Energy intensity online measurement and benchmarking system

The World Steel Association (worldsteel) and its members have developed an energy intensity measurement and benchmarking methodology to compare energy consumption per tonne with a standard reference plant. The findings of the performance gap between their own performance and the reference plant can be made both on a site and a facility level and show the potential for energy efficiency improvement. The online energy system provides a tool for worldsteel members to measure their performance on an annual or ad hoc basis, enables evaluation of the different technologies available, and build a business case for implementation based on practical performance. The report, Energy Use in the Steel Industry, *was published by worldsteel in April 2014 for participating members, based on 2010 data. The results show that if the industry moves from an average value to best performer, the energy-saving potential is 15% for the BF/BOF route and 20% for the EAF route.*

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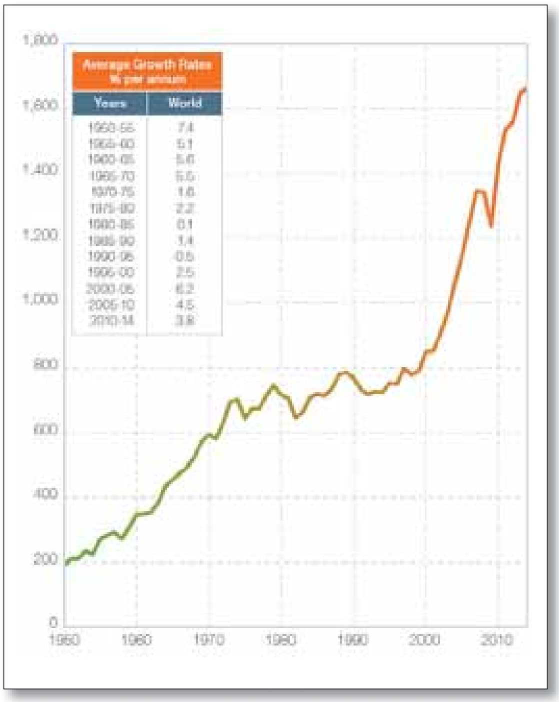

Fig 1 **World crude steel production [*from ref 4*]**

Between 2011 and 2013 the World Steel Association (worldsteel), together with members of the Technology Committee (TECO), created the *Energy Use in the Steel Industry* project, and developed an online energy intensity measurement and benchmarking system for steel industry processes. This allowed a comprehensive analysis of energy use for 2010 (although any year can be submitted). The findings of the first and second reports on energy and the steel industry were published by IISI in 1982 **[1]** and 1998 **[2]**. The 1998 report has been widely utilised and has formed the basis of many energy measurement systems since then. *Energy Use in the Steel Industry* **[3]** is the third energy study. worldsteel and its members will continue regularly to review the changes and trends of energy use in the steel industry through an energy expert group made up of worldsteel members.

World crude steel production in 2014 was 1.665Bt, of which 73.9% was via the BF-BOF route, 25.6% via EAF and 0.5% by open hearth. Over the past 10 years, the production of crude steel has seen very rapid growth and is linked directly to energy consumption (*see Figure 1*). Energy costs represent around 20-25% of the total inputs of manufacture, with coking coal accounting for more than 65% of the primary source of energy, and hence is one of the most important items to manage.

A detailed energy-intensity calculation methodology was developed. The World Steel Association invited all steel producers and steel associations within its membership to take part in the project. Data was received from 42 steelworks (21 steel companies), representing 8.8% (~126Mt) of global crude steel output in 2010 (*see Figure 2*).

METHODOLOGY

The energy system enables steel producers to make a fair comparison of their own energy consumption compared to the industry and a reference plant at site and facility level, allowing them to systematically determine the areas where energy efficiency can be improved by way of gap analysis (*see Figure 3*).

