Energy efficiency study of industrial factories using time-series data analysis and thermal imaging

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Keywords

data monitoring, electricity savings, half-hourly analysis

Abstract

With climate change issues gaining interest and awareness in recent years, many initiatives and programmes have been set up as to mitigate against climate change, many of which are bound by law. In the UK there are a few options for different sectors to reduce their emissions through programmes.

Half-hourly energy analysis is a good way to ascertain a picture of energy use in industrial and commercial applications, and the technique is used in this paper to highlight key energy saving opportunities in two case studies. Both case studies showed that one of the greatest potentials for quantitative and quick savings was to address the air compressor systems. Based upon key assumptions case A could save over €74,000 per year through compressor energy saving measures. Case B could save in excess of €55,000 per year through energy saving measures based upon key assumptions described in the body of this paper.

It was found that many energy saving opportunities were missed by energy managers due to inadequate training and knowledge in the energy field. An example is that a fully automated timer system was installed in one case study to turn off air compressors when not in use. This system cost nearly €10,000 but was not used since installation due to lack of knowledge of its purpose and/or not knowing it was there.

This paper shows that energy analysis knowledge needs to move from academia to the energy managers in companies. Based upon the two case studies, it was found that energy managers were under qualified to undertake reasonable energy analysis with the view to mitigate against energy wastage on site. A better training and awareness programme could yield substantial financial and energy savings in cases such as described in this paper.

Introduction

Climate change issues and sustainability concerns have increased in interest and awareness in recent years, since anthropogenic activities have been found to impact considerably upon the environment[1]. The way in which manmade activities contribute to climate change is mainly due to greenhouse gas (GHG) emissions. These include, among others, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that contribute to the greenhouse effect. Additionally, energy prices are set to continue to rise by alarming rates[2], thus providing an incentive for companies to reduce their consumption figures. Doing so will also better an organizations' corporate image with the general public.

As important as environmental costs are, perhaps the most convincing argument for many organisations to embark on a programme of energy savings is that of reductions to the financial bottom line. Whatever the overriding pressures it is eminently sensible to prioritise investment on the basis of financial payback, possibly coupled with a carbon price. Such a strategy ensures the investment is returned as quickly as possible to be reinvested in further measures.

It is often difficult to appreciate the opportunities through a simple walk round energy survey. To gain a detailed insight into the energy consumption of a process it is necessary to monitor enegy consumption and analyse energy consumption data. Such analysis can generate quantitative measures of energy wastage and when coupled with an estimate of the cost of intervention can be used to generate an accurate assessment of potential financial payback.

This paper is aimed at energy efficiency researchers, energy consultants and industrial energy managers. Two case studies are presented, one from an iron foundry and one from a biscuit factory. Both organisations are local to the author's institution and were chosen based on convenience and willingness to be involved in such a project. The aim of the work is to look at current practices in industrial energy monitoring and demonstrate how simple monitoring data can be used to determine wasted energy and saving opportunities.

Policy context

The UK government set out targets to reduce GHG emissions in the 'Climate Change Act' of 2008. The act presents the targets of an 80 % reduction of greenhouse gas levels by 2050, with a closer target of a 34% reduction by 2020. These two targets are based upon the level of GHG emissions in 1990[3]. The targets are legally bound and therefore need to be met, thus many initiatives and research have emerged to aid in the UK reaching these targets. There are four main initiatives relating to reducing emissions in the UK, these are;

The Carbon Reduction Commitment (CRC) Energy Efficiency Scheme, which produces league tables that shows how well, or not so well, a large emitting company compares to others. This scheme is mandatory for large emitters (over 6,000 MWhr/year) and is a great incentive for said companies to reduce their emissions year on year. It creates a mandate for the subject company to install half-hourly metering equipment, and monitor their energy use with the view to an overall reduction. However, large consumers who take part in other policies such as; Climate Change Agreements (CCA) or the EU Emissions Trading Scheme (EU ETS) are exempt[4].

The Climate Change Levy (CCL) is a tax on energy use in industry, the public sector and commerce which came into force in April 2001. It is not applicable to any domestic sector. CCAs are challenging targets that companies agree to meet in exchange for a reduction of up to 65 % off their CCL tax.

The above commitments which are mandatory for large consumers of energy, offer great opportunities for energy managers and environmental consultants to analyse half-hourly data with the view to discover energy wastages and mitigate against them. This will hopefully drive down UK emissions to aid in the accomplishment of the Climate Change Act's targets. With the aforementioned issues with the climate becoming more prevalent, this paper aims to look into the current state of the energy analysis field in an industrial context. It will look at two case studies in different industrial sub-sectors to see how they are managing their obligation under the CRC.

INDUSTRIAL EMISSIONS

The total UK CO_2e emissions in 2010 was 218.5 $MtCO_2e$ of which 26 % is attributable to the industrial sector. This initially sounds relatively small, however in 1990 the sector was responsible for nearly half of the UK's energy use[5].

Although there have been efficiency improvements in the metal industries, the reduction from 1990 is not entirely due to increased energy efficiency, rather that the UK's industrial sector has reduced in size in recent years.[6] . Therefore it is as poignant as ever to reduce the industries emissions, not only to benefit the environment, but to reduce costs in an industry that is on its knees due to high costs.

The national Non-Domestic Building Stock database contains GHG and energy data for roughly 2 million non-domestic premises throughout the UK. The purpose of the database is to provide a better understanding of the uses and energy consumption of non-domestic buildings, and to inform government policy on the mitigation of GHG emissions in adherence with international commitments[7].

Muller and Loffler[8] present the most up to date research that looked into manufacturing plant energy savings, and they discovered that factories suffered from standby losses varying between 6 and 50 % of energy consumed depending on machine class. Also peripheral machines such as fume extraction may consume around 16 % of total energy.

