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Industrial Energy Efficiency
Benchmarking Report for the Cement Sector

IEE
INDUSTRIAL ENERGY EFFICIENCY

2014

Industrial Energy Efficiency
Benchmarking Report for Cement Sector

Prepared by

AUSTRIAN ENERGY AGENCY

And

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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“, implemented by the United Nations Industrial Development Organization (UNIDO) and funded by 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 cement 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, comprehensive data single-handed collected by national experts in selected 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 cement 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.

Chapter 3.3.4 describes the main drivers for energy consumption in the cement industry. The main driver is the production process of clinker. About 96% of the total energy consumption is used for producing clinker in the kilns. The main fuels used for clinker production are Mazout and natural gas. A much smaller part of the total energy consumption is used for the preparation of raw materials and grinding the clinker to cement.

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 different production processes of the cement industry for the main cement types.

Production Process		Portland Cement (GJ/t)
Raw Materials Preparation:	Electricity	0.07
Clinker Making	Fuel	2.79
	Electricity	0.08
Finish Grinding 325 Cement	Electricity	0.06
Total Thermal Energy Use (GJ/t Cement)		2.71
Total Electricity Energy Use (GJ/t Cement)		**0.21**
Total Energy Use (GJ/t Cement)		**2.92**

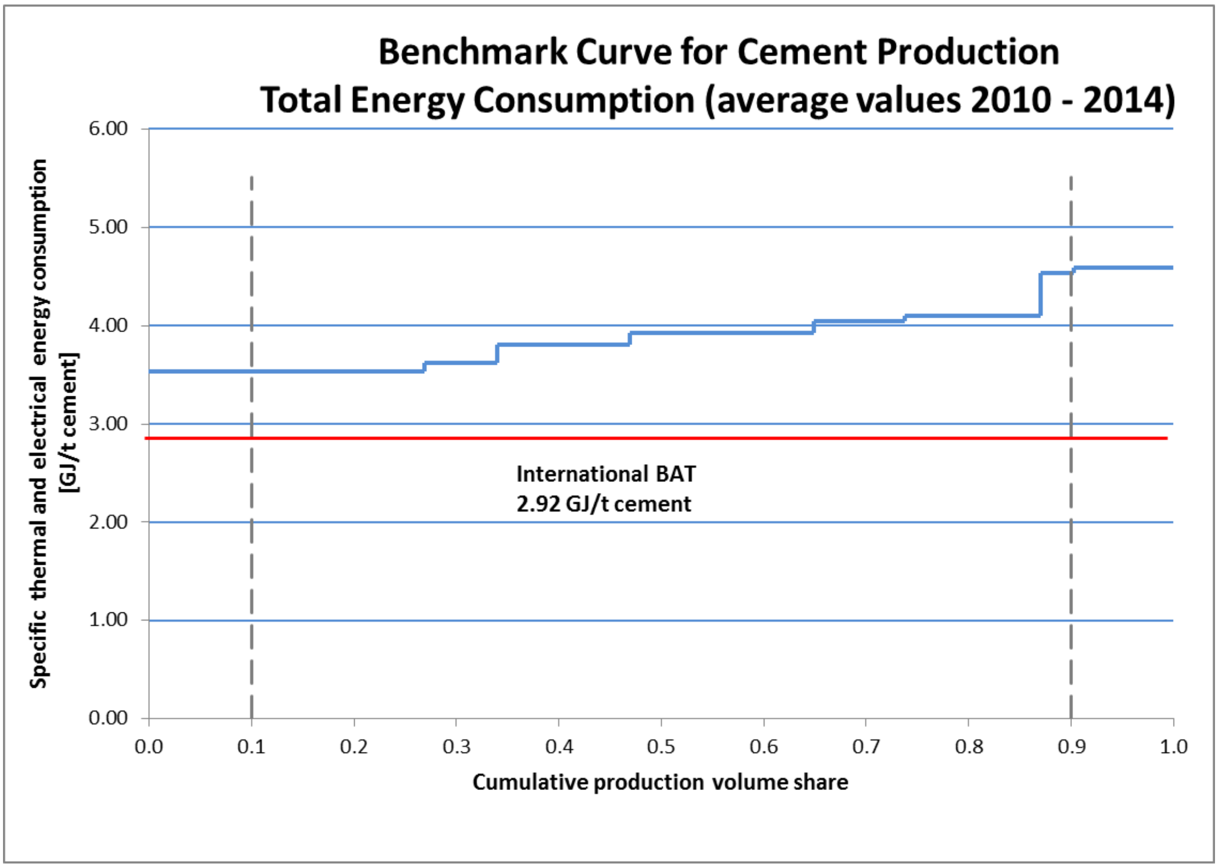
From this study, the world Best Available Technology (BAT) value with of total specific energy consumption 2.92 GJ/t cement was taken. This value was used for calculating the saving potentials of the whole cement sector in Egypt.

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 Egyptian cement plants. From the 22 cement plants operating in Egypt, 11 plants were analyzed. These 11 plants have a share of 25% of the total energy consumption of the cement sector in Egypt, which is quite a representative sample. During the data quality control one of the 11 plants was identified as an outlier. The plant was contacted to verify the data but did not reply. So this data set was dropped from further analysis.

One important result of the study is the construction of energy efficiency benchmark curves. The following graph shows the benchmark curve for the cement industry of 8 analyzed plants for the total energy consumption. The data correspond to the average specific energy consumption of the years 2010 – 2014.

These types of benchmark curves show the specific energy consumption of the analyzed companies per ton of cement 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 most efficient plant of the analyzed companies in Egypt has a specific total energy consumption of 3.53 GJ/t cement and a production volume share of 27%. This value defines the national BAT value. The red line indicates the international BAT value which corresponds to a specific total energy consumption of 2.92 GJ/t cement. The second lowest specific energy consumption in this curve is defined as the national best practice technology (BPT) value. The national BPT value is 3.62 GJ/t.

For this study, the BPT value was only applied for the saving scenarios in Chapter 4.7 in order to draw up the BPT scenario. It was defined that the lowest known BPT value, either on national or international level, would be applied for the scenario. For the cement industry, the international BPT for total energy consumption is 3.02 GJ/t cement, which is lower than the national BPT value of 3.61 GJ/t cement.

In Chapter 4.6, energy saving potentials were calculated, on the one hand, for the 10 companies that participated on the benchmarking study and on the other hand, for the whole Egyptian cement sector. The 10 companies have an energy saving potential for thermal energy of about 8.7 PJ/a. The saving potential for electrical energy of the 10 plants is about 177 GWh/a.

