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Benchmarking Report for the Iron and SteelSector

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الهيئة العامة للتنمية الصناعية
Industrial Development Authority

Industrial Energy Efficiency
Benchmarking Report for Iron and Steel Sector

Prepared by

AUSTRIAN ENERGY AGENCY

And

Eng. AYMAN ELZAHABY

Summary

The main purpose of the project "Industrial Energy Efficiency in Egypt – Development of Benchmarking Reports for Three Sectors Iron and Steel, Fertilizers and Cement", financed by the United Nations Industrial Development Organization (UNIDO) and the Global Environmental Facility (GEF), was to prepare industrial energy efficiency (IEE) benchmarking reports for the three above-mentioned sectors. This report covers the benchmarking study results for the iron and steel industry.

Chapter 2 explains the methodology applied for establishing the benchmarking studies. It relates, for the most part, to the UNIDO methodology described in the UNIDO Working Paper "Global Industrial Energy Efficiency Benchmarking – An Energy Policy Tool, Working Paper, 2010". Furthermore, Chapter 2 describes the approach for estimating energy saving potentials, for collecting data, for defining system boundaries and for checking the reliability of data.

For the Egyptian benchmarking curves, data collected by national experts in companies of the three sectors were applied. This approach gives much more precise results than simply applying statistical data. The data was checked by the national and international experts, system boundaries were kept and outliers were deleted.

Chapter 3 contains the basic sector information, including the economic and legislative framework, the number of companies and ownership, production capacities, main products and markets. Furthermore, Chapter 3 shows the main drivers for energy consumption in the iron and steel industry and the energy consumption of the whole sector according to national statistical information. These energy consumption values are not very reliable and were not taken for drawing the energy consumption and saving scenarios in Chapter 4.

The energy consumption in the iron and steel sector depends on the process routes: There are two main routes for producing steel from iron ores: Blast Furnace with basic oxygen furnace (BF-BOF, known as integrated plants) and direct reduced iron with electric furnace (DRI-EF, known as mini-mills). The most common production route in Egypt is the second route. Only 8% of total iron production in 2012 in Egypt was produced by the integrated BOF plant.

Year	2010	2011	2012
Crude steel Production, Thousand Tons	6,676	6,485	6,627
BOF crude steel production, Thousand Tons	600	545	530
EAF crude steel production, Thousand Tons	6,075	5,940	6,100

The following table from the Berkeley National Laboratory Study "World Best Practice Final Energy Intensity Values for Selected Industrial Sectors" (Ernst Worrell, 2008) shows the BAT values for different production processes of the iron and steel industry.

World Best Practice Final Energy Intensities	GJ/t Liquid Steel
Blast Furnace – Basic Oxygen Furnace – Thin Slab Casting	14.8
Smelt Reduction – Basic Oxygen Furnace – Thin Slab Casting	17.8
Direct Reduced Iron – Electric Arc Furnace – Thin Slab Casting	16.9
Scrap - Electric Arc Furnace – Thin Slab Casting	2.6

From this study, world BAT values for the different process steps within the production routes were taken.

In the beginning of the project, it was planned to establish, in addition to the benchmark curves of individual companies, similar benchmark curves as in the UNIDO working paper by using national statistical data from the Industrial Development Authority (IDA) and the Central Agency for Public Mobilization and Statistics (CAPMAS). However, during the project activities, the Egyptian experts evaluated the data of IDA and CAPMAS and came to the conclusion that the data is incomplete for benchmarking purposes. Therefore, the project team decided not to establish benchmark curves with the statistical data, but to use the outcome of this project to support IDA and CAPMAS in refining their data collection processes.

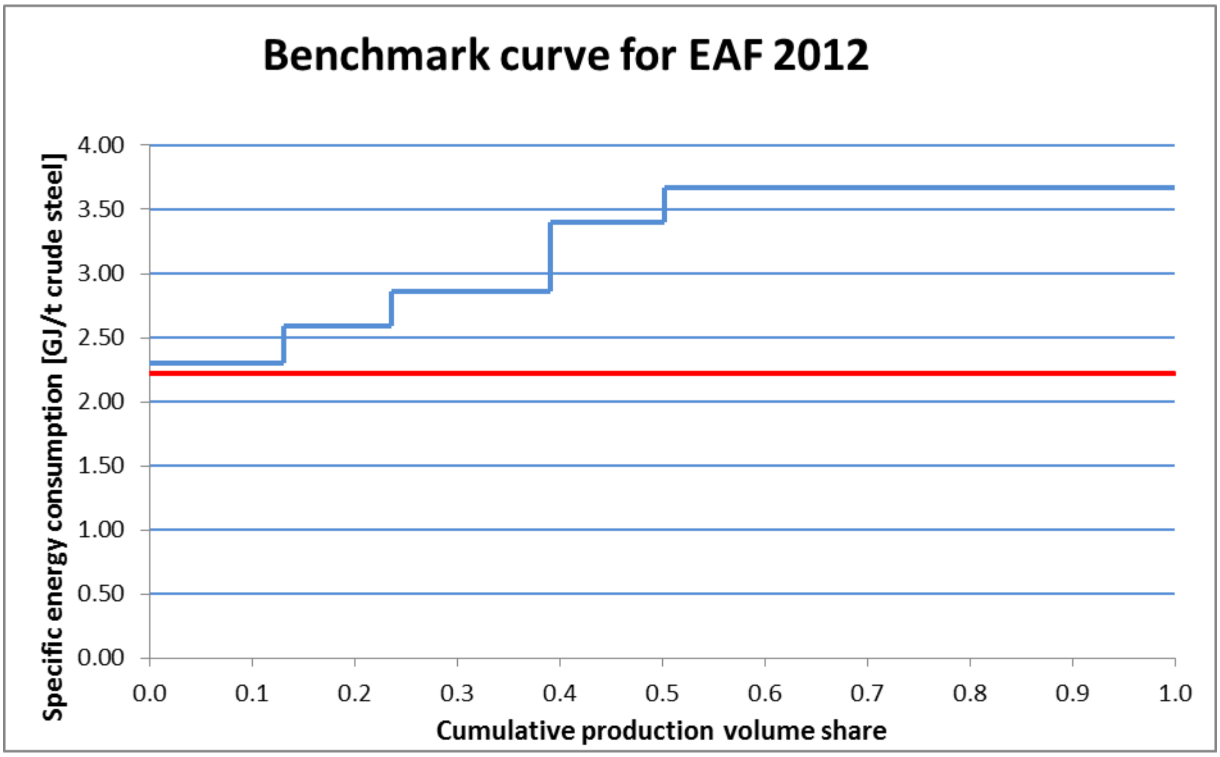
Chapter 4 shows the results of the analysis of the data collected in eight Egyptian iron and steel plants. The investigated companies represent the main iron and steel producers in Egypt with different production routes. The data of production and energy consumption for those companies were gathered for the years 2010, 2011 and 2012. The investigated companies represent almost 76% of the Egyptian iron and steel final production as illustrated in the table below.

Process	Total Capacity [t]	Studied Capacity [t]	Percentage of Capacity [%]
Direct Reduced Iron	3,000,000	3,000,000	100
Electric Arc Furnaces	7,265,122	6,800,000	94
Hot Rolling (rebar)	8,818,122	6,780,000	77
Hot Strip Mills (flat)	2,709,000	2,200,000	81
Sections	229,710	0	0
Total End Products	11,756,832	8,980,000	76

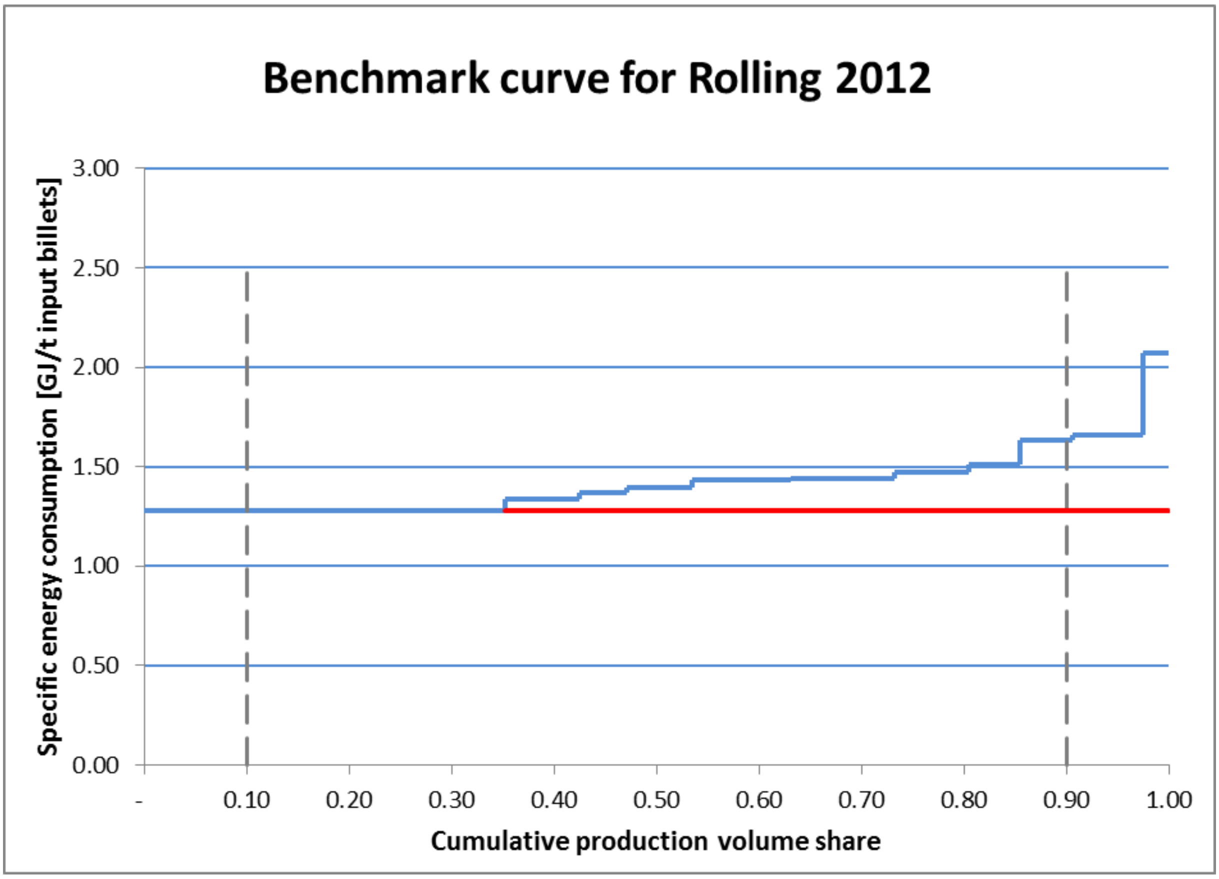
One important result of the study is the construction of energy efficiency benchmark curves for the different processes. This means that each company was split up in the different processes (DRI, EAF, hot rolling, hot strip rolling) on-site. Each process was evaluated separately. The reason was that with this approach plants with a comprehensive production route, including DRI-EAF and hot rolling (only one plant in Egypt within the studied years), could be compared with other plants having, for example, only hot rolling on-site (several plants in Egypt).

The graph below shows the benchmark curve for the iron and steel industry for the electric arc furnaces. These types of benchmark curves show the specific energy consumption of the analyzed companies per ton of crude steel produced (GJ/t) as a function of the production volume share. The most efficient plants are represented to the left and lower part of the curve, and the least efficient plants to the right and upper part of the curve.

The iron and steel plant with the lowest specific energy consumption, which is 2.30 GJ/t for crude steel production via electric arc furnaces in 2012, has a production volume share of 13%. This value defines the national BAT value that was applied for calculating the saving potential of the analyzed companies. The second lowest specific energy consumption in this curve for 2012 is defined as the national best practice technology (BPT) value. The national BPT value is 2.59 GJ/t. For this study, the BPT value was only applied for the saving scenarios in Chapter 4.9 in order to draw up the BPT scenario.



The iron and steel plant with the lowest specific energy consumption, which is 1.28 GJ/t for hot rolling in 2012, has a production volume share of 46%. The national BPT value for hot rolling is 1.34 GJ/t.



In Chapter 4.8, energy saving potentials were calculated, on the one hand, for five electric arc furnaces and for 11 rolling mills that participated in the benchmarking study, and on the other hand, for the whole Egyptian iron and steel sector. The five EAFs have an energy saving potential of 6 PJ, while the eleven rolling mills have a potential of 1 PJ. The DRI plant and the hot strip rolling plant were not included in this step as only one plant per process participated in the study for Egypt in 2012.

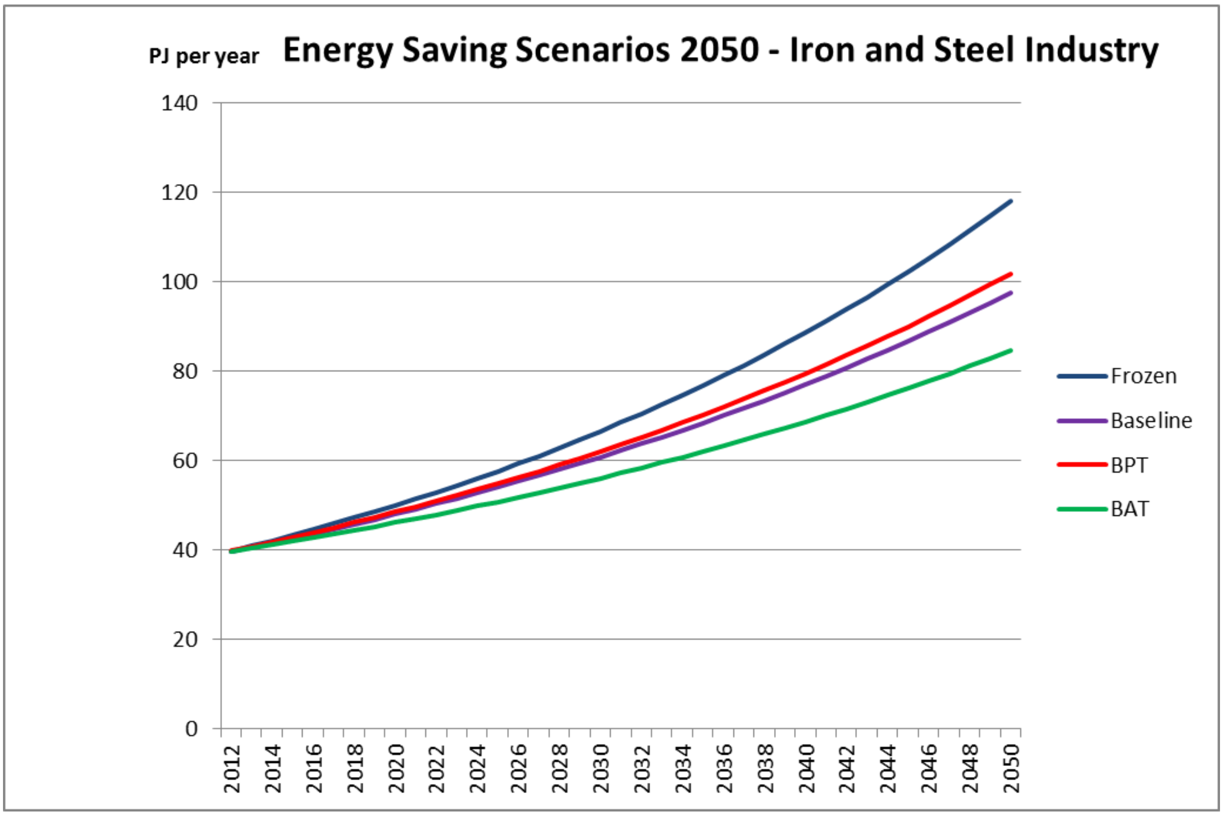
For the energy saving potential of the whole iron and steel industry sector in Egypt, the potential was also calculated for the DRI plant and the hot strip rolling plants (for both plants, the international BAT was applied, 11.7 and 0.2 GJ/t respectively). In total, the saving potential for the whole sector is 11 PJ.

Furthermore, different energy saving scenarios until 2030 and 2050 were drawn in Chapter 4.9. The scenarios correspond to the scenarios in the UNIDO Working Paper. For the saving scenarios it was decided to exclude the DRI route, as only one plant was operating at the moment which is already very close to the international BAT (11.76 GJ/t to 11.70 GJ/t). The four scenarios represent therefore the process steps EAF, hot rolling and hot strip rolling.

An important factor for drawing the scenarios is the rate of production growth. The production of the iron and steel sector in 2050 will be three times higher than today and in 2030 it will be 1.7 higher. The different scenarios were calculated by taking the growing production until 2030 and 2050 into account.

- **Frozen efficiency**: no additional energy efficiency savings are made. The current levels of energy efficiency are not improved upon.
- **Baseline efficiency**: energy efficiency improves at a rate of 0.5% a year.
- **BPT scenario**: all plants are operating at the current levels of BPT by 2030 and 2050. This is equivalent to an energy efficiency improvement of 0.41% a year in the period 2012 to 2050. The value for the BPT was derived from the second best values for 2012 from the analyzed data set. One exception was made for the hot strip mills: Only one plant was operating in 2012, therefore for the BPT value, the second best value of the best plant in the years 2010 and 2011 was chosen. As 2010 was the lowest one, the SEC of 2011 was chosen. The BPT values are 2.59 GJ/t for EAF, 1.34 GJ/t for hot rolling and 1.11 GJ/t for hot strip rolling. All values are national BPT as no international BPTs were available.
- **BAT scenario:** all plants are operating at current levels of BAT by 2030 and 2050. This is equivalent to an energy efficiency improvement of 0.90% a year in the period 2012 to 2050. The BAT is the lowest known BAT, either on international or on national level. For the iron and steel sector, the BATs are 2.22 GJ/t for EAF (national BAT), 1.28 GJ/t for hot rolling (national BAT) and 0.20 GJ/t for hot strip rolling (international BAT).

The following graph shows the four scenarios until 2050. According to the frozen efficiency scenario, the annual energy consumption in 2050 is about 118 PJ for the process steps EAF, hot rolling and hot strip rolling. The annual energy consumption in 2050 according to the BAT scenario is about 85 PJ. Comparing the frozen efficiency scenario and the BAT scenario, the annual saving potential would be about 33 PJ which is about 28%.



The following table shows the annual energy consumption of the iron and steel sector for the process steps EAF, hot rolling and hot strip rolling in 2012, 2030 and 2050 according to the four scenarios. Furthermore, the table shows the annual and cumulative energy saving potentials if all companies of the sector reach the BAT specific energy consumption in 2030 or 2050.

Year	Frozen Scenario (PJ/a)	Baseline Scenario (PJ/a)	BPT Scenario (PJ/a)	BAT Scenario (PJ/a)	Savings Frozen – BAT Scenario (PJ/a)	Cumulative Savings (Frozen-BAT) (PJ)
2012	40	40	40	40		
2030	69	63	60	50	20	172
2050	118	98	102	85	33	513

This study offers a solid basis for further energy efficiency projects for the Egyptian iron and steel sector. These projects should focus on supporting the companies in implementing energy efficiency measures and energy management systems in order to continually improve their energy efficiency.

Abstract

The report contains the main results for the Egyptian iron and steel sector of the project "Industrial Energy Efficiency in Egypt – Development of Benchmarking Reports for Three Sectors Iron and Steel, Fertilizers and Cement", financed by the United Nations Industrial Development Organization (UNIDO) and the Global Environmental Facility (GEF).

Within this project, energy efficiency benchmark curves were established. The methodology relates, for the most part, to the UNIDO methodology described in the UNIDO Working Paper "Global Industrial Energy Efficiency Benchmarking – An Energy Policy Tool, Working Paper, 2010". Furthermore, specific approaches for estimating energy saving potentials, for collecting data, for defining system boundaries and for checking the reliability of data were developed.

The main results of the study are the benchmark curves, the energy saving potentials and the energy saving scenarios. Following saving potentials were calculated:

- **Frozen efficiency**: No additional energy efficiency savings are made.
- **Baseline efficiency**: Energy efficiency improves at a rate of 0.5% a year.
- **BPT scenario**: All plants are operating at the current levels of BPT by 2030 and 2050.
- **BAT scenario**: All plants are operating at current levels of BAT by 2030 and 2050.

The table below shows the annual energy consumption of the iron and steel sector for the process steps EAF, hot rolling and hot strip rolling in 2012, 2030 and 2050 according to the four scenarios. Furthermore, the table shows the annual and cumulative energy saving potentials if all companies of the sector reach the BAT specific energy consumption in 2030 or 2050.

Year	Frozen Scenario (PJ/a)	Baseline Scenario (PJ/a)	BPT Scenario (PJ/a)	BAT Scenario (PJ/a)	Savings Frozen – BAT Scenario (PJ/a)	Cumulative Savings (Frozen-BAT) (PJ)
2012	40	40	40	40		
2030	69	63	60	50	20	172
2050	118	98	102	85	33	513

Acknowledgement

This report is one of a series of three benchmarking reports of energy intensive sectors in Egypt, namely; Cement, Iron & Steel and Fertilizers. The reports were developed by the United Nations Industrial Development Organization within the scope of the Industrial Energy Efficiency Project in Egypt (IEE). The project is funded by the Global Environmental Facility (GEF) and implemented by UNIDO in cooperation with the Egyptian Environmental Affairs Agency (EEAA), the Ministry of Industry and Foreign Trade of Egypt (MoIFT) and the Federation of Egyptian Industries (FEI).

The reports were developed under the overall responsibility and guidance of Rana Ghoneim and the coordination of Gihan Bayoumi. The Iron and Steel Sector Benchmarking Report was authored by Konstantin Kulterer and Ayman El Zahaby with inputs from Ashraf Zeitoun, Fatheya Soliman and Amr Osama.

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Contents

1 Introduction

The Egyptian industrial sector is responsible for approximately 43% of national final energy consumption and 33% of national electricity consumption (IEA, 2013). Overall industry-related emissions accounted for 29% of the total emissions in 2005 and are expected to increase their relative share to 36% by 2030 (McKinsey 2010).

The final energy consumption per unit of output in the most important industries in Egypt is typically 10 to 50% higher than the international average. Therefore, increased energy efficiency (EE) in the Egyptian industry has the potential to make a significant contribution to meeting the growing energy supply challenges facing the country.

1.1 UNIDO Industrial Energy Efficiency Program

Energy efficiency in industry contributes to decoupling economic growth and environmental impact while reducing industrial energy intensity and improving competitiveness. Industry is responsible for more than one third of global primary energy consumption and energy-related carbon dioxide emissions. Industrial energy use is estimated to grow at an annual rate of between 1.8% and 3.1% over the next 25 years. In developing countries and countries with economies in transition, the portion of energy supply (excluding transport) required for industry can be up to 50%. This often creates tension between economic development goals and constrained energy supply. Still, worldwide, the energy efficiency in the industry is well below the technically feasible and economic optimum. It has been estimated that the industry has the technical potential to decrease its energy intensity by up to 26% and emissions by up to 32% providing a striking 8.0% and 12.4% reduction in total global energy use and CO_2 emissions (IEA).

Improving energy efficiency in industry is one of the most cost-effective measures to help supply-constrained developing and emerging countries meet their increasing energy demand and loosen the link between economic growth and environmental degradation.

The UNIDO approach in energy efficiency is a holistic approach. It not only focuses on technical improvement, but also on improvement in policy, management, operations and financing. It introduces optimization of an entire energy system rather than optimization of individual equipment component. To ensure sustainability, it focuses on creating a well-functioning local market for IEE services.

1.2 Aim of the Project

The project seeks to address some of the key barriers to industrial energy efficiency (IEE), to deliver measureable results and to make an impact on how Egyptian industries manage energy through an integrated approach that combines capacity building and technical assistance interventions at the policy and energy efficiency project level.

Primary target groups of the project are industrial decision-makers (managers), engineers, vendors and other professionals and IEE policy-making and/or implementing institutions. The project will provide technical assistance to develop and help establish market-oriented policy instruments needed to support sustainable progression of Egyptian industries toward international best energy performance and to stimulate the creation of a market for IEE products and services.

The project will broaden knowledge and in-depth technical capacity for IEE with an emphasis on system organization and ISO energy management in industry, energy professionals and relevant institutions, such as the Egyptian Environmental Affairs Agency and other concerned institutions. The project will provide technical assistance, including energy audits, and support a limited number of pilot IEE projects with high replication and/or energy saving potential in the key industrial sectors to reach implementation.

The preparation of IEE benchmarking reports for the Cement, Iron and Steel and Fertilizers sectors is part of Component 1 of the IEE project.

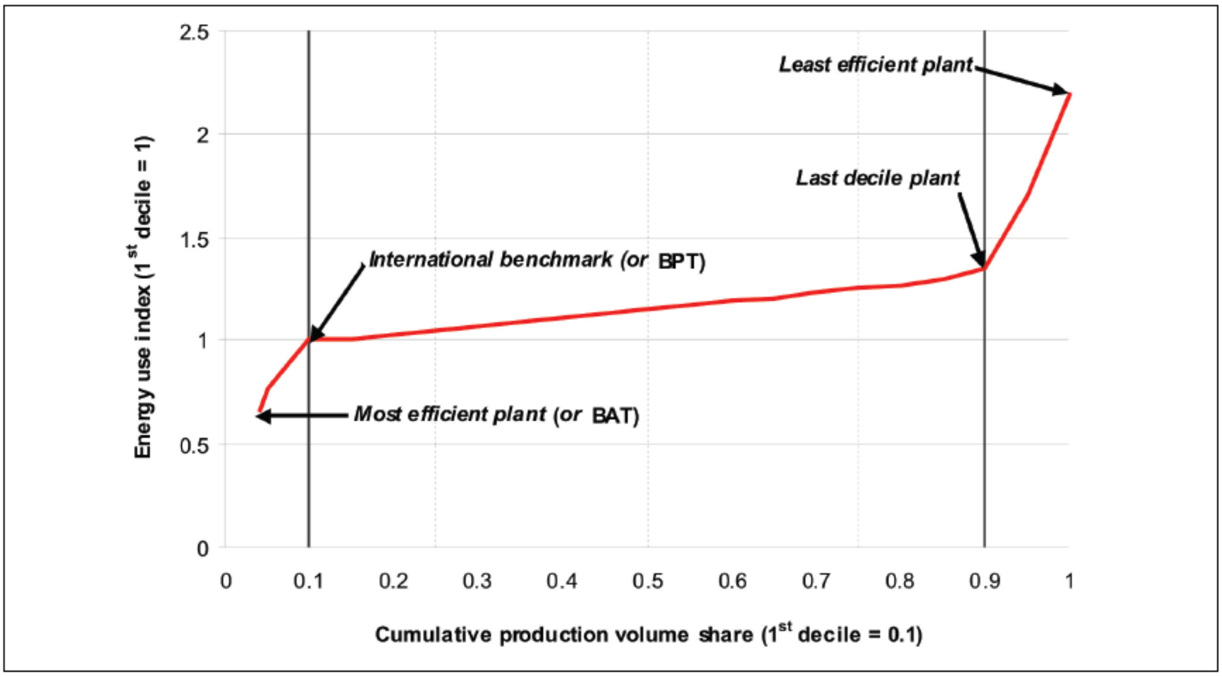
2 Methodology to Establish Benchmarking Studies

The methodology applied for establishing the benchmarking studies relates for the most part to the UNIDO methodology described in the UNIDO Working Paper "Global Industrial Energy Efficiency Benchmarking – An Energy Policy Tool, Working Paper, 2010". Furthermore the approach for estimating energy saving potentials, the data collection process, the definition of system boundaries and the process to check the reliability of data are part of the methodology and explained in this chapter.

2.1 UNIDO Benchmarking Methodology

According to the UNIDO Working Paper, a typical benchmark curve plots the efficiency of plants as a function of the total production volume from all similar plants or as a function of the total number of plants that operate at that level of efficiency or below.

Illustrative energy benchmark curve for the manufacturing industry



Note: SECs of the BAT, BPT, last decile and the least efficient plants according to this study are shown in the figure. Information on the *x* and *y*-axes has been indexed for simplicity. Normally the information would be plotted to show the specific energy consumption per unit of physical production against the cumulative production realised in the relevant year (in physical terms). The energy efficiency index for BPT is normalised to 1 for the 1st decile production share (*i.e.* the point on the *x*-axis equivalent to 0.1). More detailed explanations of the methodology are provided in the main text.

Figure 1: Illustrative Energy Benchmark Curve for the Manufacturing Industry (UNIDO, 2010)

The benchmark curve is described as follows: "The most efficient plants are represented to the left and lower part of the curve, and the least efficient plants to the right and higher part of the curve. The shape of benchmark curves would vary for different sectors and regions. However, typically a few plants are very efficient and a few plants are very inefficient. This is generally represented by the steep slopes of the benchmark curve before the first decile and after the last decile respectively." (UNIDO, 2010)

This relationship can be used to support a rough assessment of the energy efficiency potential for an industrial process, which is defined as 50% of the difference between the efficiencies observed at the first and last deciles.

The most efficient plants in the benchmark curve are used to define the Best Available Technology (BAT) and the Best Practice Technology (BPT). In the UNIDO Working Paper, the first decile is defined as the BPT and as the international benchmark. And the most efficient plant is defined as BAT.

Where possible, the analysis uses physical production levels to define the deciles. Where the lack of data makes such an approach inappropriate or unreliable, deciles are based on the number of plants.

The benchmark curves in the UNIDO Working Paper show energy efficiency benchmarks on a global level. And the data for country- or region-specific benchmarks came from statistics and further sources.

Depending on the data availability either

- the Energy Efficiency Index (EEI), or
- the average Specific Energy Consumption, also referred to as "Energy Performance Indicator" (EPI),

is calculated in the UNIDO Working Paper.

