Increased Energy Efficiency of a Steel Foundry Plant by Using a Cleaner Production Quick-E-Scan Methodology

Zelda Rasmeni[a], Dr Xiaowei Pan[b]

[a] Corresponding author: zeldarasmeni@gmail.com

Affiliation: Engineer, student

b) xpan@uj.ac.za

Affiliation: Senior lecture

Abstract. The Quick-E-Scan methodology is a simple and quick method that is used to achieve operational energy efficiency as opposed to detailed energy audits, which therefore offers a no cost or less cost solutions for energy management programs with a limited budget. The quick-E-scan methodology was used to assesses a steel foundry plant based in Benoni through dividing the foundry into production sections which entailed a review of the current processes and usage patterns of energy within the plant and a detailed analysis of options available for improvement and profitable areas in which energy saving measures may be implemented for an increase energy efficiency which can be presented to management of the company.

Key words: Energy efficiency, energy assessment, Quick-E-scan methodology

Introduction

The casting of metal in foundries has been undertaken for thousands of years and is known to be one of the oldest and largest recycling industries in the country and worldwide. All scrap metal collected for recycling is shipped to foundries to cast new products, especially scrap metal from the automobile and heavy industries. The intent of this chapter is to discuss the pre-assessment energy audit here by referred to as a “quick-E-scan” that was conducted in the steel foundry looking particularly on electrical energy. The cleaner Production quick-E-scan was conducted at a steel foundry in April 2014. The assessment entailed a review of the current processes and usage patterns of energy within the plant and a detailed analysis of options available for improvement which can be presented to management of the foundry.

The overall purpose of the assessment was to:

- ✓ Assist the foundry to quantify their energy usage and identify other major consumers within their production lines.
- ✓ Use the assessments as a tool to identify opportunities for the reduction and more efficient use of energy, within the foundry itself.
- ✓ Verify whether or not the energy is efficient and if there is an on-going programme to monitor and improve the use of energy.
- ✓ Assist in setting energy efficiency index and targets
- ✓ Assist in identifying opportunities to contribute to the overall national energy efficiency target.
- ✓ Assist in identifying opportunities for energy recovery and from processes wherever feasible.

Resource Efficiency Pre-Assessment overview (Energy Auditing)

The cleaner production Quick –E-scan assessment is a systematic and integrated approach to managing energy, water, environmental and financial resources, in order to eliminate or minimise waste and emissions to the environment, on a sustainable and cost-effective basis. It accelerates the application of preventative environmental strategies to processes, products and services, leading to increased efficiency and reduced risks to humans and the environment (Chewe, 2008). Energy efficiency is an area where most foundries recognise the existence of multiple opportunities for improvement even in the absence of commitment to effective change. The foundry uses an electric arc furnace which is a 30 years old system, in spite of its age, slowly, but surely shows a commitment to improve energy efficiency, environment performance and an increase in throughput. Efficient energy use, however, remains one of the most important challenges facing the industry in South Africa and around the world. Electrical energy is naturally the primary and a universal measure of development. It is proved to be the most ideal type of energy available. The increasing demand for power however has led to considerable fossil fuels burning, which has in turn had an adverse impact on climate change and on the environment (Chavan & Solapur,n.d). In South Africa, the steel foundry and particularly in the foundry used for this study, energy accounting is necessary to determine where and how energy is being consumed and how efficient the energy management system is and whether it is in place or not. There are many opportunities to improve energy efficiency in most foundries, some of which have been discussed by Davies (2012), Pandan (n.d.) and others. Previous research conducted by the Rescore Efficiency and Cleaner Production focusing on foundries indicated that energy efficiency is one of the most significant cleaner production (CP) options still to be addressed and implemented in the industries. The study revealed that the 50 percent of the energy consumed in a foundry is used for metal casting of which energy saving and efficiency can be achieved with more attention to this process (Nihar, 2013).