Food industry

The UK food industry is the largest manufacturing sector in the UK, with a turnover of £76.2 bn, and has been seen as to be the most stable industry in the UK recession.[9] The food and drink

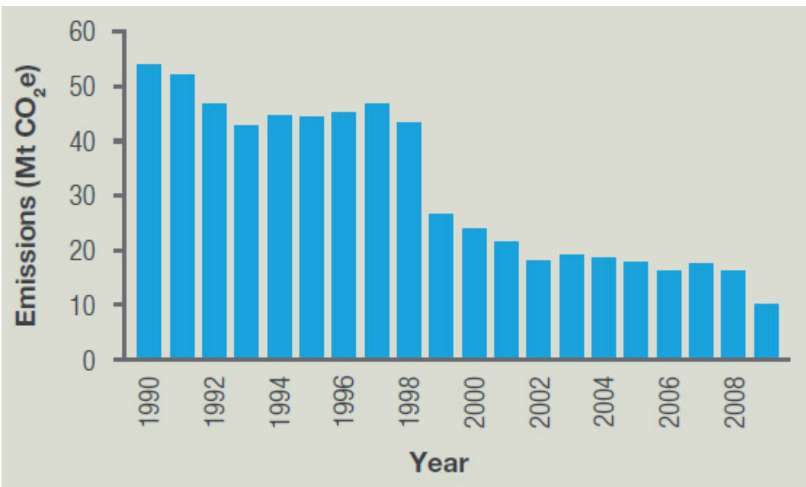

Figure 1: Industrial emissions from 1990–2008.[21]

industry has direct emissions of 152 Mt CO_2, and a further 101 Mt CO_2 that is attributable to land use change.[10]

The food industry is expanding in size and is considered to be an energy intensive industry. Many food production and storage processes include ovens that work at high temperatures and refrigeration plant to keep product fresh. Little research has been compiled regarding energy efficiency in food production factories; most information is available from websites that offer generic energy efficiency advice that is seldom production specific[11]. Institutions such as the Carbon Trust[12] rarely have significant information that can help in identifying potential energy saving measures in food production factories.

Research by Bruhns[13], shows that the aforementioned Non-Domestice Building Stock data used by policymakers on all UK factories is based upon less than a dozen case studies carried out by Sheffield Hallam University. These case studies are mostly metal manufacturing plants and none correlate with a food production factory. Therefore government policy is fundamentally biased due to the fact that it is relying upon low amounts of key data. However this research is again not biscuit bakery, or even food production in general, specific.

Therefore there is a need for conducting research on the energy consumption of the food industry. There also seems to be a gap in the knowledge where specificity in the food production processes is needed to aid companies and government institutions with the end goal of reducing their GHG emissions.

Foundry Industry

The foundry industry is a highly energy intensive sector due to the high temperatures required to melt metals, although the volume of material processed in this way is relatively small compared to continuous casting[14]. In the foundry process, a furnace is charged with cold metal which is then melted and mixed with a number of other materials according to the desired properties of the final casting before being transferred to a ladle for pouring into moulds. Most of today's cast iron foundries use electric induction furnaces which are more energy efficient than the alternatives since all the electrical energy is converted to heat in the charge, although some is then wasted through the walls and lid of the furnace and through the copper induction coils, which are water cooled.

Most of the energy used by a foundry is for melting the charge (typically 55 %) with other operations such as heat treatment, core making and mould making responsible for much smaller proportions[15]. The charge itself is usually scrap metal from other industries such as the automotive industry, which means that the foundry sector has a much smaller environmental impact than the primary metal industries that produce new metal from ore. In addition, the design of induction furnaces has been optimised for energy efficiency to the extent that most opportunities for further savings at the furnace arise from improvements in operations such as improved scheduling to minimise holding times and improved material handling to minimise the time when the lid is open. However, there are many other areas of a typical foundry where energy savings can be made, such as heat treatment, the compressed air system and in motor driven devices such as extraction fans[16].

Case 1 – Company A

Company A is a large biscuit manufacturer who run all year round and occasionally throughout the night. They operate five ovens and produce a wide variety of biscuits for themselves and for large supermarket brands. The relationship with company A was due to a project that was set up as part of the masters course offered at the Institute of Energy and Sustainable Development at De Montfort University. A student on the course was placed on site to undertake an energy analysis study as part of the final dissertation requirements.

ENERGY ANALYSIS

During the year 2010, company A consumed a total of 6,198,478 kWh of electricity and a total of 12,173,059 kWh of gas. This data was available from the electricity and gas providers for the factory during 2010 in a half-hourly format. They spent €545,250.04 on electricity and a total annual cost of €233,851.18 for gas during the 2010 year.

The following sections highlight the area where the most potential savings were found, and another area of interest is briefly explained.

Compressed Air

The Food and Drink Federation (FDF) suggest that compressed air represents 2 % of the food and drink industry's overall emissions. This may seem like a small amount, however one should consider that many sources indicate that compressed air is the most expensive utility cost in a factory environment[17,18]. This is due to the fact that the start to end use efficiency (overall compressor efficiency) of an air compressor system is estimated to be around 10 %.[17]

Saidur and colleagues[14] state that when looking at whole life costs of compressed air, the running costs associated with energy far outweigh the maintenance costs and initial investment. This is concurred by the Carbon Trust[19] with their similar results. Ergo the energy usage in compressed air systems should be evaluated in depth to identify if savings can be made, as a matter of priority.

Compressed air systems are notoriously poor on the efficiency front, mainly due to large amounts of leakage, with credible sources suggesting that;

> Even when idling, compressors can consume between 20–70 % of their full load power.[16]

> Leakage from compressed air systems is notoriously high. It is not uncommon for leaks to represent 50 % of the load![6]

The above figure of 20–70 % would suggest that a 20 % power wastage due to leaks and standby ancillaries is the smaller variable, and should be aimed towards. The latter variable one would assume is a large rate of loss and should be avoided. The Carbon Trust also state that an unmanaged air compressor system can have leaks as high as 40–50 % of generated output. The FDF[6] state that 50 % power wastage due to leaks in the system is a very high figure which correlates with the Carbon Trust's figure.

A paper by Saidur and colleagues[14] suggests that the largest opportunity to reduce energy costs in a compressed air system is to address leaks, with almost half of the total savings opportunities at a 42 % share of the overall energy saving opportunities.