2.2 Drawing the Benchmarking Curves for Egyptian Industry

For the Egyptian benchmarking curves, data collected by national experts in companies of the three sectors were applied. This approach gives much more precise results. The data was checked by the national and international experts, system boundaries were kept and outliers were deleted.

Therefore, the results of the benchmarking studies can be applied to support improving the national data collection on energy consumption and production volumes.

2.2.1 System Boundaries for Benchmarking

In order to make the energy efficiency benchmarks of different companies comparable, the data used for calculating the EPI or EEI have to be defined very clearly. Following questions have to be considered:

- Where is the boundary around the company? Is the truck fleet included? Is the storage of final products included? Is the transport and shipment of final products included, etc.?
- How to deal with the input of energy consumption? How to deal with data about on-site energy production in combined heat and power plants (CHP), or in photovoltaic (PV) plants, etc.?
- What about energy services not produced on-site but purchased? Like purchased compressed air or purchased steam?

- How to deal with raw material input and semi-finished products input (some plants produce the semi-finished products on-site, others purchase them, etc.)?
- What about final products which were not produced on-site, but are packed on-site, etc.?

The better the system boundaries are defined, the more the benchmarking will be a comparison of “apples to apples”.

For the iron and steel industry, several process routes for the production of liquid steel and further for the production of semi-finished and finished products are available.

The main two process routes are (depending on the kind of process for steel production):

- Electric arc furnace route (main route for Egypt)
- Basic oxygen furnace route (only one plant in Egypt)

The principal production process in the iron and steel industry are shown in the following figures:

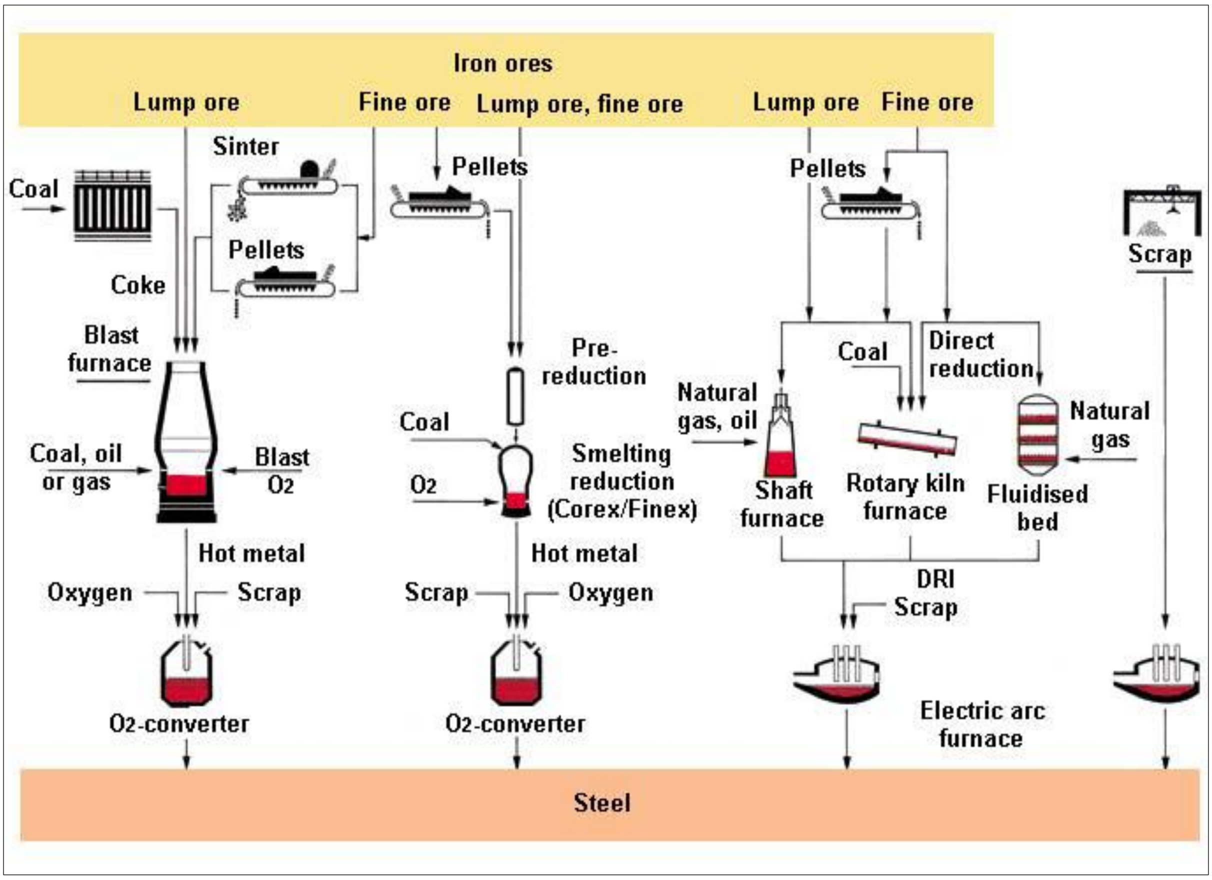


Figure 2: Crude Steel Production Methods ((European Commission, 2013) page 9)

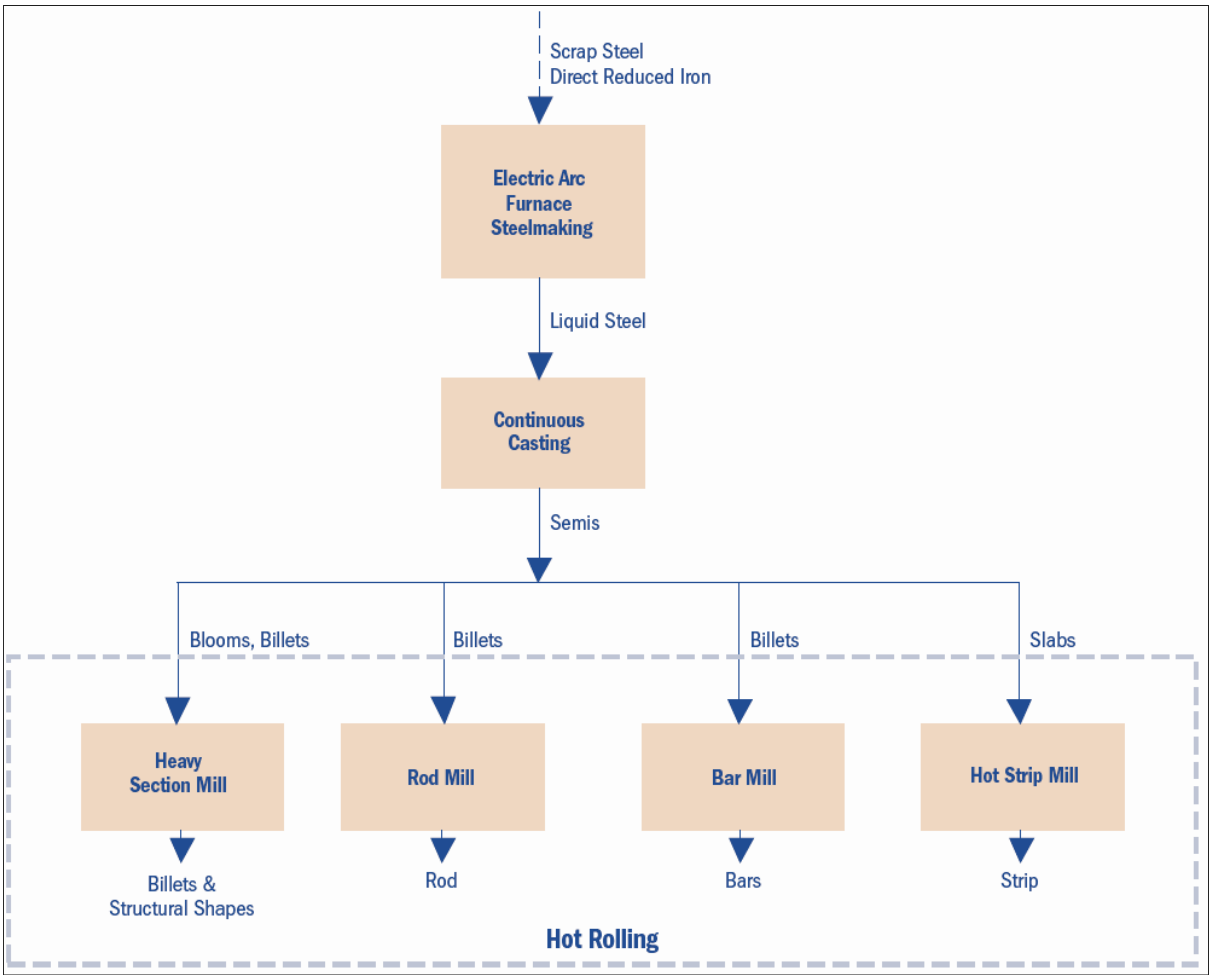


Figure 3: Electric Arc Furnace Plant – Flow Diagram ((Natural Ressources Canada, 2007), page 58

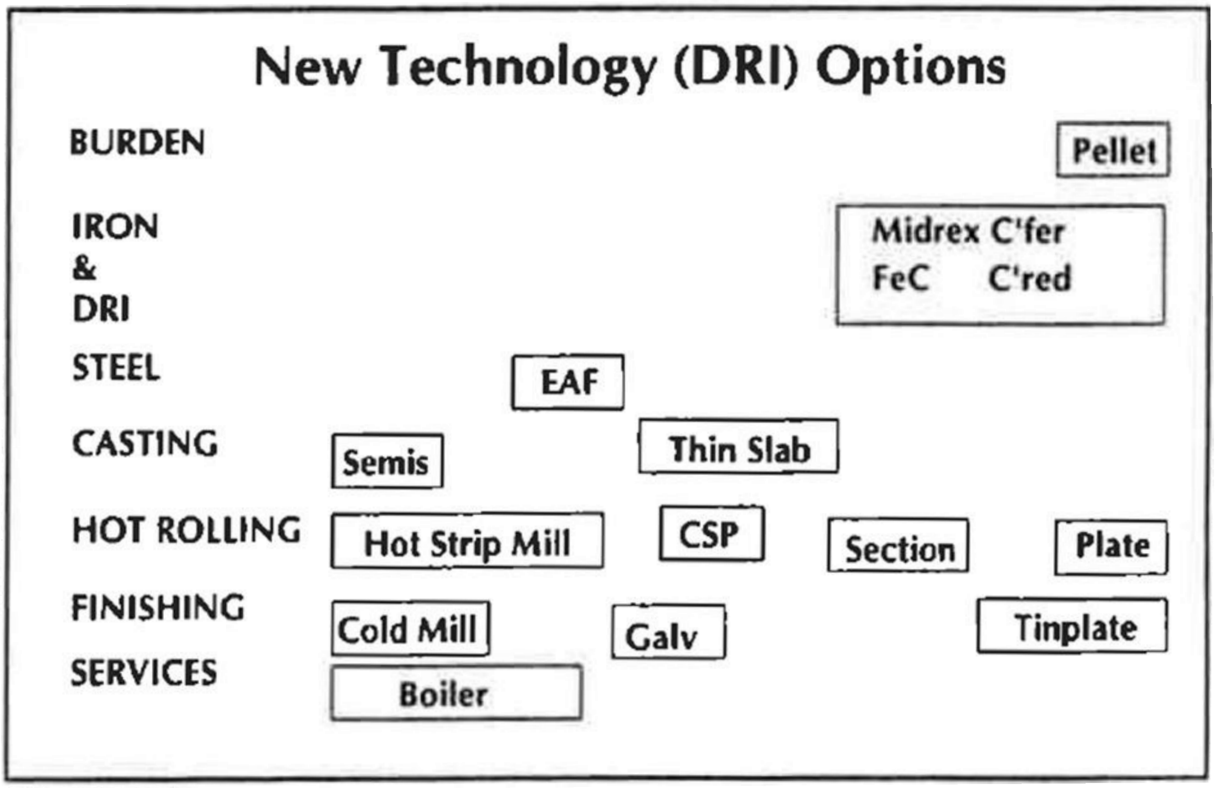


Figure 4: Processes for the New Technology Option (International Iron and Steel Institute, 1998), page 248

It was agreed upon that during the data acquisition as much data as possible on input/output of material and energy and on processes on site would be collected. This is especially necessary for knowing afterwards which materials and pre-products are produced on-site, which processes are applied and which semi-finished and finished products are produced.

Unfortunately, the exact system boundary is not described in most studies. Furthermore, a lot of benchmarks on the national level, mix energy consumed by the electric arc furnace route and the basic oxygen route and do not consider the share of scrap. The share of scrap used in electric arc furnaces for steel production is especially important: If scrap instead of direct reduced iron is used, the energy consumption for the production is considerably lower.

In principal, international benchmarks are available only on GJ/t crude steel produced, but this value also includes the energy consumption for the production of finished (rolled) products.

Therefore, it is necessary to include all processes for rolling.

During the kick-off meeting, the following suggestion for system boundaries or in this case processes to be included in the study within the iron and steel industry was made:

- Coke production
- Metal ore roasting and sintering
- Production of pig iron or steel
- Continuous Casting/Near Net Shape Casting
- Re-heating furnaces
- Hot Rolling (Hot strip mill, Plate mill, Section mill)
- Finishing (Cold Rolling, Galvanizing)

As not all processes are relevant for Egypt, the final system boundary was defined later on when it was clarified which processes should be included. The following processes were included in this study: production of direct reduced iron, electric arc furnaces, continuous casting, casting and rolling (hot rolling and hot strip rolling), incl. finishing.

For process benchmarking it is necessary to have the benchmarks per product of the specific process and not (only) per liquid steel. Therefore, it was agreed that inputs and outputs for the different processes would also be collected by the national expert and would be illustrated in some cases using a diagram.

For semi-finished products, the following products were collected:

- Direct Reduced Iron
- Liquid Steel
- Slabs
- Blooms
- Billets
- Thin slabs

For finished products:

- Reinforcing bars
- Coils
- Plates

Furthermore for this study, the following system boundaries and procedures for deriving benchmarks were defined:

Oxygen Production

The oxygen production is outsourced in several cases. The amount of energy needed for the production of oxygen will be added to the total amount of energy with a value of 650 Wh/Nm^3 Oxygen produced (Natural Ressources Canada, 2007) page 92.

Fuel Transport, Other Transport

- Storage of imported material at the harbor as well as their transport to the plant are outside system boundary (for benchmarking)
- Fuels for transport between production halls and processes (so far not considered), is not included in studies mentioned above ((Natural Ressources Canada, 2007), (International Iron and Steel Institute, 1998)

Different On-Site Processes

For comparison with international benchmarks for companies not having all processes on-site:

- The international benchmarks will be derived by summing up only those processes which are used on-site:
    - Example: As the material preparation is not done on-site (in (Worrell, Price, Neelis, Galitsky, & Nan, 2008): 2.5 GJ/t for this step), this value will not be included in deriving the international benchmark, when comparing to it.

Different Share of Scrap Used in International Benchmarks

- International benchmarks are available for EAF plants using 100% scrap and 40% scrap of total input material. For the plant with different amount of scrap used in the process (e.g. 20%) this value will be derived by extrapolating these values.

Different Casting Processes Used on the Same Site

Two companies have different casting processes on the same site: continuous casting and thin slab casting.

For comparison with international level, the international BAT value will be calculated using the share of the produced tons for the different lines:

- E.g. thin slab casting: the values 0.2 GJ/t for thin slab casting and 1.9 GJ/t for continuous casting and hot-rolling bars will be multiplied with the percentage production on thin slab casting line and the percentage production on hot rolling line respectively.

Different Energy Sources Used on Process and Company Level

Benchmarking on process-level as described above implies that for some facilities (e.g. water treatment) energy consumption is not considered on the process level. So when the different processes are summarized, the whole energy consumption is lower than for the whole plant.

Purchased or Sold Products

- In some plants, a part of the semi-finished products is purchased.
- One plant sells semi-finished products.

For data correction, the following procedure will be used:

Total energy corrected = total energy + energy consumed to produce purchased semi-finished products

Total production corrected (meant liquid steel in this case, which is a pre-product) = amount of purchased semi-finished products * correction factor (bigger 1 to reflect amount of liquid steel needed to produce amount of purchased semi-finished products) + liquid steel (reported for this plant)

Energy consumed for purchased semi-finished products (billets) = specific energy consumption for producing semi-finished products (e.g. EAF plus casting) * amount of purchased semi-finished products (e.g. billets)

2.2.2 Approach for Data Collection in Companies

Data from individual companies from the last available three years was collected. This data shows the trend in the development of energy consumption and production and allows defining the most representative EPI of the plant to be used for the benchmark curve.

For the data collection, the Austrian Energy Agency developed a data collection sheet specific for these sector. It was presented during the kick-off meeting in February 2014 and was discussed with the national expert. Based on this discussion, the template was improved further by the AEA and the national expert in the following weeks via email correspondence. In addition, the national expert included further calculations after several site visits.

Two different kind of data collection sheets were developed:

- detailed data collection sheet to be used for companies which were visited by the national expert
- simplified data collection sheet to be used for companies contacted by phone and email

For iron and steel sector it was decided to collect data not only on the company level, but also on the process level. In the data collection sheets in addition to input-output data, information on the status of energy management and implemented energy saving measures was included.

The detailed collection file contains the following excel sheets:

- General information
  - Basic information of the company
  - Collected data: plant capacity and plant production [t], number of shifts, hours of operation per year, etc.
- Technical information
  - Detailed information on kind of processes, total capacity, thermal consumption and power installed
- Input data
  - Assessment of input flow
  - Collected information: primary energy input, conversion factors, raw materials and semi-products, e.g. scrap, direct reduced iron, liquid steel, oxygen, slabs, billtes
- Output data
  - Assessment of output flow
  - Collected information: amount of produced end and semi-products per year, e.g. slabs, blooms, billets, coils, plates, bars
- Energy management
  - Information about implemented energy management systems
  - Collected data: responsible person for energy management, energy meters/sub-meters installed, energy efficiency targets available, planned energy saving measures, etc.
  - Resulting information: assessment of existing or possibility of establishing an energy management system
- Implemented energy efficiency measures
  - Written information of energy efficiency measures

The data sheets developed are presented in the Annex.

2.2.3 Selection of the Companies for Data Collection

The national team in Egypt organized a workshop on the benefits of benchmarking on the 27th of February 2014 in Cairo. The purpose of the workshop was to introduce the concept and benefits of benchmarking to the participating industries in order to ensure their active participation.

Only companies that were selected to be part of the benchmarking activities were invited to the workshop. The number of companies that were invited is 23 for cement industry, 21 for iron & steel industry and 9 for the fertilizers sector. In addition, several representatives from project partners attended and there was a high participation from the IDA.

For the iron and steel sector, the following table lists all the plants that are registered in the sector according to a list received from the IDA.

Table 1: Overview on Enterprises in the Iron and Steel Sector in Egypt (Including Main Products, Production Capacities and Processes and Contact Status for the Study)

Enterprise	Governorate	Product	Licensed Production (t/Year)	Process
Ezz dekheila steel	Alexandria	Wires, Rebar,	1,750,000.0	DRI-EAF-Rolling
Ezz dekheila steel	Alexandria	Plates	1,000,000.0	DRI-EAF-Rolling
Marakby Steel	Giza	Rebar	180,000.0	Rolling
Egyptian American steel rolling	Menoufia	Rebar	750,000.0	EAF-Rolling
Delta Steel	Cairo	Wires	64,122.0	EAF-Rolling
Suez Steel industries co. - Solb Misr	Suez	Billets	800,000.0	DRI-EAF-Rolling
Suez Steel industries co. - Solb Misr	Suez	Wires, Rebar	800,000.0	DRI-EAF-Rolling
National Portsaid Steel company	Portsaid	Rebar	350,000.0	Rolling
Ezz Steel	Menoufia	Rebar	750,000.0	EAF-Rolling
Sarhan steel - Mostafa sarhan sons	Alexandria	Rebar	40,000.0	Rolling
ElBahtimy steel rebars forming and forging	Alexandria	Rebar	35,000.0	Rolling
Modern steel forming	Alexandria	Wires	22,500.0	Rolling
United Steel Company	Cairo	Wires	35,000.0	Rolling
Egyptian enterprise for metallic industries	Kalioubia	Wires	27,000.0	Rolling
Portsaid industries and engineering	Portsaid	Wires	142,000.0	Rolling
Al Attia Steel	Sharkia	Wires	100,000.0	Rolling
International Steel Rolling	Menoufia	Rebar	180,000.0	Rolling
Ezz for plates	Suez	Plates	1,200,000.0	EAF-Rolling
Egyptian Iron and Steel Company	Cairo	Sections	927,627.0	BF-BOF-Rolling
Egyptian iron and steel products	Suez	Rebar	110,000.0	Rolling
Egypt for industries - ESTAR	Giza	Rebar	100,000.0	Rolling
Misr for iron and steel – Hawary	Giza	Rebar	100,000.0	Rolling
Maadi Steel	Menoufia	Wires	100,000.0	Rolling
Abouzaabal for engineered industries	Kalioubia	Sections	12,710.0	Rolling
EzzRollingCompany	Sharkia	Wires	300,000.0	Rolling
Metad helwan	Cairo	Wires	28,000.0	Rolling
Medi-Steel iron products	Gharbia	Rebar	100,000.0	Rolling

Enterprise	Governorate	Product	Licensed Production (t/Year)	Process
Egyptian Steel company	Kalioubia	Rebar	157,000.0	Rolling
Temsah Iron and Steel	Kalioubia	Rebar	25,000.0	Rolling
Egypt Steel Group	Sharkia	Billets	200,000.0	Rolling
Demco	Sharkia	Rebar	75,000.0	Rolling
Misr National Steel Company	Suez	Rebar	300,000.0	Rolling
Suez steel industries	Suez	Rebar	150,000.0	Rolling
Alexandria for metals import and export	Beheira	Rebar	75,000.0	Rolling
Elbeheira industries and investment	Giza	Wires	150,000.0	Rolling

2.2.4 Schedule for Data Collection

In collecting the data, the following table illustrates the dates of the first on-site meeting as well as the date of receiving the first and the latest version of the data.

Table 2: Overview on Schedule of Data Collection

Code	Date of Visit	Date of First Data	Date of Last Revision of Data
I&S – 01	3/20/2014	3/24/2014	3/29/2014
I&S – 02	3/11/2014	4/1/2014	5/22/2014
I&S – 03	4/8/2014	6/1/2014	8/17/2014
I&S – 04	3/30/2014	5/29/2014	6/17/2014
I&S – 05		6/3/2014	9/11/2014
I&S – 06	6/4/2014	6/11/2014	6/11/2014
I&S – 09	4/9/2014	8/12/2014	8/12/2014
I&S – 12	3/30/2014	9/9/2014	9/9/2014

The eight contacted companies represent almost 76% of the total Egyptian production as will be seen later in Table 27. Other five companies were contacted, and they mentioned that they were not operating at the time of collecting the data either for plant relocation, renovation or other financial reasons. Two companies didn't accept to even respond to requests from the consultant of holding a meeting to illustrate the benchmarking project. The remaining companies were not reached due to the unavailability of their contacts, those companies were all of small installed capacity (less than 100 000 tons per company per year), and they are all working on rolling of imported billets.

2.2.5 Limitations of Data Collection and Barriers Encountered

Regarding the faced barriers, the iron and steel sector does not have a clear definition regarding which plants are to be considered in this sector and which process shall be our target: Some of the plants as well as governmental officers proposed to include only steel making plants (plants with blast furnace ovens, basic oxygen plants or electric arc furnaces) as they represent the major energy consumption. Other stakeholders suggested to include also hot rolling mills. Our final decision was to include all the plants with steel making facilities and study a sample from the rolling only plants in order to have a better understanding of the sector.

Another question was whether to include the small sized rolling only plants or not. The small sized plants were included.

After defining the target producers, achieving the contact details and establish a connection with the companies was another problem. Fortunately, the large producers had websites with correct contact information so we were able to send them faxes and emails to introduce them to the project. Then for the small companies the yellow pages were checked for their contact data and some of them were reached.

Another problem was to convince the companies to cooperate. For the large companies, they had a concern regarding the confidentiality of the data they were providing, so a confidentiality and non-disclosure agreement was prepared and signed with them. Some other companies (especially the rolling only companies) believed that the rolling process is not an energy intensive process, and shouldn't be considered in the study, while another portion of the rolling companies believed that they are already running at very high energy efficiency, pretty close to the BAT norms, thus the IEE project wouldn't be of any benefit for them. Their concerns were alleviated through several meetings and phone conversations where the direct and non-direct benefits from the project were illustrated. Luckily, we were able to convince some of them to cooperate.

For the small sized rolling mills, two companies were visited to check their process and data availability, it was concluded that they don't keep records for their actual consumption/production, thus making it very difficult to get that data from them.

Another problem was that not all the companies were still operating at the time of gathering the data. Around seven of the initially targeted plants were not operating either for financial reasons or due to the restless political situation in Egypt after the 2011 revolution.

Finally, there are few plants that are listed in the IDA by the legal name, while they are known in the market and on the web by the trade name. Linking the two names together was one of the faced limitations.

2.3 International Benchmarks for Comparison

The study "World Best Practice Energy Intensity Values for Selected Industrial Sectors" from the Berkeley National Laboratory provides world best-practice EPI for the production of iron and steel, aluminum, cement, pulp and paper, ammonia, and ethylene. Although the study was published in February 2008, and the data applied for the benchmarks are even older, the benchmarks will be used for a comparison with the Egyptian benchmarks.

For the iron and steel industry, the following Best Available Technology (BAT) and Best Practice Technology (BPT) have been identified.

2.3.1 International Best Available Technologies (BAT)

According to the Berkeley National Laboratory study, “World Best Practice Energy Intensity Values for Selected Industrial Sectors”, from February 2008, the BAT values given in Table 2-1 were identified for the iron and steel industry for the different production routes.

Table 3: Summary of World Best Practice Final Energy Intensity Values for Iron and Steel (values per metric ton of steel) for the Different Process Routes (Worrell, Price, Neelis, Galitsky, & Nan, 2008)

World Best Practice Final Energy Intensities	GJ/t liquid steel
Blast Furnace – Basic Oxygen Furnace – Thin Slab Casting	14.8
Smelt Reduction – Basic Oxygen Furnace – Thin Slab Casting	17.8
Direct Reduced Iron – Electric Arc Furnace – Thin Slab Casting	16.9
Scrap - Electric Arc Furnace – Thin Slab Casting	2.6

For more information, see Table 4, where the BAT values are given in more detail for each process within the different process/production routes.

Table 4: Summary of World Best Practice Final Energy Intensity Values for Iron and Steel (values per metric ton of steel) (Worrell, Price, Neelis, Galitsky, & Nan, 2008)

		Blast Furnace – Basic Oxygen Furnace		**Smelt Reduction-Basic Oxygen Furnace**		**Direct Reduced Iron – Electric Arc Furnace**		**Scrap - Electric Arc Furnace**	
		GJ/t	**kgce/t**	**GJ/t**	**kgce/t**	**GJ/t**	**kgce/t**	**GJ/t**	**kgce/t**
Material Preparation	Sintering	1.9	65.2			1.9	65.2		
	Pelletizing			0.6	19.0	0.6	19.0		
	Coking	0.8	28.6						
Ironmaking	Blast Furnace	12.2	414.9						
	Smelt Reduction			17.3	591.6				
	Direct Reduced Iron					11.7	399.6		
Steelmaking	Basic Oxygen Furnace	-0.4	-15.4	-0.4	-15.4				
	Electric Arc Furnace					2.5	85.6	2.4	80.6
	Refining	0.1	4.3	0.1	4.3				
Casting and Rolling	Continuous Casting	0.1	2.0	0.1	2.0	0.1	2.0	0.1	2.0
	Hot Rolling	1.8	62.5	1.8	62.5	1.8	62.5	1.8	62.5
Sub-Total		**16.5**	**562.2**	**19.5**	**664.0**	**18.6**	**633.9**	**4.3**	**145.1**
Cold Rolling and Finishing	Cold Rolling	0.4	13.7	0.4	13.7				
	Finishing	1.1	38.1	1.1	38.1				
Total		**18.0**	**613.9**	**21.0**	**715.8**	**18.6**	**633.9**	**4.3**	**145.1**
Alternative: Casting and Rolling	Replace Continuous Casting and Rolling with Thin Slab Casting	0.2	6.9	0.2	6.9	0.2	6.9	0.2	6.9
Alternative Total		**14.8**	**504.5**	**17.8**	**606.4**	**16.9**	**576.2**	**2.6**	**87.5**

For Egypt, the electric arc furnace route is most relevant and detailed data can be found in Table 5.

Table 5: World Best Practical Final and Primary Energy Intensity Values for Direct Reduced Iron – Electric Arc Furnace Route (values per metric ton of steel) (Worrell, Price, Neelis, Galitsky, & Nan, 2008)

Direct Reduced Iron – Electric Arc Furnace Route			kgce/t	GJ/t
Material Preparation	Sintering	Fuel	67.8	2.0
		Steam	-7.6	-0.2
		Electricity	5.1	0.2
		Final Energy	65.2	1.9
		Primary Energy	74.3	2.2
	Pelletizing	Fuel	15.6	0.5
		Electricity	3.3	0.1
		Final Energy	19.0	0.6
		Primary Energy	25.7	0.8
Ironmaking	Direct Reduced Iron	Fuel	440.9	12.9
		Electricity	-41.4	-1.2
		Final Energy	399.6	11.7
		Primary Energy	315.6	9.2
Steelmaking	Electric Arc Furnace	Fuel	19.2	0.6
		Electricity	57.8	1.7
		Oxygen	8.6	0.3
		Final Energy	85.6	2.5
		Primary Energy	202.9	5.9
Casting	Continuous Casting	Fuel	1.0	0.03
		Electricity	0.9	0.03
		Final Energy	2.0	0.1
		Primary Energy	3.9	0.1
Hot Rolling	Hot Rolling – Strip	Fuel	44.8	1.3
		Steam	0.7	0.02
		Electricity	10.2	0.3
		Final Energy	55.7	1.6
		Primary Energy	76.5	2.2
	Hot Rolling – Bars	Fuel	53.8	1.6
		Electricity	8.8	0.3
		Final Energy	62.5	1.8
		Primary Energy	80.4	2.4
	Hot Rolling – Wire	Fuel	57.3	1.7
		Electricity	13.5	0.4
		Final Energy	70.9	2.1
		Primary Energy	98.4	2.9
Total (based on hot rolling-bars)		Fuel	598.3	17.5
		Steam	-7.6	-0.2
		Electricity	34.6	1.0
		Oxygen	8.6	0.3
		Final Energy	633.9	18.6
		Primary Energy	702.7	20.6

Note: Primary energy includes electricity generation, transmission, and distribution losses of 67%.