Methodology

Energy assessments, referred to as audits, quantify energy usage according to specific discrete functions and process areas. An industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programme (Prashanth, 2014). It addresses questions such as: how much energy is used? Where is the energy consumed? How is it used? and how can the foundry reduce energy cost/ consumption? Specific energy consumption is defined as the energy consumed per ton of liquid metal produced (Worrell, 200). The data collection was carried out using surveys and historical data for energy consumption in different sections/ equipment. This section describes the methodology flow used for the foundry assessment, which was adapted from the cleaner production. Fig 1 represents the typical methodology used for energy consumption studies in foundry, as adapted from Chavan and Solapur (n.d).

<u>Cleaner Production Assessment</u>

A thorough walkthrough and site inspection of the production areas of the company was conducted and the specific energy users (SEUs) were identified, before investigating areas of high resource (Electrical energy) consumption. This stage of the survey also known as the 'quick scan' examines the quality of the processes for their CP potential and defines the parameters by indicating focus areas to be investigated during the detailed audit stage.

The assessment follows the NCPC Resource Efficiency Workshop guidelines, i.e. the use of Pre – Assessment Questionnaire, Quick Scan and the In – Plant Assessment. The detailed RECP assessment requires accurate collation of data and monitoring by investigating the following:

⇒ What are the main environmental influences and production costs?

⇒ Are relatively large volumes of (problem) materials or energies utilised?

⇒ Is there any production of (problematic) wastes or emissions?

⇒ Is the production technology in use modern?

⇒ Is there any potential for cleaner production measures to optimise the processes, thereby increase eco-efficiency, and cost efficiency?

⇒ What would be the financial savings and environmental benefits of these CP improvement options?

⇒ Is there an energy management system in place?

The results of the assessment would indicate the *status quo* of the company in terms of electrical energy consumption.

<u>Identification of Saving Opportunities</u>

This stage of the project analyses the data and identifies specific improvement opportunities through various research methodologies. These methodologies include using exiting RECP manuals, guidebooks and checklists. The improvement options evaluate the financial, technical and environmental feasibility of the options, which constitute the foundation for the next chapter.

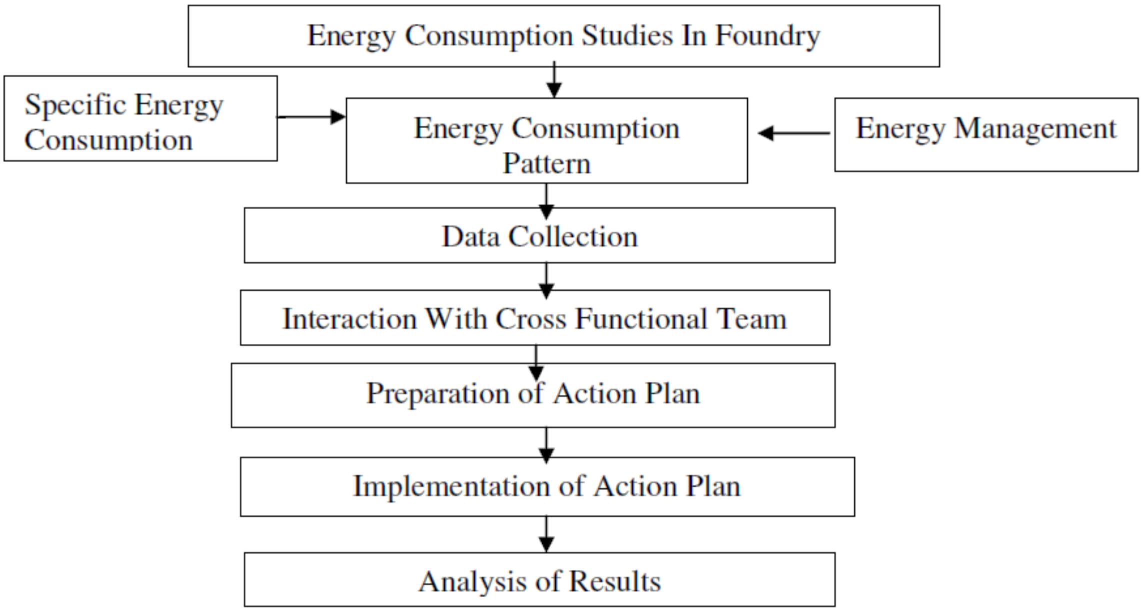

FIGURE 1: Methodology for energy consumption studies

Production Flow and Assessment Boundaries

The main steps in the production process at the studied foundry are shown in Fig 2 below with the assessment boundary sectioned in red. The supporting operations and utilities include the maintenance of foundry machinery. Quality control and assurance, sales, administration, finance and auxiliary systems such as cooling towers, compressed air, and dust extraction fan systems, are also described.