Users of the web tool will be able to:

- Calculate their energy performance and compare it to the reference data at the site and facility level (for example, sinter plant, or hot strip mill)
- Compare their energy performance with peer companies at the site and facility level
- Calculate the energy improvement potential and run scenarios if various technologies or practices are implemented
- Analyse the performance gap to understand which part of the gap is due to raw material selection and which part can be reduced using good practices and energy-efficient technologies
- Analyse the gap performance on a process by process basis (raw materials through to hot rolling), identifying each area of non-performance and extent compared to the reference
- Test the effectiveness of installed energy-saving technologies against the industry best
- Test or justify (energy intensity benefit per tonne crude steel) implementing new technologies with a clear and practical energy-saving potential.

The metallurgical processes covered by the energy benchmarking system are sintering, pelletising, direct reduced iron, coking, BF iron making, BOF, EAF, continuous casting, hot rolling mill, air separation unit, power plant and flares.

The reference plant values were developed on the basis of energy data, project team experience and reports from more than 60 sites globally over a five-year period. The energy intensity of participating companies was then compared with the reference plant values. The project team agreed to set the reference at the top 25% of performance of the practical plant performance.

Figure 4 shows the example for sinter plants.

Table 1 illustrates the method used to calculate the roll-up energy intensity of steel production. The roll-up includes the cumulative energy intensity of all processes up to the stage being analysed or, for a whole site, up to the hot rolling mill. The rolled up method stops at the hot rolling process, as this accounts for more than 90% of most sites energy consumption and, up to this level, processes are common for most companies. Beyond hot rolling, the process configuration varies enormously and would be difficult to compare.

Fig 2 **worldsteel members who participated in the energy use project**

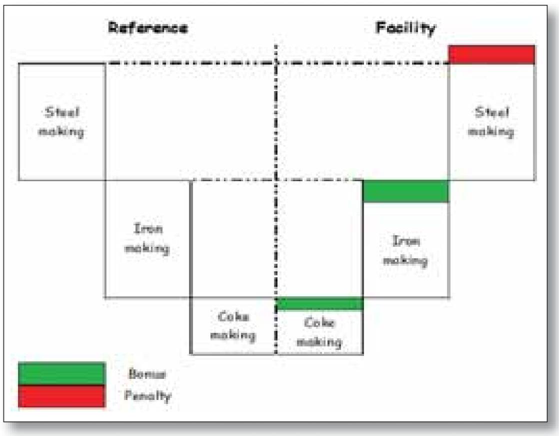

Fig 3 **Principle of performance assessment for multi-step production routes**

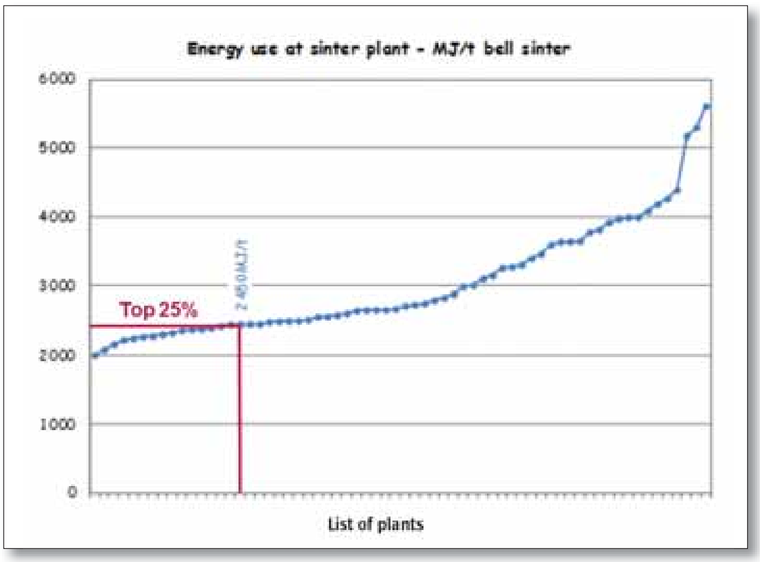

Fig 4 **Example of sinter plant reference plants**

1	Roll-up Primary Metal level	Sinister Plant + Coke Oven Plant+... + BF Plant
2	Roll-up Crude Steel level	(1 + Steel Shop)
3	Roll-up Hot Rolled level	(2 + Hot Rolling Mill)
4	Roll-up site level	(3 + Power Plant + Air Separation Unit + Flares)