It has to be noted that the source of the world best practical final and primary energy intensity values of Worrel et al. 2008, mentioned above, is a study published in 1998 by the International Iron and Steel Institute (International Iron and Steel Institute, 1998), esp. page 167 of this study.

In the JRC Reference Report Best Available Techniques (BAT) Reference Document for Iron and Steel Production, the energy consumption for electric arc furnaces is given in the following ranges:

Table 6: Input/Output Data for Electric Arc Furnaces Within the EU ((European Commission, 2013) page 429)

Energy	Unit	Value
Electricity	MJ/t liquid steel	1,454–2,693
Fuels	MJ/t liquid steel	30 –1,500

In this document, the specific energy inputs per produced direct reduced iron are also given depending on the manufacturer for the main production process:

Table 7: Characteristics of Commercially Available Direct Reduction Processes ((European Commission, 2013) page 524)

	Midrex	HyL III	Fastment/Inmetco	Finmet
Energy input (GJ/t product)	10.5	11.3	12.6	12.5

Furthermore, within the BAT document of the JRC, tables are available for other processes as electric arc furnaces and steelmaking and casting, but here only ranges and not BAT levels are provided.

2.3.2 International Benchmarking Curves

Within the UNIDO Report (UNIDO, 2010), an estimated benchmark curve for the iron and steel industry for 2005 is published. For each country, an EEI value is estimated that reflects the process mix and includes the production processes of the most important end products into which crude steel is further processed.

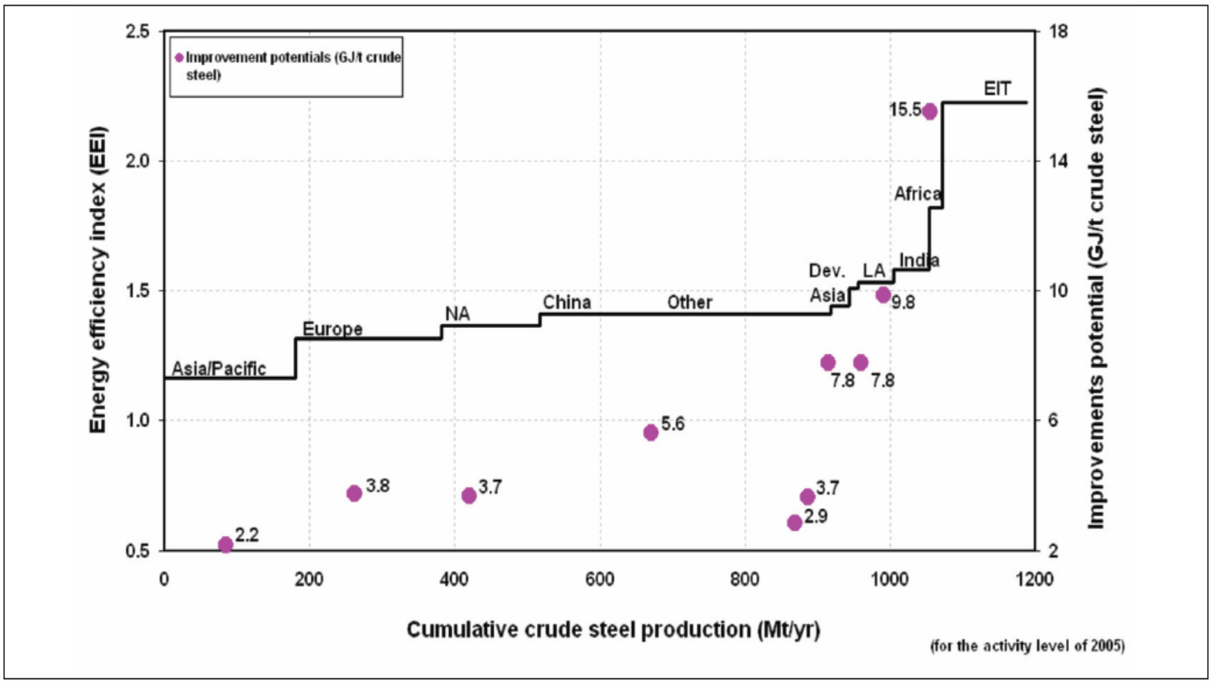
Processes:

- Blast Furnace (BF)/Basic Oxygen Furnace (BOF)
- Smelt reduction/Basic Oxygen Furnace (BOF)
- Direct Reduced Iron (DRI)/Electric Arc Furnace (EAF)
- Scrap/Electric Arc Furnace (EAF)

Products:

- Hot-rolled flat products
- Hot-rolled bars and concrete reinforcing bars
- Wire rod

The used best available technologies values for the different products and/or processes are not published within the report (UNIDO, 2010).



Note: The benchmark curve is based on the left hand y-axis. The dots show the specific improvement potentials in each region relative to BPT based on the right hand y-axis.

Figure 5: Estimated Benchmark Curve for the Iron and Steel Industry, 2005 (UNIDO, 2010)

In the German study “Zukunftsmarkt Energieeffiziente Stahlherstellung”, international benchmarks based on ENERDATA (a database for energy consumption on country and sector level) and World Steel data (for production) were published, in relation to the share of steel produced within electric arc furnaces. But it did not indicate the size of the share of DRI iron in relation to scrap input in the steel production.

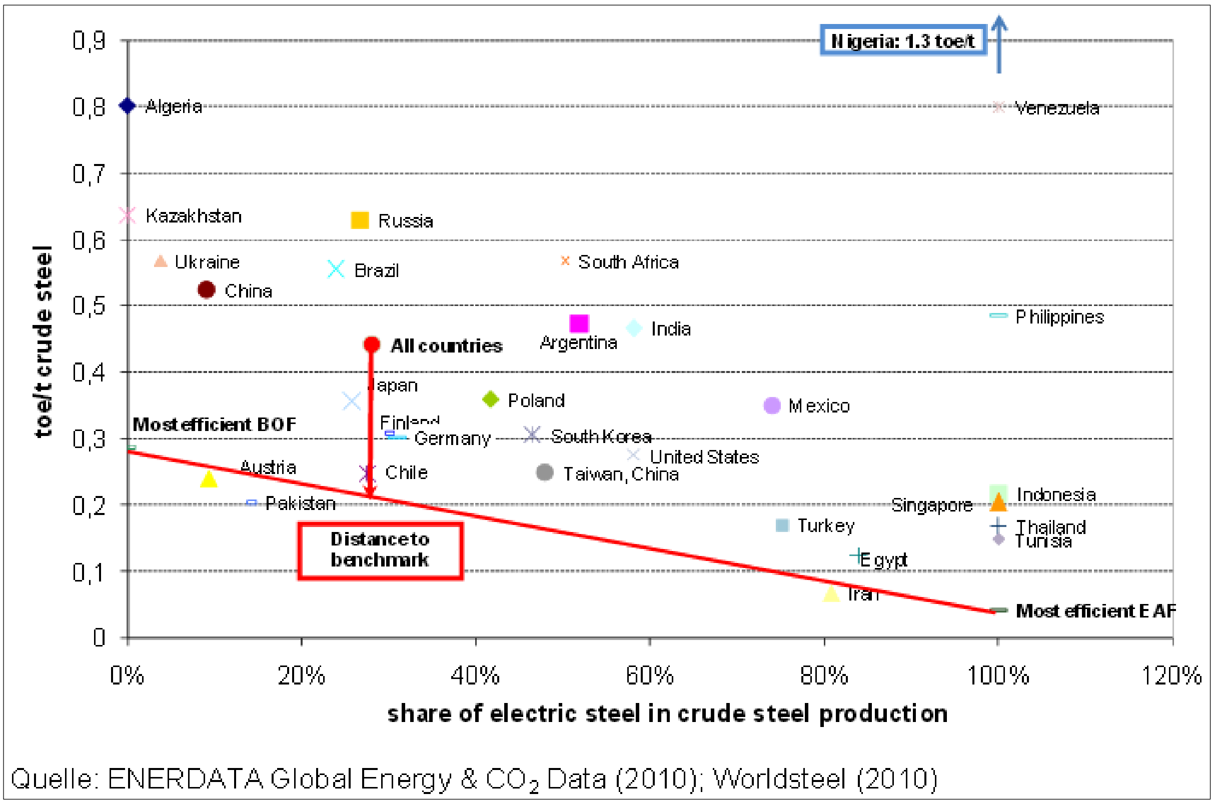


Figure 6: Specific energy Input Per Ton Steel, Depending on Share of Electric Produced Iron (EAF) of the Total Steel Production (2007) (Fraunhofer Institut für System- und Innovationsforschung (ISI), 2011) (http://www.isi.fraunhofer.de/isi-media/docs/e/de/publikationen/Fallstudie_Eisen-Stahl.pdf)

The World Steel Association collects data for the energy consumption and the GHG emissions for the iron and steel industry. The indicators are calculated using route-specific energy and CO_2-intensities for three steel production routes: basic oxygen furnace, electric arc furnace and open hearth furnace.

Figure 7: Energy Intensity and GHG Emissions (World Steel Association, 2013)

2.4 Approach for Estimating Energy Saving Potentials

The following chapter describes the methods for calculating the energy saving potentials for the iron and steel sector in Egypt. The results of this method are shown in Chapter 4.

2.4.1 Saving Potential of Participating Companies

The first type of saving potentials calculated was the saving potential of each company. Therefore the following method was used:

- For each participating company, the specific energy consumption (SEC) was calculated.
- The lowest SEC of all analyzed companies is defined as best available technology (BAT) and the second lowest SEC is defined as best practice technology (BPT).

Assumption for saving potentials of companies which participated on the benchmarking study:
All participating companies achieve the SEC of the company with the lowest SEC (BAT). The potential for each company will be calculated as:

$$\text{Potential of each company}(x) = 1 - \frac{BAT\ national}{\text{SEC}_x}$$

2.4.2 Saving Potential of the Whole Sector in Egypt

The second type of saving potentials calculated was the saving potential of all companies of the sector in Egypt. For this calculation the following data was necessary:

- The total annual production of the sector. This information was taken from the IDA data.
- The SEC of the total sector: As this information is not available, the project team defined the weighted average SEC of the analyzed companies in the current benchmarking project as SEC of the total sector. This assumption is eligible as the companies participated in the current benchmark project gave a good sample of the whole sector.

With this information the saving potential of the whole sector can be calculated with the same formula:

Potential of the Whole Sector = (International BAT – Weighted SEC of the Analyzed Companies) * Total Production of the Whole Sector

The saving potential of the whole sector is calculated with the lowest known BAT. This can be either the national BAT or the international BAT.

2.4.3 Saving Potentials for the BPT Scenario

In Chapter 4 different saving scenarios are shown. For the BPT scenario the lowest known BPT value was also taken. This value can either be a national or an international one.

2.5 Possible Sources on National Level

In the beginning of the project it was planned to establish in addition to the benchmark curves of individual companies, similar benchmark curves as in the UNIDO working paper by using national statistical data from the Industrial Development Authority (IDA) and the Central Agency for Public Mobilization and Statistics (CAPMAS).

During the project activities the Egyptian experts evaluated the data of IDA and CAPMAS and came to the conclusion, that the data is too outdated and in some cases not reliable. Therefore the project team decided not to establish benchmark curves with the statistical data.

2.5.1 Energy Consumption Data on National Level (Top-Down)

On the national level, the information about energy consumption of individual companies is collected by the Ministry of Electricity and Renewable Energy and by the Ministry of Petroleum. The ministries in charge of electricity and energy in Egypt collect accurate data from industrial companies on energy consumption on a monthly basis. As this data is not publicly available it requires approval from individual companies to be shared. Unfortunately, it was not possible to get the data for the UNIDO project. Basically the Egyptian government could establish benchmark curves with the energy consumption data from the ministry and the production data from CAPMAS.

Another source for energy consumption data on national level is the IDA. IDA is responsible for granting licenses for energy supply for industrial enterprises. If a factory starts its operation, it will get a contract and license for five years of energy supply from IDA. Therefore, IDA data reflect “planned energy consumption data” and not “metered energy consumption data”. Every five years the license for energy supply needs to be renewed that brings an update of the planned data of IDA.

The energy consumption would have been overestimated as it reflects the licensed energy supply, but knowing this, the curve would have given a first insight in the sectors’ specific energy consumption. As already mentioned, after a closer evaluation of the IDA and CAPMAS data it was decided not to use this data for establishing benchmark curves.

UNIDO's main counterpart is EEAA which represented the Ministry of Environment. The other project partners are the Industrial Development Authority (IDA), Industrial Modernization Center (IMC) and Egyptian Organization for Standardization (EOS) from the Ministry of Industry and Foreign Trade (MoIFT) and the Federation of Egyptian Industries (FEI).

2.5.2 Production Data on National Level (Top-Down)

For establishing benchmarks, data on annual production of the three sectors is also required. The federation of Egyptian industries – chamber of metallic industry- collected production and consumption data on sector level in 2010. The national expert met with the chairman of the chamber and acquired that data as illustrated in Table 8 below.

Table 8: Analysis of Data of the Federation of Egyptian Industries – Chamber of Metallic Industry

Statistical Data of 2010

Process	Actual Production (Million Tons)	Installed Production (Million Tons)	Natural Gas SEC (m3/t)	Electricity SEC (KWh/t)	SEC (GJ/t product)
DRI	3	5	300	100	11,682
EAF	5,5	8	20	550	2,735
Rolling	9,5	12	40	90	1,834
Received data: Actual production, Installed production, Natural gas SEC and Electricity SEC					
Analysis: SEC (GJ/t Product)					
Data source: Federation of Egyptian Industries - Chamber of Metallic Industries					

2.5.3 Company Data Collection (Bottom-Up)

The Egyptian experts collected the data according to the established data collection sheets from March till June 2014. From companies using four main production routes / processes data were received:

Table 9: Number of Companies for Which the Data was Included Within the Report

Production Routes /processes	Number of Companies
DRI/EAF/Rolling	1
EAF/Rolling	4
Rolling only	3

All those 8 companies filled out the detailed data sheet.

2.6 Process to Check Data Reliability

The data collected from the companies have been checked by the national experts and by the AEA experts according to their competence and branch-specific knowledge.

The calculated EPI were compared with international and national benchmarks and outliers were analyzed. Data sets containing not explicable substantial deviations from the average were excluded from the benchmark curve.

Plausibility check of data filled into the excel sheets, like:

- annual production hours in comparison to maximum annual hours
- production capacity to production output
- trend of energy consumption and production (3 years)
- total energy consumption / production (EPI)
- input/output balance (check semi-finished products, purchase of semi-finished etc.)
- check of reported measures

3 Basic Sector Information

3.1 Economic and Legislative Framework

The iron and steel industry is considered one of the most important metallurgical industries that assists in the industrialization and development of countries. The iron and steel industry was first introduced in Egypt during the 1940's. The aim at that time was to reuse the scrap left from the World War II and to convert it into steel reinforcement bars.

In the late 1950's, the first integrated steel complex was established in Helwan – Cairo governorate. That complex was considered the first plant that produced steel products from iron ore in Egypt. The raw material used was locally extracted from Aswan governorate - it was of low grade and rich in impurities. In the 1980's, another steel complex was installed at Dekheila – Alexandria Governorate. This plant produces steel from imported high grade pellets.

Lately, due to development projects, which resulted in a rapid increase on demand, Egypt's production of steel products showed a remarkable boom in the installed capacity; several mini-mills were installed to convert imported billets to long products.

There are two main routes for producing steel from iron ores: Blast furnace with basic oxygen furnace (BF-BOF, known as integrated plants) and direct reduced iron with electric furnace (DRI-EF, known as mini-mills). Figure 8 below illustrates the different routes of steel production.

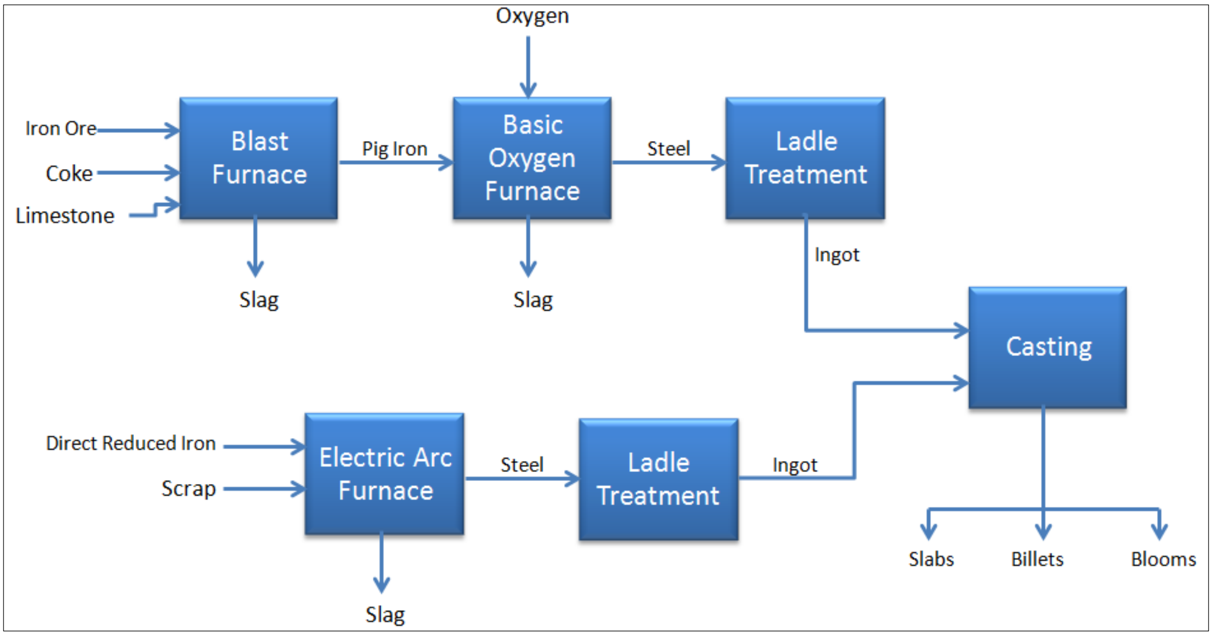


Figure 8: Simplified Iron and Steel Production Flow-Chart, (Worrell, Blinde, Neelis, Blomen, & Masanet, 2010)

The EAF route is more common for the Egyptian market as Egypt had surplus of electricity and natural gas for decades; this also encouraged investors and the government to issue new licenses for direct reduction facilities.

As a consequence of the revolution of 2011, power generation projects faced several drawbacks that can be summarized with the following words: lack of maintenance, shortage of fuel, as well as halting of new installations. This is due to the political and financial unrest conditions. Those drawbacks forced several projects to be postponed including the construction of new iron and steel production facilities that started at the end of 2010 and early 2011.

Other than the delay of new facilities, the existing facilities also faced shortage of energy problems, as the country's generated electricity was below the consumption, hence the government attempted to reduce the power supply to energy intensive plants during peak hours in order to sustain the supply to residential and commercial facilities. This led to a drop of four hours per day in the electricity supplied to steel making plants to almost half their contractual demand.

Moreover, as most of the fuel was directed to the power plants (natural gas and fuel oil), the supply to the plants was decreased below their contractual demand.

3.2 Number of Companies and Ownership

The production of the iron and steel industry can be viewed as three main products: iron, steel and end-products. For Egypt, the installed capacity for each of those main products was estimated as:

Table 10: Egyptian Installed Capacity for Main Products

Product	Number of Plants	Installed Capacity (t)	Share of End Production (%)
DRI	1	3,000,000	26
Pig Iron	1	1,000,000	9
Steel	8	7,265,122	62
Long products	25	8,818,122	75
Flat products	3	2,709,000	23
Sections	2	229,710	2
Total	**32**	**11,756,832**	**100**

The production of iron in either the form of pig iron or direct reduced iron is limited due to the unavailability of the raw material (iron ore) and the production facilities. By the end of August 2014, there are only two plants running with direct reduction facilities, but as one of them was commissioned in 2013, its data was not included in this report. Moreover, there is one plant running with pig iron production (blast furnace). There are three additional direct reduction plants that are under construction and are expected to be commissioned early 2015.

Pig iron and direct reduced iron are considered as the input to the steel making plants; however, not all the input to the steel making is virgin iron as it can be substituted by scrap, and that is the case for most of the Egyptian industries where the ratio between the used direct reduced iron to the used scrap was almost 47% DRI to 53% scrap among the studied plants. In the steel making plants, the input mix (DRI + Scrap + pig iron) is transformed to steel via the reduction of the carbon content and the removal of other impurities to form steel which is then cast to billets, slabs or thin slabs depending on the desired end product. In Egypt, there are currently seven facilities running with the electric arc furnaces as their steel making plants, and one plant running with both the electric arc furnace and basic oxygen furnace as the steel making plant. Other plants are currently installing electric arc furnaces that shall increase the value added to their production facilities and reduce the dependence of the sector on the import of billets.

As cast steel is not a useful product, it shall undergo further processes to be transferred to useful end products. The three available forms of end products in Egypt are long product (rebars and wire rod), flat products, and sections. The long products represent the majority of the Egyptian production with an installed capacity of around 75% from 25 plants, followed by the flat production with an installed capacity representing 23% from three plants, whereas the sections are only produced in two plants and with very low quantities that can thereby be neglected (almost 2% of the total production).

On the other side, due to the political and economic situation that occurred in Egypt after the 25^{th} of January revolution, and the increase in the prices of imported billets, a few number of the rolling mills decided to close their production facilities either temporarily or permanently.

The ownership of the iron and steel production companies is mainly for the private sector with three major enterprises holding around 75% of the installed capacity, while the state-owned companies represent 11% of the installed capacity.

The tables below list the iron and steel registered companies with their installed capacities as well as the ownership. The indicated capacities are based on data received from the IDA, however some of the contacted companies mentioned different installed capacities from those indicated in the IDA data, hence they were updated in the tables. Each table illustrates the production of one main product.

Table 11: Iron Production Plants and Their Ownership

Plant	Ownership	Process	Iron Installed Capacity (Thousand Tons)
Egyptian Iron and Steel Company	State owned	Blast Furance	1,000
Ezz dekheila steel	Private	Direct Reduction Plant	3,000

Table 12: Steel Making Plants and Their Ownership

Plant	Ownership	Steel Installed Capacity (Thousand Tons)
Ezz dekheila steel	Private	3,000
AlEzz Flat Steel	Private	1,200
Egyptian American steel rolling	Private	1,000
Ezz Steel	Private	800
Suez steel co.	Private	800
Egypt Steel Group	Private	200
Delta Steel	State Owned	64
Egyptian Iron and Steel Company	State Owned	201

Table 13: Rebar Producing Plants and Their Ownership

Plant	Ownership	Rebar Installed Capacity (Thousand Tons)
Marakby Steel	Private	180
Ezz dekheila steel	Private	1,750
AlEzz Flat Steel	Private	1,200
Egyptian American steel rolling	Private	1,000
Ezz Steel	Private	1,000
Misr National Steel Company	Private	300
Egypt for industries - ESTAR	Private	100
National Portsaid Steel company	Private	350
Suez steel co. - Solb Misr	Private	850
Egyptian iron and steel products	Private	110
Metad helwan	Private	28
International Rolling Mills Co.	Private	500
Ezz Rolling Company	Private	500
Demco	Private	75
Sarhan steel - Mostafa sarhan sons	Private	40
ElBahtimy steel rebars forming and forging	Private	35
Delta Steel	State Owned	64
Egyptian enterprise for metallic industries	Private	27
Temsah Iron and Steel	Private	25
Egyptian Steel company	Private	157
Maadi Steel	Private	100
Al Attia Steel	Private	100
Suez steel industries	Private	150
United Steel Company	Private	35
Portsaid industries and engineering	Private	142

Table 14: Flat Producing Plants and Their Ownership

Plant	Ownership	Flat Products Installed Capacity (Thousand Tons)
Ezz dekheila steel	Private	1,000
AlEzz Flat Steel	Private	1,200
Egyptian Iron and Steel Company	State Owned	509

3.3 Production Capacities

The total annual installed capacity of the steel final products in Egypt was estimated to be around 11 million tons. However, even though the 11 million tons are for final product form, the quantity of raw material and intermediate products are completely different as there are only two plants with the capability to convert the raw material (iron ore or pellets) to final products. Other plants depend on importing scrap to be converted to steel and then final product, or import billets to be converted to final products. Table 10 illustrates the great variation in the installed capacities for each process.

Chapter 3.3.1 and several subsequent subchapters list the definition of intermediate and final products, as well as the actual production capacity for each product based on published data.

3.3.1 Main Products

Throughout the iron and steel production process, iron takes different forms. The definitions of these different forms are indicated in the first part of this chapter. The second part discusses the quantities produced and imported from the intermediate products as well as the final products which are sold to consumers.

3.3.1.1 Definitions for Different Forms of Iron and Steel

Iron Ore: Naturally occurring rocks and minerals that are rich in iron as iron oxides**.** The iron oxide can be in the form of hematite (Fe_2O_3) or magnetite (Fe_3O_4). Iron Ore is the main raw material for the iron production. However, for improved iron content and physical properties, it needs to be processed to form sintered iron ore or pellets before being introduced to the iron-making equipment.

Sintered Iron Ore: It is produced by mixing and combustion of iron ore fines with other iron bearing wastes and coke dust. This leads to fusion of the fines to form coarse lumps that can be fed to the blast furnace (BF).

Pellets: Iron ore when crushed, ground, mixed with binding agent and heated form durable marble-sized pellets that are suitable as feed material for both BF and DRI.

Pig Iron: Cast molten iron that is allowed to go cold to solidify. Pig Iron can be used as a high quality scrap substitute. Pig iron is produced in the BF through the reduction of the oxygen from the iron ore via the oxidation of carbon monoxide from the combustion gases (indirect reduction) and the carbon from the coke (direct reduction). This process involves a shaft furnace, where iron ore, coke and limestone (fluxing agent) are fed from the top part, and hot air for combustion is introduced from the bottom part. The counter-current movement of the iron ore and coke lead to the combustion of coke and the reduction of iron ore to metallic iron and slag (a collecting of the fluxing agent and the residual components of iron ore and coke) (Laboratory & Institute, 2010).

Direct Reduced Iron (DRI): The other alternative way for reducing iron ore to metallic iron is by the direct reduction using reducing gas to produce direct reduced iron. The reducing gas is either CO or H_2. Most of the DRI is produced in counter-current shaft furnaces, similar to the blast furnace. In this furnace, iron ore is introduced from the top of the furnace in the form of pellets, while the reduction gasses are preheated in an external heat exchanger and introduced in the middle of the furnace. Most operating DRI use natural gas as the reduction gases (Laboratory & Institute, 2010).

Ladles (molten steel): They are produced as a transition product to convert the iron into tough and tenacious refined steel, where iron from BF or DRI undergoes several treatment processes to eliminate the carbon and unwanted elements. Ladles are produced either by the Electric Arc Furnace (EAF), where the majority of the raw material is scrap steel, or by the Basic Oxygen Furnace (BOF), where the majority of the raw material is pig iron. The output from both types of furnaces as molten steel is tapped into ladles and delivered to be cast in semi-finished products.

Ingots, slabs, blooms and billets: They represent different forms of semi-finished products. They are produced in casting yards or through continuous casting. In casting yards, ladle transferred from the furnace is poured into an ingot casing to solidify, then the casing is removed and the ingot is sent to primary mills to be rolled into slabs, blooms or billets. In continuous casting, the ingot production is eliminated, and the steel proceed directly to the rolling or forming while retaining significant heat, thus reducing the downstream reheat cost and time.

Rolled products: Even though the semi-finished products can find a market for their sale, this market is limited to the trade between steel producers. Rolled products are sold to the construction or fabrication entities. They include steel plates, pipes, coils, bars, rods and sections. Various forms of the finished products depend on the finishing process, where hot rolling semi-finished products are heated to over 1,000^{o}C, before they pass through a multiple set of rollers to reduce their thickness to the set thickness while increasing in length and width. In cold rolling, the hot rolled product is further rolled at ambient temperature to improve the surface finish and the strength. Forming is similar to hot rolling, but the rollers have special shapes to produce bars, rods or sections.

Finished products: Rolled products can be one form of finished products. For some cases, rolled products are subject to further finishing processes to satisfy special physical specifications. Finishing processes include pickling (acid treatment), heat treatment (tempering), quenching or coating.

3.3.1.2 Production

As mentioned in Chapter 3.2 of this report, there is only one company having the BF-BOF technology and consequently, the amount of pig iron is limited to the capacity of that company. Similarly, for the DRI, as it is produced from only one company, its quantities are limited to the production capacity of that company. For the other facilities, scrap, and billets are imported for the production of final products.

From statistical data, the actual production of crude steel increased in Egypt from around 4.4 million tons in 2003 to over 6.6 million tons in 2012 with an increase rate of 4.7% annually as illustrated in Table 15 and Table 16 below. This increase is mainly due to the introduction of new facilities.