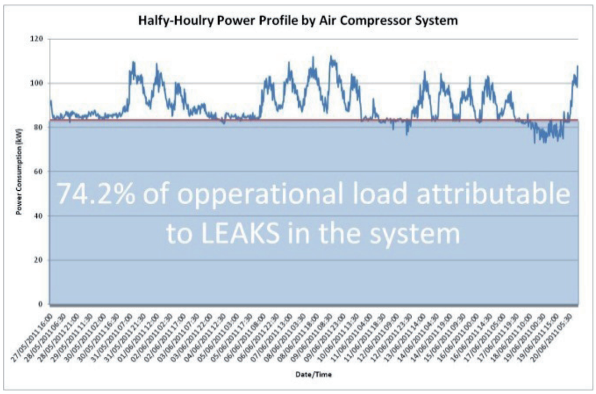

Figure 2: Half-hourly profile of air compressor.

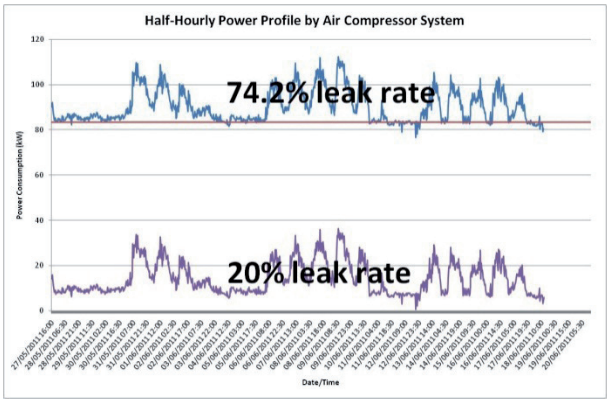

Figure 3: Half-hourly profile of air comp reduced to 20 % leaks.

Compressed Air Analysis

The compressed air system was logged for a short period with half hourly equipment. Figure 2 shows the half-hourly profiles for the air compressor system. The first noticeable energy saving opportunity is switching off the air compressors when not in use. The weekend periods shown to the left have no production attributed to them, and thus should warrant the air compressor system to be turned off during this time. If the compressors were to be turned off during weekends, power consumption would be expected to be zero, and such no energy to be consumed. For the period opposite, based upon the average base load for the period, 18,020.20 kWh could be saved. This amounts to €1,645.92 for the period denoted.

According to managers at the factory, there are a total of 74 days per year where there is no occupancy and thus no production related to that day. Therefore a prediction can be made of total energy that can be saved, just by turning the compressors off, per year. Assuming that the above profile is common throughout the year, one can multiply the average base load by the hours when not in use to determine the potential savings. This amounts to; 147,976.32 kWh per year, costing €13,515.70. This cost figure is considered to be a conservative estimate, as it only takes into consideration full non-production days. For example; 00:00 to 23:59 hours Saturday, it does not take into consideration the end of production Friday night at 18:00 until 00:00 hours, nor the period from 00:00 until start of production the next day at 06:00 hours.

Surprisingly, anecdotal evidence presented by operators showed that the factory had installed timers for the air compressor system in previous years at a cost of €9,776.49. However they were not used at all by the management team.

Assuming that the three weeks' worth of data logged is typical, and can be extrapolated over the year then if the Carbon Trust's 20 % leak rate were to be attained this would equate to annual savings of €60,868.78. Figure 3 shows how reducing the leak rate could reduce the half-hourly profiles of the compressor system. Leaks are relatively easy to fix, by undertaking regular inspections of the system using audible and visual aids. Additionally ultrasonic leak detection devices can highlight leaks in noisy factory environments. Another shocking piece of anecdotal evidence received from operators in the factory indicated that the company had ultrasonic leak detectors that were not in use.

After highlighting the benefits of leak reduction, it was advised to implement a weekly or bi-weekly inspection and tagging regime. Most of the leaks found during the study were simple to fix leaks concerning loose connectors or perished rubber hosing. These are very simple and easy to fix.

Gas Ovens

The factory uses 5 gas ovens throughout the year for the baking of the biscuit mixtures. Each oven requires around 4 hours of warm up time to initiate a productive run, and they are seldom ran continuously. Each biscuit mixture requires different heating patterns and temperatures, thus it is difficult to make assured recommendations as to the efficiency of each oven. The difficulty lies in where regression plot analysis of each oven cannot be directly comparable to the next, as a ton of one product may require a hotter bake than a ton of another.

As briefly mentioned above, regression plots were ascertained as to elucidate any issues with the ovens;

Figure 4 shows the energy used against weight of biscuit produced in tonnes for each of the five ovens over the same period of time. The primary information that can be gained from the regression plots is the efficiency of the ovens and the consistency associated with baking biscuits and energy used to do so. Where the best fit line intercepts the y axis can indicate the energy required to bring the ovens up to operating temperature. When compared it can be seen that, theoretically and based on assumptions that each oven bakes to a similar temperature, we can assume that oven 5 is the most efficient, and oven 1 is the least so. This was compared to thermal imaging of the ovens in question to verify the claims;

As can be seen in Figure 5, oven 1 (right) seems to be emitting more heat. One can assume that this heat loss from insulation degradation needs to be compensated for by the gas control to keep the oven up to operating temperature.

This verifies the claim that oven 1 appears to be less efficient than oven 2. The thermal imaging also indicates that this may be due to degradation of insulative materials causing heat losses.

The circles seen in Figure 4 indicate where product was baked using vast differences in energy, producing relatively equal weight. Oven 1's data shows how on one day 31,512 kgs of biscuit can be made using 12,651 kWh of energy. On another day 6,499 kg of biscuit can be made using 12,517.7 kWh of energy. Therefore a very similar amount of energy for 25,013 kg more product. The reason for this was never ascertained, however anecdotal evidence suggests that ovens were often left on during shifts where no production was required (often up to 4 hours).