Table1 Roll-up energy intensity of steel production

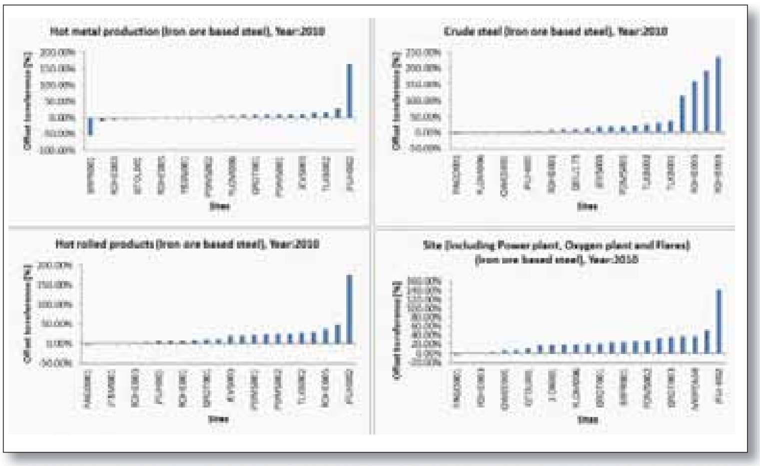

Fig 5 Four examples of site level roll-up analysis ranking results

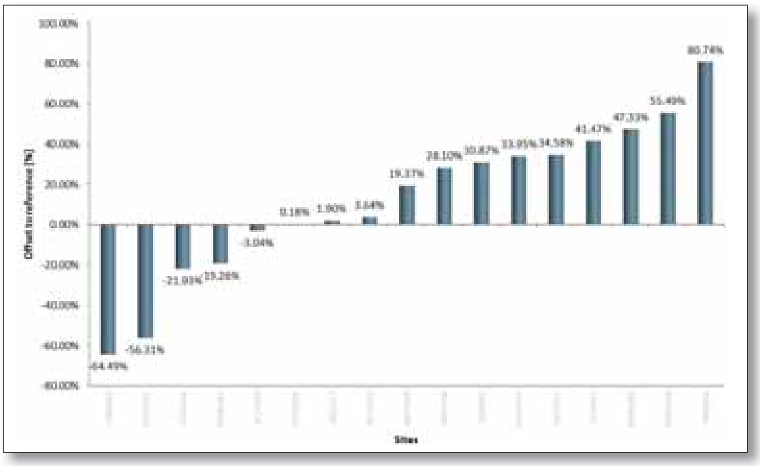

Fig 6 Example of facility level (coke oven) benchmarking analysis

ENERGY DATA COLLECTION SYSTEM

To access the energy data collection system a user ID and password are needed. These are only available on application to worldsteel for its members (contact: **technology@worldsteel.org**).

There are two levels of access to the Energy Data Collection System: Superusers and Users. A Superuser oversees the data collection and approves data for a company overall once it has been input by the Users for each site.

All information is stored on secure servers to ISO 27001, and all submissions are anonymised and coded to ensure plants or companies cannot be identified. Reports can be selected by each user or worldsteel administrator.

Data collection through an Excel template is the easiest way to collect data from your reports or systems. The template allows the key data sets to be gathered over time and it is important that units and cells locations are not altered. The whole data sheet can be uploaded directly into the system once completed, thus avoiding having to key it in again. Even multiple sheets for different sites can be uploaded.

The system was developed in English and translated into French, Russian and Chinese. More languages will be made available in future by translating key words.