Through reviewing the split of the produced steel between the BOF and the EAF, it appears that the productivity of the BOF in 2012 showed a decrease of almost half the production of 2003, with a maximum of 1,300 tons recorded in 2006, whereas the production from the EAF process showed an increase from the 2003 production by almost 100% in 2012. This implies that more plants and licenses are issued using the EAF technology for its suitability to the sources of energy available in Egypt.

Table 15: Egyptian Crude Steel Production trend (Source: (World Steel Association, 2013b))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Crude Steel Production, Thousand Tons	4,398	4,810	5,603	6,045	6,224	6,198	5,541	6,676	6,485	6,627
BOF Crude Steel Production, Thousand Tons	1,150	1,280	1,100	1,300	1,000	900	840	600	545	530
EAF Crude Steel Production, Thousand Tons	3,250	3,530	4,500	4,750	5,225	5,300	4,700	6,075	5,940	6,100

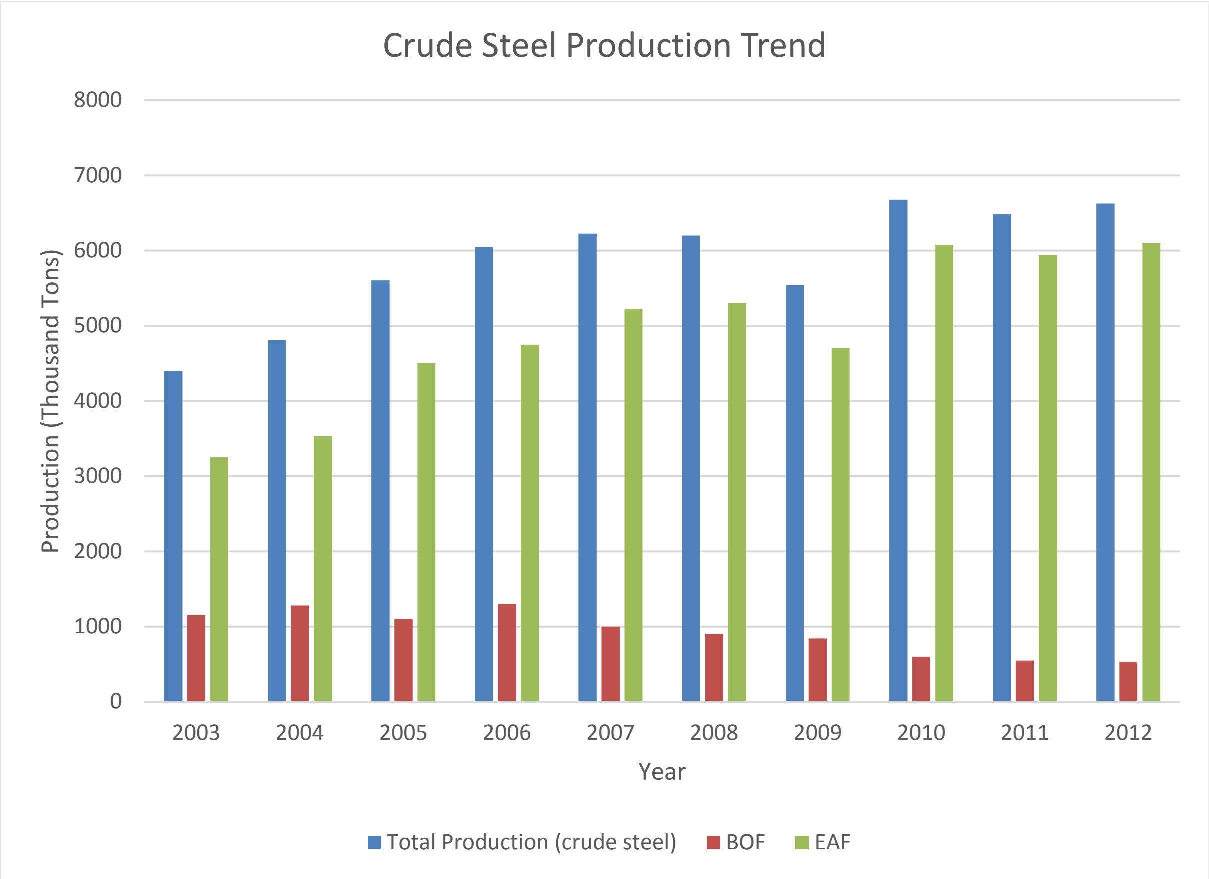


Figure 9: Crude steel Production Trend

Regarding the iron input to the steel making plants, namely BOF and EAF, the statistics for iron use are illustrated in Table 16 and Figure 10. It should be noted that the convention is to use the pig iron as the input to the BOF, and use scrap together with the direct reduced iron as input to the EAF. For that convention, the increase in the import of scrap and the decrease in the production of pig iron are in line with the decrease in the steel production from the BOF and the increase in the EAF capacities, while keeping the direct reduction capacities more or less constant at the installed production capacity.

Table 16: Egyptian Trend of Iron Use (Source: (World Steel Association, 2013b))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pig Iron (Thousand Tons)	1,080	1,000	1,100	1,100	1,000	900	800	600	600	550
Direct Reduced Iron (Thousand Tons)	2,870	3,020	2,900	2,800	2,786	2,643	3,051	2,965	2,932	3,068
Imported Scrap (Thousand Tons)	543	1,045	1,226	2,244	2,274	1,457	1,269	1,950	2,612	1,975

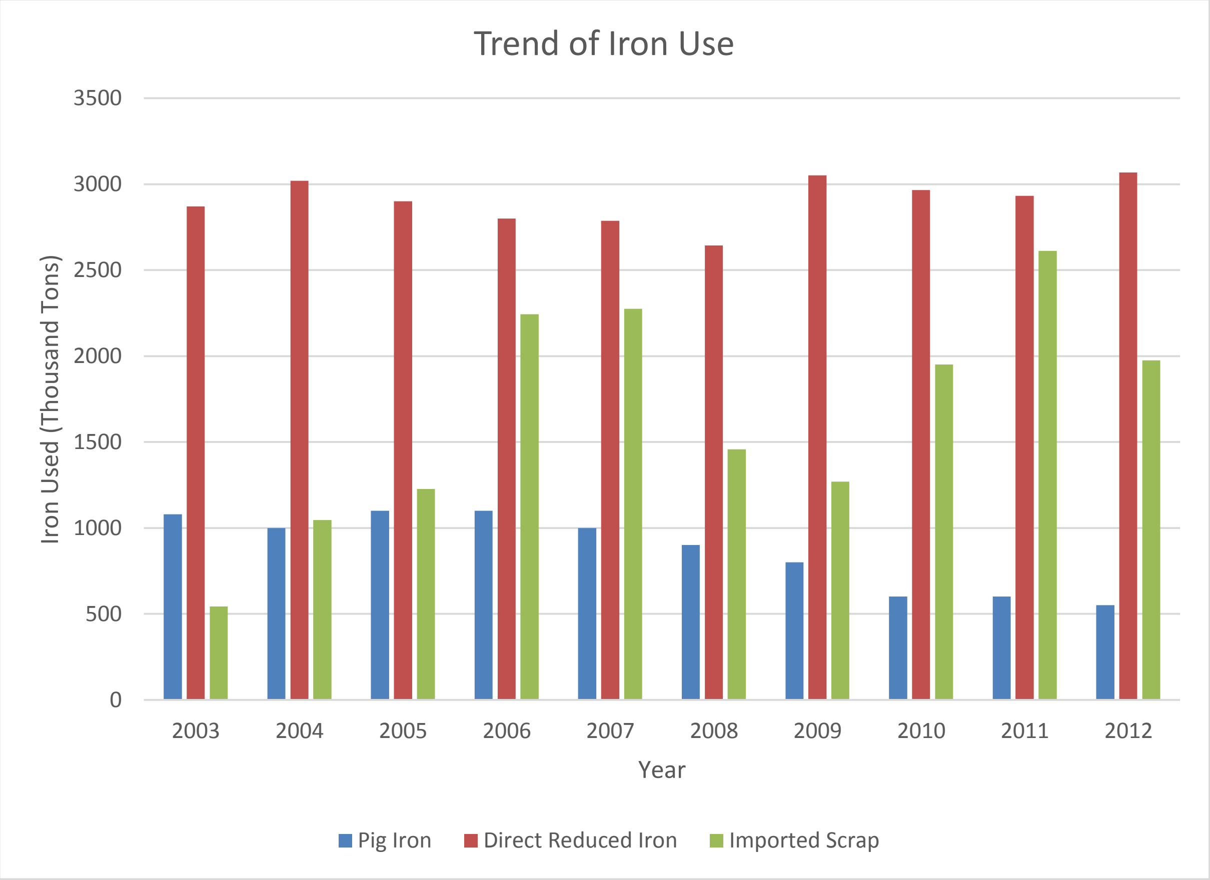


Figure 10: Trend of Iron Use

The actual production of the hot rolled products, which represent the final product from the iron and steel industry, is illustrated in Table 17. Hot rolled products are classified into long products which include the steel rebars (reinforcing bars) and wire rods, and flat products which can be either in coil form or flat plates.

From the statistical data, it can be concluded that the total production increased by almost 40 % in 10 years with its peak in 2010 reaching 7,939 tons/year, the long products increase was almost 78 % with its peak in 2010 as well with a production of 6,302 tons/year, while the flat products decreased by 40% for the same period with the peak of flat products at 2006 and 2007 with 2,095 tons/year and 2,061 tons/year.

Table 17: Egyptian Final Steel Production Trend (Source: (World Steel Association, 2013b))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Hot Rolled Products (Thousand Tons)	5,200	5,100	6,800	6,420	6,687	6,766	6,352	7,939	6,588	7,265
Long Products (Thousand Tons)	3,500	3,400	4,800	4,326	4,626	5,037	5,200	6,302	5,426	6,229
Flat Products (Thousand Tons)	1,700	1,700	2,000	2,095	2,061	1,729	1,152	1,637	1,162	1,036

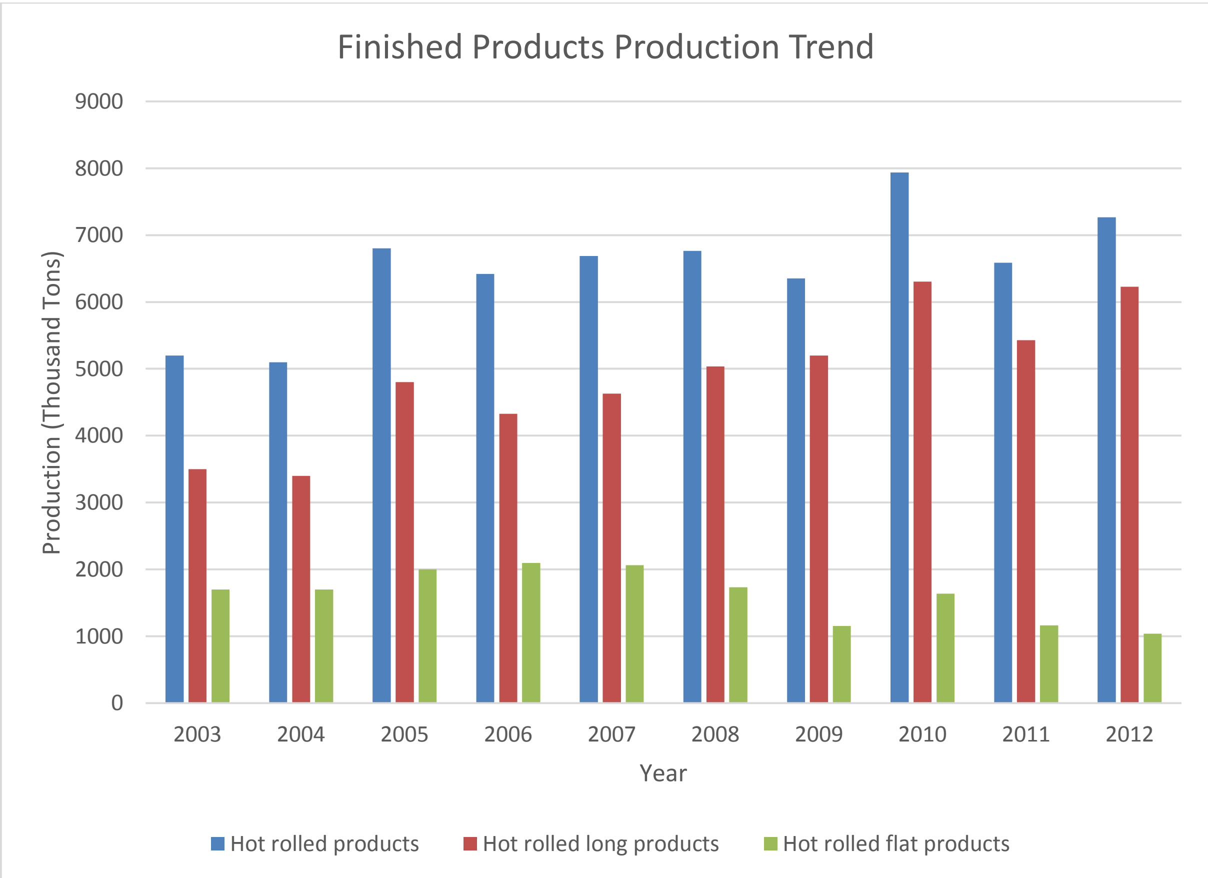


Figure 11: Finished Products Production Trend

From the above analysis, it can be concluded that Egypt is on the track of increasing the crude steel production through installing more electric arc furnaces. Moreover, Egypt's production of hot rolled products is increasing through installing more rolling mills. Those increases are aiming at developing a self sufficiency from the iron and steel production as a strategic product, and in the same time better utilization of the available energy sources.

3.3.2 Annual Turnover

The iron and steel industry is one of the most intensive industries in terms of energy use and turnover. Regarding the annual turnover, the last available statistical data reporting the whole sector was published by the CAPMAS for the year 2007/2008, where it reported the total production and the corresponding sales value during the period from 1996/1997 to 2007/2008 as follows:

Table 18: Egyptian Annual Steel Production and Turnover Trends (Source: (CAPMAS, 2008))

Year	Production (t)	Value (EGP)	Average price (EGP/t)
1996/1997	1,350,008	1,544,838,000	1,144
1997/1998	1,804,370	1,733,828,000	961
1998/1999	2,263,065	2,238,381,000	989
1999/2000	3,788,261	3,336,021,000	881
2000/2001	5,215,874	4,566,805,000	876
2001/2002	4,069,520	4,211,395,000	1,035
2002/2003	3,157,895	4,736,843,000	1,500
2003/2004	3,044,516	8,627,765,000	2,834
2004/2005	4,540,237	12,353,376,000	2,721
2005/2006	4,241,757	11,580,077,000	2,730
2006/2007	3,902,707	18,732,992,000	4,800
2007/2008	5,840,112	27,585,701,000	4,723

With the current steel price fluctuating around 4600 – 4800 EGP/t since 2008, the annual turnover for the 2012 production can be estimated to be 34,145,500 EGP.

Other indicators were calculated from data provided in a reports prepared by the Egyptian Electric Utility and Consumer Protection Regulatory Agency (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2011; Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2012) where they provided the total electricity consumed by the sector together with other sectorial data as shown in the following table.

Table 19: Indicators for the Egyptian Iron and Steel Sector (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2011), (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2012)

	2010/2011	2011/2012
Electricity (Million kWh)	6,877.80	6,905.49
Value added (Million EGP)	4,645.00	6,847.00
Production (t)	6,114,000.00	7,995,571.00
# of employees	39,961.00	41,922.00
Electrical SEC, kWh/t	1,124.93	863.66
Value added per ton, EGP/t	759.73	856.35
Electricity per value added, kWh/EGP	1,481.00	1,009.00

From those figures, it was concluded that the sector electrical consumption showed an improvement in 2011/2012 from 2010/2012, with an increase in the value added per ton steel produced. This resulted in a large decrease in the electricity used per value added to the product.

3.3.3 Main Markets

The main markets for the Egyptian iron and steel production are local markets in order to fulfil the market needs. However, exporting surplus portion of the production to African and Arab countries appeared in the last decade, with the increase in the installed capacities, and the decrease in the local demand.

According to the statistical data from the world steel association (World Steel Association, 2013b), Egypt exports finished products in the form of flat steel or long products; however, the percentage of export from the total production is not really significant for the long products (almost 2 % of the long production), while the flat exports reached 36% of the flat production. However, as a net trade, Egypt is still considered as a steel importer country where it imports iron ore in the form of pellets, imports scrap and billets, and imports finished products. Net imports of semi-finished and finished products in 2012 recorded 3,390,000 tons, 44 % of them in the form of ingots or billets.

Table 20: Trend of Semi-Finished and Finished Trade (World Steel Association, 2013b)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Semi-Finished and Finished Products Exports (Thousand Tons)	1,337	1,793	1,883	2,219	1,000	1,065	337	446	557	262
Semi-Finished and Finished Products Imports (Thousand Tons)	2,052	1,622	3,410	2,905	2,249	3,066	5626	3324	2574	3652
Net Imports (Thousand Tons)	715	-171	1,527	686	1,249	2,001	5,289	2,878	2,017	3,390

3.3.4 Main Drivers for Energy Consumption

First of all, the energy consumption in the iron and steel sector depends on the process routes.

The main further factors affecting the energy consumption in the iron and steel industry are:

- Production volume
- DRI/Scrap ratio for the EAF
- Scrap grade
- Billet grade
- Kind of products

Whereas for some drivers, namely production volume and DRI/scrap ratio, it is relatively easy to establish benchmarks, for some drivers, i.e. kind of products, it is more difficult. Especially for rolling mills, the energy consumption depends on the time necessary to roll a specific product.

3.4 Energy Data

In analyzing the energy data, following conversion factors were used in order to convert the reported energy to GJ.

Table 21: Conversion Factors Used in the Study

Convert from	To get	Multiplication factor	Source
kWh	MJ	3.6	(IEA, 2014)
Nm3 Natural gas	MJ	37.74	IPCC
Mbtu	MJ	1,055	(IEA, 2014)
Ton Coal	MJ	35,638.04163	(Azhar University, 2014)
Nm3 oxygen	kWh	0.65	(Canadian Steel Producers Association & Natural Resources Canada, 2007)
Ton Lime	MJ	450	Estimated based on the data of one of the plants

Even though some plants provided different conversion factors for the natural gas based on their utility invoices, those factors were neither consistent for all plants nor for the three studied years, so it was preferred to stick to a fixed conversion factor for the study.

The iron and steel industry is considered one of the most energy-intensive industries throughout the world, where according to data from 2007, the total global energy consumed in the iron and steel industry alone was almost 0.5 Mtoe. The total energy consumed in all the industrial sectors was around 3Mtoe (IEA, 2010).

Energy intensity in the iron and steel industry differs depending on the process implemented in the plant, where according to the BAT, the Sintering-Coking-BF-BOF-Refining-Continuous Casting-Hot Rolling route consumes about 16.5 GJ/t of crude steel, whereas the Sintering-Pelletizing-DRI-EAF-Continuous Casting-Hot Rolling route consumes around 18.6 GJ/t, while the EAF-Continuous Casting-Hot Rolling consumes 4.3 GJ/t, and Hot Rolling only consumes 1.8 GJ/t (Worrell, Price, Neelis, Galitsky, & Nan, 2008).

3.4.1 Thermal Energy Consumption

Thermal energy is extensively required for the heating of iron oxide in order to convert it to iron in either BF or DRI and also in the preheating of the billets entering the hot rolling section. Thermal energy that is widely used in the iron and steel industry is from the combustion of coal, coke or natural gas with little or no dependence on light fuel oil.

Thermal energy sources can be classified based on the production process: the BF depends mainly on the coke in the iron oxide reduction process, the direct reduction plants can run by natural gas as the source of reduction gas with plants in few regions of the world run the direct reduction plants through a different technology where the coke is used as the reduction gas.

Since there is only one plant operating the BF-BOF route, and as Egypt is not rich in coal that is needed to produce coke, the production and consumption of coke in Egypt is only limited to the demand of that single plant.

Regarding the most important source of thermal energy in Egypt, namely natural gas, Egypt used to have reasonable quantities of natural gas reserves, which encouraged investors as well as the Government of Egypt to install direct reduction plants. Egypt had only one plant running with direct reduction facility until few years back, when four new licenses were issued to install new direct reduction plants, one of which was commissioned in 2013, while the other three are currently installing their natural gas operated direct reduction plants and are expected to be commissioned in 2015.

Relatively small quantities of natural gas or heavy fuel oil are used in reheating the billets entering the hot rolling mills.

Other than the natural gas, imported coal or coke are sometimes used in the electric arc furnace to assist in forming foamy slag, which improves the electrical power efficiency by around 20 % (Worrell, Blinde, Neelis, Blomen, & Masanet, 2010) or to adjust the chemical composition of the produced steel.

Unfortunately, there were no statistical data available for the sector consumption of natural gas or coal.

3.4.2 Electricity Consumption

Electricity is mainly needed in the electrical arc furnace which consumes extremely high quantity of electricity. According to a study conducted by Worrel et. al (Worrell, Price, Neelis, Galitsky, & Nan, 2008), the best practice scrap fed EAF consumes 474 kWh/t liquid steel for the EAF and ladle refining, whereas for the EAF that is fed by DRI and Scrap at a ratio of 60:40 consumes 595 kWh/t liquid steel.

Other than the EAF, electricity is needed to run the motors and other electrical equipment available in the iron and steel plant, as well as the ancillary oxygen and lime plants.

The best practice for a DRI-EAF-Hot rolling plant consumes around 230 kWh/t liquid steel, as the waste heat from the DRI can be used to generate around 609 kWh/t, while the whole process consumes around 839 kWh/t.

From the annual reports prepared by the Egyptian Electric Utility And Consumer Protection Regulatory Agency (EGYPTERA), the Egyptian Iron and Steel total production, electric consumption and electrical specific energy consumption were reported for 2010/2011 and 2011/2012 (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2011; Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2012) as illustrated in the following table.

Table 22: Iron and Steel Production and Electric Consumption (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2011), (Egyptian Electric Utility And Consumer Protection Regulatory Agency, 2012)

Year	Production (t)	Electric Consumption (GWh)	SEC (kWh/t product)
2010/2011	6,114,000	6,877.8	1,125
2011/2012	7,995,571	6,905.5	864

From the above table, it can be concluded that the efficiency of utilizing the electric energy improved in 2011/2012 from 2010/2012; however, the reasons for that improvement are not clear from only those two data sets.

Also the report mentioned the share of electricity consumed in the iron and steel sector relative to the other industrial sectors in Egypt and relative to the total electricity consumed in industrial and non-industrial applications as follows:

Table 23: Share of Iron and Steel Electric Consumption Among the Country's Total Electric Consumption

Year	Iron and Steel Electric Consumption (GWh)	Total industrial Electric Consumption (GWh)	Total Electric Consumption (GWh)
2009/2010	6,342.1	31,548.8	118,903
2010/2011	6,877.8	31,779.1	125,159
2011/2012	6,905.5	34,763.6	133,969

With the share of iron and steel represents around 13 % of the electricity consumed in the industrial sector, and representing the largest consumer of electricity among the industrial sectors followed by the cement industry consuming around 10 % and the aluminium industry consuming around 9 % of the electricity consumed in the industrial sector.

3.5 Energy Efficiency Measures Implemented and/or Planned

Due to the importance of energy for the iron and steel production facilities, and following the shortage in energy supply and the increase in energy tariff, several plants started analyzing their energy use, and trying to improve their energy efficiency.

From the contacted plants, three plants mentioned that they plan to be ISO 50001 certified in 2014. They started implementing that plan through receiving consultancy services from the UNIDO on implementing an energy management system. Other than those three plants, one fourth plant started receiving the same services from the UNIDO EnMS training.

Other plants keep records for their energy efficiency, in which they estimate the thermal and electrical SEC and compare them to international records without having a systematic approach to reduce that SEC.

Through the replies on the energy efficiency measures from the plants, for three plants running steel making process, following measures were concluded:

Table 24: Percentage of Three Steel Making Plants with Saving Measures Already Implemented

Measure	% of application
Improved process control (neural network)	100%
Adjustable speed drives	100%
Transformer efficiency - Ultra high power transformers	100%
Bottom stiring/stiring gas injection	0%
Foamy slag practice	100%

Measure	% of application
Oxy-fuel burners	67%
Post-combustion of the flue gases	33%
DC arc furnace	0%
Scrap preheating - tunnel furnace (Consteel)	33%
Scrap preheating, post combustion - shaft furnace (Fuchs)	33%
Engineered refractories	100%
Airtight operation	0%
Contiarc furnace	0%
Flue gas monitoring and control	67%
Eccentric bottom tapping on existing furnace	100%

While for the measures for the hot rolling mills, following measures were concluded:

Table 25: Percentage of Four Hot Rolling Mills With Saving Measures Already Implemented

Measure	% of Application
Proper reheating temperature	100%
Avoiding overload of reheat furnaces	100%
Energy efficient drives in the rolling mill	75%
Process control in hot stip mill	100%
Recuperative and regenerative burners	0%
Flameless burners	50%
Insulation of furnaces	100%
Walking beam furnace	75%
Controling oxygen levels and/or speed on combustion air fans	100%
Heat recovery to the product	50%
Waste heat recovery (cooling water)	0%

Regarding the general measures that serve as an energy efficient measure, following were concluded:

Table 26: Implementation Rate of General Measures of Four Companies

Measure	% of Application
Preventive maintenance	100%
Energy monitoring and management system	0%

4 Analysis of Results

4.1 Achieved Data Sets for Analysis

In preparing this report, twenty-two companies were contacted, of which nine companies participated in providing their production and energy consumption data, while five were not operating and hence didn't participate, two provided incomplete data (only the average values or the consumption without the corresponding production), one company was excluded as it was a non-comparable company (the only company operating the BF-BOF route), and five companies refused to cooperate. The remaining companies were not contacted due to the unavailability of their correct contacts.

The data collection from the plants was conducted through direct contact with the companies; this involved a process where we tried to convince them by filling in the data collection sheet for their production and consumption from the company records and utility invoices. Most of the contacted companies were very cooperative in providing the data; however, some had some concerns regarding the confidentiality of their data or in terms of the possibility of achieving benefits for the participating companies. Those concerns were alleviated through several meetings and discussions as well as by providing case studies for similar companies in other countries that implemented the Industrial Energy Efficiency Project with the UNIDO.

The investigated companies represent the main iron and steel producers in Egypt with different production routes. The data of production and energy consumption for those companies were gathered for the years 2010, 2011 and 2012. The investigated companies represent almost 76 % of the Egyptian iron and steel final production as illustrated in Table 27.

Table 27: Capacity of Analyzed Companies

Process	Total Capacity	Studied Capacity	% of Capacity
DRI	3,000,000 t	3,000,000 t	100.0
EAF	7,265,122 t	6,800,000 t	94.0
Hot Rolling (rebar)	8,818,122 t	6,780,000 t	77.0
Hot Strip Mills (flat)	2,709,000 t	2,200,000 t	81.0
Sections	229,710 t	0	0.0
Total End Products	11,756,832 t	8,980,000 t	76.4

The graph below gives an overview of the different plants and their processes:

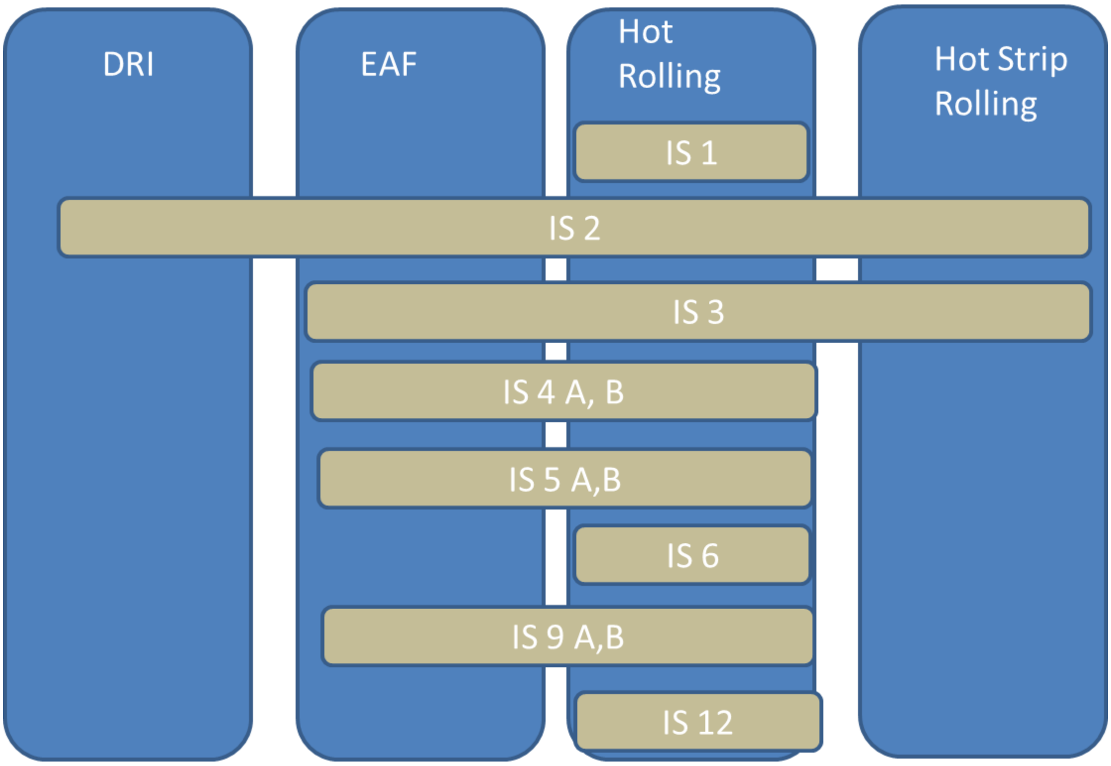


Figure 12: Overview on the Participating Plants (IS Numbers) and Applied Processes

Table 28 to Table 31 illustrate the aggregated material balance for the participating plants for each production process.