The total energy saving potential of the whole cement industry sector in Egypt is about 52 PJ/a.

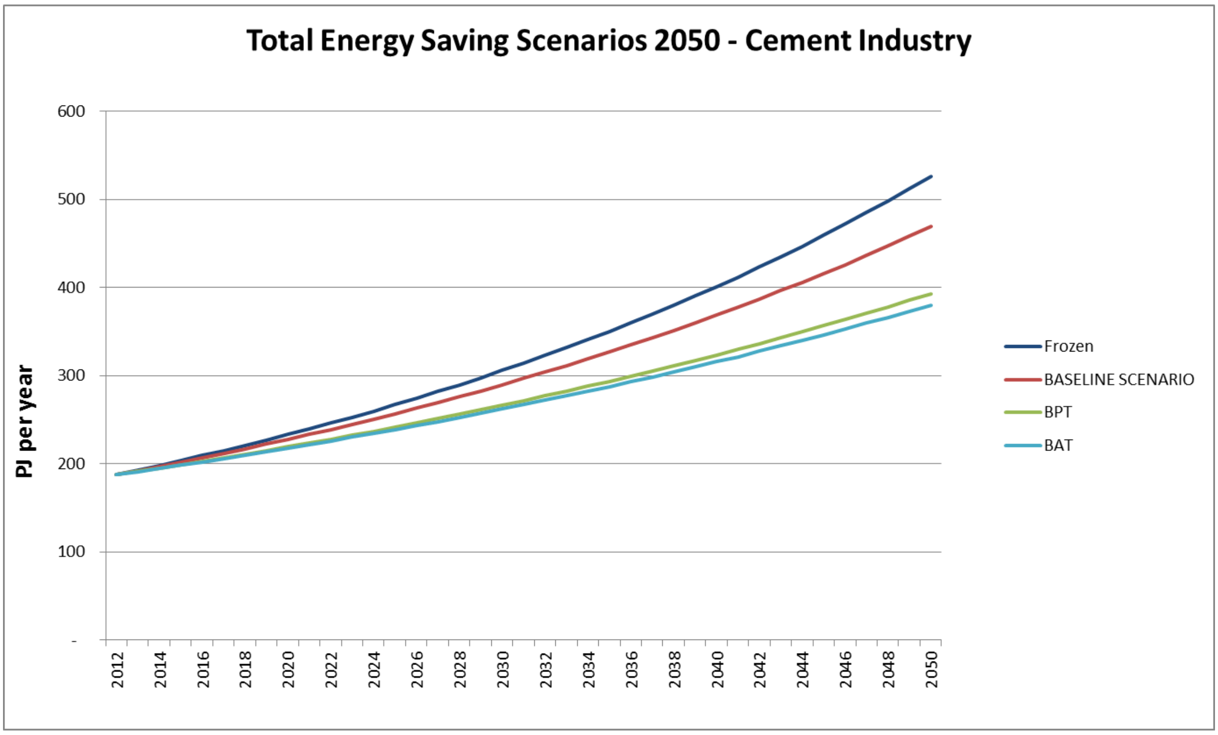
Furthermore, in Chapter 4.7 different energy saving scenarios until 2030 and 2050 were drawn. The scenarios correspond to the scenarios in the UNIDO Working Paper. The four scenarios are:

- **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 0.3% a year.
- **BPT scenario**: All plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 1.65% a year in the period 2012 to 2030. The BPT is the lowest known BPT, either on international or on national level. For the cement sector the international BPT value was chosen (3.02 GJ/t cement).
  All plants are operating at the current levels of BPT by 2050. This is equivalent to an energy efficiency improvement of 0.78% a year in the period 2012 to 2050.
- **BAT scenario:** All plants are operating at the current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 1.84% a year in the period 2012 to 2030. The BAT is the lowest known BAT, either on international or on national level. For the cement sector the international BAT value was chosen (2.92 GJ/t cement).
  All plants are operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 0.87% a year in the period 2012 to 2050.

An important factor for drawing the scenarios is the rate of production growth. The production of the cement sector in 2050 will be 2.8 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.

The following graph shows the four scenarios until 2050 for the growth of total energy consumption in the cement industry. The basis for calculating these scenarios was the annual production volume of the whole sector according to the IDA which was 46.5 Mt of cement for the year 2012. Multiplied with the weighted average total energy consumption of the analyzed companies which is 4.04 GJ/t cement these to figures led to the total annual energy consumption of the cement sector in Egypt in the year 2012. This total energy consumption of 187.9 PJ in the year 2012 was the basis for all 4 scenarios.

According to the frozen efficiency scenario, the annual total energy consumption in 2050 is about 526 PJ for the whole sector. The annual energy consumption in 2050 according to the BAT scenario is about 380 PJ. Comparing the frozen efficiency scenario and the BAT scenario, the annual saving potential would be about 145.8 PJ, which is 28%.



The following table below shows the total annual energy consumption of the whole sector 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)	Baseline Scenario (PJ)	BPT Scenario (PJ)	BAT Scenario (PJ)	Savings Frozen - BAT Scenario (PJ)	Cumulative Savings BAT Scenario (PJ)
2012	187.9	187.9	187.9	187.9		
2030	319.3	302.5	238.7	230.8	88.5	750.5
2050	526.0	469.3	393.2	380.2	145.9	10,651.3

In order to reach the savings of 88.5 PJ in 2030 the sector would need to implement energy saving measures of about 4.9 PJ per year. Per company this means annual savings of about 224 TJ.

In order to reach the saving of 145.9 GJ in 2050 the sector would need to implement energy saving measures of about 3.8 PJ per year. Per company this means annual savings of about 174 TJ.

In Chapter 4.8, the sector-specific energy saving opportunities and measures are described. This study offers a solid basis for further energy efficiency projects for the Egyptian cement 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 cement 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. The following saving potentials were calculated:

- **Frozen efficiency**: No additional energy efficiency savings are made.
- **Baseline efficiency**: Energy efficiency improves at a rate of 0.3% 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 following table shows the annual energy consumption of the whole sector 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)	Baseline Scenario (PJ)	BPT Scenario (PJ)	BAT Scenario (PJ)	Savings Frozen - BAT Scenario (PJ)	Cumulative Savings BAT Scenario (PJ)
2012	187.9	187.9	187.9	187.9		
2030	319.3	302.5	238.7	230.8	88.5	750.5
2050	526.0	469.3	393.2	380.2	145.9	10,651.3

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 Cement Sector Benchmarking Report was authored by Petra Lackner and Amr Osama with inputs from Ashraf Zeitoun, Fatheya Soliman and Ayman El Zahaby.