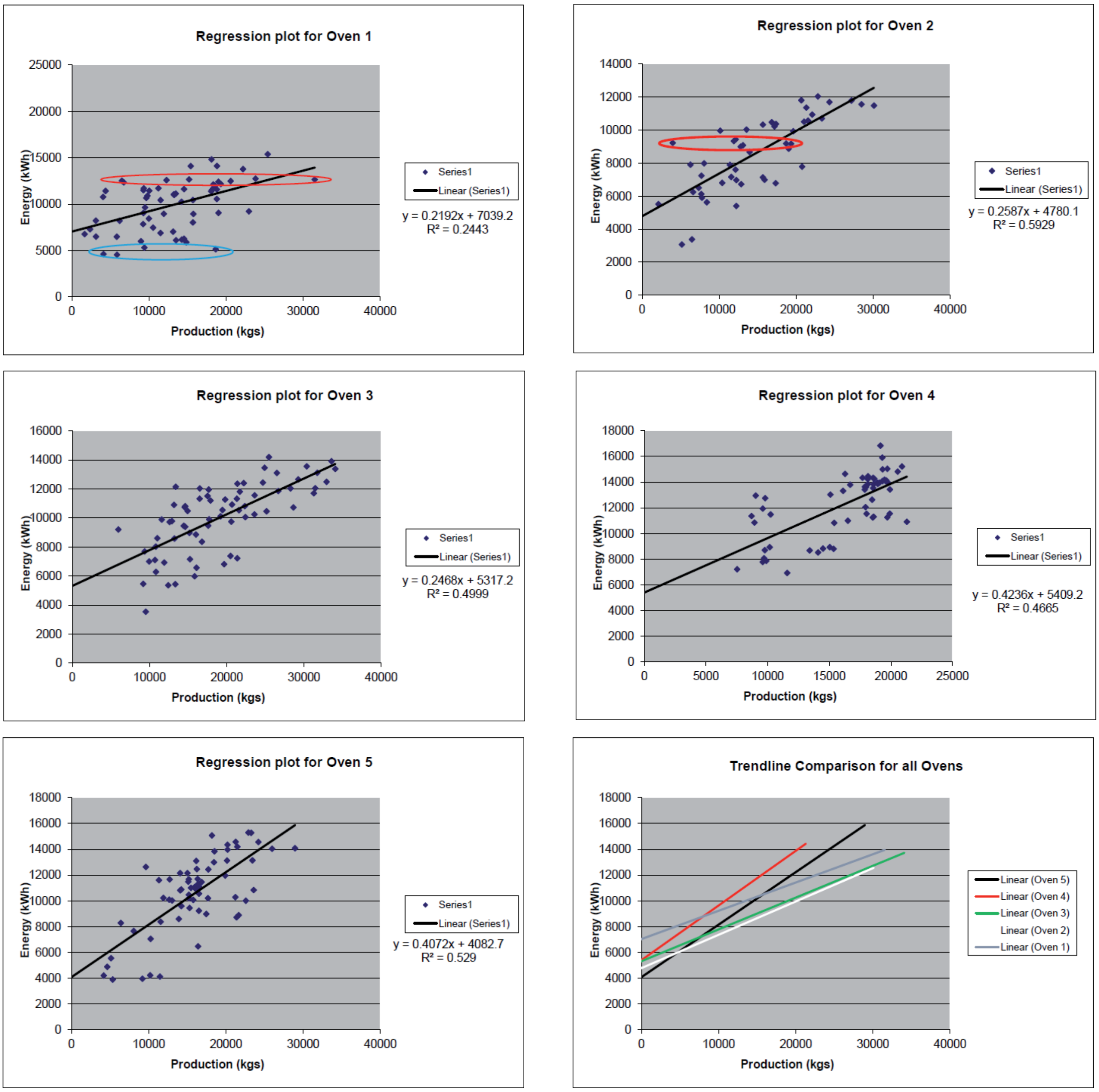

Figure 4: All gas oven regression plots, plus trend line comparison.

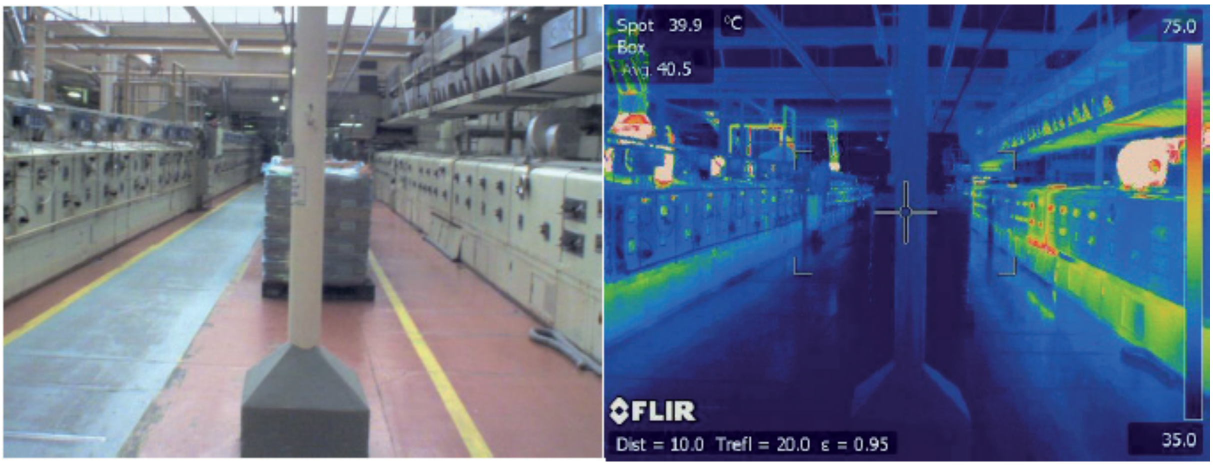

Figure 5: Thermal image of oven 2 (l) and oven 1 (r).

CASE 1 – CONCLUSIONS

During the study of the case in question there were many potential energy saving opportunities identified, however the most promising was the air compressor system. Analysis showed that the system was inefficient overall due to leaks and leaving the system in operation on non-productive days. Remarkably, it was shown that the upper management were gravely concerned regarding energy use in the view to reducing costs and bettering their environmental credentials, however many instances were uncovered where the equipment was in place to save energy, which was ignored, forgotten or unknown how to use.

Recommendations were made to initially turn off the system when not in use, using the installed timers. Also a regular weekly or bi-weekly inspection and maintenance program to find and fix leaks was recommended.

The above brief snapshot of the oven analyses showed how there was an apathy towards energy preservation when operating the ovens. There were often left on for long periods to save turning them off and on again. The reason for this was often as it took up to 4 hours for an oven to get up to operating temperature, however analysing the production log as to move shifts back to back would alleviate this issue. Oven efficiency was also elucidated through regression plot analysis. It highlighted the most inefficient ovens, and as such could help identify which oven to use the most as to save energy. Additionally, one could try to understand why one is performing better than the others, and try to replicate this operation throughout.

Case 2 – Company B

Company B is a medium sized iron foundry who produce such products as turbo charger and gearbox housings. They use scrap iron melted through three induction furnaces to create their products.