ENERGY INTENSITY MEASUREMENT AND BENCHMARKING

The system enables members to calculate the level of energy improvement in terms of gigajoules (GJ) of energy per tonne of specific product, or GJ per tonne of crude steel. Examples of the results at site and facility level are shown in *Figures 5* and *6*. In the future, processes beyond hot rolling could be added, however, over 90% of the energy intensity occurs in this part of the steelmaking and shaping process so the present model covers the main items. The measurement comparison and data collection system have been established as online tools and are available to any worldsteel member. Members are enabled to enter data for any site or facility and analyse their own results across multiple sites. They can also compare their performance relative to reference data developed from existing sites.

The system enables the energy-saving opportunities to be determined by break down analysis of each process (*see Figure 7*), operational factors (*see Figure 8*), and to get the quantitative energy-saving potential in different process (*Figure 9*). The energy-saving gap between reference plant value and specific operational value is demonstrated by a waterfall graph, such as *Figure 7* for site and *Figure 8* for process. In the waterfall graphs, the blue bars represent the reference plant value (as a 100% base line), summary score of site-specific operational performance and corrected score for adjusting the impact of slag, scrap or pig iron and DRI, respectively. If the summary or corrected score is lower than 100% it means the performance is better than the reference plant without/with raw materials' correction. The red and green bars in the graph mean worse or better performance than the reference plant value, and so can provide clues for improving energy efficiency.

ENERGY INTENSITY SURVEY

The energy intensity of 26 iron ore-based steel production sites were analysed (17 BF/BOF route, three BOF plus EAF and six EAF with DRI input higher than 50%). The results show that the DRI/EAF route has a higher energy intensity than the BF/BOF route. Only one site was close to the worldsteel reference (mainly because this site has implemented hot DRI charging to the EAF). Generally, the DRI/EAF with hot charging is 25% more energy-intensive than the BF/BOF route, but CO_2 emissions are lower due to natural gas DRI process.

Thirteen sites with a scrap-based steel production route were analysed. The energy-saving correction factor for pig (cold) iron is 1kWh per tonne of crude steel for each 1% of pig iron charged. This balances the actual energy used and covers the change in the carbon content of pig iron (approximately 4.2%) which is reduced to below 0.8% carbon in the steelmaking process. The energy intensity of the EAF increases when the percentage of DRI in the charge increases. The DRI correction factor is usually around 200kWh/t DRI, this value being in line with the value obtained from the real-life experience of project members of 217kWh/t DRI, and is used for this model.

From the survey, the global energy intensity for the BF/BOF route ranges from 15.8 to 22.8GJ/t of crude as-cast steel with an average of 18.7GJ/t. For an EAF using 100% scrap, the energy intensity varies between 5.5 and 8.7GJ/t of crude cast steel, with an average of 6.7GJ/t.

ENERGY-SAVING TECHNOLOGY SURVEY

To investigate the most-implemented energy-saving technologies, a questionnaire was prepared using the technologies listed in the 1998 IISI energy report and supplemented by others from available literature. Information based on the practical experience of project members was also taken into account. The questionnaire covered more than 190 energy efficiency techniques and technologies utilised worldwide in the steel industry, and was developed to reveal the gap between plants and sites analysed. Every technique and technology has the potential to decrease the energy intensity of the steel production process, increase productivity or improve product quality, however, it is essential to note that the technologies are not cumulative, as energy can only be saved once. Project members analysed the implemented technologies and ▷