A special thanks to the staff and management of the Industrial Development Authority especially El Saaed Ibrahim for their valuable support in facilitating the data collection, without which the development of these reports would not have been possible.

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% 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 components. 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.

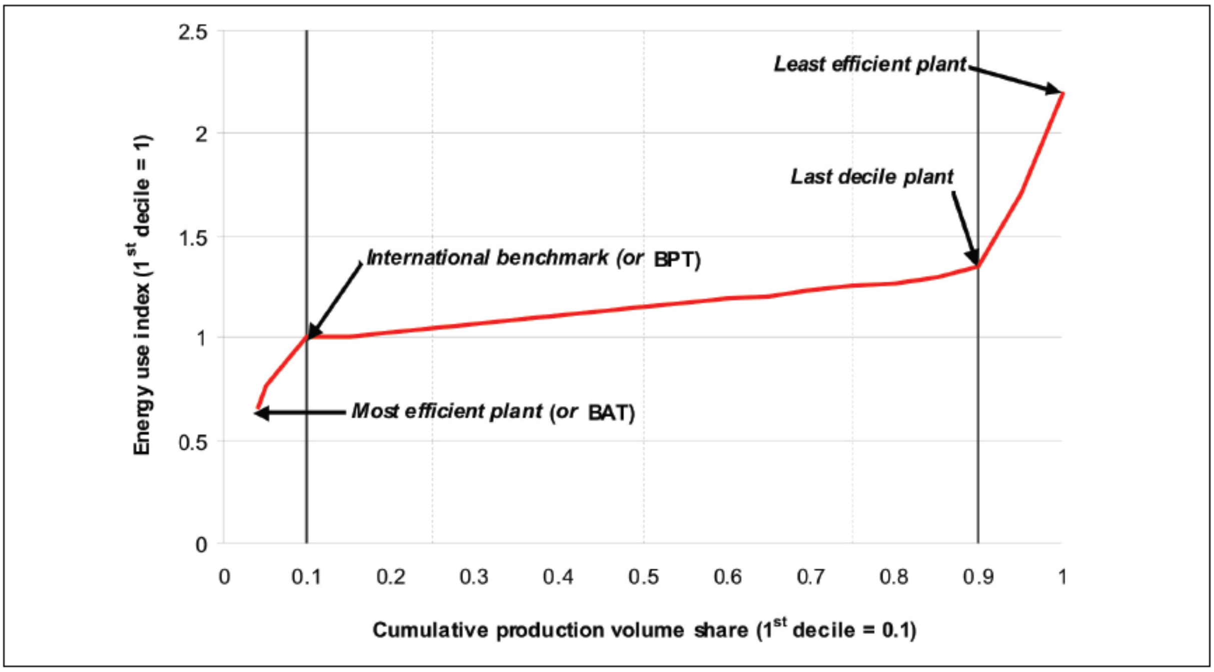
2 Methodology to Establish Benchmarking Studies

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 are 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)

SEC in figure 1 is “Specific Energy Consumption”, BAT means “Best Available Technology” and BPT means “Best Practice Technology”. 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 upper 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.”

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 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 Best Available Technology (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 the 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 quarry included? 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, other purchase them etc.
- What about final products that 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".

In the US Energy Star EPI program for cement industry, the following definitions for energy data are given:

Energy Input: All energy inputs must be metered or otherwise verifiable (e.g. utility bills, delivery receipts). Energy values are entered as net values (i.e. purchases and transfers in minus sales and transfers out), subject to the descriptions below.

- Electricity: Data for electricity includes only total electricity purchased or transferred into the plant from another facility, net of sales or transfers. Purchased or transferred electricity is entered into the "electricity column" on the EPI worksheet.
- Compressed Air: Account for the energy used to produce compressed air if compressed air is transferred in from an external or third-party site whose energy does not appear in your plant's energy total. The kWh for producing compressed air is calculated using actual conversion efficiencies of the external or third-party producer, and added to the plant's energy total.
- Electricity from On-site Renewables: Include the electricity consumed from on-site renewable generation (e.g. solar PV, wind, small hydro) in your total energy consumption. Excess electricity from on-site renewable generation that is sold or transferred off-site is not accounted for in the EPI.
- Electricity from All Other On-site Generation: Do not include the electricity consumed from all other on-site generation (e.g. CHP, diesel generators) in your total energy consumption. When electricity is generated on-site from these other sources, include the fuel that is purchased or transferred into the plant to operate other on-site generation, but do not include the electricity generated by those systems.
- Electricity from on-site generation that is sold or transferred off-site must be subtracted from the total purchased electricity to represent "net of sales or transfer".
- Non-Electric Energy Use: Include all other forms of energy purchased or transferred (natural gas, oil, coal, etc.), net of sales or transfers. This EPI includes a field for waste-derived fuels (e.g. tires). For fuels not defined in the EPI, use the "other" column.
- Steam: Account for the energy used to produce steam if steam is transferred in from an external or third-party site whose energy does not appear in your plant's energy total.
- Recovered Energy: Do not include energy recovered from the production process (e.g. waste heat, process byproducts) in the energy accounting of the EPI. The EPI's underlying statistical model recognizes that plants have an opportunity to recover or self-produce a portion of the energy they require, and is adjusted based on plant characteristics and purchased energy inputs to the EPI.

For collecting the energy consumption data in the Egyptian cement companies, the above-described process was taken into account.

The production process in the cement industry is shown in the following figure:

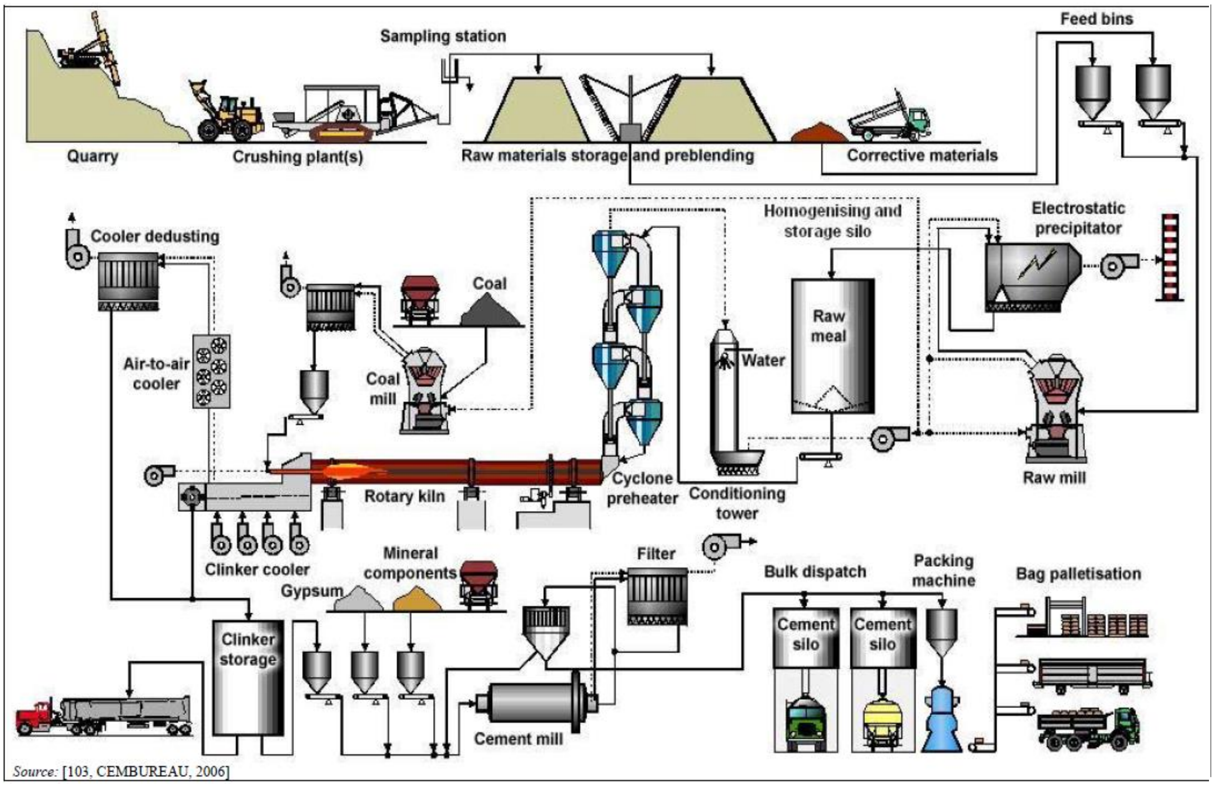


Figure 2: General overview of a cement making process, (European Commission, 2013)

The defined system boundary for the cement industry within this benchmarking study is "the process from the limestone quarry to the cement storage and packaging". The transportation of the final product (shipping, trucks) is not part of the benchmarks.

An important question is how to deal with purchased clinker?

If clinker is purchased, the EPI is calculated in the following way:

Thermal energy consumption: clinker that is produced in the facility is the value to be used for calculating the specific energy consumption (SEC), excluding the purchased clinker
Electricity consumption: the electricity should be adjusted as follows:

- Adjusted electricity = total electricity consumed in the plant * percent clinker purchased * percent of electricity for grinding
- Adjusted cement = total cement grinded – purchased clinker (clinker : cement ratio)

2.2.2 Approach for Data Collection in Companies

Data from individual companies from the last available three years was collected. These data show 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, two different kinds of data collection sheets were developed:

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

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.
  - Resulting information: amount of produced end products [t], load shape of production
- Basic technical information
  - Detailed information about end products, semi-finished products and energy demanding production facilities
  - Collected data: type and amount of end products, type and amount of semi-finished products, boilers, compressors, etc.
  - Resulting information: type and amount of end products, type and amount of semi-finished products, energy consumption of most energy demanding production facilities
- 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
- Input data
  - Assessment of input flow
  - Collected information: primary energy input, conversion factors, raw materials and semi-products, clinker produced on-site, clinker imported, additives, gypsum, slags and others
- Output data
  - Assessment of output flow
  - Collected information: amount of produced end products per year
- Process information
  - Additional written information about the different production processes
  - Collected information: specific manufacturing process information
  - Resulting information: detailed information of production process
- Implemented energy efficiency measures
  - Written information of energy efficiency measures
  - Collected information: saving potential of realized and planned energy efficiency measures

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 22 for cement industry, 21 for iron & steel industry and 9 for the fertilizer sector. In addition, several representatives from project partners, especially from IDA have attended.

All 22 Egyptian cement plants were invited to participate on the project and data collection:

Table 1: Overview of Companies Selected for Data Collection

Number	Plant name	Location of the plant
1	Arabian Cement Company	Suez
2	Medcom Aswan Cement Co	Cairo Office
3	El Sewedy Cement	Suez
4	Amreyah Cement	Alexandria
5	Al-Nahda Cement Company	Qena
6	Misr Cement Company (Qena)	Qena
7	Lafarge Cement	Suez
8	South Valley Cement	Beni Suef
9	Wadi El Nile Cement	Beni Suef
10	Titan - Beni Suef Plant	Beni Suef
11	Misr Beni Suef Cement Company	Beni Suef
12	ASEC - Minya Plant	Minya
13	Titan- Alexandria Portland Cement	Alexandria
14	Cemex Egypt	Assiut
15	Building Materials Industries Co.	Assiut
16	Misr Cement Company (Qena)	Qena
17	Suez Cement Company	Suez
18	Suez Cement Company - Kattameya Plant	Cairo
19	Tourah Cement Company	Cairo

Number	Plant name	Location of the plant
20	Helwan Cement Company	Cairo
21	Sinai Grey Cement	North Sinai
22	Arish Cement	North Sinai

2.2.4 Schedule for Data Collection

For the purpose of data collection, cement plants were contacted and site visits were arranged. However, several plants showed reluctance to cooperate

Table 2: Schedule for data collection

Plant No.	Start Visit Date (Planned)	Actual Visit Date
Plant 1	25 March 2014	25 March 2014
Plant 2	25 March 2014	25 March 2014
Plant 3	13 March 2014	13 March 2014
Plant 4	31 March 2014	31 March 2014
Plant 5	23 March 2014	23 March 2014
Plant 6	27 April 2014	27 April 2014
Plant 7	19 March 2014	19 March 2014
Plant 8	23 April 2014	1 May 2014
Plant 9	17 April 2014	Done by Phone
Plant 10	Not willing to cooperate	
Plant 11	Not willing to cooperate	
Plant 12	14 April 2014	14 April 2014
Plant 13	07 August 2014	07 August 2014
Plant 14	Not willing to cooperate	
Plant 15	No Contact Details	
Plant 16	Not willing to cooperate	
Plant 17	Not willing to cooperate	

Plant No.	Start Visit Date (Planned)	Actual Visit Date
Plant 18	No contact details	
Plant 19	Not willing to cooperate	
Plant 20	Not willing to cooperate	
Plant 21	Not willing to cooperate	
Plant 22	No contact details	

2.2.5 Limitations of Data Collection and Barriers Encountered

Due to the current energy crisis in Egypt, some of the cement companies; specifically the large cement players, were not willing to participate in the project. The Egyptian Environmental Affairs Agency (EEAA) is developing new guidelines for the use of coal in cement industry. The guidelines are expected to be released before the end of 2014, which may help solve the energy crisis in the sector.