ENERGY ANALYSIS

During the year 2011, company B used 9,952,852 kWh of electricity at a total cost of €1,149,751. These data were available from their electricity providers during 2011 in a half-hourly format and are shown in Figure 6 and Figure 7.

These data show that the factory is highly energy intensive, which means that significant CO_2 savings will result from even quite small percentage reductions in energy consumption that might be identified through detailed analysis. Such analysis does not rely on the utility provider's data, since the foundry has its own energy logging system.

At present, the foundry has an obsolete half-hourly energy logging system that was installed in previous years. During the initial stages of the project it was discovered that the energy data logging system was not in use due to technical difficulties in retrieving data from the system. This was believed to be related to a damaged PC that had been used to collect the data, but fortunately it proved possible to reinstate the system using a new PC.

The basic principle of a half-hourly logging system is that a current transformer (CT) is used to sense the alternating current in a cable supplying a piece of machinery. This CT sends a signal to a logger that also measures the voltage supplied to the machinery and the power factor before calculating the electrical power usage, which is converted this into a stream of pulses. Each pulse represents a particular amount of energy and they are transmitted to a Pulse Logic Controller (PLC) which aggregates the pulses to derive half-hourly energy data. The electrical power is related to the sensed current and voltage by this simple equation:

$$P = \frac{V\ I\ \mathrm{Cos}\phi}{1000}$$

Where;
P = Power [kW]
V = Voltage [volts]
I = Current [amps]
Cosϕ = Power Factor

The pulse then travels to the main central Pulse Logic Controller (PLC) where all of the loggers' data are stored where an operator can retrieve the data for analysis purposes.

The technical difficulty previously mentioned was regarding retrieving the data from the PLC to the user's computer. We found that there was an error with the version of software that was being used at case study B, and after contacting the software provider, an older version of the software was acquired which now allows full use of the existing system from the SHE managers' computer.

To ascertain whether or not case study B are logging all processes using electricity the half-hourly data from the utility pro-

Bill Date	Month	Gross Cost
06/01/2012	December	£82,957.56
06/12/2011	November	£95,853.03
07/11/2011	October	£94,606.51
06/10/2011	September	£81,695.37
06/09/2011	August	£78,159.46
04/08/2011	July	£44,453.38
07/07/2011	June	£69,649.36
07/06/2011	May	£70,516.64
06/05/2011	April	£55,272.63
06/04/2011	March	£89,630.32
04/03/2011	February	£82,609.22
08/02/2011	January	£95,426.18
Total		**£940,829.66**

Figure 6: Bills in GBP.

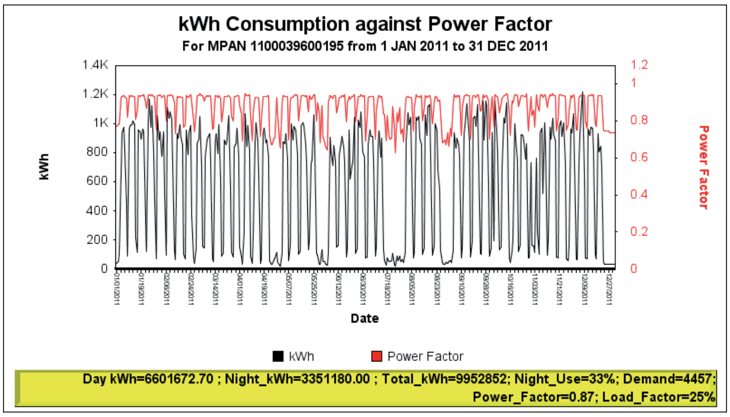

Figure 7: Daily profiles.

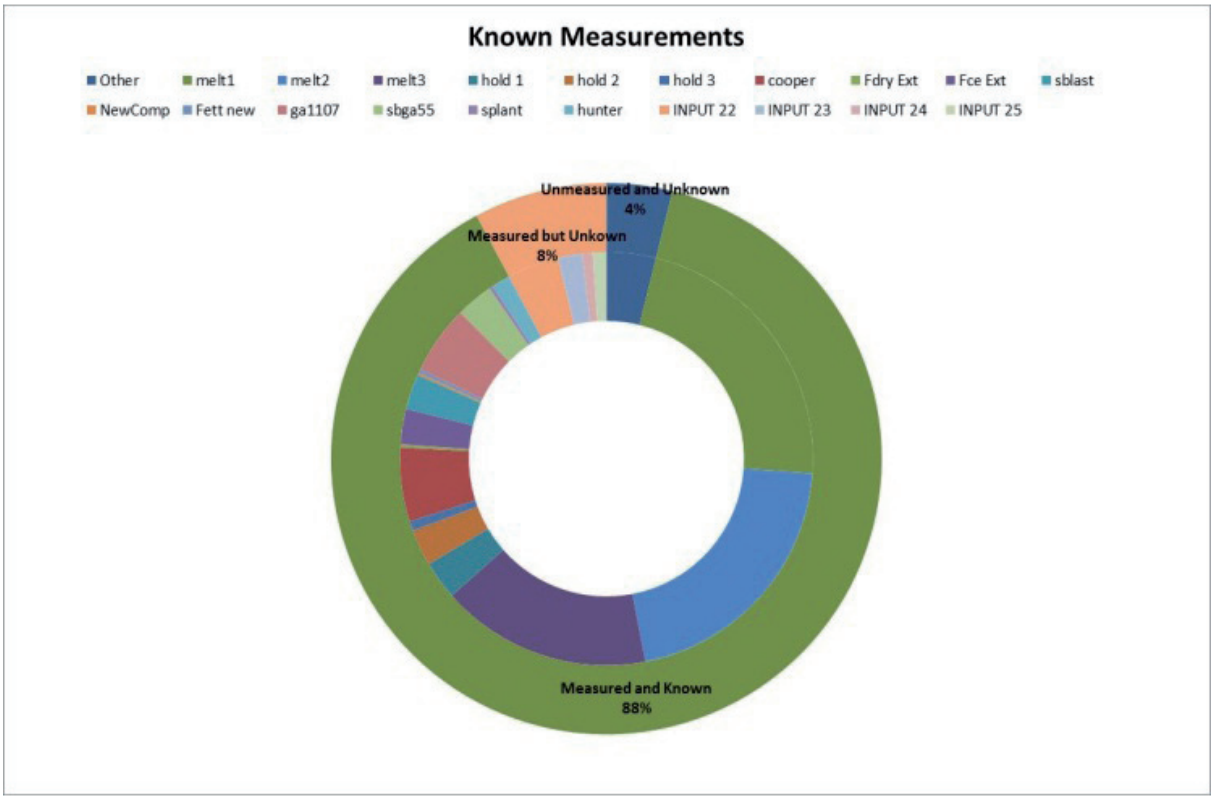

Figure 8: Known measurements logged.

