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Reducing industrial energy costs through energy efficiency measures in a liberalized European electricity market

- Case study of a Swedish iron foundry

Patrik Thollander^{a,*}, Magnus Karlsson^a, Mats Söderström^a, Dan Creutz^b

^aDepartment of Mechanical Engineering, Division of Energy Systems, Linköping University,

SE-581 83 Linköping, Sweden

^bSwedish Foundry Association, SE-550 02 Jönköping, Sweden

Abstract

Swedish industry, which has one of the lowest electricity prices in the European Union, will face higher electricity prices due to the Union's electricity market liberalization. Rising electricity prices together with a larger use of electricity than other European countries pose a threat to industrial activity in Sweden. The Swedish foundry industry, with large proportions of energy costs in relation to the added value, is particularly sensitive to higher electricity costs. The aim of this paper is to study the effect of higher electricity prices on the Swedish iron and steel foundry industry, quantify an energy efficiency potential for a medium-sized Swedish iron foundry resulting from a thorough industrial energy audit, and investigate what impact they have on the energy cost.

* Corresponding author. Fax: + 46-13-28 17 88

E-mail address: patth@ikp.liu.se (P. Thollander).

1 Introduction

The liberalization of the gas and electricity markets in the European Union scheduled for July 2004, will certainly cause future prices of gas and electricity to converge as the aim of the liberalization of the market is

increased cost effectiveness through market mechanisms [1]. A homogenous, symmetric gas and electricity market will, as a consequence of the market liberalization, cause prices in the EU countries to fall. However, a study of the effects of the liberalization in Sweden shows that electricity prices will not fall because Sweden already has very low electricity prices [2-5]. In fact, a recent study of electricity prices in the European Union conducted by EEPO (European Electricity Prices Observatory) indicates that Sweden has the lowest industrial electricity prices in the Union [6]. The study's mean value for enterprises using 1-50 GWh annually indicates that European electricity prices are about twice as high as in Sweden. This is partly for historical reasons and because Sweden has been part of the integrated Nordic electricity market since 1996, and is thus already liberalized [7].

In comparison with European competitors, low electricity prices in Swedish industry seem to have influenced domestic enterprises to use more electricity and favour the use of electricity over other energy carriers [2, 3, 8]. A comparison between the foundry sectors in some European countries indicates extensive relative use of electricity in the Swedish and Danish foundry industries as presented in Fig. 1 [9-11]. Fig. 1 also indicates that low electricity prices seem to be related to a large relative use of electricity, except in Denmark. The difference in the Danish foundry industry is partly explained by the great predominance of iron and steel foundries where electricity-driven inductive furnaces are the most widely used technology [12].

Fig. 1. Foundry sector's average use of electricity in relation to the total energy use [%] and electricity prices for 1-9 GWh and 9-50 GWh enterprises in some European countries [6, 9-11]. For the Netherlands, too few observations were made in order to state a figure for enterprises using 9-50 GWh annually [6].

Higher electricity prices together with a greater use of electricity than other European countries poses a threat to domestic industrial activity in Sweden. Higher energy costs have a negative impact on results, stock values, and

competitiveness, which in turn may lead to lower production and perhaps even cause enterprises to consider moving to another country [5].

Industrial enterprises are affected differently by increased energy prices depending on the energy cost in relation to the added value. Industrial enterprises like foundries are thus threatened to a much larger extent than the engineering industry. While the engineering industry has energy costs in relation to the added value of only 1-2%, foundries are facing values as high as 5-15% [13]. This high figure corresponds to increased energy costs in relation to the added value of 2-6%, assuming that Swedish foundries will face the average electricity price found in the EEPO study, i.e. twice present domestic electricity prices. Swedish foundries' use of energy thus needs to be reduced.

Recent industrial energy audits of 11 Swedish industries in various fields show an electricity saving potential of 48% on average, and an average energy saving potential of 40%, indicating substantial possibilities to reduce the threat of rising energy costs [3]. The aim of this paper is to study the effect of rising electricity prices on the Swedish iron and steel foundry industry, quantify an energy efficiency potential for a medium-sized Swedish iron foundry resulting from a thorough industrial energy audit and investigate what impact they have on the energy cost.