2.3 International Benchmarks for Comparison

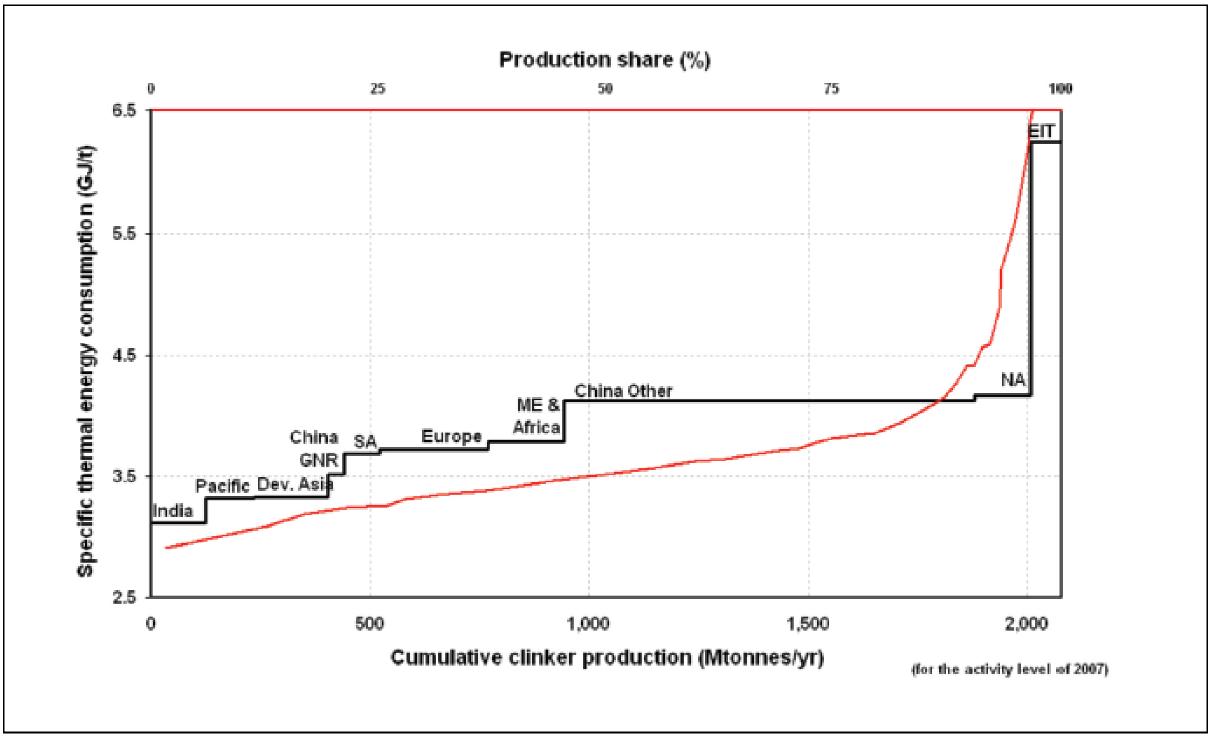
The study "World Best Practice Energy Intensity Values for Selected Industrial Sectors" from the Berkeley National Laboratory provides world best practice EPI for the production of iron and steel, aluminum, cement, pulp and paper, ammonia, and ethylene. Although the study was published in February 2008, and the data applied for the benchmarks are even older, the benchmarks for the cement industry are still up to date.

The "Best Available Techniques (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide", published in 2013, indicates "BAT-associated energy consumption" that are higher than the world best practice benchmarks from the Berkeley study (see Table 3).

Table 3: Energy Intensity Values for Clinker Making (Ernst Worrell, 2008)

Source	Energy intensity values (Berkeley) Energy consumption level (BAT REF)
Berkeley Study, 2008	2.79 GJ / t clinker
BAT Reference Document, 2013	2.9 – 3.3 GJ / t clinker

The "UNIDO Working Paper on Global Industrial Energy - Efficiency Benchmarking" also used the benchmarks published in the Berkeley study. The following graph shows the international benchmark curve for clinker production according to the UNIDO Working Paper.



Black line: own estimates based on CSI (2009a) and IEA (2009c). Red line: based on the GNR database.

Note: "China GNR" is estimated based on GNR database which covers 4% of China's cement production (from a total of 60 plants). "China Other" is our own estimate for the remaining 96% of production, based on a total China average of 4.1 GJ of thermal energy per tonne of clinker (IEA, 2009c).

Figure 3: International Benchmark Curve for Clinker Production, 2007 (UNIDO, 2010)

2.3.1 International Best Practice and Best Available Technology

According to the Berkeley National Laboratory study from February 2008 "World Best Practice Energy Intensity Values for Selected Industrial Sectors" the world best practice final energy intensity values given in Table 4 were identified for the cement industry.

Table 4: Summary of World Best Practice Final Energy Intensity Values for Selected Products of the Cement Industry (Ernst Worrell, 2008)

Production process	Portland cement	Cement < 25% fly ash	Cement 65% blast furnace slag
Total (GJ / t cement)	2.92	2.11	1.75

A more detailed account about the final energy intensity values for selected products of cement industry is shown in Table 10.

The UNIDO Working Paper also applies the values of the Berkeley National Laboratory study for the cement industry.

Table 5: Overview of Energy Performance Indicators for the Cement Industry (UNIDO, 2010)

Benchmark (BM)	Selected Industrial Countries	Selected Develo-ping Countries	Global Average	Best Available Techno-logy (BAT)	Inter-national BM (lowest EEI)	Last Decile Plant or Region	Worst Plant or Region
GJ/t clinker	3.3 – 4.2	3.1 – 6.2	3.5	2.9	3.0	4.4	6.6
kWh/t cement	109 - 134	92 - 121	109	56	88	133	144
GJ/t cement (total energy)	-	-	-	**2.92**	**3.02**	-	-

For calculating the energy saving scenarios in chapter 4.7 the following values, from table 5 were taken to calculate the scenarios for Best Practice Technology (BPT) and Best Available Technology (BAT):

Total Energy Consumption:

- BAT value = 2.92 GJ/t cement
- BPT value = 3.02 GJ/t cement

Thermal Energy Consumption ((Ernst Worrell, 2008)

- BAT value = 2.71 GJ/t cement
- BPT value = 3.00 GJ/t cement

2.3.2 Best Available Techniques (BAT) Reference Document

The “Best Available Techniques (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide”, published in 2013, indicates “BAT-associated energy consumption levels for new plants and major upgrades using dry process kiln with multistage preheating and precalcination”.