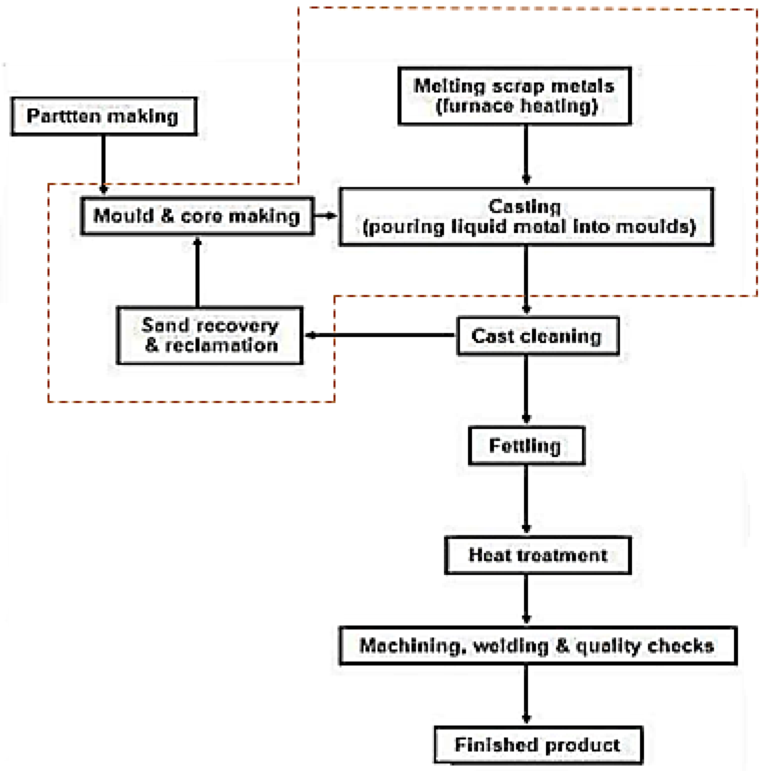

FIGURE 2: Production flow and boundaries

Audit outcomes and analysis

Initial environmental assessment

This section discusses the initial evaluation of the company's environmental performance. This first evaluation provides a first impression of how the consultant/ auditor sees the company before the detailed assessment. The strengths and weaknesses of areas with environmental impact are described in order to define the goals. A first assessment or "initial diagnosis" of the current situation is provided with the 3eco inspector.