2 Method

Energy costs at industrial plants can be reduced in three principal ways; reduction of energy use, load management measures, and changing energy carriers. In order to investigate the energy efficiency potential in the Swedish iron and steel foundry industry, an industrial energy audit was carried out over about 6 months during 2003. It was based on experience from several hundred industrial energy audits in various industrial fields, performed over the last 20 years by the Division of Energy Systems at Linköping University.

The industrial energy audit stresses all three ways in which energy costs may be reduced. Some behavioural aspects such lowering idling demand have been quantified, while aspects like closing scuttles during the heating season has been identified but not quantified. The reason for not converting qualitative data into quantitative data, like in the case of closing scuttles, was the great uncertainty with regard to the figures, as it is very difficult to estimate people's behaviour in this case. On the basis of the results from the industrial energy audit carried out at the analysed iron foundry, computer calculations were made to study the consequences of energy efficiency measures and electricity price fluctuations in terms of energy costs.

3 Case study

3.1 *Energy and the Swedish foundry industry*

The Swedish foundry industry, mainly producing for the domestic market, involves 133 enterprises and employs some 7,350 people [13]. Annual production in Sweden amounts to 325,000 tons of castings of which 76% is iron castings, 18% non-ferrous and 6% steel where the total annual energy use is about 1 TWh [14]. For a general overview of the foundry industry's production process, please see reference [12]. The foundry industry in general is a significant user of energy and in the majority of the foundries, processing (in particular melting and holding) is the major energy-using process, which was also seen in the case study [15]. The quantity of energy used by the melting process is approximately proportional to the amount of metal melted. As the energy use in melting operations is so high, improving the casting output makes for a worthwhile reduction in a foundry's overall operating costs. For instance, achieving high yield (the total weight of good castings in relation to the total weight of metal melted) puts the focus on good foundry practice and key areas like melting, pouring, moulding, and core making. The casting yield varies between 85 and 95% when producing simple shape heavy grey iron castings, to between 40 and 50% when producing small ductile iron castings in mechanized volume production [16].

The melting and pouring areas must be both equipped and organized to deliver metal into the moulds at the appropriate temperature and required composition. While it is important that unsatisfactory metal is pigged¹ rather than poured into moulds, the amount of pigged metal should be monitored and action taken if it becomes excessive. The production of defective castings is another important issue that has to be addressed. Reducing scrap has a two-fold effect. Firstly, less energy is required for metal melting and secondly, materials, consumable items, and labour are also reduced, thus increasing the foundry's capacity.

Apart from processing, energy usage in the support processes, i.e. ventilation, internal transportation, pumping, compressed air, lighting, space heating and tap water, are often not identified. Energy savings, particularly in these non-production process areas of the operation, are rarely given priority by management. A number of reasons are put forward for this, including a history of low electricity prices [3], lack of awareness of problems and solutions, limited capital, over-long payback periods, limited expertise, and staff or personal resistance to change

[17]. However, it is clear that energy is a major controllable cost and that opportunities exist for significant savings in the area of support processes [3, 18]. Moreover, as this paper indicates, some of these measures can be implemented by adopting a small number of relatively cost effective solutions and simple courses of action.

3.2 Energy use at the analysed iron foundry

The analysed iron foundry, located in the south east of Sweden, produces among other things bearing housings and castings mainly for the automotive industry. The annual capacity amounts to 24,000 tons mainly grey ductile iron and the foundry employs some 100 people. The analysed foundry focuses on environmental issues and was one of the first foundries in the world certified with an EMS (Environmental Management System) according to ISO 14001 [19]. The production processes at the iron foundry consist of 5 open inductive melting furnaces, 2 holding furnaces, ladle heating, sand preparation, and 3 moulding processes with subsequent sand blasting and cleaning. The support processes consist of hot tap water, space heating mainly aggregated in the ventilation systems, and a centralized compressed air system. Losses in the excessive numbers of transformers at the plant have also been allocated to the support processes while pumping has not been allocated in the study but aggregated within the other processes. Also, energy usage in the laboratory and offices is also considered as being used in support processes. The iron foundry has a maximum hourly power demand of 9,500 kW and the annual use of energy, divided into production and support processes, is presented in Fig. 2. Fig. 2 also shows that melting and holding are the largest energy-using processes at the plant together with space heating and ventilation.