The range of BAT-associated energy consumption levels reaches from 2.9 GJ/t clinker to 3.3 GJ/t clinker. Those levels do not apply to plants producing special cement or white cement clinker that require significantly higher process temperatures due to product specifications.

Table 6: BAT-Associated Energy Consumption Levels (European Commission, 2013)

Process	Unit	BAT-associated energy consumption levels ([1])
Dry process kiln with multistage preheating and precalcination	GJ/t clinker	2.9 – 3.3 ([2, 3])
1) Levels do not apply to plants producing special cement or white cement clinker that require significantly higher process temperatures due to product specifications.		
2) Under normal (excluding, e.g. start-ups and shutdowns) and optimized operational conditions		
3) The production capacity has an influence on the energy demand, with higher capacities providing energy savings and smaller capacities requiring more energy. Energy consumption also depends on the number of cyclone preheater stages, with more cyclone preheater stages leading to lower energy consumption of the kiln process. The appropriate number of cyclone preheater stages is mainly determined by the moisture content of raw materials.		

2.4 Approach for Estimating Energy Saving Potentials

The following chapter describes the methods for calculating the energy saving potentials for the cement sector in Egypt. The results are shown in chapter 4.6.

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:

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).

Saving Potential of Company x = (BAT national – SEC of Company x) * Production of Company 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 4.7 different saving scenarios are shown. For the BPT scenario also the lowest known BPT value was 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 on national level, data on annual production of the whole cement industry is also required. The Central Agency for Public Mobilization and Statistics (CAPMAS) collects production data on sector level. The national expert analyzed the CAPMAS data and came to the conclusion that this data is not reliable. Therefore this report does not contain a benchmark curve with national statistical data but with much more reliable data from individual companies.

2.6 Process to Check Reliability of Data

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 with 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

Egypt is one of the major and oldest cement producers in the world and the leading country in the Middle East, Africa, and the Arabian Region.

The cement industry was first introduced to Egypt in the beginning of the 20th century, where the first cement plant was established in the region of "Al-Maasra". Torah Portland Cement Company of Egypt was then established in 1927 and started production in December 1929 with an anual production capacity of 160,000 tons. In 1929, Helwan Portland Cement Company was founded afterwards and its production began in April 1930 with an annual production capacity of 95,000 tons.

Currently, the Egyptian cement industry comprises 22 cement plants with a total production capacity of about 68 million tons of cement per year. Ordinary Portland Cement (OPC) is the most common type of cement produced in Egypt.

With the construction boom on the rise over the years, high demand for cement that was met through new cement companies in Egypt and enhancement of existing production lines to meet the increase in local demand. However, the country is currently experiencing a fuel crisis and the cement companies are struggling to operate at full capacity since year 2013.

Portland cement is made from limestone or chalk and shale or clay (i.e. calcium carbonate and siliceous material). There are two main methods of cement manufacture, the wet process and the more modern dry process. In the wet process, soft raw materials are reduced to a water suspended-slurry in wash mills, hard oversized material being separated by screens and ground in a tube mill. The slurry has a creamy consistency and a water content of approximately 40%. The slurry is pumped to storage tanks, which are continuously agitated to prevent the solid particles from settling out. Because the raw materials can contain varying amounts of calcium and silica, it may be necessary to blend different slurries in order to obtain the desired chemical composition before feeding into the kiln.

In the dry process, the materials are crushed and fed through a raw mill, which reduces them to a fine meal. The meal is then stored in a silo from where it is transported to the kiln pre-heater. The material then cascades downwards while warm exhaust gas from the kiln passes through it. The raw materials are fed through the kiln, which can be up to 250 m long and 6m in diameter (the length of the kiln depends on which process is used). In the kiln-firing zone, the material reaches a temperature of 1400 °C before leaving the kiln in the form of clinker.

The clinker is rapidly cooled and stored until required for milling, when it is fed into cement mills where about 3-5% gypsum is added to control the setting of the finished product and the materials are ground to the required fineness. Increasingly, other additives which impart water-reducing properties to the cement and aid grinding are incorporated during the grinding stage. The cement is then fed to storage silos until required for delivery or diverted to a bagging plant

The best available techniques (BAT) for the production of clinker is the dry process kiln with multi-stage preheating and pre-calcination (a six-stage pre-heater and pre-calciner kiln); here the energy consumption ranges between 2.9 GJ to 3.3 GJ per ton of clinker. For this reason, the percentage of the dry process use in the EU production in the cement industry has increased from 78 % in 1997 to 90 % in 2008.

Clinker plants with the lowest final energy consumption are operated in India at 3.1 GJ per ton of clinker followed by the plants in the Pacific region and developing Asia at around 3.3 GJ per ton. The least energy efficient plants are located in North America at 4.2 GJ per ton and in EIT countries (countries with Economies in Transition) at 6 GJ per ton.

3.2 Number of Companies and Ownership

As of today, there are 22 grey cement plants in Egypt owned by 20 cement companies with a total production capacity of around 68 million tons cement per year. The following table demonstrates the production capacity of each cement plant in addition to the plant ownership. The latest data on production capacities were obtained from either IDA or the companies' websites.

Table 7: Number of Cement Companies in Egypt and their Ownership

Plant		Production Capacity Mt/yr	Ownership
1. Egyptian Cement - Lafarge		10.00	Owned by Lafarge
2. Assuit Cement (Cemex Egypt)		5.70	Owned by CEMEX
3. Arabian Cement		5.00	Owned by Cementos La Union S.A.
4. Suez Cement	Suez plant Kattameya plant	3.00 1.50 1.50	53.15 % of the Company is owned by Italcementi Group
5. Helwan Cement		3.50	98.69% of the Company is owned by Suez cement company, which in turn is owned by ItalCementi Group
6. Tourah Portland Cement		3.00	66.12% of the Company is owned by Suez cement company, which in turn is owned by ItalCementi Group
7. National Cement		3.90	77% of the company is owned by the Government, and 23% of the company is owned by other shareholders
8.Titan Cement Egypt	Beni Sweif Alexandria	3.00 2.30	Owned by Titan
9. Sinai Cement (Vicat)		3.80	40% of the company is owned by Vicat Group and the remaining percent is owned by other shareholders
10. Amreyah Cement (Cimpor)		3.10	Owned by InterCement SA Group
11. Misr Beni Suef Cement		3.00	Egyptian joint stock company