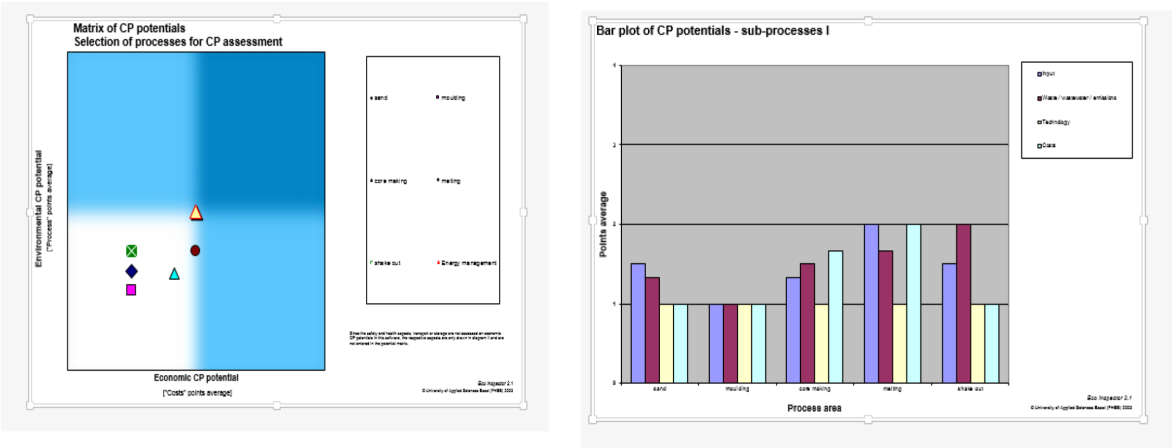

FIGURE 3: Environmental cleaner production potential

The foundry acknowledges that there is a potential for saving energy, water and material and has demonstrated commitment to maximising the saving of energy and resources. The main focus of this study was energy because unlike for the other resources, the responsibility for energy had not been assigned to a particular person. Therefore, linking these responsibilities to a person's Key Performance Indicator (KPI) would re address the situation. There was an understanding of Significant Energy Users (SEU's), but no data based existed on the historical consumption, of which measurements need to be done to clarify the complete the Electrical energy balance. There was no Baseline in place, other than the online electrical metering, which covers the whole foundry and historical usage. The evaluation of the current situation is further supported by the "initial diagnosis" with the "Radar chart" which is presented in Fig 4.

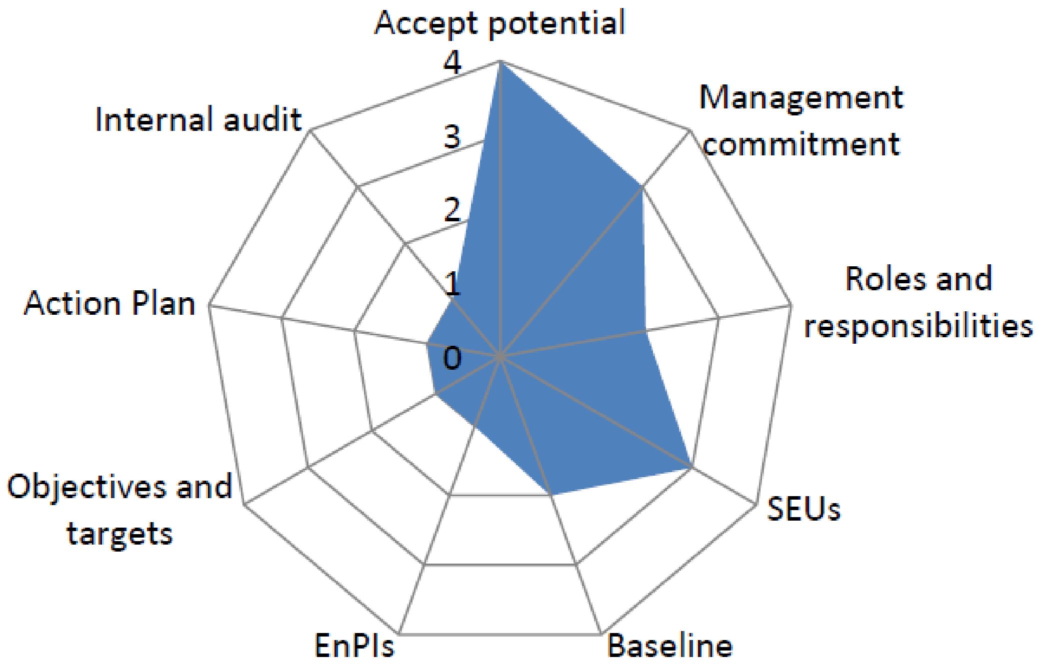

FIGURE 4: Radar chart for environmental assessment

Foundry Assessment

From the site walkthrough conducted in April 2014, the areas of potential energy savings were identified as:

- Melting department (furnaces)
- Moulding, shake out and core making departments

Electricity is the primary source of energy in the Foundry. This document therefore focuses on electrical driven systems in terms of energy assessment, covering the objectives as already highlighted above. Fig 5 is the typical power distribution tree adapted from Jens Decker (2009), which reflects the condition of the studied foundry.