vider was totalled and compared to the logger data for the same period. For the period 15th Dec 2011 @ 00:00 to 23rd Jan 2012 @ 23:30 the utility provider state that 872,184.10 kWh were used, whereas the logger states that 838,526.10 kWh were used. This is a discrepancy of 33,658 kWh, which when compared to the overall consumption it is not considerable; however during the logging period mentioned above around €3,055.15 was spent on an unknown source. This 'Other' usage can be attributable to site and office lighting and other single phase points such as plug sockets for the computers and other office equipment. However we can't be sure if any other process is also under this segment.

The initial data taken from the loggers shows the obvious, that the furnace's melt facility is the most energy intensive process in the foundry with a combined share of 59 % of the total energy consumption at case study B. The hold facility in the furnaces is relatively small with a combined value of 7 % of the total electricity usage. Therefore the furnaces total 66 % of the total foundry's electricity usage.

The furnaces will be evaluated separately from the rest of the processes as they are such a large portion of the electricity consumption with 66 % of overall consumption. When the furnaces are removed from the graph, one can get a better understanding of the other main consumers in the foundry.

Even though appearing as a very intensive consumer of energy in the case study B foundry, the percentages correlate with what is expected by the U.S. Department of Energy, Energy Efficiency and Renewable Energy (EERE)[20]. Their report shows that melting is a large percentage of energy use in the foundry environment (55 %) and the figures match well with the logged data in the foundry. Another area to correlate with logged data is the heat treatment section that exactly matches the EERE suggested 6 % of total energy use.

Cooper Heat, ga1107, and INPUT 22 are the three main areas of interest, however ga1107 denotes that this segment is the 110 kW air compressor, thus the sbga55 can be merged with this to represent total compressed air energy use as this is the smaller 55 kW air compressor. This makes the compressed air usage the greatest segment once the melts have been removed with 20 %, closely followed by the Cooper Heat treatment at 14 % and INPUT 22 with 10 %. INPUT 22 has been somewhat illusive as to what it denotes. It would be advisable to find out what this process is as soon as possible, to look at energy saving opportunities related to it, as it has such a large proportion in relation to the other processes.

Compressed Air

An initial idea of the performance of an air compressor system is to look at the base loads of a system, and whether the compressors are left on when there is no production in the foundry. The larger 110 kW compressor shows both good practice and bad. Figure 11 shows the half hourly profiles of energy use in the 110 kW system.

The breaks in each column denote a period of time where the air compressors were turned off as they were not in use. This seems to be at the end of each day, however a few times the air compressors were left on overnight for no apparent reason. If they were still in use, one would expect to see a high peak that matched the day use, however in the graph it is visible that they appear to sit at the 'base load'.

The average base load for the period to the left is 41 kWh per half hour which as can be seen below represents 65.5 % of the

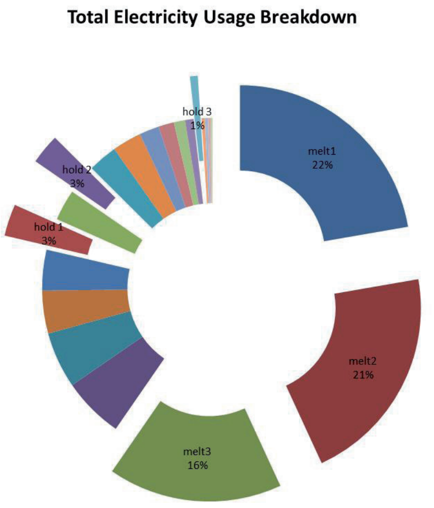

Figure 9: Total electricity use breakdown.

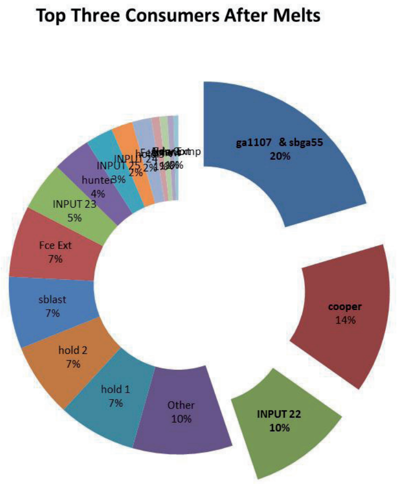

Figure 10: Top three consumers once melt function removed.

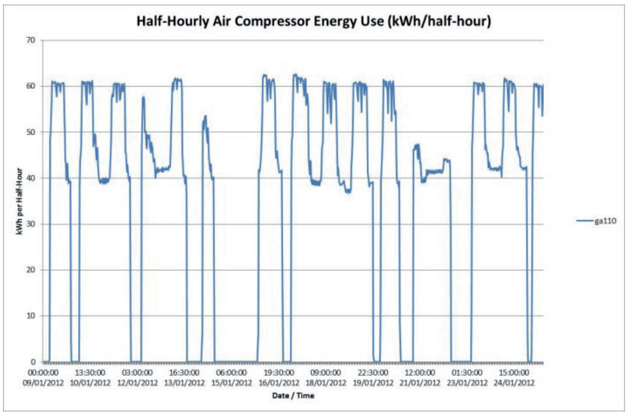

Figure 11: Half-hourly air compressor profile.