Fig 7 Example of site waterfall graph

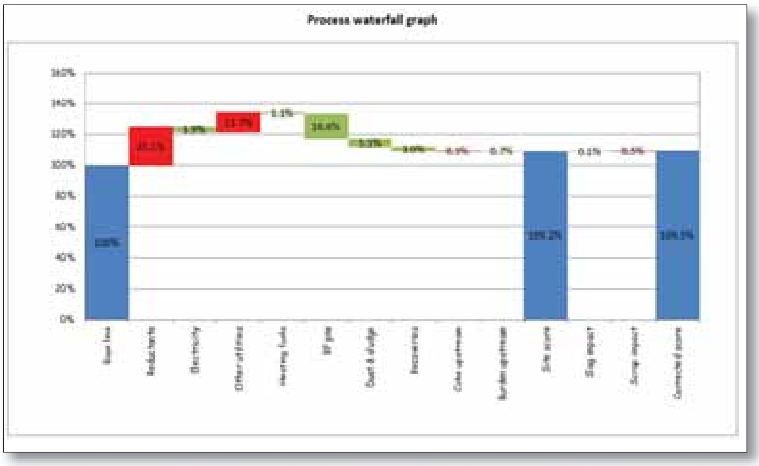

Fig 8 Example of process waterfall graph

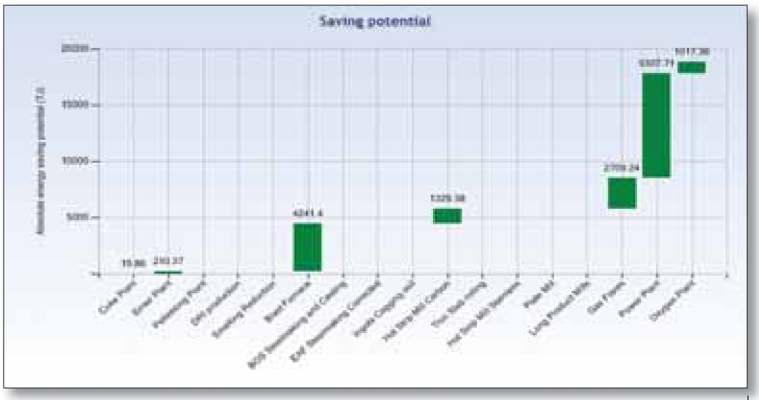

Fig 9 Example of quantitative energy-saving potential by process

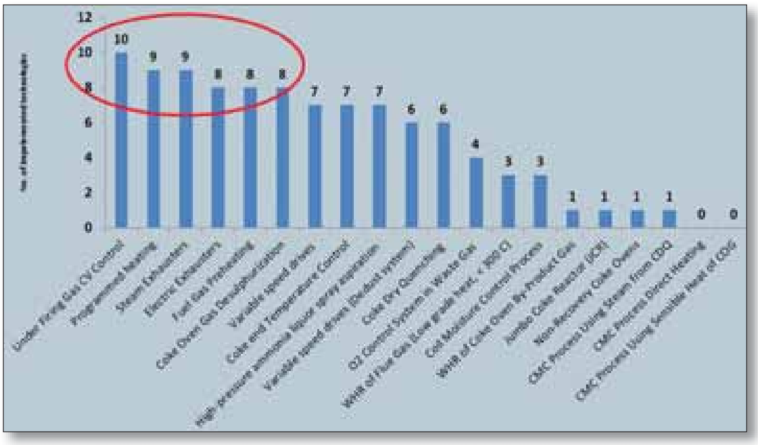

Fig 10 **Energy-saving technologies survey – technologies most implemented in coke ovens**

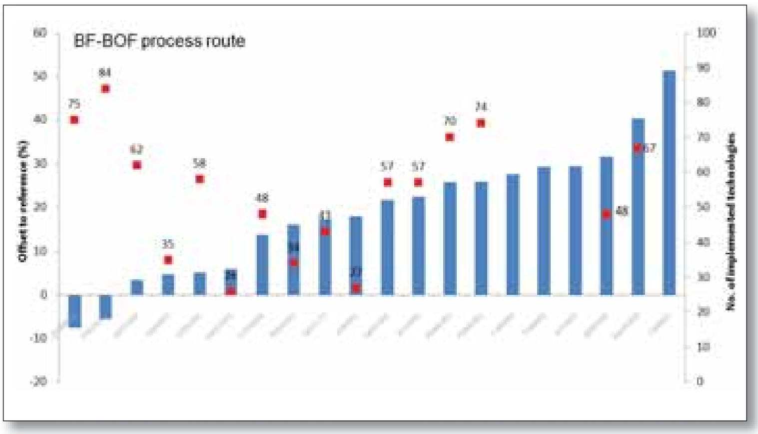

Fig 11 **Energy intensity of BF-BOF route compared to the number of implemented energy-saving technologies**