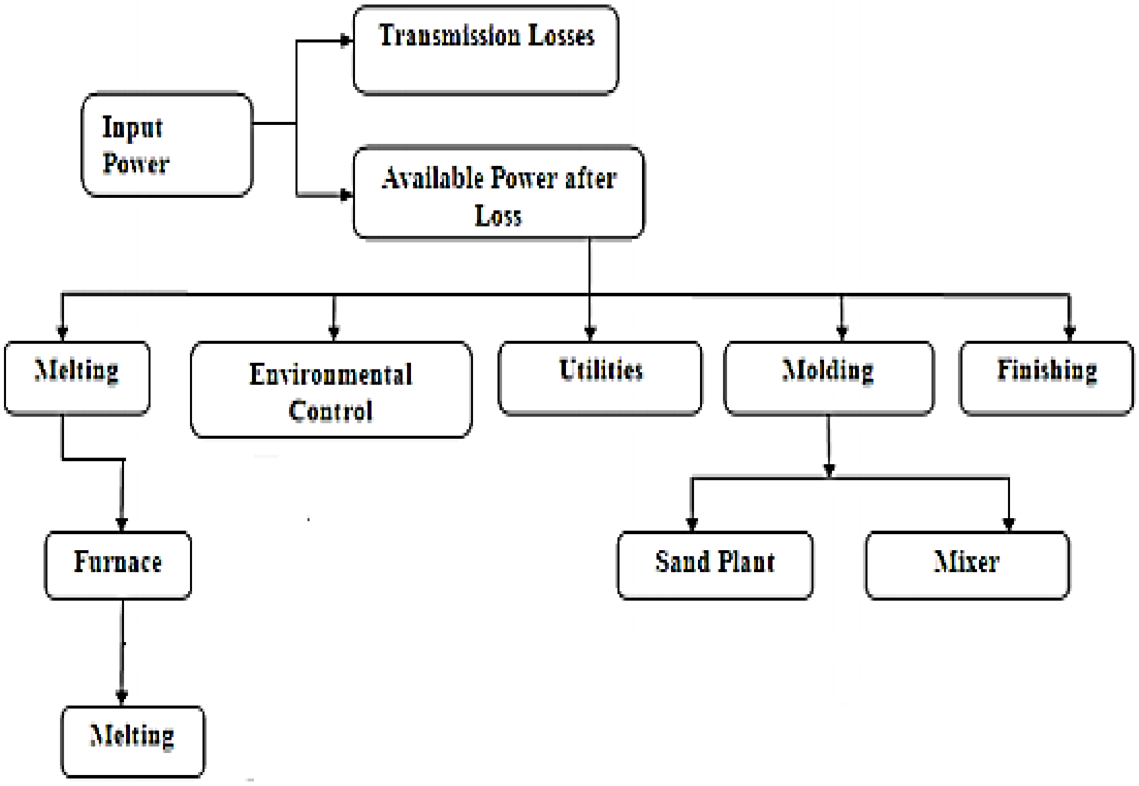

FIGURE 5: Typical power distribution tree (Jens Decker 2009)

Significant Energy Users

The significant energy users in the studied plant are the following

- Furnaces(3 phase Electric Arc furnace)
- High pressure moulding machine
- Core making machine
- Sand mixer
- Shake out machine

Operation times and electricity rates

The Foundry operates 9 hours per day from Monday to Thursday, and 6 hours on Friday. The melting department operates during off peak hours from 9 pm to 6 am periodically, Monday to Friday. This scheduling is one of the energy efficiency initiatives practised by the foundry, which motivated the scoring of commitment from management in the radar chat. The only exception is an annual shutdown of approximately 3 weeks between December and January. TABLE 1 illustrates the foundry's operation hours. The hours in the TABLEs are approximates, which can be influenced by a shutdown due to cleaning or production breakdown.