Table 28: Studied DRI Material Balance

Year	Input Material	Output Material	Metallization Factor (Output/Input)
	Pellets (t)	DRI (t)	
2010	4,298,068	2,855,195	66%
2011	4,441,417	2,973,204	67%
2012	4,198,560	2,835,451	68%

Table 29: Studied EAF Material Balance

Year	Input Material					Output Material	Metallization Factor (Output/ Input)
	Scrap (t)	DRI (t)	Imported Pig Iron (t)	FeSi (t)	FeSiMn (t)	Produce Steel (t)	
2010	3,674,545	3,304,747	-	2,137	6,399	6,089,324	87%
2011	3,713,381	3,301,858	11,746	2,154	5,835	6,040,712	86%
2012	3,745,417	3,207,202	8,025	2,246	5,617	6,166,973	88%

Table 30: Studied Rebar Production Material Balance

Year	Input Material	Output Material	Metallization factor (Output/Input)
	Billets (t)	Rebars (t)	
2010	5,288,880	5,089,960	96%
2011	5,308,289	5,067,155	95%
2012	6,030,268	5,734,157	95%

Table 31: Studied Flat Production Material Balance

Year	Input Material	Output Material	Metallization Factor (Output/Input)
	Thin Slabs (t)	Flat (t)	
2010	1,496,722	1,433,040	96%
2011	1,044,164	1,001,084	96%
2012	919,741	893,434	97%

From the above tables, it can be concluded that the metallization factor – which indicates the ratio between the weight of output material produced by each ton of input material – for the DRI is around 67 %, 87 % for the steel making, and 95 % for the rolling mills. Furthermore, the share of flat production from the total final products decreased from 23 % in 2010 to 14 % in 2012. This decrease was mainly due to the shutdown of the flat production line in one of the plants and operating all that plant's production on rolling of rebar. Another conclusion is the quantity of imported steel in the form of billets. This quantity ranges from 3-7 % for the three reported years; however, as the number of rolling only plants is not representative in the studied sample (77 % of the total production), and 12 % of the number of rolling only plants (3 out of 25 operating were analyzed), the quantity of imported billets is expected to be around 10 % based on the installed capacities. Furthermore, the share of scrap to virgin iron used in steel making is around 52 % of scrap. The virgin iron used in the electric arc furnaces was in the form of direct reduced iron, pig iron or hot briquetted iron (FeSi or FeSiMn).

4.1.1 Production Volume of Analyzed Companies

The following tables represent the breakdown of finished steel production volume among the analyzed companies for 2010, 2011 and 2012.

Table 32: Finished Steel Production Volume of Analyzed Companies

	Design Capacity (Tons/Year)	2010 Production (Tons/Year)	2011 Production (Tons/Year)	2012 Production (Tons/Year)	Average Production (Tons/Year)
IS01	180,000	139,472	146,458	143,974	143,301
IS02	2,750,000	2,829,470	2,750,771	2,850,096	2,810,112
IS03	1,200,000	448,725	417,743	584,493	483,654
IS04	1,000,000	993,575	935,364	832,451	920,463
IS05	1,000,000	1,045,953	956,281	980,743	994,326
IS06	300,000	337,330	312,825	291,223	313,793
IS09	850,000	354,198	423,733	643,751	473,894
IS12	500,000	374,278	125,064	300,718	266,687
Total	**7,780,000**	**6,523,000**	**6,068,239**	**6,627,449**	**6,406,229**

Regarding the utilization of the plants in the three years, the following tables illustrate the utilization factor for each production process. From those tables, it is clear that 2012 has the highest utilization factor for both the steel production and the rebar production.

Table 33: Utilization Factor for Collected DRP Data

Code	Installed Capacity (T)	Utilization factor (%)		
		2010	2011	2012
IS02	3,000,000	95%	99%	95%
Total	**3,000,000**	**95%**	**99%**	**95%**

Table 34: Utilization Factor for Collected EAF Data

Code	Installed Capacity (T)	Utilization factor (%)		
		2010	2011	2012
IS02	3,000,000	99%	98%	102%
IS03	1,200,000	59%	48%	58%
IS04	1,000,000	87%	104%	95%
IS05	800,000	104%	103%	101%
IS09	800,000	90%	84%	82%
Total	**6,800,000**	**90%**	**89%**	**91%**

Table 35: Utilization Factor for Collected Rolling Mills Data

Code	Installed Capacity (T)	Utilization factor (%)		
		2010	2011	2012
IS01	180,000	77%	81%	80%
IS02	1,750,000	105%	106%	112%
IS03	1,200,000	0%	26%	49%
IS04	1,000,000	99%	94%	83%
IS05	1,000,000	105%	96%	98%
IS06	300,000	112%	104%	97%
IS09	850,000	42%	50%	76%
IS12	500,000	75%	25%	60%
Total	**6,780,000**	**75%**	**75%**	**85%**

Table 36: Utilization Factor for Collected Flat Products Data

Code	Installed Capacity (T)	Utilization factor (%)		
		2010	2011	2012
IS02	1,000,000	99%	90%	89%
IS03	1,200,000	37%	8%	0%
Total	**2,200,000**	**65%**	**46%**	**41%**

4.1.2 Energy Consumption of Analyzed Comanies

The conversion factors mentioned in Table 21 were used to calculate the energy consumption of the analyzed companies.

4.1.2.1 Thermal Energy Consumption

The following tables represent the amount of thermal energy consumed and the thermal SEC for each plant. The thermal energy consumed in the analyzed iron and steel plants are from the natural gas used for combustion as well as the direct reduction process and the coke and lime addition to the electric arc furnace.

Table 37: Thermal Energy Consumption of Analyzed Companies

	2010		2011		2012		Average	
	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t
IS01	216,233	1.55	236,136	1.61	250,062	1.74	234,144	1.63
IS02	41,282,022	14.59	42,373,115	15.40	40,227,699	14.11	41,294,279	14.70
IS03	1,395,281	3.11	1,192,757	2.86	1,525,772	2.61	1,371,270	2.86
IS04	1,650,883	1.66	1,694,254	1.81	1,684,137	2.02	1,676,425	1.83
IS05	1,575,818	1.51	1,464,135	1.53	1,509,059	1.54	1,516,337	1.53
IS06	422,812	1.25	387,946	1.24	354,651	1.22	388,469	1.24
IS09	857,479	2.42	1,014,169	2.39	1,430,368	2.22	1,100,672	2.35
IS12	595,900	1.59	172,931	1.38	412,944	1.37	393,925	1.45
Total	**47,996,427**	**7.36**	**48,535,444**	**8.00**	**47,394,692**	**7.15**	**47,975,521**	**7.50**

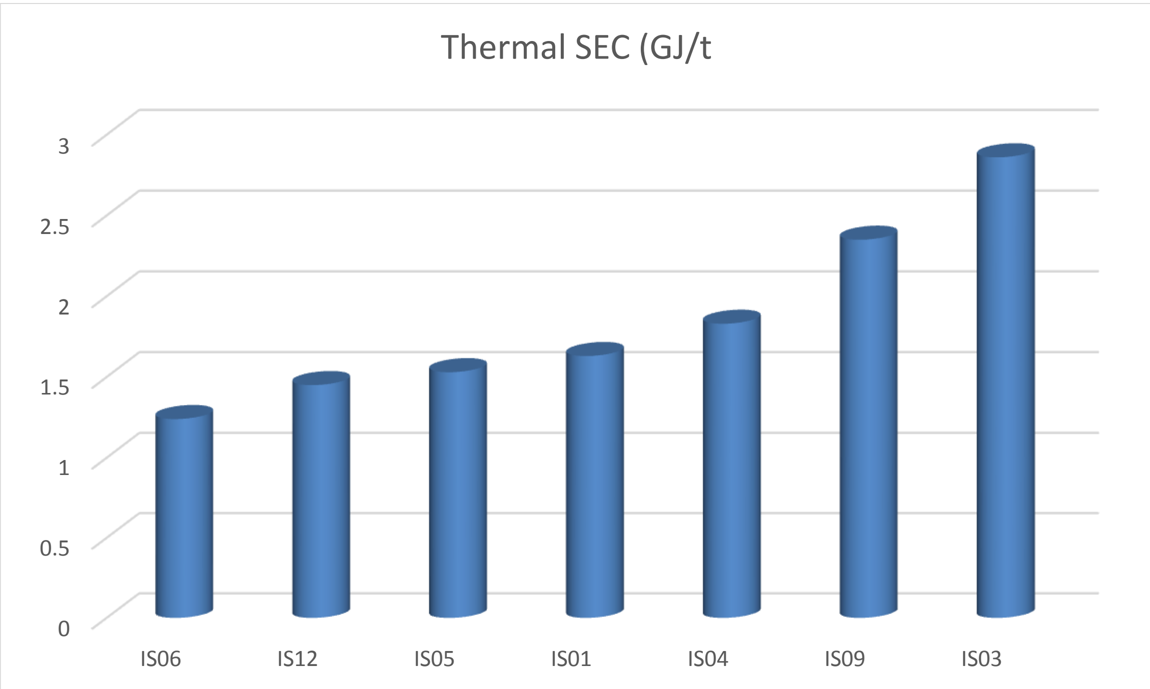


Figure 13: Thermal SEC of Analyzed Companies

From the chart and table, it appears that the thermal SEC shows great variability ranging between 1.44 GJ/t for rolling only companies and 2.14 GJ/t for companies running EAF+Rolling. Data of the company running DRI+EAF+Rolling was omitted from this chart for better illustration purpose.

4.1.2.2 Electrical Energy Consumption

The following tables represent the amount of electrical energy consumed and the electrical SEC for each plant. The electrical energy consumed in the analyzed iron and steel plants are from the electric consumption in the process equipment as well as from the oxygen production plant.

Table 38: Electrical Energy Consumption of Analyzed Companies

	2010		2011		2012		Average	
	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t
IS01	55,706	0.40	54,891	0.37	59,094	0.41	56,564	0.39
IS02	11,206,769	3.96	11,007,125	4.00	11,204,980	3.93	1,139,625	3.96
IS03	1,810,366	4.03	1,417,620	3.39	1,694,281	2.90	1,640,756	3.44
IS04	1,928,830	1.94	2,483,064	2.65	2,366,644	2.84	2,259,512	2.48
IS05	2,155,854	2.06	2,157,543	2.26	2,144,824	2.19	2,152,740	2.17
IS06	118,469	0.35	107,363	0.34	97,967	0.34	107,933	0.34
IS09	1,456,086	4.11	1,482,633	3.50	1,586,459	2.46	1,508,393	3.36
IS12	118,602	0.32	46,760	0.37	94,093	0.31	86,485	0.33
Total	**18,850,682**	**2.89**	**18,756,999**	**3.09**	**19,248,343**	**2.90**	**18,952,008**	**2.96**

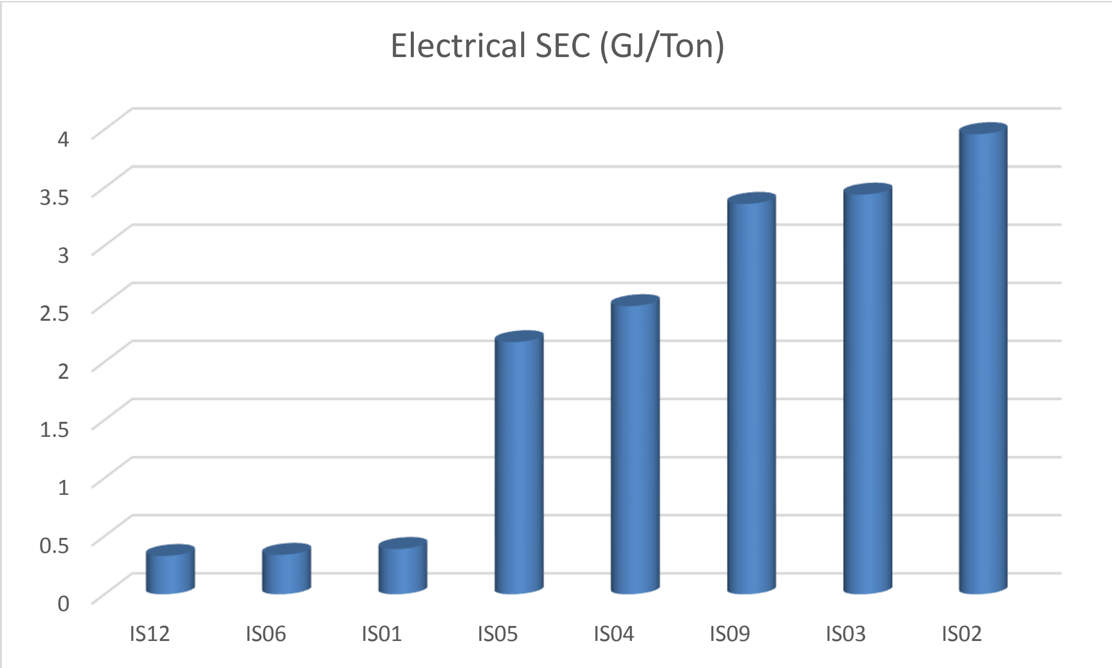


Figure 14: Electrical SEC of Analyzed Companies

From the chart and table, it appears that the electrical SEC shows great variability among the studied plants. This is mainly due to the difference in the production process, where the rolling only plants range around 0.353 GJ/t, while the EAF+Rolling has an average of 2.86 GJ/t and the DRI+EAF+Rolling approaches 4 GJ/t.

4.1.2.3 Total Energy Consumption

The following table illustrates the aggregation of the thermal and electrical energy consumption as well as the total SEC for each plant.

Table 39: Total Energy Consumption of Analyzed Companies

	2010		2011		2012		Average	
	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t	GJ/Year	GJ/t
IS01	271,939	1.95	291,027	1.99	309,156	2.15	290,708	2.03
IS02	52,488,791	18.55	53,380,240	19.41	51,432,680	18.05	52,433,904	18.67
IS03	3,205,647	7.14	2,610,377	6.25	3,220,053	5.51	3,012,025	6.30
IS04	3,579,712	3.60	4,177,318	4.47	4,050,781	4.87	3,935,937	4.31
IS05	3,731,671	3.57	3,621,678	3.79	3,653,883	3.73	3,669,078	3.69
IS06	541,281	1.60	495,308	1.58	452,618	1.55	496,402	1.58
IS09	2,313,564	6.53	2,496,803	5.89	3,016,827	4.69	2,609,065	5.70
IS12	714,502	1.91	219,691	1.76	507,037	1.69	480,410	1.78
Total	**66,847,108**	**10.25**	**67,292,443**	**11.09**	**66,643,034**	**10.06**	**66,927,528**	**10.46**

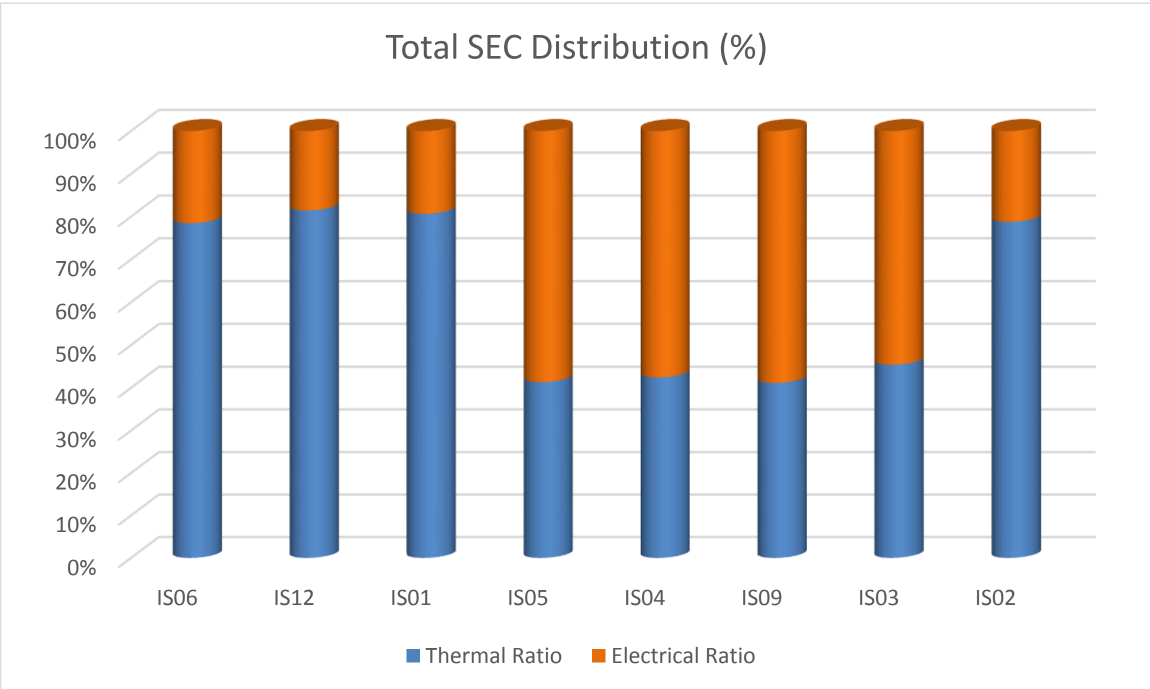


Figure 15: Total SEC Distribution among Studied Companies

From the chart and table, it appears that the total SEC shows great variability among the studied plants depending on the production process, where for the companies with rolling only, the share of thermal energy represents almost 80 % of the total energy use, while for the companies with EAF+Rolling the thermal energy is around 42 % of the total energy and for the DRI+EAF+Rolling the thermal energy is around 78 % of the total energy.

4.2 Cost of Energy

The cost of energy didn't really represent a burden on the Egyptian industries as the energy was subsidized by the GoE. However, due to the shortage in the natural gas and petroleum supplies, as well as the international boom of fuel prices in 2004 and 2008, fuel and electricity costs went up in an attempt to eliminate the subsidy.

Among the first industries that were subject to the reduction of the subsidy was the iron and steel industry together with other energy-intensive industries, where the cost of one MBTU of natural gas was increased from 0.85$/thousand cubic feet in March 2004 to 1$/thousand cubic feet in September of the same year. It remained steady till July 2006 where it increased to 1.25$/ thousand cubic feet.

In 2007, the unit of measuring of consumption was changed from thousand cubic feet to Million British Thermal Unit (MMBTU) with the tariff increasing to 1.72 $/MBTU. In 2008, the tariff increased to 3$/MBTU, and remained fixed until 2012 where it increased to 4$/MBTU, and finally reaching 7$/MBTU in 2014.

Neglecting the effect of currency conversion from $ to EGP (the exchange rate increased by about 25% from 5.75 EGP/$ in 2006 to 7.14 EGP/$ in 2014 with a minimum of 5.3 EGP/$ in August 2008 as per Figure 16), the natural gas tariff had two major increases in 2008 and 2014, where at both times it increased by 75%. Table 40 illustrates the history of natural gas tariff with the related decrees.

Figure 16: History of EGP-US$ Exchange Rate

Table 40: History of the Natural Gas Tariff

Year	Tariff ($/MBTU)	Decree
2004	0.85	470/2004
2004	1	1516/2004
2006	1.25	1325/2006
2007	1.72	1914/2007
2008	3	1795/2008
2010	3	1953/2010
2012	4	MOM ministereal meeting 27/11/2011
2014	7	1162/2014

For the electricity, the tariff was increased from 0.111 EGP/kWh to 0.133 EGP/kWh in 2007 followed by another increase to reach 0.202 EGP/kWh in 2008. In 2010, it increased again to 0.235 EGP/kWh. In July 2014, a decree was issued with the increase of the electricity tariff for five years ending at 0.433 EGP/kWh in 2018. Table 41 illustrates the history of electricity tariff with the related decrees. For the sake of unifying the monetary values throughout the report, the tariff is expressed in terms of $ with an exchange rate of 7.14 EGP/$ (Central Bank of Egypt, 2014)

Similar to the natural gas tariff, the electricity tariff had two major increases where it increased by 52 % in 2008 and by 57 % in 2014.

Table 41: History of the Electricity Tariff

Year	Tariff (EGP/kWh)	Tariff ($/kWh)	Decree
2007	0.111	0.016	1914/2007
2007	0.133	0.019	1914/2007
2008	0.202	0.028	1795/2008
2010	0.235	0.033	2130/2010
2014	0.369	0.052	1257/2014
2015	0.384	0.054	1257/2014
2016	0.393	0.055	1257/2014
2017	0.410	0.057	1257/2014
2018	0.433	0.061	1257/2014

Figure 17 & Figure 18 illustrate the trend of both the natural gas and the electricity tariffs.

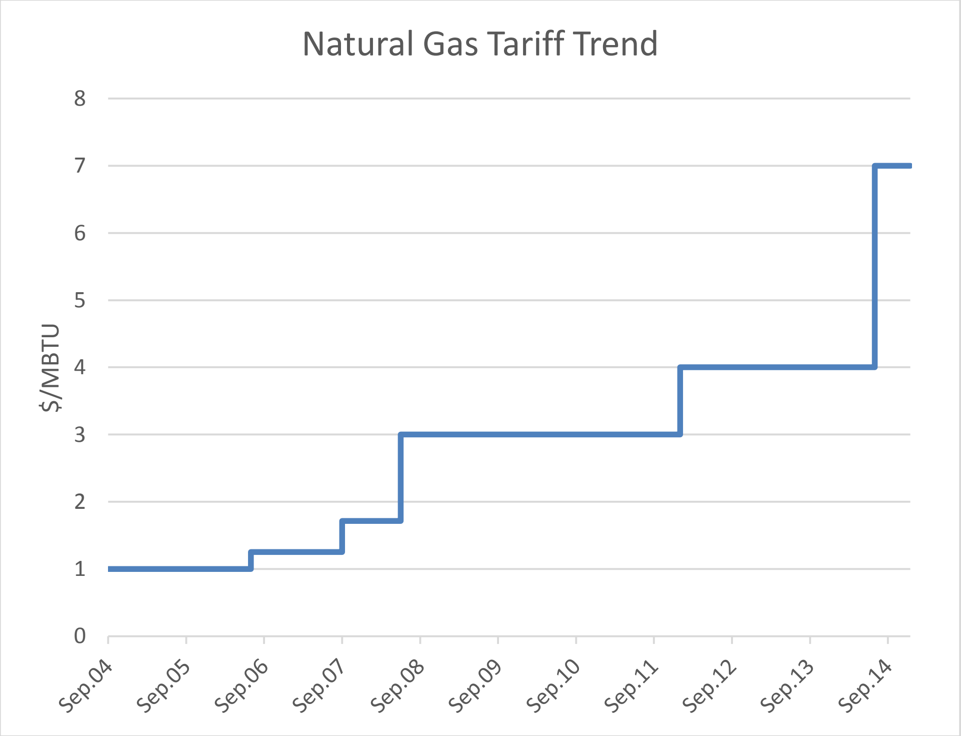


Figure 17: Natural Gas Tariff Trend

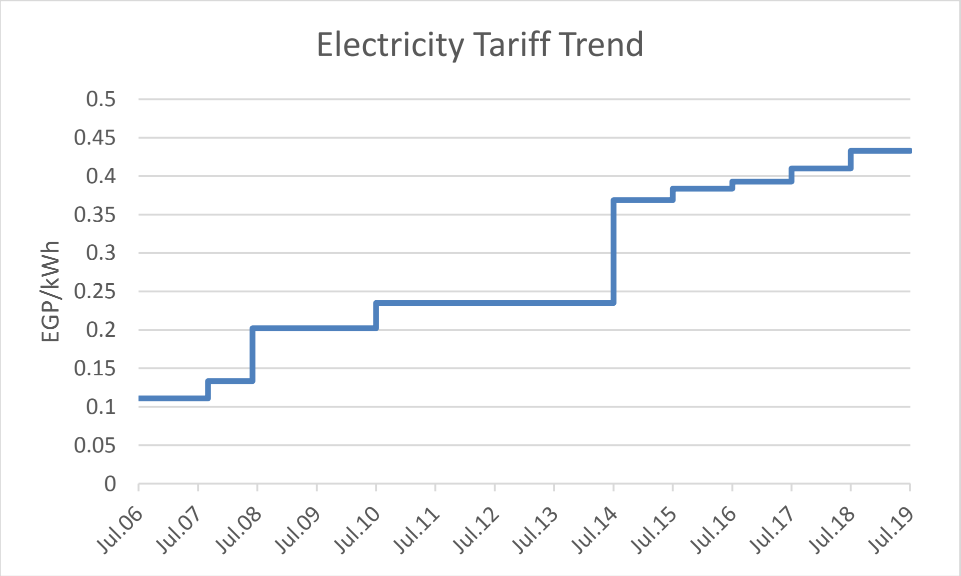


Figure 18: Electricity Tariff Trend

4.3 Status of Energy Management System Implementation

Until the date of writing this report, none of the steel plants in Egypt had implemented energy management systems. However, several plants were in the process of planning their energy management system to be qualified for the ISO 50001 by the end of 2014 or early in 2015.

Within the questionnaire that was collected from six running plants, there were some yes/no questions on their readiness to implement energy management system.

The following table illustrates the percentage of yes answers received on each question

Table 42: Percentage of Yes Answers Received on Each Question

Question	Percentage of Yes	Percentage of No
Q1: Energy Management system applied?	0%	100%
Q2: Responsible Person for Energy issues (e.g. Energy manager)?	43%	57%
Q3: Do you analyze your energy consumption?	86%	14%
Q4: Are energy meters/sub-meters installed?	100%	0%
Q5: Resources available for Energy management?	50%	50%
Q6: Energy efficiency considered in investment decisions?	60%	40%
Q7: Energy Efficiency Targets available?	50%	50%
Q8: Previous Energy Audits Available? If yes date of audit?	0%	100%
Q9: Energy saving measures planned?	57%	43%

Though there is no company implementing energy management systems, 43 % of the companies already assigned an energy manager and 86% analyze their energy consumption. From the meetings with the plants, all the plants are willing to improve their energy efficiency and hence reduce the consumption. This will is strongly driven by the scarcity of energy sources, and the rapid increase in the unit price.

4.4 Benchmark Clusters and/or Adjustment Factors

In order to be able to analyze the data, following benchmarking clusters were set for the study:

- Plants running with Direct Reduced plant + Electric Arc Furnace + Rolling
- Plants running with Electric Arc Furnace +Rolling (incl. DRI plant above)
- Plants running with Rolling (Rolling plants only)

The benchmark curves shall be drawn for:

- Benchmark curves for EAF alone
- Benchmark curves for Rolling alone
- Benchmark curves for EAF+Rolling

Furthermore, as all the data was collected on process level, we defined model plants more than the real-life plants. For example, one real life plant runs DRI-EAF and produces reinforcing bars and flat plates and is defined as:

- One EAF-Continous casting plant producing billets
- One hot rolling mill consisting of reheating and rolling plant producing reinforcing bars
- One hot strip mill plant producing flat products
- One plant running EAF - Continous casting- hot rolling plant producing reinforcing bars

The correction factor for each process was estimated by averaging the input:output ratio of the process from available plants data, for example the ratio between input billets to output rebars from the hot rolling mills was available from the data of 5 plants. This ratio was averaged and applied to the other two plants to estimate their input billets. Applied correction factors are illustrated in Table 43. This data was used for deriving the Energy Performance Indicators if semi-finished products were sold or purchased (detailed description is given in the following chapter).

Table 43: Correction Factors Estimated for Material Correction of Each Process

Process	To convert from	Multiply by	To get
Direct Reduction plant	Pellets	0.67	DRI
EAF	Scrap	0.87	Steel
Hot Rolling	Billets	0.955	Rebars
Hot Strip Mill	Slab	0.96	Flat coils

4.5 Energy Performance Indicators of Analyzed Companies

The approach implemented in analyzing energy performance for the companies was to analyze each process separately while fixing its system boundaries. Furthermore, and to be able to draw benchmark curves, following criteria was used in selecting the process and plants analyzed:

- They are applicable at two or more plants.
- They contain comparable process equipment.
- They have the essentially the same material input and output streams.

The direct reduction facility was analysed, though it did not fit the above criteria, as it was the only direct reduction facility in Egypt within the studied years. As indicated in chapter 3.2 there are new direct reduction facilities recently commissioned or are due to be commissioned by early 2015, so it is necessary to include the analysis of that plant.

The input and output material for each of the above mentioned plants shall be corrected to factor out the purchase and sale of intermediate products (steel, iron, billets). This was achieved by the following calculation:

For plants where the SEC for different processes is available the following procedure will be applied:

- Total energy corrected = total energy + energy consumed to produce purchased semi-finished products
- Total production corrected (meant liquid steel in this case, which is a pre-product)= amount of purchased semi-finished products * correction factor (bigger 1 to reflect amount of liquid steel needed to produce amount of purchased semi-finished products)+liquid steel (reported for this plant)
- Energy consumed for purchased semi-finished products (billets) = specific energy consumption for producing semi-finished products (e.g. EAF plus casting) * amount of purchased semi-finished products (e.g. billets)

Table 44 to Table 47 illustrate the collected energy data for each process, while the mass balance for each process was illustrated in Table 28 to Table 31.