Fig. 3, which compares 6 Swedish iron and steel foundries, indicates a great diversion in the use of energy in relation to the casting output (t/yr). Table 1 also indicates a great difference in the use of district heating, oil, and LPG. Moreover, the foundry proved to have a larger casting output than all but one of the other compared foundries. The different casting output figures can partly be explained by the different degrees of mechanization in the moulding process but also by different ways of categorizing a good casting. While some foundries use tons of melted metal as their measure of production, others use tons of finished products. Using the casting output ratio thus

¹ Liquid metal that is unsuitable for pouring purposes, due to unsatisfactory composition or low temperature, must be pigged. If it is poured into moulds, the scrap which will probably be the result will increase the production cost and waste more energy since the pigged metal needs to be re-melted.

includes variances due to uncertainties with regard to the figures, yet it is a better comparative figure than merely comparing the use of energy.

Fig. 2. Annual energy balance for the foundry under study [2003].

Fig. 3. Annual energy and electricity use in relation to annual tons of good castings [annual production] in six Swedish iron and steel foundries, including the foundry under study [16]. The calculations have been conducted by dividing an enterprise's annual energy and annual electricity use with annual tons of good casting.

Table 1: Production data for six Swedish iron and steel foundries [16].

Production data	Foundry	Foundry	Foundry	Foundry	Foundry	Analysed
	1	2	3	4	5	foundry
Good castings [tons/year]	550	14,700	11,200	2,500	5,000	9,200
Total energy use [GWh/year]	2.4	37.3	23.3	7.1	5.3	34.6
Electricity [GWh/year]	2.1	33.1	19.0	4.1	5.1	26.6
Oil [GWh/year]	0.2	2.7	4.0	0.1	0.2	---
LPG [GWh/year]	0.1	1.5	0.3	0.3	0.1	1.3
District heating [GWh/year]	---	---	---	2.5	---	6.7

3.3 Energy price estimates

Swedish industry, with one of the lowest electricity prices in the European Union [6], will experience electricity price increases due to the electricity market liberalization within the Union [2-5]. A study at the University of Linköping, financed by the power company Sydkraft, one of the three main power producers in Sweden, indicates that future electricity prices in Sweden can be expected to converge toward 80 €/per MWh, Monday through Friday, from 6 am to 6 pm, and 44 €/per MWh during the rest of the week [20]. In the study it is assumed, among a number of assumptions, perfect market mechanisms and a CO₂ price of 10 €/per ton. A sensitivity analysis carried out in the study indicates that the CO₂ price does not seem to have a very large impact on the electricity price with a price decrease of 3 to 4 €/per MWh if the CO₂ price is excluded [20]. A report by ECON on electricity price elasticity indicates similar results [5]. The average electricity price found from the EEPO study [6] corresponds very well to the prices found in the above-mentioned study, taking the average price of a 24-hour weekday, except that prices in the EEPO study are slightly higher. The future electricity prices found in the above study, together with present electricity prices and local prices of LPG and district heating are used in the calculations of the foundry's energy costs in this study. Table 2 presents the different energy prices used in the calculations.

Table 2: Future and present electricity prices and energy prices used in the computer calculations [electricity prices include network and power charges].

Scenarios	Electricity price [Mon -Fri, 6 am - 6 pm] [€MWh]	Electricity price [6 pm - 6 am, and Sat 6 am - Mon 6 am] [€MWh]	Price of LPG [€MWh]	Price of district heating [€MWh]
Present				
Base A, B	34.7 ^{1, 2}	34.7 ^{1, 2}	50.0 ¹	40.7 ¹
Future				
Case 1A, 1B, 2A, 2B	80.5	44.3	50.0 ¹	40.7 ¹

¹ 1 €= 9.0852 SEK

² Arithmetic mean value [tradable green certificates (TGC) are not included in the price]

3.4 Energy efficiency potential at the iron foundry

The energy audit at the Swedish iron foundry resulted in a number of potential energy efficiency measures with the aim of reducing energy costs. The largest energy saving measures are found in the melting and holding processes. Proposed measures include investment in a new induction furnace. Delivery of waste heat to the local district heating system and strategic production planning in combination with load management to reduce power demand during peak hours are also suggested. Furthermore, large energy savings could be found in the compressed air system through the elimination of leaks, lower idling energy demand during weekends and holidays, investment in a new sand preparation process, and more efficient ladle heating.