TABLE 1: Foundry operating hours per month

Foundry SEUs	Operating hours Monthly
Melting furnaces	180
High-pressure moulding machine	168

Core machine	168
Sand mixer	168
Shake out	168

Features of the Ekurhuleni municipality, Benoni (municipality where the studied Foundry is located) with energy charges varying according to the month of the year ((R/kWh) are:

- September to May (Low Season) - 1.06 R/kWh (peak)-0.69(standard)-0.55(off-peak)
- June, July and August (High Season) – 2.81 R/ kWh (peak)-0.98(standard)-0.59(off-peak)
- Maximum demand charge- 46.12 R/kVA

The electricity and power subscription

The foundry is using tariff D from the Ekurhuleni municipality, which is available for bulk supplies at any voltage and with a capacity of at least 1 MVA and a network access charge of at least 1 MVA over the previous 12 months. The foundry's subscription of electricity consists of four parts. First part being the fixed charge, which is a monthly charge to recover the costs of the administration such as meter reading, billing and meter capital which is applicable whether or not electricity is consumed. Second part being the Network Access Charge, a tariff component per kVA registered which is based on the highest demand registered over a rolling 12 month period, during different peak of the day. The third part is the demand charge, which is seasonally defined charge based on the highest demand registered during a billing month for all time periods or only those specified measured in kVA and last, the actual consumption cost of which is an energy charge per kWh consumed. Solding & Thollander (2006) indicated that it of significance to keep the electricity consumption low due to the variable price and the variable part of the cost addressed but also to keep the peak loads to a minimum during the current year to decrease this cost for the following years. The benefit of keeping the load low is that a usage of more power than the prescription amount is subjected to a fine.

Energy consumption data

TABLE 2: Electrical cost breakdown

			Demand cost			
Month	Total kWh	kWh cost	Max demand KVA	Demand cost	kWh and Demand cost	Cost per kWh Avarage
Jan-14	405480	265645.9	3917.911	180694.1	446339.9	0.76
Feb-14	616777	409428.1	3724.916	171793.1	581221.3	0.76
Mar-14	641360	414340.7	4033.03	186003.3	600344.1	0.76
Apr-14	661225	432134.5	4308266	198697.2	630831.8	0.76
Total	2324842	1521549		737187.8	2258737	
Average	581210.5	380387.3	1079985	184296.9	564684.3	0.76

TABLE 2 is the electrical breakdown for a four-month period as described on the online electrical bills. Since the foundry pays through the Peak Demand option, there is a benefit in understanding which equipment and production area functions during each time period. This information may enable the foundry to identify specific production lines, which are essential and non-essential production lines for specific time slots and be able switch off the non-essential lines during certain time slots to avoid co-incidence of demand. This is known as Demand Management and can be combined with a control of the peak Maximum Demand in order to further reduce the charges being levied.

Energy Usage Profiles

The foundry used in this study has no energy management systems in place and no data was received from the Foundry to assess and profile their energy consumption against production. This makes the assessment of the consumption per process and production area. Based on average electricity as described in TABLE 3, which covers the whole facility, i.e the studied plant, a second plant of the same size as the one on investigation and office space. The consumption is estimated at 581210.5 kWh ~ R 380387.3 on average. The approximate amount excludes the fixed charge, demand and network access. The next chapter discusses the measuring and baseline formation as preconditions of any possible improvement to be made. Such information is of great importance particularly if energy efficiency should be linked to a person's KPI.

3.3 Identification of Optimisation Options and Improvement Opportunities

There are various areas where modifications could result in a reduction in resource consumption. These are subdivided into recommendations which are specific to the process and only focusing on electrical energy as input energy.

Option 1: Energy Management System

To achieve lasting results and sustainably increasing savings requires an on-going focus on resource usage, particularly energy. Introduction of an energy management system is good way of doing so because it results in a structured system. Once policies are in place, typically an energy management system would include: Allocation of responsibility to specific people, monitoring of energy usage, awareness raising training and allocation of responsibly

Linking energy to a person's key performance area will trigger interest in energy improvement and sustainability, energy management and efficiency is a collective effort thus every one need to play a role so as to reap maximum benefit.