Table 44: Energy Data for Direct Reduction Plants

Year	Consumed Electricity (kWh)	Consumed NG (Nm^3)	Output DRI (t)
2010	279,756,000	883,535,945	2,855,195
2011	282,404,000	942,978,490	2,973,204
2012	275,245,000	857,495,688	2,835,451

Table 45: Energy Data for Electric Arc Furnaces

Year	Consumed Electricity (kWh)	Consumed NG (Nm^3)	Consumed Coal (t)	Consumed Oxygen (Nm^3)	Consumed Lime (Nm^3)	Output Steel (t)
2010	3,560,325,286	63,461,676	101,344	230,097,336	342,911	6,089,324
2011	3,555,087,088	64,666,539	86,707	213,301,896	290,960	6,040,712
2012	3,668,329,913	67,134,521	102,855	226,167,831	367,592	6,166,973

Table 46: Energy Data for Rolling Mills

Year	Input Billets (t)	Consumed Electricity (kWh)	Consumed NG (Nm^3)	Output Bars (t)
2010	5,288,880	464,625,210	158,157,713	5,089,960
2011	5,308,289	465,412,906	153,168,984	5,067,155
2012	6,030,268	527,808,655	175,855,905	5,734,157

Table 47: Energy Data for Hot Strip Mills

Year	Input slabs (t)	Consumed electricity (kWh)	Consumed NG (Nm^3)	Output flats (t)
2010	1,496,722	205,687,650	28,599,326	1,433,040
2011	1,044,164	144,712,400	17,962,828	1,001,084
2012	919,741	131,531,000	15,684,413	893,434

4.5.1 On National Level

In preparing the benchmark on national level, separate benchmark curves were prepared for each process as per the following system boundaries:

4.5.1.1 Plant Level Analysis

This analysis considers the actual energy consumption as reported by the plants for all the production processes divided by the steel production. The focus of this analysis is the whole energy consumption per plant.

The analysis is conducted only for steel making plants where the rolling only plants are analysed in a later section. The total energy used per plant is illustrated in terms of GJ as:

Table 48: Total Energy Consumption for Analyzed Steel Making Plants

Plant	Energy Use (GJ)			
	2010	2011	2012	Average
IS02	52,488,791	53,380,240	51,432,680	52,433,904
IS03	3,205,647	2,610,377	3,220,053	3,012,026
IS04	3,579,712	4,177,318	4,050,781	3,935,937
IS05	3,731,671	3,621,678	3,653,883	3,669,077
IS09	2,313,564	2,496,803	3,016,827	2,609,065

Following are the actual crude steel production for the plants:

Table 49: Crude Steel Production from Analyzed Steel Making Plants

Plant	Produced Steel (t)			
	2010	2011	2012	Average
IS02	2,971,230	2,932,189	3,068,329	2,990,583
IS03	707,523	576,437	690,705	658,222
IS04	865,319	1,040,536	948,641	951,499
IS05	828,204	823,416	804,344	818,655
IS09	717,048	668,133	654,955	680,045

The calculated EPI which represent the specific energy consumption relative to the crude steel for the different plants are:

Table 50: Plant Level EPI for Analyzed Steel Making Plants

Plant	EPI (GJ/t steel)			
	2010	2011	2012	Average
IS02	17.666	18.205	16.762	17.533
IS03	4.531	4.528	4.662	4.576
IS04	4.137	4.015	4.270	4.137
IS05	4.506	4.398	4.543	4.482
IS09	3.227	3.737	4.606	3.837

From the above analysis, it is impossible to compare plants based on plant level analysis due to the difference in the production processes, product mix and the possible purchase and sale of intermediate products, thus we shall go for process level analysis as illustrated in the following sub-chapters.

4.5.1.2 Electric Arc Furnaces Benchmarks

This curve includes the energy consumed in the electrical arc furnace, ladle treatment, continuous casting, oxygen plant and lime plant. Energy consumed in this boundary includes: electricity, natural gas, oxygen and coal. For the lime, as there was no specific conversion factor indicated in previous studies, the total energy consumed by the lime plant was included in the input energy.

The energy performance indicator was estimated by converting all the input energy sources to GJ equivalent from the conversion factors (illustrated in Table 21), then summing up all the input energy and divide it by the output steel for each plant.

The results of the analysis of the electric arc furnaces are illustrated in Table 51:

Table 51: Achieved EPI for EAF

Plant	2010		2011		2012		Average	
	EPI (GJ/t)	Scrap %	EPI (GJ/t)	Scrap %	EPI (GJ/t)	Scrap %	EPI (GJ/t)	Scrap %
IS02	3.768	16	3.578	14	3.673	16	3.673	16
IS03	3.471	62	3.415	66	3.399	70	3.429	66
IS04	2.338	100	2.566	100	2.857	100	2.587	100
IS05	2.253	87	2.217	93	2.299	94	2.257	91
IS09	2.414	97	2.730	94	2.592	89	2.579	93

From the above data, the achieved curves were as follows:

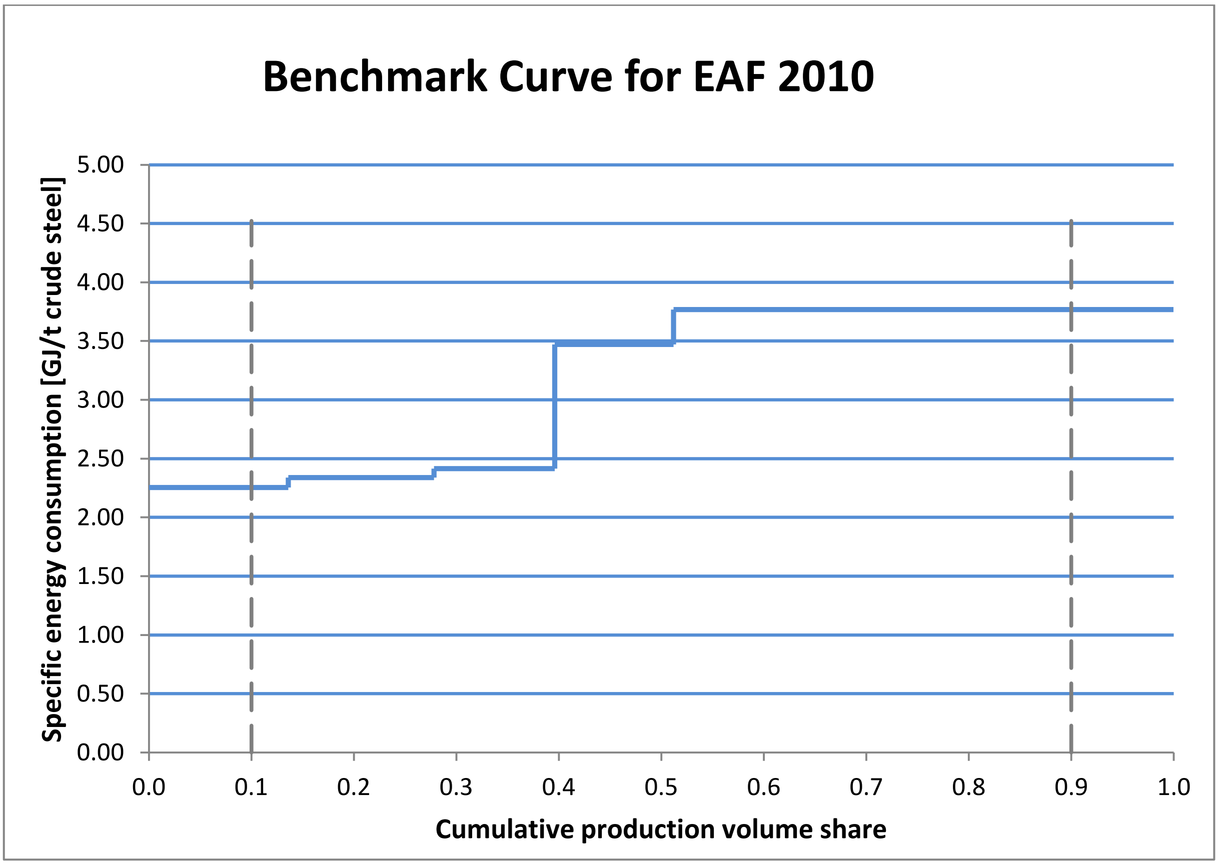


Figure 19: Benchmark Curve for EAF for Year 2010

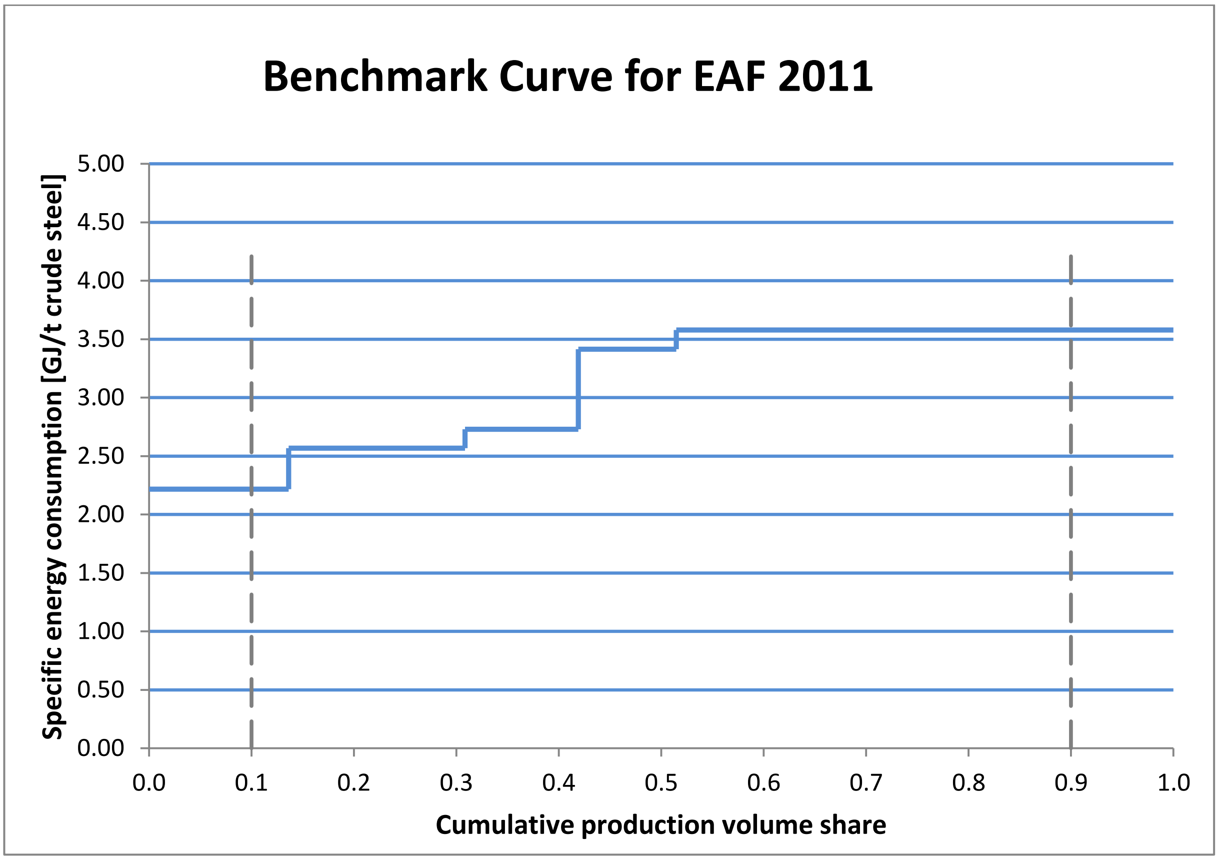


Figure 20: Benchmark Curve for EAF for Year 2011

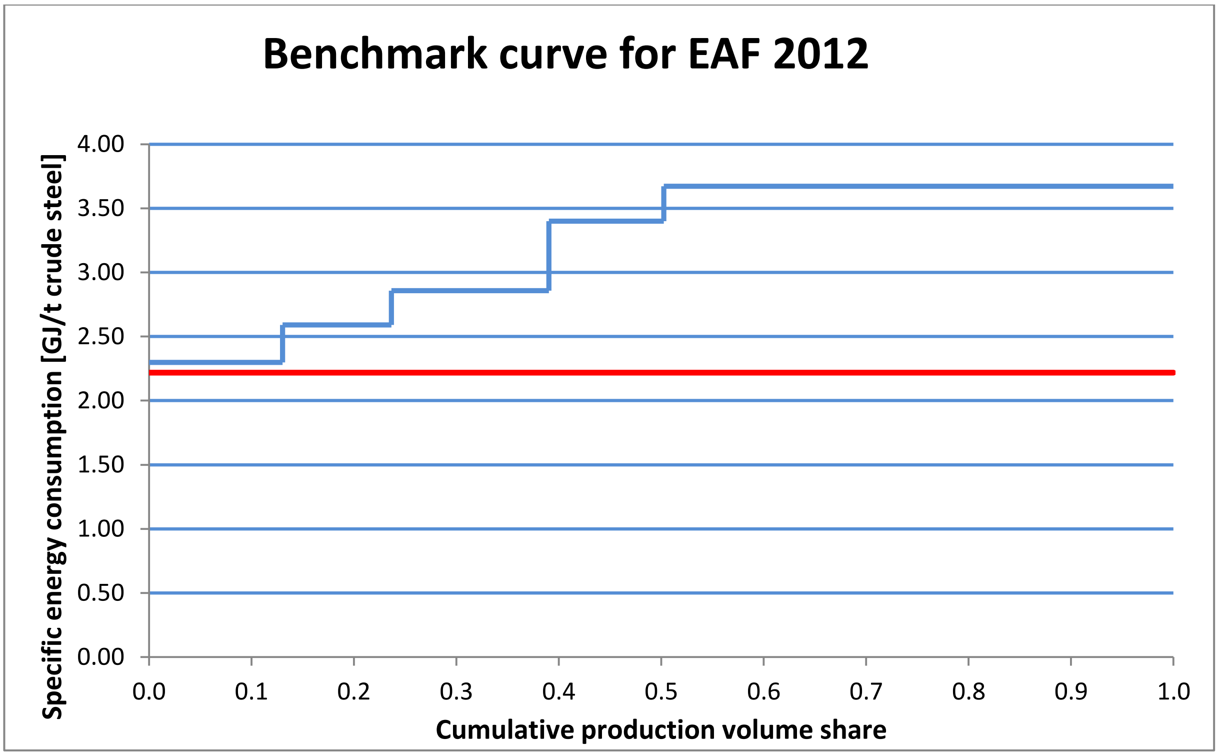


Figure 21: Benchmark Curve for EAF for Year 2012

Table 52: Achieved EPI for EAF for the Years 2010, 2011 and 2012

BPT/BAT Value	2010 (GJ/T Billet)	2011 (GJ/T Billet)	2012(GJ/T Billet)
BPT	2.338	2.566	2.592
BAT	2.253	2.217	2.299

Through aggregating the data of the three years by summing the production and consumption of each plant for the three years in order to achieve the average EPI, following data were achieved:

Table 53: Achieved EPI for EAF for Aggregated Data for three years

Plant	Production Volume Share	EPI (GJ/T Crude steel)
IS02	49%	3.673
IS03	11%	3.430
IS04	16%	2.594
IS05	13%	2.256
IS09	11%	2.575

With the benchmark curve as follows:

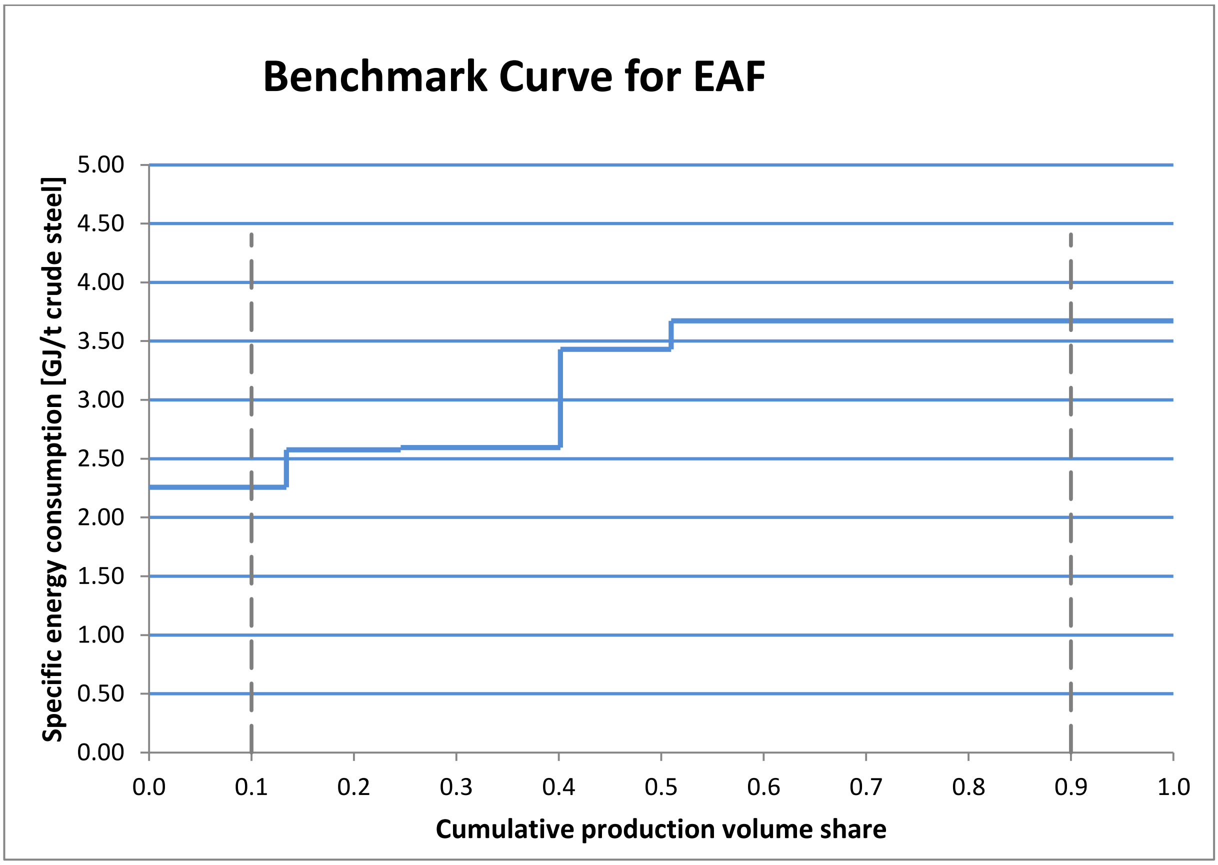


Figure 22: Benchmark Curve for EAF Average of three years

And the sector **BAT** is taken as 2.256 GJ/t crude steel which corresponds to the lowest EPI with an average scrap ratio of 91%, and the second best EPI which corresponds to the **BPT** was 2.575 GJ/t crude steel with an average scrap ratio of 93 %. The last percentile had an EPI of 3.673 with an average scrap ratio of 16 %.

The great variability in the EPI of the studied electric arc furnaces is mainly due to the difference in the share of scrap used for steel production. The quantity of coal consumption was found to be inversely proportional to the scrap ratio. As the virgin iron increases (smaller scrap ratio), more coal is needed to adjust the carbon content of the produced steel. The energy content of the carbon is added to the energy needed, therefore the energy performance index is higher for companies using a lower amount of scrap. Regarding other sources of energy (electricity and natural gas), their correlation with the scrap ratio was found to be very poor (R-square or 0.57 for electricity and 0.55 for natural gas). Usually a R-square of above 0.75 (with a maximum of 1) is an indicator for good correlation between two independent variables.

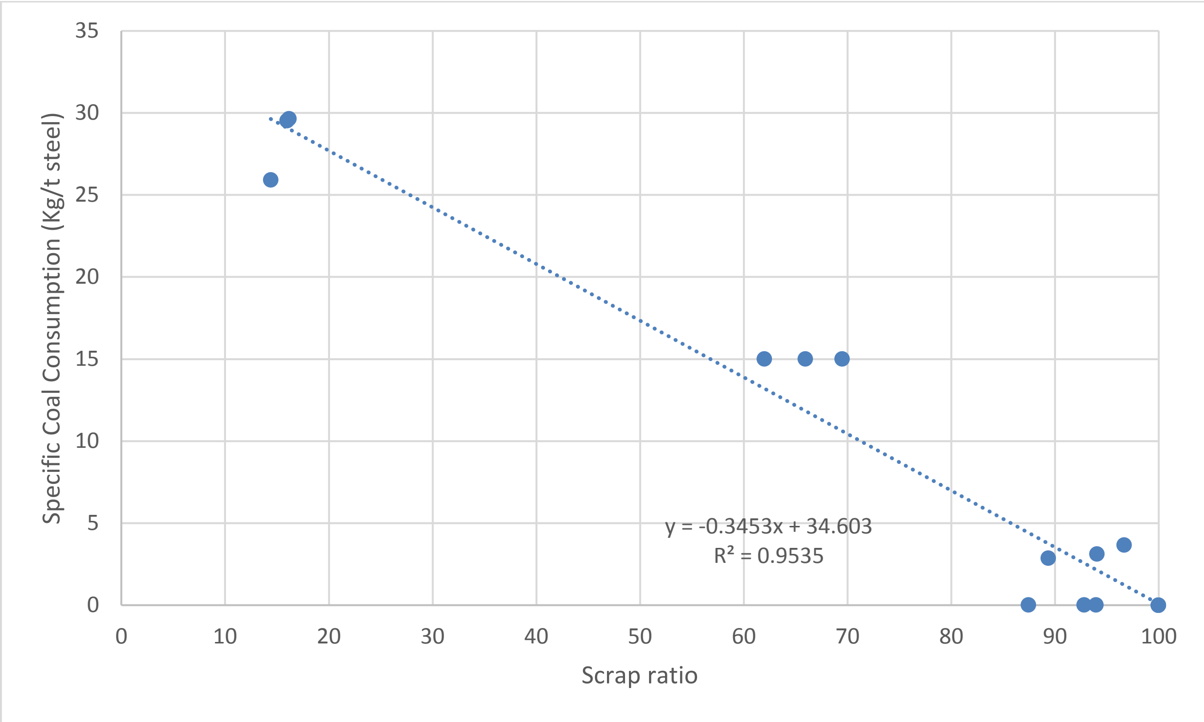


Figure 23: Relation between Coal Consumption and Scrap Ratio

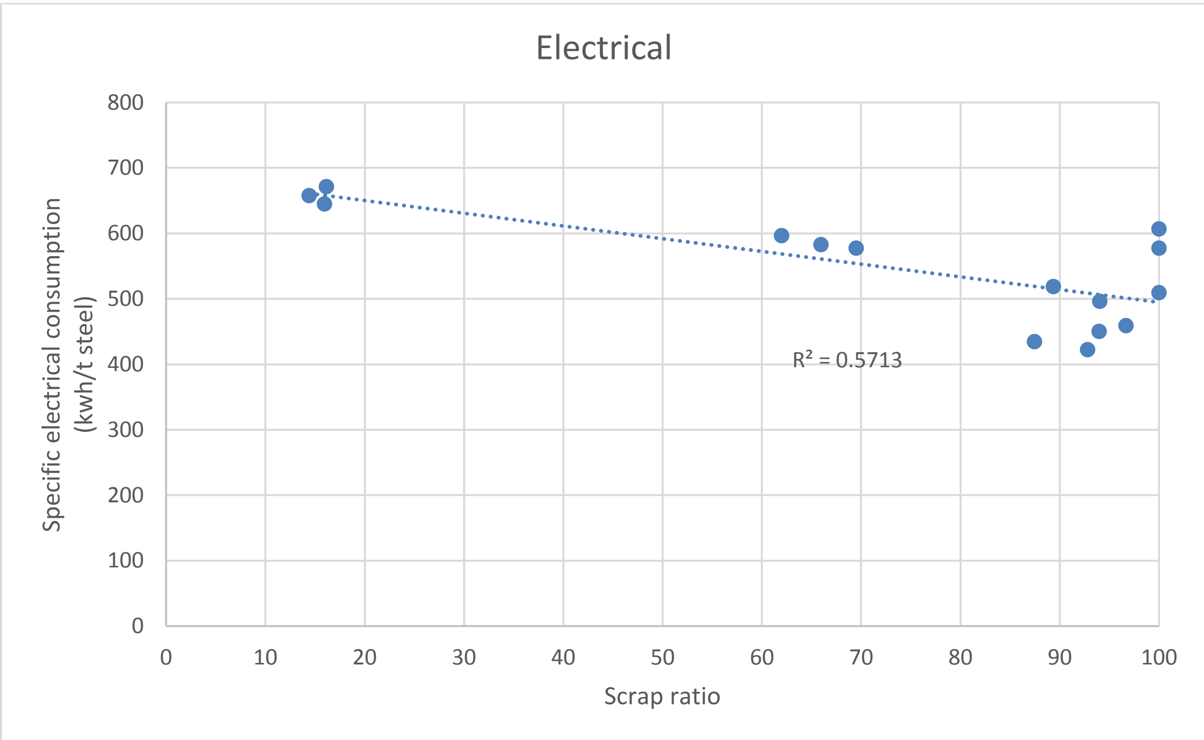


Figure 24: Relation between Electrical Consumption and Scrap Ratio

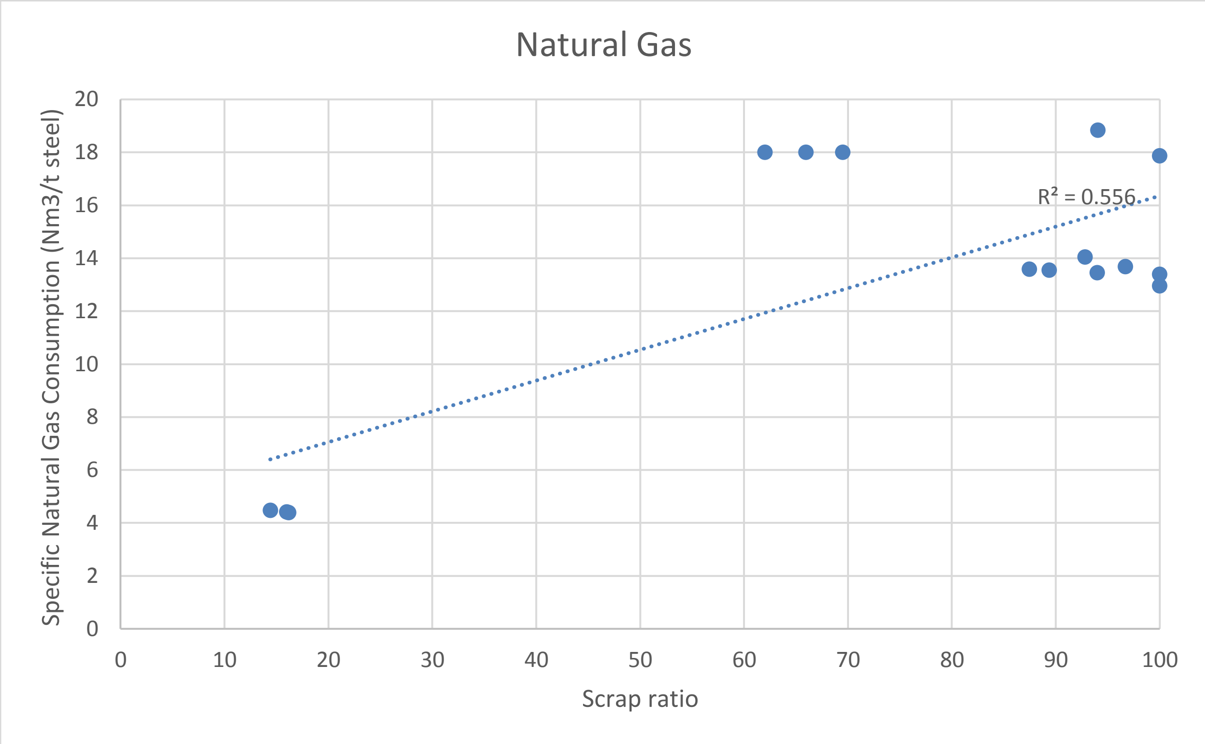


Figure 25: Relation between Natural Gas Consumption and Scrap Ratio

4.5.1.3 Rolling Mills Benchmarks

This curve includes the energy consumed in the reheating furnace as well as the rolling mills. The energy sources are either natural gas (for the reheating furnace) or electricity for the rolling mills.