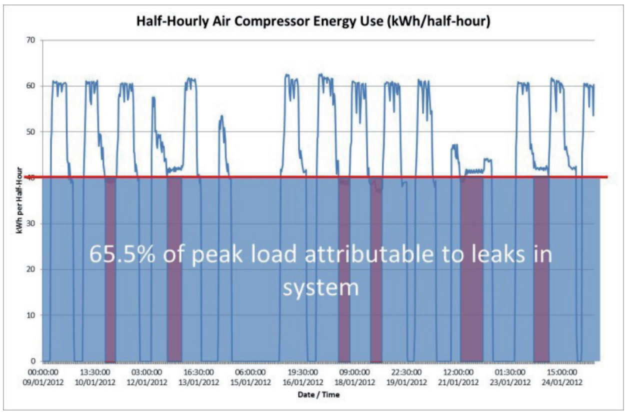

Figure 12: Half-hourly profile analysed.

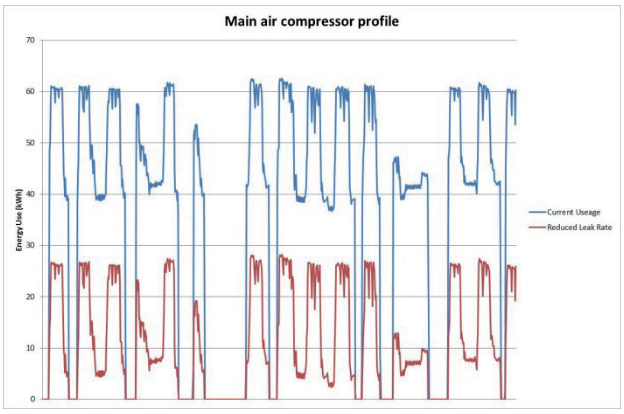

Figure 13: Main air compressor profile w/reduced leak rate.

air compressor's energy use. The base load can be understood as the amount of leakage present in an air compressor system.

The way in which a compressor works is to use electricity to bring a master cylinder up to pressure, then cut off. The air compressors would only use more electricity to top up to master cylinder once air has been utilized from the master cylinder for production. Thus any electrical load associate with non-productive hours is the leak rate, where the air compressor motor is topping up the cylinder due to leaks causing pressure drop.

The dark highlighted areas in Figure 12 show where the air compressors were left on overnight with no production associated with the time period. These areas can be calculated of how much energy was used in that period when they should have been off. For the period analysed above the total energy used when the compressors could have been turned off was 6838.50 kWh which would have cost around €884.17 based upon the average price paid in 2010 of 10.58p per kWh.

The Carbon Trust[16] indicate that an expected leak rate for good practice should be around 20 % for a well maintained system. The graph above clearly shows that the leak rate at case study B is 65.5 % of the peak load. This is to say that when not in use, the compressor is using 65.5 % of the energy that is required during peak use of a productive day. Therefore it would be advisable to look into a regular, fortnightly maintenance program where the system is checked for leaks and fixed to reduce the leak rate.

The graph in Figure 13 shows what the half-hourly profiles might look like if a stringent leak reduction plan was put into place at case study B. The Carbon Trust[16] report on air compressor leaks indicates that a 20% leak rate is good practice, as they suggest leak rates can be between 20 %–70 %. Thus if the lower variable was aimed for one could see the following energy profile in the ga110 compressor:

The difference between the blue and red line indicates the potential amount of energy that can be saved by reducing the leak rate to 20 %. This potential energy saving was calculated as 19,637 kWh which comes to a cost of €2,540 for the period selected. Based upon the assumption that the above snapshot is representative of the overall profile for the year, one can extrapolate that 431,682.20 kWh can be saved by reducing leaks to 20 %. This amounts to €55,814 per year, however it is not clear when production is ceased for days off and could present a false projection. Therefore it would be wise to use the average daily difference from the snapshot above to ascertain how much could be saved per day by leak reduction to the 20 % figure. Based upon the data above, €152.76 per day could be saved.

Heat Treatment Machine

The cooper heat treatment presents a large energy consumption pattern compared to the total energy use with 6 % of total use. This equates to 597171.12 kWh based upon the 2010 data set provided by the utility provider. Anecdotal evidence presented by an area manager states that the cooper heat treatment facility is wasteful via missing insulative bricks in the ceiling section.

Additionally, as can be seen in Figure 14, the thermal imaging survey identified there may be a poor seal on the cooper heat closing. The spot reading suggests that around 284 °C of heat is being lost in the white area on the thermal image.

When looking at the closing from the front with the thermal imaging camera, one can see that the insulation may be underperforming in certain areas.

Not only does the image further highlight the loss of heat through the main seal, Figure 15 shows how small spots of degraded insulation can reduce the thermal capacity of the closing, and radiate heat from inside the machinery. The light spot shows an area that is in excess of 120 °C. A more in depth thermal imaging survey of this equipment is highly recommended as to ascertain where areas of concern may lie, and how severe they are.

CASE 2 – CONCLUSIONS

It was found at the foundry that the lack of efficiency regarding air compressors was the area where the majority of energy saving potentials were located. Overall the furnaces are the most energy intensive, however savings related to this process were smaller than the potential savings in the air compressor system. In fact, only two of the three air compressors were looked at,

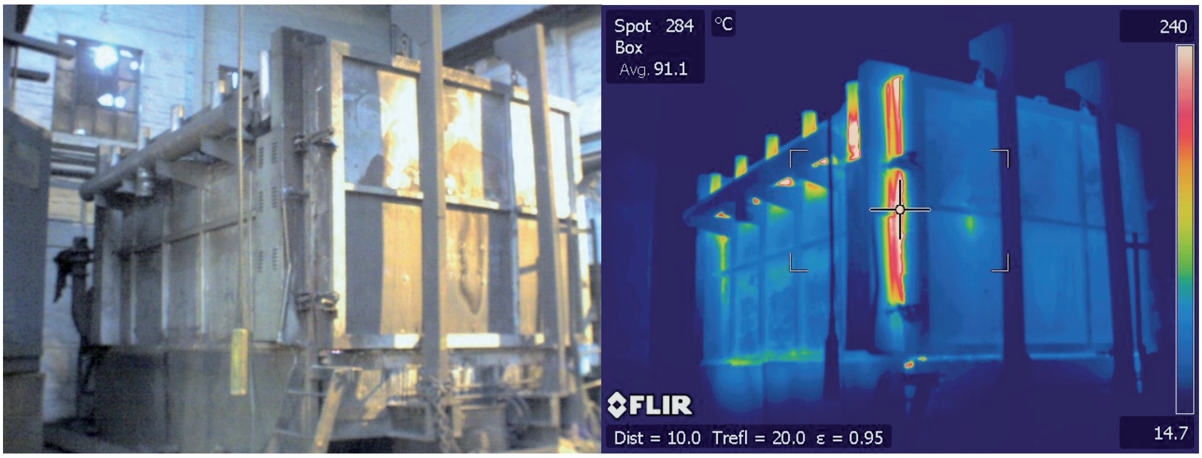

Figure 14: Thermal image of heat treatment.