Plant	Production Capacity Mt/yr	Ownership
12. Misr Cement (Qena)	1.90	ASEC cement owns 27.55% of the company, and the remaining percentage is owned by other shareholders
13. Arab Swiss Engineering (ASEC)	2.00	45.1% of the company is owned by ASEC and the remaining percent is owned by other shareholders
14. El Nahda Cement Company	2.00	Egyptian joint stock company
15. Wadi El Nile Cement Company	1.65	Owned by Energya Holding
16. El Sewedy Cement	1.65	Owned by ElSewedy Group
17. Building Materials Industries Company	1.50	Subsidiary company of the Egypt Kuwait Holding (EKH)
18. South Valley Cement	1.50	Egyptian joint stock company
19. Medcom Cement Company	0.75	Egyptian joint stock company
20. Al Arish Cement Company	3.00	Ministry of Defense
Total Cement Production Capacity in Egypt (2013)	**68.3**	

3.3 Production Capacities

3.3.1 Main Products

Cement products are described in a format that indicates the cement type, main constituents, strength class and rate of early strength development. The following cement types are the most commonly produced cement products in Egypt:

1. CEM I 42.5 N (Portland Cement)

This is the basic cement and is commonly used for general construction work. This cement is frequently combined with ground granulated blast furnace slag or pulverized fuel ash. It consists mainly of Portland cement and up to 5% of minor additional constituents.

2. CEM I 42.5 R and 52.5 N (Portland Cement)

This cement is normally made by grinding the same clinker as CEM I 42.5 N to a great fineness in order to prevent the rapid set that occurs in CEM I 42.5 N. Extra gypsum is usually added at the grinding stage. CEM I 42.5 R or 52.5 N is used where there is a requirement for early strength, for example in precast applications. It consists of Portland cement and up to 35% of certain other single constituents.

3. Sulfate Resisting Portland Cement (SRC)

To produce this cement, iron oxide is added to the raw feed in the kiln that results in the production of a material low in tricalcium aluminate (C_3A). This is the compound that reacts with sulfates to potentially result in sulfate attack, which may lead to the disintegration of the hardened mortar. The increased iron oxide content gives sulfate resisting Portland cement a darker color than plain Portland cement. Sulfate resisting Portland cement is often ground finer than CEM I Class (42.5 N) in order to compensate for the reduced early strength caused by its low C_3A content.

4. CEM II/A (Portland Limestone Cement)

This cement is produced by blending or grinding 6-20% of ground limestone with Portland cement.

5. CEM II/B

This cement type is made by grinding together silicate clinker, granulated blast furnace slag, fly ash and gypsum. Slag and fly ash adjust the cement content and decrease hydration heat and its cement content is max. 35%. Gypsum acts as a regulator preventing cement flash setting.

6. CEM III (Blast furnace cement)

The molten slag from the production of iron in a blast furnace is rapidly cooled by high pressure water jets that subjects the slag to instantaneous solidification in the form of granules - these are then dried and ground to a similar fineness to CEM I Class (42.5 N) in the mill. It may be described as a latent hydraulic material, which means it will gain strength on its own, but very slowly. It consists of Portland cement and higher proportions of blast furnace slag than in CEM II cement.

The following table describes the main cement products produced by each cement plant in Egypt.

Table 8: Main Cement Products Produced by Each Cement Plant in Egypt

Company and Main Products		
1. Suez Cement Company – Suez Cement Group	1.a. Kattameya Plant	– - CEM I 42.5 N – - SRC 42.5 N
	1.b. Suez Plant	– - CEM I 42.5 N
2. Helwan Cement Company - Suez Cement Group	– CEMI 42.5 R – CEMII B-L 32.5N	
3. Tourah Cement Company - Suez Cement Group	– CEM I 42.5 R – Super CEM II/A-S 32.5 N – High Slag CEM III/A 32.5N	
4. Lafarge	– CEM I 42.5N – Portland Limestone Cement (PLC) – Portland Slag Cement (PSC) – SRC (42.5N)	

Company and Main Products		
5. Cemex Egypt	– CEM I (32.5 N) – CEM I (42.5N) – SRC (32.5R) – SRC (42.5N)	
6. Arabian Cement Company	– Clinker – SRC 42.5 N – CEM I 42.5N – CEM II / A-S 42.5 N – Ready Mix Concrete	
7. National Cement Company	– CEM I (32.5 N) – CEM I (42.5N)	
8. Titan Egypt	8.a. Titan Egypt Beni Suef 8.b. Alexandria Portland Cement	– CEM II / B-L 32.5 R – CEM II /A-L 42.5 R – CEM I 42.5 R
9. Sinai Cement Company	– CEM I 42.5 – CEM I 52.5 N	
10. Ameryah Cement Company	– CEM I 42.5N – CEM I 32.5N – SRC 42.5 N	
11. Misr Beni Suef Cement Company	– Clinker – CEM I 42.5N – CEM I 32.5N	
12.Misr Cement Co. (Qena)	– CEM I 32.5N – CEM I 42.5N	
13. AlArish Cement Company	– CEM I 42.5	
14. Arab National Cement Company-Asec	– SRC 42.5 N – CEM I 32.5N	
15. Al-Nahda Cement Company	– CEM I 32.5N	
16. Wadi El Nile Cement	– Clinker – CEM I 42.5N – CEM I 32.5N	

Company and Main Products	
17. El Sewedy Cement	– CEM I (42.5N) – CEM I 32.5N
18. Building Materials Industries Co.	– CEM I 42.5
19. South Valley Cement Co	– CEM I 42.5
20. Medcom Aswan Cement Co	– CEM I 42.5

The main cement product in most of the Egyptian cement plants is CEM I 42.5. Other types of cement products are produced with fewer quantities or as per the market request. Consequently, it can be considered that the main product is CEM I 42.5 and there is no need to create a benchmark cluster based on the type of cement product with different energy intensities.

3.3.2 Annual Turnover

The Egyptian Cement industry is considered to be one of the most energy intensive industries, with numerous employment opportunities and cash flow. Regarding the annual turnover, there is only one plant with published data that reports the company's annual revenues.

For this specific plant with published data, the total energy consumption (thermal and electrical) was estimated to be 10,683,213 GJ/year with a net profit of 399,368,311 EGP/year. The ratio of energy consumption to the net profit of this company is estimated to be (MJ/EGP) is 26.75 MJ/EGP.

3.3.3 Main Markets

The following table represents the main markets of a sample of Egyptian cement plants that have been examined during the study.

Table 9: The Main Investigated Markets of a Sample of Egyptian Cement Plants.