The analysis was conducted similar to that of the electric arc furnaces in estimating the EPI, but here we divide by the input billets. The achieved data from this analysis were as illustrated in Table 54:

Table 54: Achieved SEC for Rolling

Code	EPI (GJ/T billets)			
	2010	2011	2012	Average
IS01	1.88	1.92	2.07	1.96
IS02	1.33	1.28	1.28	1.30
IS03	1.44	1.44	1.44	1.44
IS04A	1.56	1.59	1.66	1.60
IS04B	1.50	1.54	1.47	1.50
IS05A	1.31	1.34	1.34	1.33
IS05B	1.38	1.34	1.43	1.38
IS06	1.55	1.54	1.51	1.53
IS09A	1.39	1.39	1.39	1.39
IS09B	0	1.37	1.37	1.37
IS12	1.85	1.70	1.63	1.74

It should be noted in the above table that the rolling mills for some plants are split to A and B as those plants have two rolling sections with the data available for each rolling section. From the above data, the achieved curves for rebar rolling were as follows:

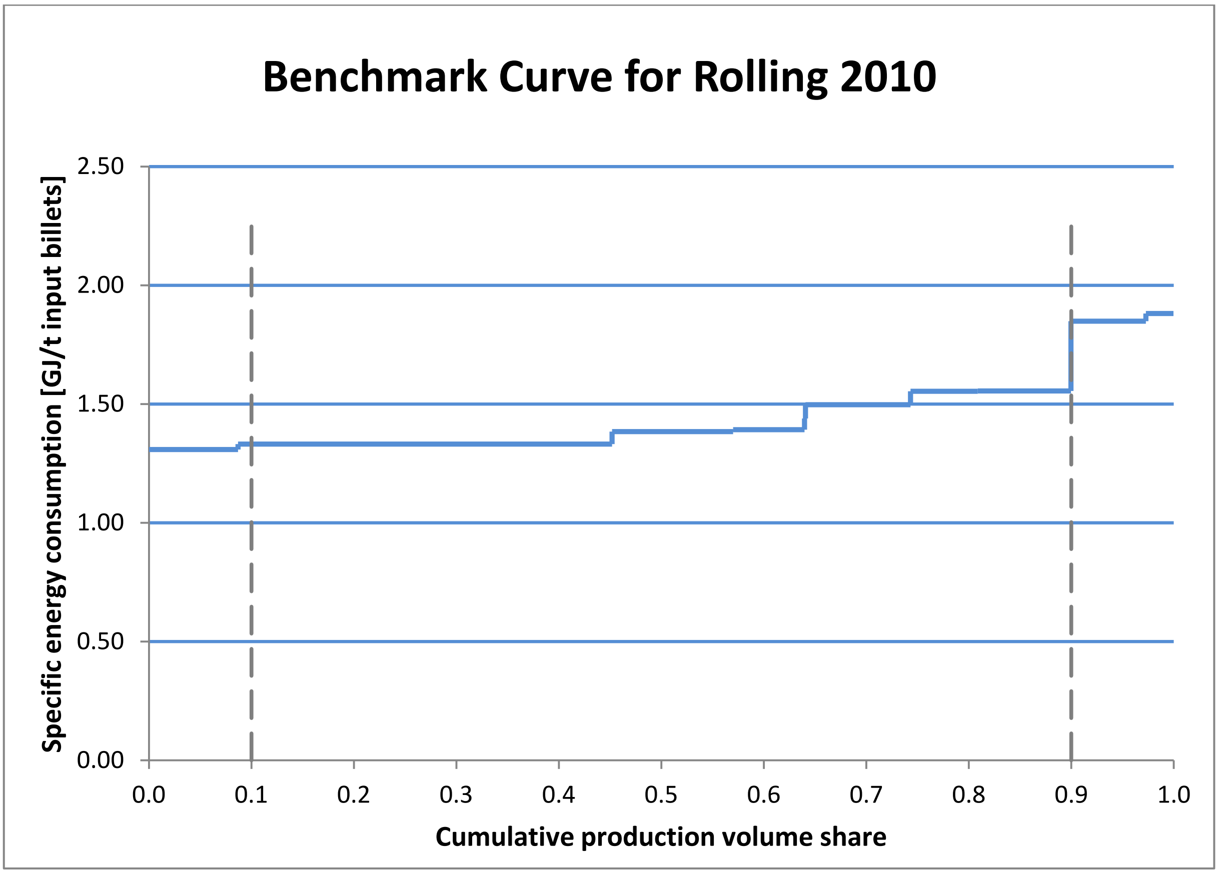


Figure 26: Benchmark Curve for Rebar Rolling for Year 2010

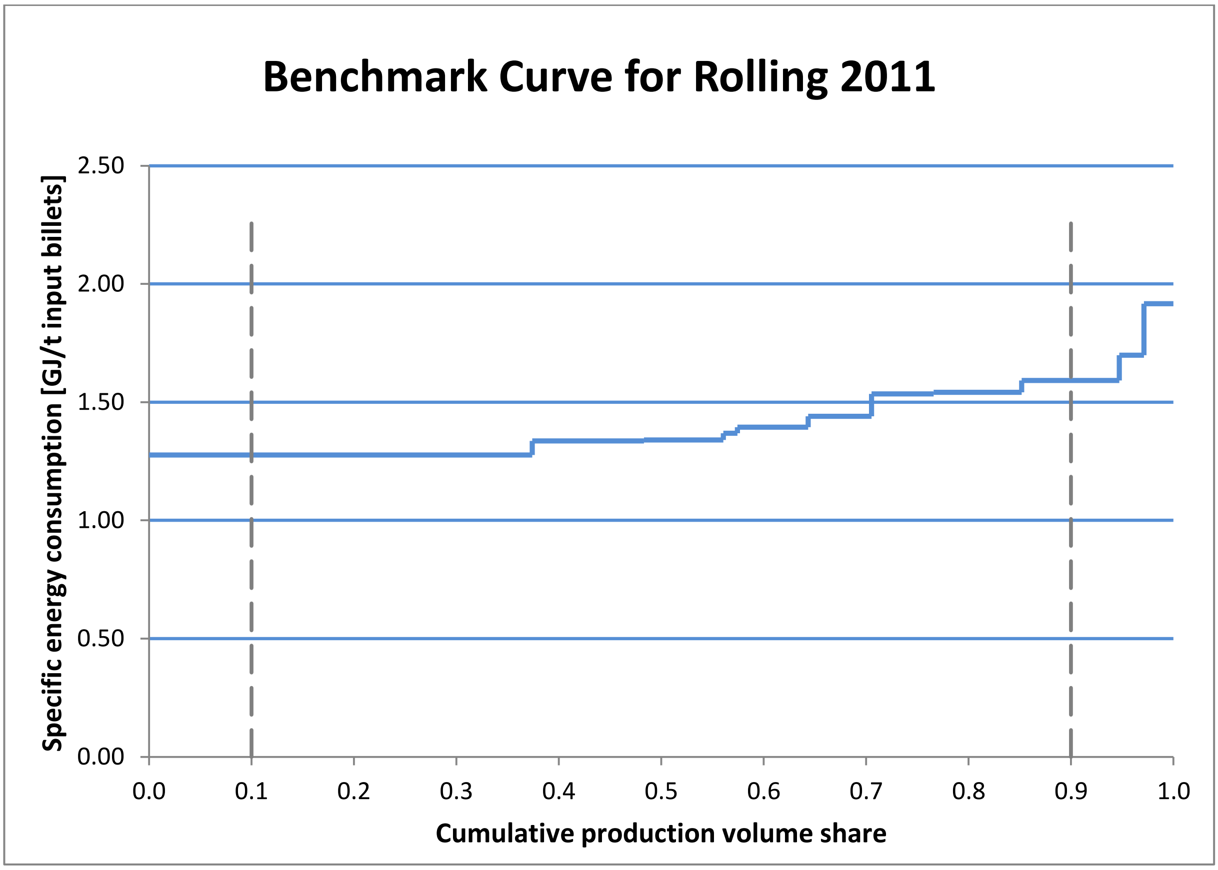


Figure 27: Benchmark Curve for Rebar Rolling for Year 2011

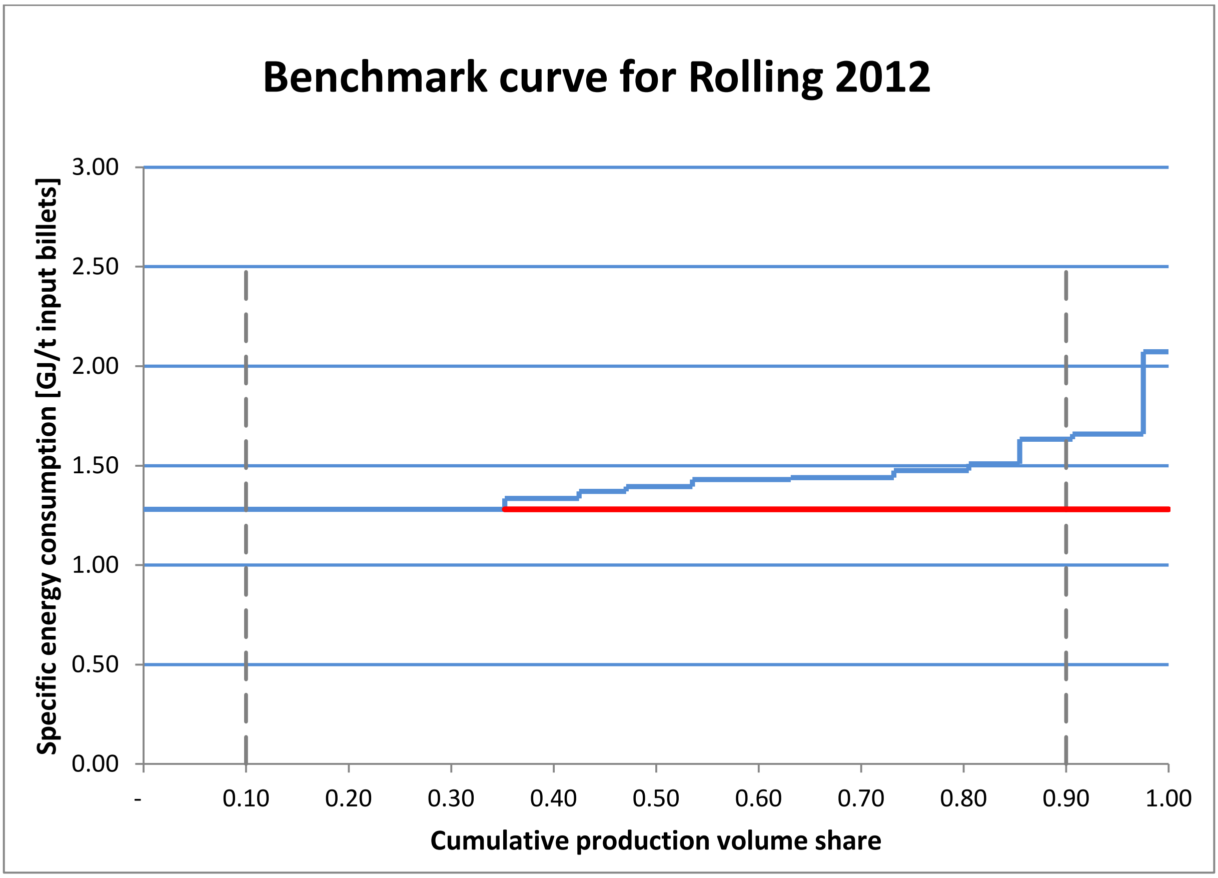


Figure 28: Benchmark Curve for Rebar Rolling for Year 2012

Table 55: Achieved EPI for Rolling for the Years 2010, 2011, 2012

BPT/BAT Value	2010 (GJ/T Billet)	2011 (GJ/T Billet)	2012(GJ/T Billet)
BPT	1,331	1.337	1.335
BAT	1.309	1.277	1.280

Through aggregating the data of the three years by summing the production and consumption of each plant for the three years in order to achieve the average EPI, following data were achieved:

Table 56: Achieved EPI for Rolling for Aggregated Data

Plant	Production Volume Share	EPI (GJ/T Billet)
IS01	3%	1.957
IS02	36%	1.295
IS03	6%	1.440
IS04A	8%	1.599

Plant	Production Volume Share	EPI (GJ/T Billet)
IS04B	9%	1.504
IS05A	8%	1.328
IS05B	11%	1.384
IS06	6%	1.534
IS09A	7%	1.394
IS09B	2%	1.369
IS12	5%	1.744

With the benchmark curve as follows:

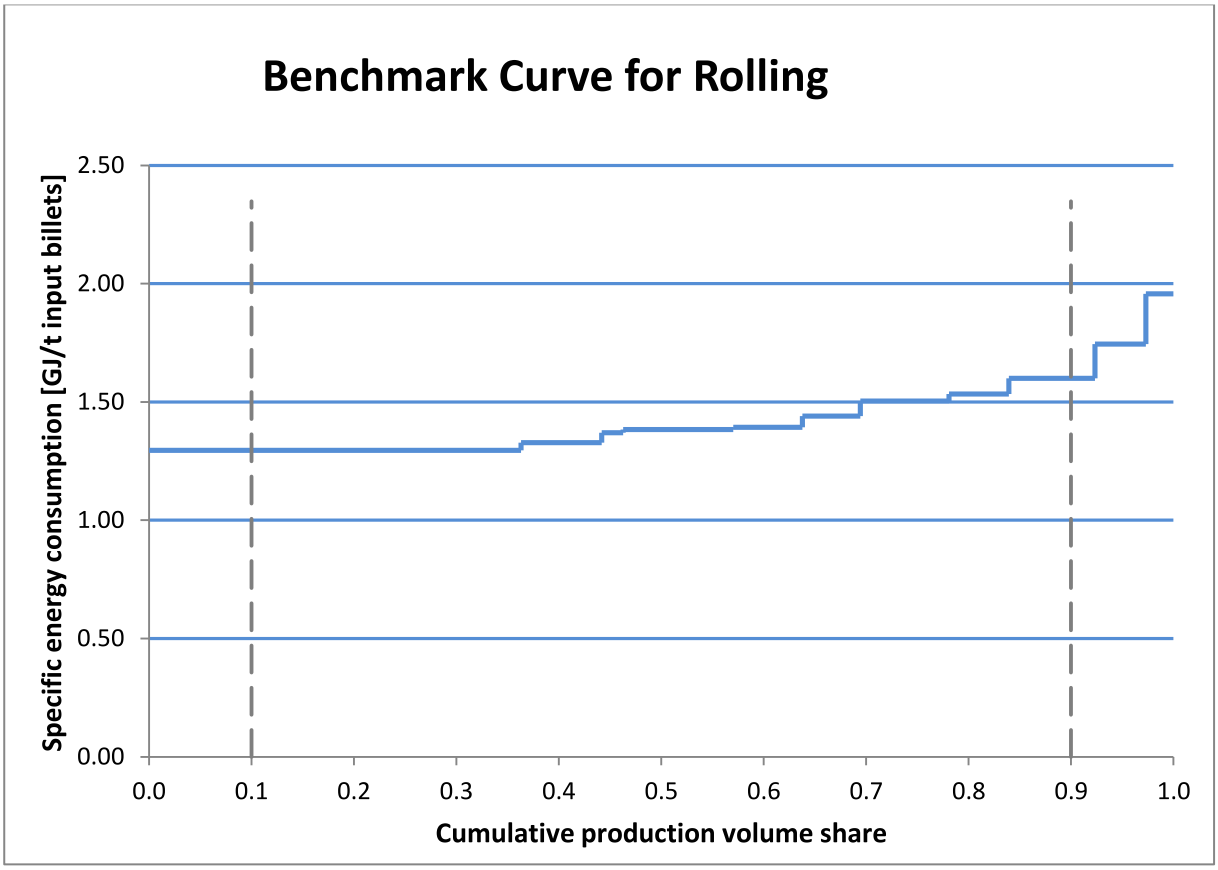


Figure 29: Benchmark Curve for Rebar Rolling

And the sector **BAT** is taken as 1.295 GJ/t Billet, which corresponds to the lowest EPI from the aggregated data, and the second best EPI which corresponds to the **BPT** was 1.328 GJ/t.

4.5.1.4 Hot Strip Mills Benchmarks

This curve includes the energy consumed in the thin slab casting and hot strip mill. For the studied plants, both processes are combined in a continuous line, hence their split is impossible. The energy sources are natural gas and electricity. Since there are only two plants running this process, and as one of them was stopped since 2012, the possible curves are only for 2010 and 2011 according to the following table and curves:

Table 57: Achieved SEC for Hot Strip Mills

Code	EPI (GJ/T Slabs)		
	2010	2011	Average
IS02	1.060	1.113	1.086
IS03	1.544	1.416	1.518

4.5.1.5 EAF-Rolling Mills Benchmarks

This curve aggregates the performance of the EAF-Continuous Casting with the performance of the corresponding hot rolling mills. The purpose of that curve is to check the performance on a plant level for plants producing rebars starting by the electric arc furnaces.

It should be noted that the reported production in this curve does not represent actual production for the corrections made to account for the sold and/or purchased billets as discussed in Chapter 4.5.1.

The achieved data from this analysis were as illustrated in Table 58:

Table 58: Achieved SEC for EAF-Rolling

Code	EPI (GJ/T Billets)			
	2010	2011	2012	Average
IS02	5.099	4.854	4.953	4.97
IS03	4.911	4.855	4.839	4.87
IS04	3.863	4.134	4.421	4.14
IS05	3.605	3.556	3.689	3.62
IS09	3.616	4.126	3.941	3.96

From the above data, the achieved curves for EAF-rebar rolling were as follows:

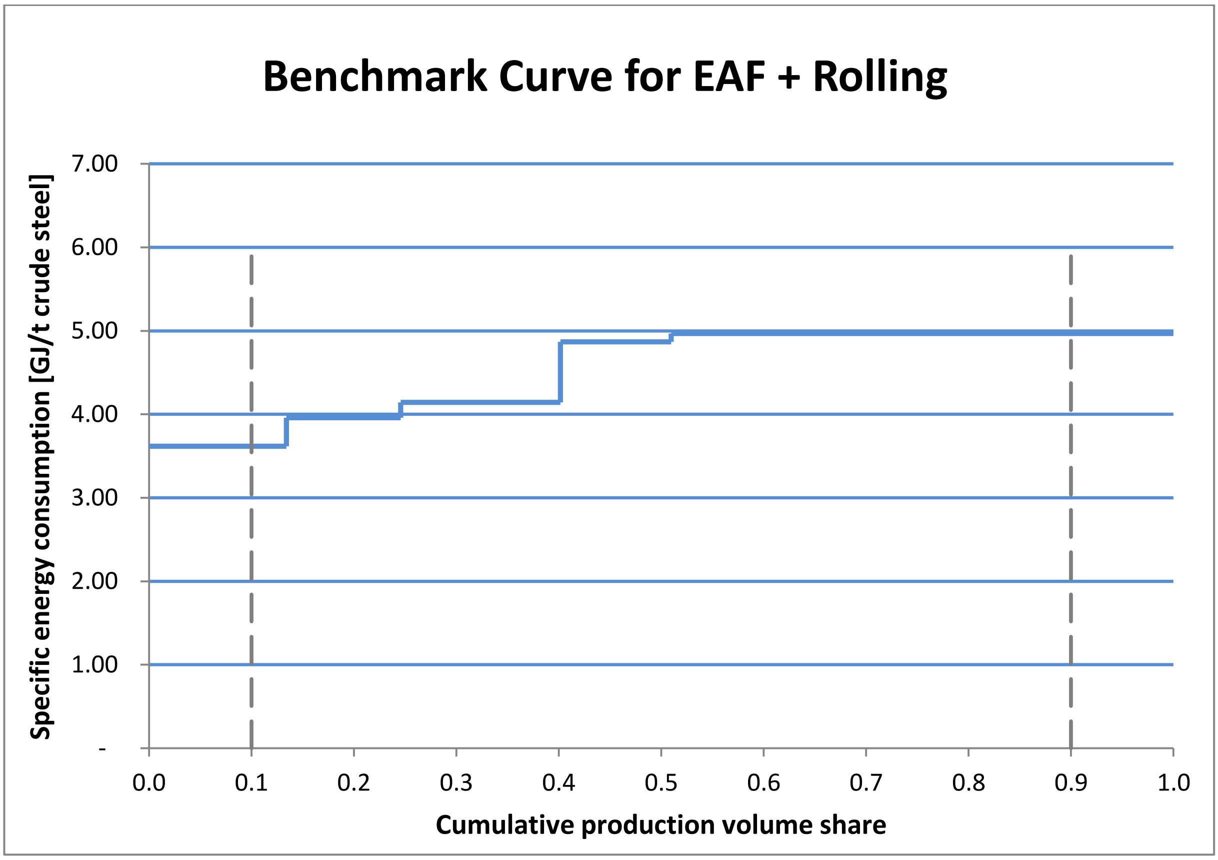


Figure 30: Benchmark Curve for EAF + Rolling

And the sector **BAT** is taken as 3.62 GJ/t Billet, which corresponds to the lowest EPI from the aggregated data, and the second best EPI which corresponds to the **BPT** was 3.96 GJ/t.

4.5.1.6 National BAT Values

For the BAT values, the lowest values available of all three years of all plants were chosen.

For the BPT values, the second best value of 2012 was chosen. For hot strip mills an exception was made. Usually the second best value was from a different plant than the BAT value. But as the values of the second hot strip mill analyzed would be higher than the average specific consumption, in this case the BPT was chosen as the second best value of the same plant, of which the data was derived for the BAT value.

From the data analysis on process level, following BAT values were obtained:

Table 59: Achieved National BAT and BPT Values per Process

Process	BAT SEC GJ/T Steel – Lowest of All Years	BPT SEC GJ/T Steel (2012 Values, except for BPT)
DRI	11.763	11.763
EAF	2.217	2.592
Rolling	1.28	1.335
Hot Strip Mill	1.060	1.113
EAF-Rolling	3.605	3.941

4.5.2 BAT on International Level

For the international energy performance indicators, BAT values from the Worrell study (Worrell, Price, Neelis, Galitsky, & Nan, 2008) are used for comparison. In that study, the following BAT figures were available:

Table 60: International BAT

Process	Electrical (GJ/T)	Thermal (GJ/T)	Oxygen (GJ/T)	Total (GJ/T)
DRI	-1.2	12.9	0	11.7
EAF (40% Scrap)	1.7	0.6	0.3	2.5
EAF (100% Scrap)	1.5	0.6	0.3	2.4
Continous casting	0.03	0.03	0	0.1
Hot Rolling Mills	0.3	1.6	0	1.8
Thin Slab Casting + Hot Strip Mill	0.2	0.1	0	0.2

From the collected data, two issues were faced as follows:

- The scrap ratio for most of the **EAF** plants is other than 40 % or 100 %. Consequently, we had to extrapolate the BAT figures, which would be 2.4 for 100 % scrap and 2.5 for 40 % scrap to fit for each plant conditions according to the following formula

$$BAT = \frac{BAT_{100\%\,scrap} - BAT_{40\%\,Scrap}}{100-40} * (scrap\ ratio - 40) + BAT_{40\%\,scrap}$$
$$= \frac{2.4-2.5}{100-40} * (scrap\ ratio - 40) + 2.5$$

From which, the following table illustrates the interpolated international BAT for each EAF plant/year:

Table 61: Corrected International BAT for EAF Plants

Code	Scrap Ratio (%)			BAT (GJ/t Crude Steel)		
	2010	2011	2012	2010	2011	2012
IS02	16%	14%	16%	2.540	2.543	2.540
IS03	62%	66%	70%	2.463	2.457	2.451
IS04	100%	100%	100%	2.4	2.4	2.4
IS05	87%	93%	94%	2.421	2.412	2.41
IS09	97%	94%	89%	2.406	2.41	2.418

4.6 Share of Energy Costs of Turnover

Not available for Iron and Steel.

4.7 Energy Cost Benchmark Curve for Egyptian Companies

For the energy cost per ton of product, four figures were calculated for each year: energy cost per ton direct reduced iron, energy cost per ton steel, energy cost per ton rebar and energy cost per ton flat product. The average values for each of the studied years are illustrated in the following table, where the curves are drawn with the plant identification code rather than the production share on the x-axis.

Table 62: Average Energy Cost per Process

Process	Average Energy Cost EGP/t Product		
	2010	2011	2012
DRI	260	265	332
EAF	152	155	162
Rolling	48	47	57
Hot Strip Mill	52	52	53
EAF-Rolling	192	195	212

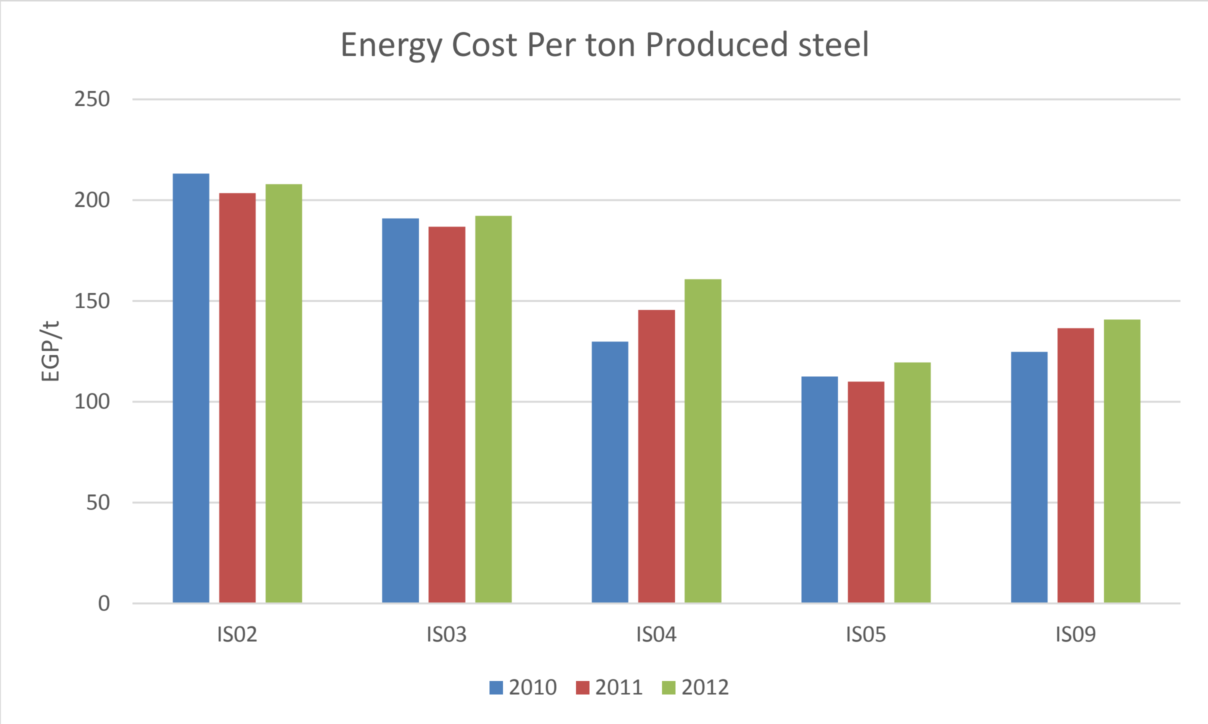


Figure 31: Cost of Energy for Electric Arc Furnaces

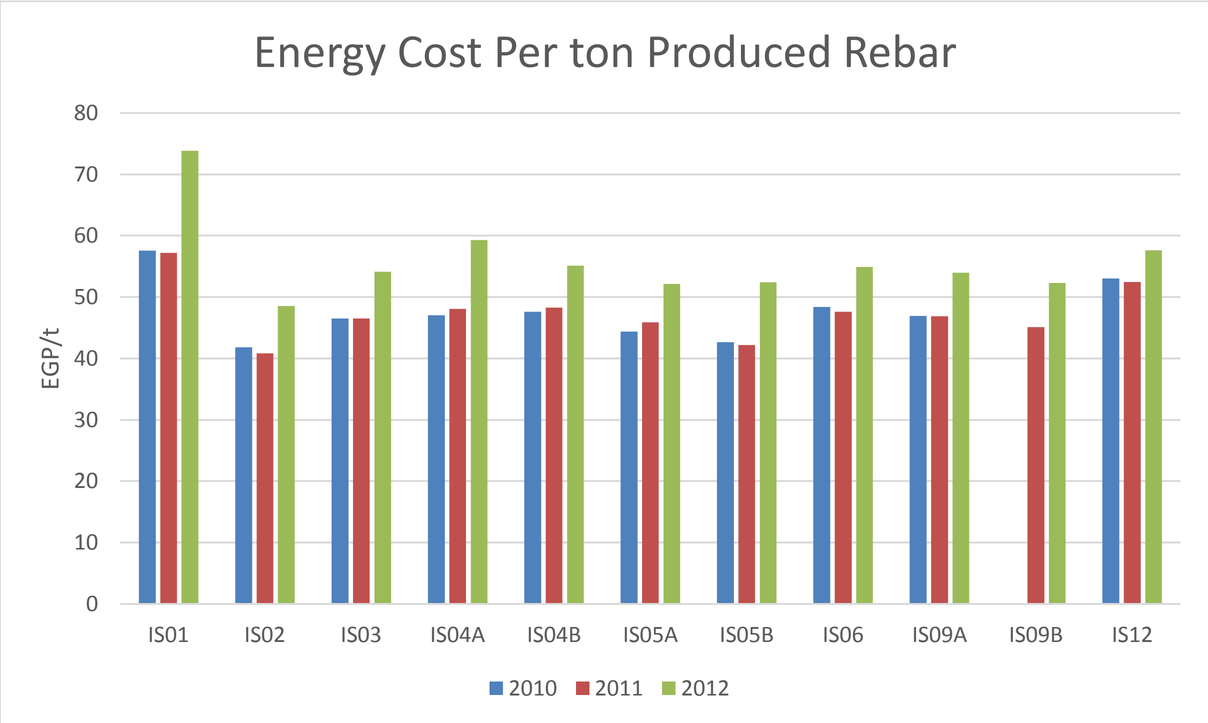


Figure 32: Cost of Energy for Rolling Mills

4.8 Annual Saving Potential

The saving potential was calculated for each plant (against the national BAT of the year 2012) for the process-steps EAF and Rolling Mills. As for Direct Reduced Iron and Hot Strip Mills, only one plant is currently operating and so the savings were not calculated for this step.

In addition, the saving potential was calculated for the whole sector. For this and the following scenarios, the BAT values were defined a little different to the plant level saving calculation. The BAT was taken either from international sources or from national data (with the lowest value of all plants of all three analyzed years). Furthermore, the saving potential was calculated for DRI and for Hot Strip Mills with current production data from IDA.

4.8.1 Annual Saving Potential for Each Plant

On plant level, the following table illustrates the estimated saving potential based on the national BAT values for 2012 and the following equation:

$$\text{Potential of each company (x)} = 1 - \frac{BAT\ national}{\text{SEC}_{\text{x}}}\ x\ annual\ production\ (t)$$

Table 63: Saving Potential for EAF

Code	BAT Based Saving Potential (%)	BAT Based Saving Potential (GJ)
IS02	37%	4,214,956
IS03	32%	759,724
IS04	20%	529,144
IS05	0%	0
IS09	11%	191,466
Total	**29%**	**5,695,290**

Table 64: Saving Potential for Rolling Mills

Code	BAT Based Saving Potential (%)	BAT Based Saving Potential (GJ)
IS01	38%	118,098
IS02	0%	0
IS03	11%	96,537
IS04A	23%	157,608
IS04B	13%	85,718
IS05A	4%	24,036
IS05B	10%	87,062
IS06	15%	68,704
IS09A	8%	44,368
IS09B	7%	24,846
IS12	22%	109,356
Total	**10%**	**816,334**

4.8.2 Annual Saving Potential for the Whole Sector

The annual saving potential for the whole sector was calculated for the following steps:

- Step 1: First, data from the analyzed plants of 2012 is used for deriving the average specific energy consumption.
- Step 2: Total energy consumption of Egypt is calculated by multiplying the total Egyptian production from IDA data with the specific energy consumption derived in Step 1.
- Step 3: This production value is also multiplied by the national or international BAT value (which is lower)
- Step 4: The difference of the values of Step 2 and 3 is to get the saving potential if the total Egyptian current production volume would be produced with the Best Available Technology.