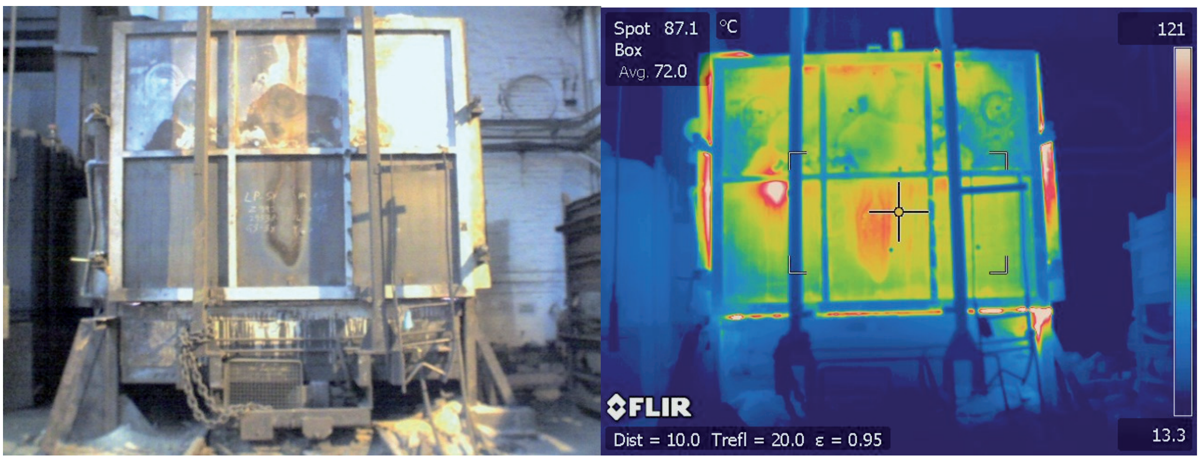

Figure 15: Thermal image of heat treatment (2).

and only one in great detail. Therefore the savings evaluated above are only foe one of the three compressors.

As was found in case study A, the energy manager did not have the facilities or knowledge to undertake adequate energy analysis for the factory. The equipment in use was out of date and did not work correctly, however once the software was fixed, it did provide basic half-hourly data for certain process machinery. Most surprisingly, it was found that not all processes were monitored, and some were monitored that were unknown. This is due to a poor setup where not all process were labelled initially. It is detrimental in this case as the unmonitored unknowns account for 10 % or the total energy use after the melts were removed. Additionally one of the monitored unknowns (INPUT 22) is also 10 % of total energy use after the melts were removed. This is a lot of energy to not monitor and not understand where it is going.

Findings

Even though the processes involved in each case study where so different, the air compressor system was highlighted in both cases as the area where the most energy savings potentials were located. The scale of the potential savings, alongside the ease of implementation signify that, in these studies, the air compressor system is the most wasteful energy utilisation process. Combined potential savings at case study A total €74,384.48 and 814,396.32 kWh per year for compressed air alone. Case study B could see savings 431,682.20 kWh, this amounts to €55,814 per year for reducing leaks to 20 %.

In both case studies it was found that the upper management who were pushing the savings in the energy field were only motivated by financial savings. This clouded vision of energy savings made it difficult to justify expenditure to mitigate against energy wastage. In addition, it was found that there was a disparity between the knowledge of systems in place between the upper management and the operators in both instances. Both cases showed how the energy managers were under-qualified for the role, and as such could not elucidate key energy wastages highlighted in this paper.

It was also found in both case studies that the existing energy monitoring systems were out of date and did not monitor all processes. This hampered the energy analysis as some unmonitored activities were rather substantial when compared to total energy consumption.

These studies provide evidence that the potential of energy analysis to identify waste and promote savings is not clearly understood and embraced by industry. Substantial savings can be made through a stringent and strategic energy analysis programme. However it must be set up correctly and used to its full potential which typically requires significant financial outlay, but this has been shown to be easily recovered through savings that are a product of the initial outlay.

Conclusion

Two industrial case studies were analysed through various energy data analysis techniques as to elucidate energy saving potentials. It was found that compressed air systems show great potential for significant savings in both instances. Other areas were analysed in both studies but are not included, due to the purpose of this paper.

In both cases energy monitoring was already in place prior to the authors involvement. In both cases the data collected was used to uncover clear opportunities that were previously not so clear. In both cases compressed air was a significant opportunity.

Due to the findings highlighted above, it would be advisable for industrial cases to evaluate their energy saving management structure. It was found that there was a clear break in communication between upper management and operators. It is advisable to change the structure to accommodate a clear link between all involved in the energy area. Additionally it was found that energy managers and energy 'champions' were undereducated in the energy field. In both cases the energy management and 'champion' tasks were not issued to someone trained in those skill areas, it was given to an existing employee who had no prior experience in the area. Therefore it is advisable to provide clear training in the area, or to employ an individual trained in this area of expertise. The savings ascertained in both cases for the air compressor systems alone, justify employing a trained energy manager at each venue. In recent years, economic hardship has made it difficult to justify when employees are often made redundant. However the evidence above shows how the cost of employing an adequately trained energy manager could easily be recovered by the resultant energy saving.

Not only must the manager be adequately trained in the field, the equipment at the manager's disposal must be useable. Half-hourly logging equipment and software may initially seem to be expensive, however it is a vital tool in reducing energy waste. It must be set up correctly and used by an operator that understands its principles and operation to ascertain tangible benefits. As highlighted in this paper, the savings from one process are enough to justify investment in energy saving equipment and personnel.

Energy concerns are starting to become a concern for industrial entities, and they are more interested in this field than ever before. It would appear from these two case studies, that the field is still misunderstood by industry, and that there is a need to disseminate knowledge of energy analysis tools and techniques from academia to industry. Hopefully studies such as this can show that energy and financial savings can be substantial in a time where reducing costs are paramount for the industry to survive.

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