The industrial energy audit resulted in the proposal of seven major energy efficiency measures and a number of minor measures (included in other measures), as presented in table 3. Implementing the measures could reduce the use of energy at the foundry by about 33%, and more specifically the use of electricity by 23%. By far the most economically advantageous energy efficiency measure at the foundry is to aggregate load management practices with the foundry's strategic production planning. At present, melting furnaces are intended to be used during periods when the power demand is low. Studying the foundry's power demand over the year indicates that this is not always practised. Possible cuts of 3,000 kW in the power demand were identified, implemented simply by shifting the melting process to periods when the power demand is low, i.e. very little investment is needed for implementation.

Table 3: Energy efficiency measures for the foundry under study resulting from the industrial energy audit.

Energy efficiency measures	Electricity	LPG	District heating
	savings	savings	savings
	[MWh/year]	[MWh/year]	[MWh/year]
New melting furnaces	2,300	---	---
District heating supplied to municipality	---	---	2,200
Compressed air leak elimination	1,100	---	---
New sand preparation	780	---	290
Different ladle heating	---	660	420
Lowering idling losses	1,140	---	---
Load management	--- ¹	---	---
Other measures	920	0	1,770
Total figure	6,240	660	4,680
Total figure [%]	23%	51%	70%

¹ Power reduction of 3 MW during peak-hours. The energy use is not affected by this measure but the cost of power is reduced.

3.5 Assumptions

In the computer calculations, only electricity prices are assumed to rise and show daily price fluctuations, while LPG and district heating prices are assumed to remain at present levels and are assumed not to fluctuate. The calculation function is linear where electricity use and electricity prices are calculated on an hourly basis while the price and use of LPG and district heating are calculated on an annual and seasonal basis respectively.

4 Analysed cases

Six different scenarios have been analysed. The scenarios have been classified into two major cases where one deals solely with the use of electricity while the other deals with the total energy use, including the use of

electricity. The reason for this is to present two types of cases which give a clear picture of the impact of energy efficiency measures that does not concern savings in electricity alone. In 3 scenarios, savings in LPG and district heating are also included. Further cases studying price variations in district heating, oil, and LPG are not presented in this paper, as LPG is a relatively small energy carrier at the 6 compared foundries and because not all of the 6 foundries' energy use involves the use of district heating and oil (See table 1).

Two base scenarios, Base A and Base B, are used as reference scenarios using present electricity prices. The A-scenarios include all energy carriers, including electricity, while the B-scenarios only include the use of electricity. Case 1A and Case 1B represent the foundry's energy costs with future electricity prices and undertaken energy system measures implemented, while Case 2A and Case 2B represent the energy costs with energy efficiency measures resulting from the industrial energy audit and future electricity prices implemented.

5 Calculation results

The calculation results are presented in Fig. 4. A comparison of Base A with Case 1A and Base B with Case 1B indicates that energy and electricity costs will increase by 42% and 56% respectively, which corresponds to increased energy costs in relation to the added value of 4%. The results from Case 2A and Case 2B show that the foundry under study may be able to reduce the costs significantly by implementing energy efficiency measures. However, when the measures are implemented, as considered in Case 2A and Case 2B, future energy costs may still increase in comparison with the base scenarios. A comparison of Base A with Case 2A shows a 3% increase in the annual energy cost, while a comparison of Base B with Case 2B indicates an annual electricity cost increase of 16%, which corresponds to increased energy costs in relation to the added value of less than 0.5 % and 1% respectively.