For these BAT values the lowest values of all companies of all three years, or if even lower the international BAT was used.

Table 65: Sector EPI Calculation

2012	DRI	EAF	Hot Rolling[1]	Hot Strip Rolling[2]
Total Production analysed plants (tons)	2,835,451	6,166,973	6,030,268	919,741
Percentage of total Egyptian production [%]	100	85	65	33
Energy Consumption analysed plants (GJ)	33,352,769	19,875,111	8,536,913	1,065,441
Average Specific Energy Consumption (GJ/t)	11.763	3.223	1.416	1.158
BAT Value (GJ/t)	11.700 (International)	2.217 (National)	1.280 (National)	0.200 (International)
BPT Value (GJ/t)	11.763 (National)	2.592 (National)	1,335 (National)	1.113 (National)
Total Egyptian Production (t)[3]	**2,835,451**	**7,265,122**	**9,226,623**	**2,814,456**
Total Energy Consumption Egypt = Total Egyptian Production * Average SEC	33,352,769	23,414,260	13,061,920	3,260,306
BAT Based Saving Potential (%)	1	31	10	83
BAT Based Saving Potential (GJ)	177,993	7,307,484	1,251,843	2,697,415

Total Egyptian production is based on the data of installed capacities received from the IDA.

[1] Weights indicated in this column correspond to input billets, where billets = bars/0.9557 as the SEC and BAT values are per ton billet
[2] Weights indicated in this column correspond to input slabs, where slabs = flat/0.9625 as the SEC and BAT values are per ton slab
[3] Total Egyptian Production is based on the data of installed capacities received from the IDA

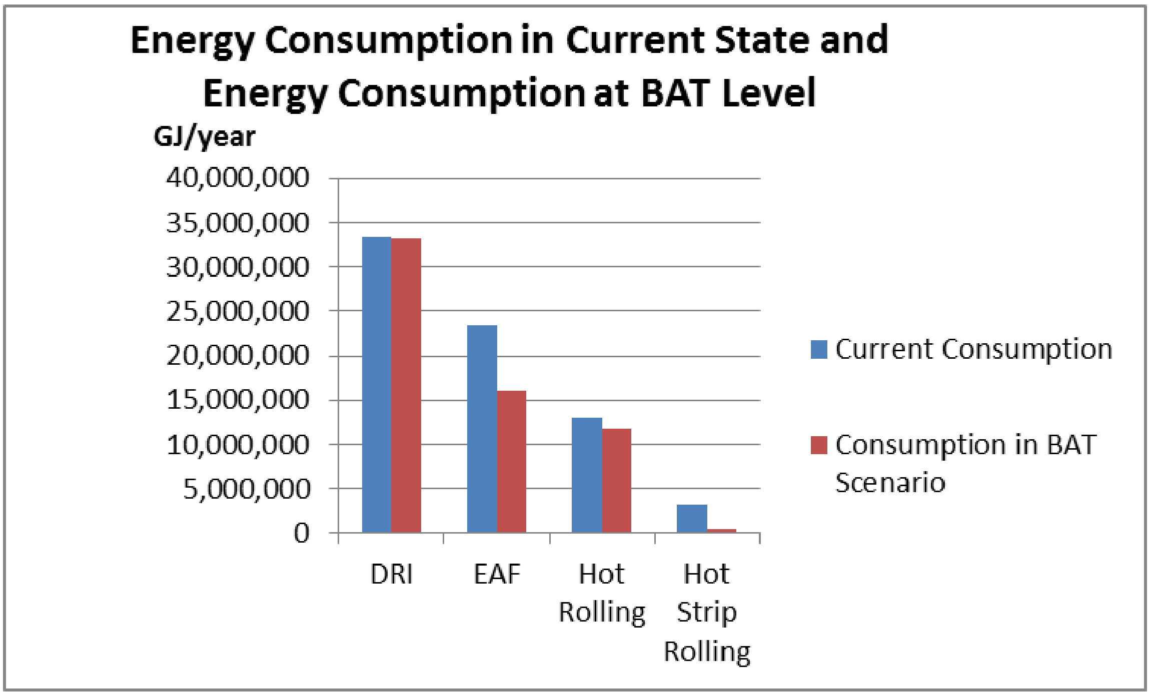


Figure 33: Energy Consumption in Current State and Energy Consumption at BAT Level with Current Production Volume

4.9 Saving Scenarios until 2050 and 2030

For iron and steel, the following procedure was applied to derive the energy savings till 2050:

In this study, the steel production steps DRI, EAF, rolling and hot strip mills were analyzed separately. In each process different amounts of steel are produced or machined (see table above). For the saving scenarios it was decided to exclude the DRI route, as only one plant was operating in the analyzed years which is already very close to the international BAT (11.76 GJ/t to 11.70 GJ/t Therefore this process step would not contribute a lot to the estimated saving based on the following calculations.

For deriving the production values for iron and steel in 2050 the following approach was chosen:

- In IEA 2009 Energy Technology Transitions for Industry (OECD, 2009) (p.58), the crude steel demand projections for the low- and high demand cases from 2006 to 2050 (with additional projection for 2015 and 2030) are published. The crude steel demand is given in per capita (kg/cap) for the regions "South Africa and Other Africa" (among others).
- For the scenario, the value for "Other Africa" was chosen and corrected (via interpolation of the values 2006 and 2015) to get the value for 2012. The corresponding increase to 2050 was calculated as a factor. For this study, the average between high and low demand case was chosen (for crude steel demand this factor is 1.97). This means the average per capita demand increases by approximately the factor of two between 2012 and 2050.
- In addition, the population growth for Egypt for this period was taken from the United Nations, World Population Prospects: The 2012 Revision, available on:
  http://esa.un.org/wpp/unpp/panel_population.htm
  From this source the factor for the population growth between 2012 to 2050 for Egypt was taken (1.51).

- To get the factor for the increase of the demand between 2012 and 2050 those two factors are multiplied: For crude steel it is 2.8. This means that until 2050 the demand for iron and steel increases by a factor of three (which corresponds to an annual growth rate of 2.91 %).
- This factor was applied to all three production volumes and the annual increase was calculated for the production scenario.

For the different efficiency scenarios, the specific energy consumptions mentioned in table 65 were used. The production values were calculated for each year by multiplying the current production volume with the calculated annual growth rate. This volume was multiplied with the different specific energy consumption values calculated for each year to get the forecasted energy consumption for each production step. For each year, the three derived energy consumption values were added to get one energy consumption value for the sector iron and steel in Egypt.

As the BOF route was excluded from the whole analysis, these values do not include this route, which was below 10% in 2012 and is diminishing each year. In addition the DRI route was also not included for reasons mentioned above.

Frozen efficiency: no additional energy efficiency savings are made. The current levels of energy efficiency are not improved upon.

Baseline efficiency: energy efficiency improves at a rate of 0.50% a year.

BPT scenario: all plants are operating at the current levels of BPT by 2050. In the years between 2012 and 2050 the specific energy consumption improves gradually from the current SEC to reach the BPT value by 2050.

The value for the BPT was derived from the second best values for 2012 from the analysed data set. One exception was made for the hot strip mills: Only one plant was operating in 2012, therefore for the BPT value, the second best value of the best plant in the years 2010 and 2011 was chosen. As 2010 was the lowest one, the SEC of 2011 was chosen.

This is equivalent to an energy efficiency improvement of 0.41% a year in the period 2012 to 2050. The BPT is the lowest known BPT, either on international or on national level.

BAT scenario: all plants are operating at current levels of BAT by 2050. In the years between 2012 and 2050 the specific energy consumption improves gradually from the current SEC to reach the BAT value by 2050.

This is equivalent to an energy efficiency improvement of 0.90% a year in the period 2012 to 2050. The BAT is the lowest known BAT, either on international or on national level.

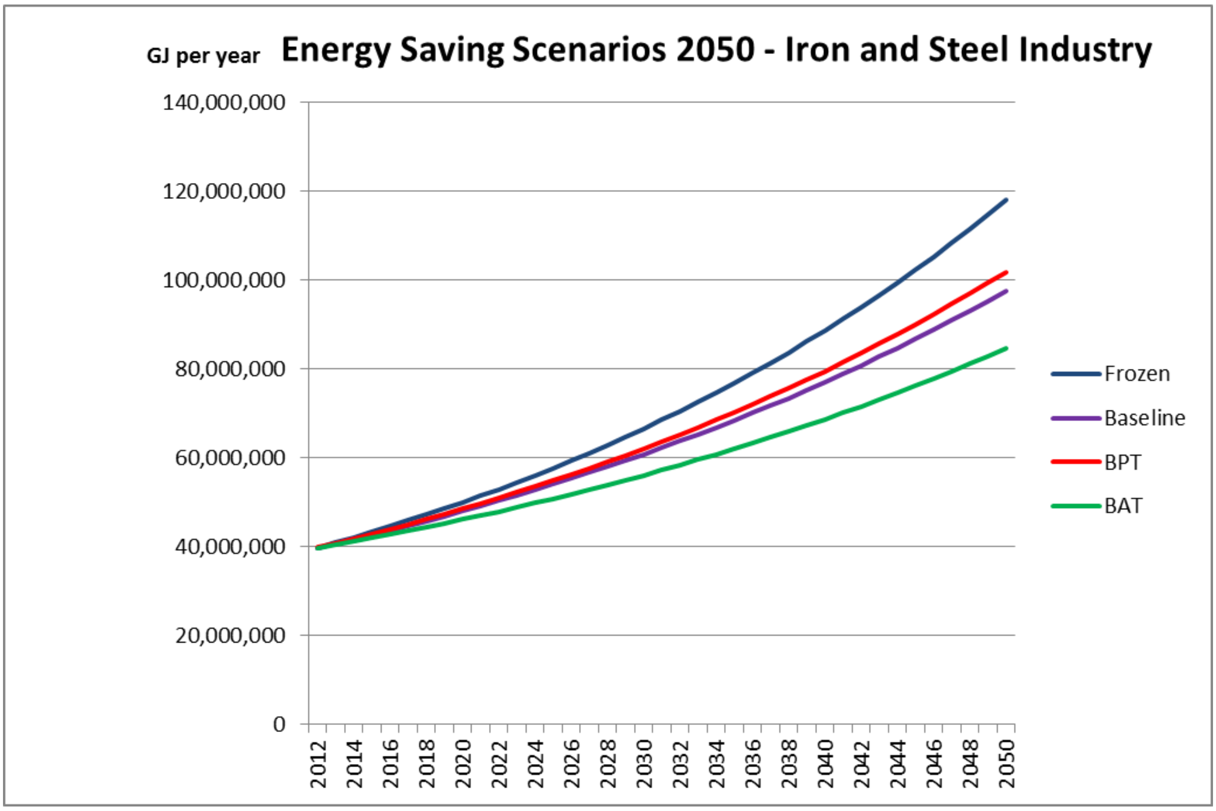


Figure 34: Energy Consumption Growth for Egyptian Iron and Steel Sector for the Process Steps EAF, Hot Rolling and Hot Strip Rolling for the Different Scenarios, 2012-2050

For the scenario until 2030, the same procedure as for the scenario for 2050 was applied. The difference is that the same BAT and BPT values are already reached in 2030 instead of 2050. For the production volume, the values were calculated with the corresponding 2030 values from the same sources mentioned above. The annual production growth rate based on this calculation is 3.12%.

BPT scenario: all plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 0.84% a year in the period 2012 to 2030.

BAT scenario: all plants are operating at current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 1.89% a year in the period 2012 to 2030. The BAT is the lowest known BAT, either on international or on national level.

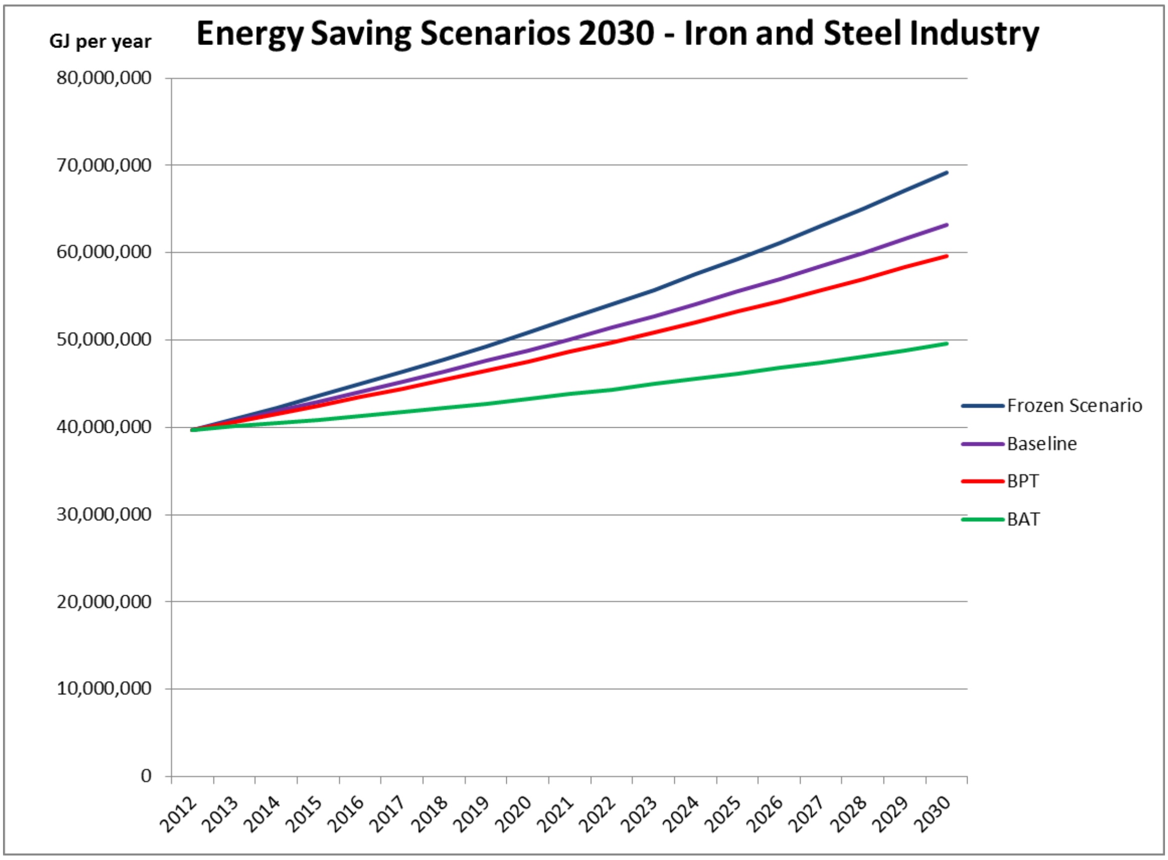


Figure 35: Energy Consumption Growth for Egyptian Iron and Steel Sector for the Process Steps EAF, Hot Rolling and Hot Strip Rolling for the Different Scenarios, 2012-2030

Table 66: Energy Consumption for Egyptian Iron and Steel Sector for the Different Scenarios (without BOF Route) and Energy Saving of the BAT Scenario in Comparison to the Frozen Scenario

Year	Frozen Scenario (TJ/a)	Baseline Scenario (TJ/a)	BPT Scenario (TJ/a)	BAT Scenario (TJ/a)	Savings Frozen – BAT Scenario (TJ/a)	Cumulative Savings (Frozen-BAT) (TJ)
2012	39,740	39,740	39,740	39,740		
2030	69,147	63,181	59,649	49,555	19,592	172,184
2050	118,026	97,556	101,815	84,585	33,442	513,387

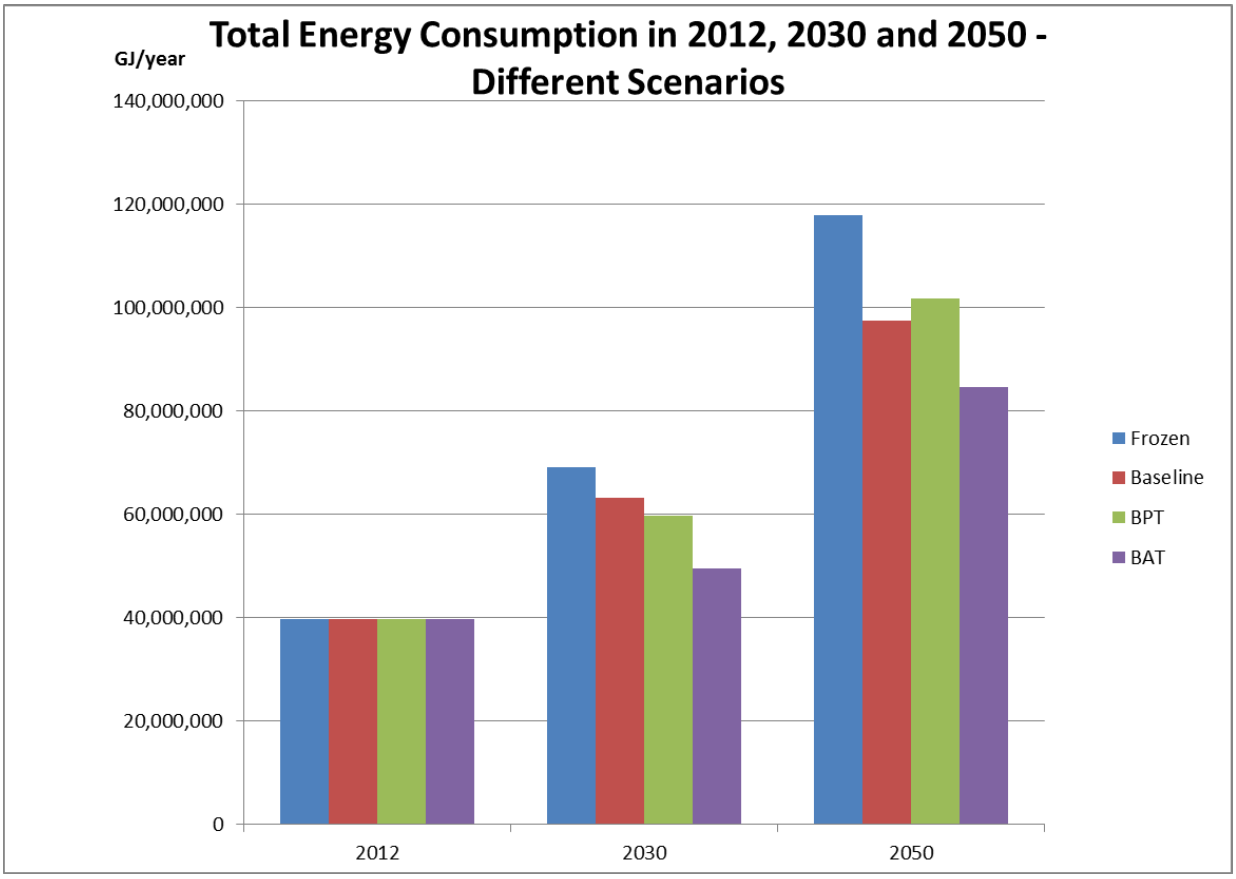


Figure 36: Energy Consumption for Egyptian Iron and Steel Sector for the Process Steps EAF, Hot Rolling and Hot Strip Rolling for the Different Scenarios

The saving potential for both years 2030 and 2050 is 28.3% in the BAT scenario in comparison to the frozen scenario.

4.9.1 Conclusions from Saving Analysis and Further Work Needed

First of all for the scenarios a sum of all energy consumption values for the different production processes was calculated. Therefore the different saving assumptions for the different processes is not visible on these charts:

For the electric arc furnaces a quite a high saving potential of approximately 30% is estimated. But it has to be mentioned that especially those plants with a low scrap ratio have a high specific energy consumption which lies considerably above the international benchmark and the national BAT, which is derived from plants with scrap ratio of 90% and above. Therefore those plants would have to be analyzed in more detail to verify that saving potential. In addition an international BAT for lower scrap ratios (below 40%) would have to be elaborated.

For hot rolling the current saving potential is estimated to be low as the mills in comparison to the BAT value are already quite good. Here a more detailed analysis of more current international BAT values would be necessary.

For hot strip rolling the international BAT value (0.20 GJ/t) is very low compared to those derived from the Egyptian plants (above 1 GJ/t). For these plants a more detailed study is recommended to find reasons for the explanation of this big difference.

5 Recommendations

5.1 Strengthening the Statistical Data Collection Process in Egypt

The statistical energy relevant data for industrial sectors in Egypt are not based on real production capacity and energy consumption data, but on planning data. This should be improved and the statistical data collection process of energy relevant data of companies in Egypt should be optimized including following steps:

1. Each company has to report relevant data like energy consumption and production volumes on a regular basis (monthly/yearly) to the statistical authorities. A standardized data collection template should be applied. This template can be elaborated based on the data collection sheet for the analysis in the participating companies.
2. Collection and aggregation of data should be done by the statistical authorities.
3. The statistical authorities should publish the aggregated data annually.
4. Regarding to the collected data an energy balance should be established.

To support the energy relevant statistical process the following steps and requirements are important:

- Plausibility checks of all collected data
- Received data should be verified onsite at random
- There have to be enough personnel resources
- Experts of statistical authorities, sector associations and companies (private and state owned) should be well trained

5.2 Implementing Support Programmes for Industry

5.2.1 Energy Management Programmes

In companies not having an energy management system in place there is no structured approach to improve their energy performance. Although the possibilities to improve the energy performance may be known, either identified within an energy audit or by internal staff, the measures are not simply implemented. This is due to several reasons, one being that the top-management or other key stakeholders oppose such measures or prefer other investment measures with better return on investment. In case the measures are implemented, often the energy consumption starts to rise again after a certain time because there is a lack of precise roles and responsibilities for maintaining the optimized systems.

Therefore a systematic approach is needed. Energy management can offer this approach: First of all, energy must be a key topic in the company, from top-management down to all employees all relevant persons shall be engaged in saving energy. Clear target setting and the follow-up of saving measures ensure that energy efficiency steadily increases. Systematic energy management as systematic tracking, analysis and planning of energy use is one of the most effective approaches to improve energy efficiency in industries ((IEA, 2012).

Energy management programmes are policies and initiatives that encourage companies to adopt energy management.

There are various approaches to implement energy management programmes in a country or a region. The approach depends on the existing policy framework, objectives, industrial composition and other country- or region-specific factors.

Energy management programmes are most effective when planned and implemented as part of broader energy efficiency agreements with the government. During the planning stage the purpose of the program should be articulated, including inter-linkages with other policies. Important design steps include establishing what support systems need to be created to boost implementation, how progress will be monitored, and setting up plans for evaluating the results of the program. The success of the energy management program is clearly correlated with the provision of appropriate resources and supporting mechanisms, including assistance, capacity building and training, and provision of tools and guidance during the implementation stage.

Benefits of Energy Management Programmes

The main objectives of energy management programmes are to decrease industrial energy use and reduce greenhouse-gas emissions. If properly designed they also can help attain other objectives. By supporting industry in using energy more productively they can boost competitiveness and redirect savings to more productive uses and reduce maintenance cost.

A further benefit is that energy management programmes are flexible instruments that can be adapted to changing policy needs and changes in industry thereby ensuring continued effectiveness and relevance. By continuously monitoring implementation and through regular evaluation, policy makers can identify opportunities to include new mechanisms or establish linkages to emerging policies.

In implementing energy management programmes, governments can play an important role in establishing a framework to promote uptake of energy management systems, by developing methodologies and tools, and promoting the creation of new business opportunities in the area of energy services. Energy management programmes can tend to achieve significant and sustainable savings at very low cost in the initial years.

5.2.2 Energy Audit Programmes

Energy audit programmes are a very cost efficient way to reach national targets on greenhouse gas reduction or increase of energy efficiency. From the energy audits, energy saving potentials and saving measures are identified. The companies and organisations then decide whether to carry out saving measures or not, or put them in a framework for a more years investment and execution planning.

From the policy design point of view, an energy audit program usually consists of several elements:

- The implementing instruments like the legislative framework, the subsidy /financial scheme and other incentives/promotion and marketing activities.
- The administration of the program with the interaction of the key players: the administrator (very often a government level body), the operating agent (e.g. an energy agency), the auditors and the participating organizations. The operating agent is responsible for the development of the energy audit models and the monitoring system.
- Quality assurance comprises the training and/or the authorization of the auditors and the quality control (checking of the reports).
- In addition, audit tools should be made available.

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7 Abbreviations

AEA	Austrian Energy Agency
BAT	Best Available Technology
BPT	Best Practice Technology
CAPMAS	Central Agency for Public Mobilization and Statistics
CHP	Combined Heat and Power
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EE	Energy Efficiency
EEI	Energy Efficiency Index
EGP	Egyptian Pound
EPI	Energy Performance Indicator
IEA	International Energy Agency
IDA	Industrial Development Authority
IEE	Industrial Energy Efficiency
JRC	Joint Research Centre
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
SEC	Specific Energy Consumption
SME	Small and Medium Sized Enterprise
TFEU	Total Final Energy Use
UNIDO	United Nations Industrial Development Organization

8 Annex

Table 67: Data Collection Sheet General Information

Company Data	
Company Name	
Company Code	
City	
Contact Name	
Email Address	
Phone Number	
Website	

Table 68: Data Collection Sheet General Information

Plant Description	2010	2011	2012
Plant Capacity [t]			
Actual Production [t]			
Number of Shifts			
Hours of Operation Per Year			
Number of Employees (incl. Sub-contracted)			
Year of Starting Production of This Site			
Total Plant Size [m²]			

Table 69: Detailled Data Collection Sheet

Basic Technical Information	Number	Total Capacity [t/h]	Technology applied	Thermal Power installed	Thermal Cons.	Electric Power installed	Electrical Consumption
Sintering Plants							
Coke Ovens							
Blast Furance							
Basic Oxygen Furance							
Direct Reduction Plant							
Electric Arc Furance							

Basic Technical Information	Number	Total Capacity [t/h]	Technology applied	Thermal Power installed	Thermal Cons.	Electric Power installed	Electrical Consumption
Continous Casting/Laddle Treatment							
Re-Heating Furnace							
Hot Strip Mill							
Plate Mill							
Section Mill							
Acid Treatment							
Cold Rolling							
Finishing							
Oxygen Plant							

Table 70: Data Collection Sheet Input Data

Energy (per year)	
Electricity	
Heavy Fuel Oil (Mazout)	
Liquified Petroleum	
Propane	
Butane	
Natural Gas (combustion) + LC	
Natural Gas (process)	
Natural Gas (others)	
Natural Gas (total)	
Coal	
Steam Purchased	
District Heating, Hot Water	
Compressed Air Purchased	
Fuels (for material transport on site)	
Coke	

Energy (per year)	
Oxygen (purchased)	
Alternative Fuels	
Others	

Table 71: Part of Data Collection Sheet Input Data

Energy (per year)	
Electricity	
Heavy Fuel Oil (Mazout)	
Light Fuel Oil (Solar)	
Natural Gas	
Coal	
Coke	

Table 72: Part of Data Collection Sheet Input Data

Iron & Steel	
Iron Ore	
Sinter	
Pellets	
Scrap	
Direct Reduced Iron	
Pig Iron (Hot Metal)	
Ingots	
Liquid Steel	
Oxygen	
Plastic	
Slabs (Semiproduct)	
Billets (Semiproduct)	
Lime	

Table 73: Part of Data Collection Sheet Output Data

Pig Iron	
DRI (Sponge Iron)	
Liquid Hot Metal	
Crude Steel	
Slabs	
Blooms	
Billets	
Thin Slabs	
Reinforcing Bars	
Coils	
Plates	
Others	

Table 74: Data Collection Sheet Part Energymanagement Information

Energy Management Information	
Management system applied? If yes, which one	
If the answer to question 1 is not ISO 50001, please answer the following questions:	
Responsible Person for Energy issues (e.g. Energy manager)?	
Do you analyse your energy consumption?	
Are energy meters/sub-meters installed?	
Resources available for Energy management?	
Energy efficiency considered in investment decisions?	
Energy Efficiency Targets available?	
Previous Energy Audits Available? If yes date of audit?	
Energy saving measures planned?	

Table 75: Implemented General Energy Saving Measurements

General	
Preventive maintenance	
Energy monitoring and management system	
Combined heat and power/cogeneration	
High efficiency motors	
Variable speed drivers: flue gas control, pumps and fans	

Table 76: Implemented Energy Saving Measurements: Steelmaking

Steelmaking - Electric Arc Furnace (EAF)	
Improved process control (neural network)	
Adjustable speed drives	
Transformer efficiency - Ultra high power transformers	
Bottom stirring/stirring gas injection	
Foamy slag practice	
Oxy-fuel burners	
Post-combustion of the flue gases	
DC arc furnace	
Scrap preheating - tunnel furnace (Consteel)	
Scrap preheating, post combustion - shaft furnace (Fuchs)	
Engineered refractories	
Airtight operation	
Contiarc furnace	
Flue gas monitoring and control	
Eccentric bottom tapping on existing furnace	
DC twin-shell with scrap preheating	
Casting	
Efficient caster laddle/tundish heating	
Near net shape casting - thin slad	
Near net shape casting - strip	

Table 77: Implemented Energy Saving Measurements: Hot Rolling

Hot Rolling	
Proper reheating temperature	
Avoiding overload of reheat furnaces	
Energy efficient drives in the rolling mill	
Process control in hot stip mill	
Recuperative and regenerative burners	

Hot Rolling	
Flameless burners	
Insulation of furnaces	
Walking beam furnace	
Controling oxygen levels and/or speed on combustion air fans	
Heat recovery to the product	
Waste heat recovery (cooling water)	

9 List of Figures

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