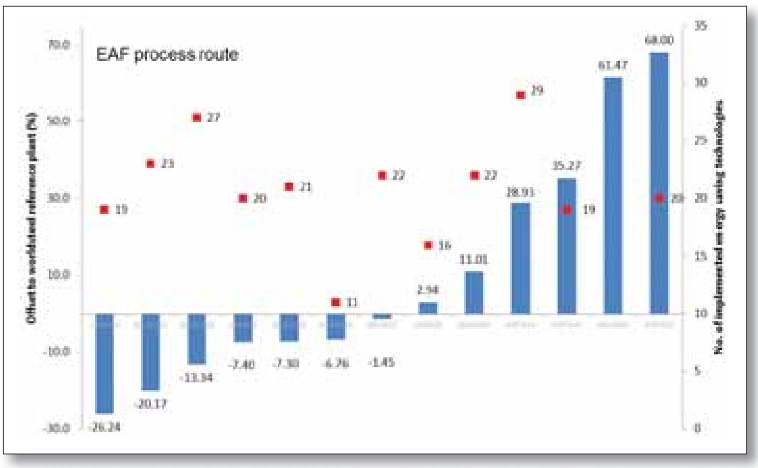

Fig 12 **Energy intensity of EAF route compared to the number of implemented energy-saving technologies**

described the main drivers behind their implementation. The technology questionnaire was divided into two parts:

1. A list of techniques and technologies defined in the 1998 IISI report. This accounted for 100 of the techniques and technologies and covered all metallurgical production steps

2. A list of other energy-saving technologies identified from other reports. The 83 most energy-efficient techniques and technologies were included from available technical literature

Both parts of the questionnaire were divided into eight subheadings covering the main metallurgical production steps (BF, BOF, coke, DRI, EAF, hot mill, power plant and sinter plant). Project members were asked to indicate:

- Whether the technology had been implemented in their plants
- What were the drivers behind the implementation of these technologies
- Whether the implemented technologies were delivering expected results.

Figure 10 is one example, showing the 20 energy-saving technologies analysed in coke ovens and their popularity. worldsteel's benchmarking results showed that 80% of the most energy efficient coke oven batteries were equipped with coke dry quenching (CDQ) technology with an energy intensity between 18.9 and 55.0% better than that of the reference plant. The results in figure 10 show, however, that CDQ does not feature in the top 30% (6/20) most implemented energy-saving technologies. By comparison, for coke plants using water quenching, the average energy intensity is 13.3% worse than that of the reference plant.

Installing energy-saving technologies has been the main task for steel producers who want to reduce their energy intensity, however, the installation of new technology has to be considered very carefully and its influence on other processes and the site must be analysed. It is recommended that the analysis is carried out using the worldsteel methodology and its online system to provide a holistic overview of the site and its impact.

Project members collected information about the energy-saving technologies implemented within their sites. One of the results is shown in *Figure 11* (the horizontal axis are the individual sites, and the red squares and numbers refer to the right-side vertical axis). The number of energy-saving technologies implemented by project members varies widely, but does not follow the energy intensity curve as expected. For instance, some sites have a large number of implemented energy efficiency technologies, but their energy efficiency has not significantly improved. Companies have implemented 30-40% of the existing 190 worldsteel energy-saving technologies available.

The energy-saving technologies implemented in EAF plants averaged 23 and are more balanced (*see Figure 12*).

The energy intensity of the EAF processes used by members of this project range from 26.2% below the reference level to 68.0% above. The wide range is due to the type and quality of raw materials used, for instance, some companies operate EAFs with DRI input higher than 50%. The penetration of energy-saving technologies in EAF plants is more consistent than in the BF/BOF process route.