6 Concluding discussion

As presented, it can be expected that the energy costs in relation to the added value for Swedish iron- and steel foundries, without energy efficiency measures, will rise by 2-6% in the liberalized European electricity market. Through a case study of a Swedish iron foundry it has been shown that substantial measures can be implemented to reduce this threat. There is qualitative data from the energy audit which also indicates that the possible energy efficiency measures exceed the resulting 33%. This qualitative data, i.e. energy efficiency measures such as closing scuttles during the heating season, increased yield through more efficient production processes and other energy

efficiency behavioural gains, for example from educating employees in energy matters, have not been converted to quantitative data as the output was too uncertain. Furthermore, in order to gain valid and reliable results from the energy audit, in cases where different figures have been calculated for an energy efficiency measure, the figure with the lowest value has consequently been chosen. On the other hand, a few of the potential investments in energy efficient machinery etc. are costly investments which may be difficult to undertake simultaneously. Furthermore, it is not likely that all the proposed energy efficiency measures will be implemented, so in practice it is a complicated matter to express an exact energy efficiency measure figure explicitly for the analysed foundry, and consequently for the sector as a whole.

Fig. 4. The analysed foundry's annual energy costs and annual energy use for the 6 considered scenarios. Base A uses present electricity prices and no undertaken energy efficiency measures, Case 1A uses future electricity prices and no undertaken energy efficiency measures and Case 2A uses future electricity prices and undertaken energy efficiency measures. Base B uses present electricity prices and no undertaken energy efficiency measures, Case 1B uses future electricity prices and no undertaken energy efficiency measures and Case 2B uses future electricity prices and undertaken energy efficiency measures.

The future electricity prices used in the calculations were calculated on the basis of a liberalized electricity market and thus marginal pricing mechanisms [20]. Moreover, on the basis of experiences from market reforms in the UK, Norway, Alberta and California, Woo, Lloyd and Tishler conclude that *it is an unrealistic expectation that restructuring will achieve perfect competition in a properly functioning market. A more realistic expectation is workable competition in a reasonably well-functioning market environment. This would hopefully produce prices that are close to the marginal costs under least cost dispatch* [21]. However, to calculate future electricity prices in any other way than using marginal cost pricing in a liberalized market would prove very difficult. With market liberalization, electricity prices in Sweden will rise, but to what extent is not easy to foresee. The future electricity prices used in the calculations can therefore be regarded as estimations.

On the basis of a number of qualitative data indicating a greater energy saving potential, uncertainty as to whether one can assume that all investments will be implemented and assumptions made in order to state future electricity prices, the calculation results indicating rising energy- and electricity costs within the analysed foundry of 3% and 16% respectively, with the energy efficiency measures implemented, can be seen merely as estimations. However, the result strongly implies that the studied iron foundry, having undertaken major energy efficiency measures, will be able to preserve energy costs to a certain degree in the liberalized electricity market. The calculations indicate a total energy cost increase of +42% for the analysed foundry if no energy efficiency measures are undertaken. This substantial energy cost increase indicates an investment opportunity of about 50% of the foundry's annual energy cost. The significant increase in energy cost must be seen in the light of foundries' large energy cost in relation to the added value, and that Swedish foundries in general use more electricity than their European competitors. Thus, to neglect the threat that the liberalization of the electricity market poses to the Swedish steel and iron foundry industry's energy costs may prove harmful as foreign competitors may steal market share.

If all the proposed energy efficiency measures are undertaken, it can be concluded that the effect of rising electricity prices has only a marginal effect on the production cost of the foundry under study. However, no general conclusions should be drawn from this as the foundry under study has a larger casting output than all but one of the studied foundries. This means that other foundries will not necessarily be able to lower their energy cost as much as the analysed foundry, which in turn will lead to higher energy costs with rising electricity prices. On the other hand, one might claim that these foundries may very well be more adapted to European electricity pricing and consequently less affected. Nonetheless, with rising electricity prices, energy costs can only be reduced by implementing substantial energy efficiency measures.

Though it is difficult to draw general conclusions in quantitative terms, some general conclusions can however be drawn from the study: i. The European electricity market liberalization, and thus rising electricity prices, will significantly affect energy costs at Swedish iron and steel foundries but to what extent depends on a foundry's present energy efficiency status and the future electricity price. ii. Major action to reduce energy cost in order to reduce the effect of rising electricity prices has been proven to be possible with the method used. However, more foundries must be investigated before general conclusions can be drawn in quantitative energy efficiency terms.

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