions by 7%, and elimination of the pressure drops would therefore introduce an energy saving of 5%.

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