Awareness Raising

Alerting all employees to the evident cost of energy, how it affects the business and their future employment is an excellent, low cost, way of reducing energy consumption. However, the awareness raising training to be delivered is just a start. It needs to continue and involve all employees. Specific recommendations regarding on-going energy awareness training are: Graphic posters should be used to keep the message visible this also accommodates semi and unskilled employees, management must be seen to be taking the lead as to demonstrate that it is possible and doable and energy savings competitions, with incentives, can be used as a great motivator.

Monitoring

Savings are dependent on quantifying resource use of the foundry. Therefore, introduction of an energy management system should go together with additional metering, recording and analysis of consumption, to provide the required data to manage energy use downwards and feedback to everybody on progress.

Option 2: Energy-Efficient Improvement in Electric Motors

Energy-efficient motors is said to reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques and with proper installation. They are known to stay cooler which may assist in reducing facility heating loads and have higher service factors which includes longer bearing life, longer insulation life, and less vibration (Galitsky, 2006). The decision of installing an energy efficiency motor strongly depends on the motor operating conditions and the life cycle costs associated with the investment. The rewinding of existing motors in general cases may be cost-effective to rewind an existing energy-efficient motor instead of purchasing a new motor. When rewinding costs exceed 60% of the costs of a new motor, purchasing the new motor may be a better choice. Ensuring that motors are properly sized and that oversized motors are replaced can save a significant amount of total motor system electricity consumption. Several valuable information is required to complete an accurate assessment of energy savings which are: the load on the motor, the operating efficiency at that load point, the full-load and the full-load speed of the downsized replacement motor.

Option 3: Switching off equipment if not used

The sand mixing and the moulding line are usually left in the idling mode when not used especially during lunch time, tea times and cleaning times. If these machinery are routinely left running when not in use, this could in a long run, be adding up to a significant period of non-productive running time. A better option to tackle this would be to raise an awareness or a ‘switch-off ‘campaign to raise awareness among staff of all levels meaning semi – skilled to skilled man about the need to turn off unused equipment. It may also be possible to automate the switch-off process. Interlocking control circuits may be able to be installed to automatically switch off ancillary equipment such as fans, pumps and conveyors when the equipment they serve is not in use (FTJ, 1998b). It may also be possible to reprogram major equipment to power-down or switch off during known breaks or after a time delay.

Option 4: Sub-metering and Reduce Maximum Demand

There have not been any sub-meters installed at the studied foundry, with online metering only installed on the main incoming meter. The information from a sub metering system is important as it can be used to determine the electricity cost and demand of each department within the plant particularly of the furnaces. The moving of Demand to different times is known as ‘shifting’ and the benefits can be substantial of which the foundry is practising most of the time. The Maximum Demand should be monitored and possibly reduced. In the month of April the billing showed that up to 26% of the total electricity charges are due to the Maximum Demand section of the bill. It would be advantageous to install live on-line metering which could be monitored so as to identify in an event were the demand is high than what the foundry subscribed to and allow interventions such as changing production schedules or switching off non-essential items until the high demand has reduced in that way avoiding penalties. Monitoring and managing the running times of the big electrical users will reduce the peaks and therefore save money.

Recommendation

Though this study only focused on electrical energy, there is an immense potential for savings if one covers the whole scope of resource efficiency i.e other alternative of energy used at the foundry. A further study should be conducted covering the whole energy resource spectrum.

Conclusion

The pre-assessment was conducted at the studied foundry with specific emphasis on electrical energy utilisation. This assessment entailed a review of the current processes and usage patterns of energy and possible options for improvement were discussed. The historical consumption data by area and process was not available because the foundry had no energy management policy or systems in place. This therefore made it difficult to draw the energy balance and to study the consumption profile. There have not been any sub-meters installed and no tangible data on energy use and consumption. The recommendations made in this chapter are not in any order of priority, but are regarded as financially and technically sound, i.e low cost or no cost. The next chapter focuses on the foundry measurement and baseline formation. Measurements are done to evaluate and analyse the baseline demand in the foundry, which consist mainly of the furnaces and several machinery associated with the melting processes.

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