Energy specialists worldwide agree on the following philosophy: *Measure - Evaluate - Take action.*

There is no single solution to decreasing energy intensity. The first step is to measure the current operation and its performance. Without a standardised methodology, process and system, it is difficult to objectively evaluate the current situation. It is possible to forecast the impact of implementing technologies or practices at a specific site using the worldsteel model. Capital and energy-saving investments should not be made without a deep process and site impact analysis. Implementing 25-30% of the energy-saving technologies available appears to be sufficient to reach the worldsteel reference energy intensity levels or to be best in class. However, these are only effective if the technologies, processes or improvements are operated continuously, and run at their full practical potential.

Management of these plants must use sound decision-making principles based on objectively acquired facts and data. This enables them to obtain a high-level of reliability, low maintenance and improve process and product yield. Five steps to improve energy efficiency for steel production are shown in *Figure 13*.

CONCLUSIONS

worldsteel and its members have developed an energy intensity measurement and online benchmarking system for making a comparison of their internal energy consumption by process with a standard reference plant. The energy intensity per tonne of process product is analysed and integrated, which enable comparisons to be made on a site and facility level. Steel producers can therefore monitor their improvement of their energy intensity, taking into account all key factors.

The report, *Energy use in the steel industry*, was published by worldsteel in 2014 and provides participating members, with a complete analysis based on 2010 data. The global energy intensity for the BF/BOF route ranges from 15.82 to 22.82GJ/t of cast steel, with an average of 18.68GJ/t. For an EAF using 100% scrap, energy intensity varies between 5.34 and 8.66GJ/t of cast steel, with an average of 6.74GJ/t.

The results show that if the industry moves from an average value to the reference plant value, energy-saving potential for the BF/BOF route is 5% (the EAF is about average now), and then if the industry moves from an average value to best performer, the energy-saving potential is 15% for the BF/BOF route and 20% for the EAF route.

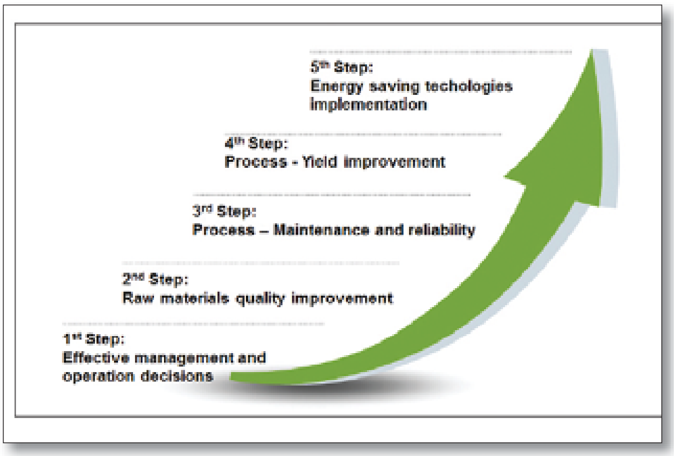

Fig 13 **Five steps to improve energy efficiency**

RECOMMENDATIONS FOR STEEL PRODUCERS

The energy intensity of steel production is complex for any site configuration, as steel producers must manage many variables to optimise energy use. Energy represents 20-25% of the total cost of steel production, depending on local cost of energy. Key recommendations from this report are:

- Undertake an energy analysis using the worldsteel model for each of the organisation's sites and facilities
- Use recycled scrap to the maximum economically feasible limit
- Transfer best practices across company and industry
- Only apply technologies that show improvement levels that justify the investment and suit your business
- Through your procurement team, demand improvements in raw material quality, balancing the economic cost against the organisation's energy and process efficiency
- Forecast or justify the value of your changes of decisions, operation or energy-saving technologies implementation by using the worldsteel model MS

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[1] International Iron and Steel Institute, *Energy and the Steel Industry*, 1982

[2] International Iron and Steel Institute, *Energy Use in the Steel Industry*, 1998

[3] World Steel Association, *Energy Use in the Steel Industry*, 2014

[4] World Steel Association, *World Steel in Figures 2015*, p7