Plant Number	Main Market
Plant 1	Egypt (specifically Alexandria, Matrouh & North Coast)
Plant 2	Egypt (specifically Alexandria, Matrouh & North Coast)
Plant 3	Egyptian Market + Exporting
Plant 4	Egyptian Market
Plant 5	Delta Region
Plant 6	Upper Egypt
Plant 7	Aswan - Red Sea - Qena
Plant 8	Egyptian Market + Exporting
Plant 9	Egyptian Market
Plant 10	Egyptian Market + Exporting
Plant 11	Egyptian Market + Exporting

3.3.4 Main Drivers for Energy Consumption

For the cement industry the main driver for energy consumption is the production process of clinker. About 96% of the total energy consumption is used for producing clinker in the kilns.

According to the BAT Reference Document for the production of cement, lime and magnesium oxide, several factors affect the energy consumption of modern kiln systems, such as:

- raw materials properties like moisture content and burnability
- the use of fuels with different properties
- the use of a gas bypass system
- the production capacity of the kiln has an influence on the energy demand

A much smaller part of the total energy consumption is used for raw materials preparation and grinding the clinker to cement.

The energy consumption differs also by the type of cement produced. The most energy intensive product is the Portland cement, followed by cement with less than 25% fly ash and finally, the least energy intensive cement is the “cement with 65% blast furnace slag”.

The following table shows the different energy inputs for raw material preparation, solid fuels preparation, clinker making, additives preparation and finish grinding cement.

Table 10: Overview of Specific Energy Consumption of Different Production Processes for Different Cement Types (Ernst Worrell, 2008)

Production Process	Portland Cement	Cement < 25% Fly Ash	Cement 65% Blast Furnace Slag
	GJ/t	GJ/t	GJ/t
Raw Materials Preparation:	0.07	0.05	0.03
Solid Fuels Preparation:			
Clinker Making	2.79	1.95	1.03
Additives Preparation			0.54
Finish Grinding 325 Cement	0.06	0.08	0.15
Total (GJ / t Cement)	**2.92**	**2.11**	**1.75**

3.4 Energy Data of the Whole Sector

This chapter gives an overview of the thermal and electricity consumption and of the energy costs. The following conversion factors were used in the calculations.

Table 11: Conversion factors

Source	Natural Gas (MJ/m^3)	Diesel (MJ/kg)	Mazout (MJ/kg)
IPCC 2006 Guidelines (Default Values)	37.74	43.00	40.40

3.4.1 Thermal Energy Consumption of the Whole Sector

Previously, the commonly used fuels in the Egyptian cement sector were Natural Gas, Diesel & Mazout. However, due to the shortages in these fuels supplies, most of companies are switching to coal/petcoke in addition to small amounts of other alternative fuels (RDF, TDF, Biomass residues and Used Oil).

The Egyptian cement sector consumes around 4,953 Million m^3/year, and around 1.4 Million tons of Mazout per year, with limited amount of diesel consumption (around 43,377 tons/year). The total thermal energy consumption of the Egyptian cement sector is estimated to be 245,927,986 GJ/year[1].

[1] These figures were obtained from IDA's database for year 2013. However, the data of some plants were missing/not correct, so their values were obtained from the UNIDO's data collection sheets.

3.4.2 Electricity Consumption of the Whole Sector

The total electrical energy consumption of the Egyptian cement sector is estimated to be 4,950 GWh/year. Most of these companies obtain their electricity from the National Electricity Grid. Two plants generate their own electricity using diesel generators.

3.4.3 Energy Costs

For studying the economic performance in the cement production, the energy cost per ton of cement was calculated for each cement plant along the plant's year of operation, and the energy cost varied from one year to another in each plant. Thus, averaging the energy cost per ton cement for each plant would provide a general energy cost for the ton of cement in Egypt. Average energy costs per ton of cement ranged from 93.5 EGP/t to 167 EGP/t throughout the years 2010 - 2014.

3.5 Energy Efficiency Measures Implemented and/or Planned

Most Plants are implementing energy efficiency plans by improving the processes of raw materials preparation and clinker making processes. And several plants applied energy efficiency measures in the final grinding of products in their cement plants. And very few of these plants applied changes to their feedstock and products to improve the energy efficiency in the clinker production.

Two of the nine plants are currently in the process of implementing an Energy Management System according to ISO 50001 with the support from the UNIDO IEE Project.

4 Analysis of Results

For the purpose of this study, 18 cement companies were contacted out of the 20 companies in the Egyptian cement sector, and the remaining two companies were not contacted due to the unavailability of the correct contacts information. Ten site visits were conducted and one company was contacted through the phone in order to present the benefits of the project and the methodology of data collection. However, only nine companies agreed to participate, and two of the participating companies did not provide complete data. In addition, the publicly available data of two companies have been analyzed in the study; however, their data of was found to be incomplete.

The methodology of data collection involved sending a simplified data collection sheet to the companies that were contacted via phone or e-mail before the site visit, and presenting and discussing the detailed data collection sheet during the site visit. Some companies had concerns regarding the confidentiality of the data provided from their side, and this issue was solved by signing a confidentiality letter with UNIDO. Frequent communication was maintained with the participating companies after the site visits to follow up on the data collection and also to address their inquiries regarding the detailed data collection sheets.

The cement production capacities of the 11 analyzed plants out of the 22 cement plants represent around 30% of the total production capacity of the Egyptian cement industry.

4.1 Achieved Data Sets for Analysis

This subsection describes the data regarding cement production and energy consumption of the analyzed companies. These data were gathered for years 2010, 2011, 2012, 2013 and 2014. It is important to note that one cement plant has provided data for year 2014 only since it has started operation in the same year.

4.1.1 Production Volume of Analyzed Companies

The following table represents the cement production volume of the analyzed companies for years 2010, 2011, 2012, 2013 and 2014.

Table 12: Production Volume of Analyzed Companies

	Design Capacity (t cement/a)	2010 (t cement/a)	2011 (t cement/a)	2012 (t cement/a)	2013 (t cement/a)	[2]2014 (t cement/a)
Plant 1	2,000,000	-	1,976,621	1,889,303	-	-
Plant 2	1,200,000	-	1,091,234	1,110,697	-	-
Plant 3	4,200,000	1,485,743	3,290,800	4,340,839	-	-
Plant 4	1,500,000	-	-	-	1,011,976.0	-
Plant 5	1,650,000	-	1,813,041	2,240,420	-	-
Plant 6	1,500,000	-	-	1,394,810	1,523,184	-
Plant 7	750,000	726,900	783,065	857,492	850,791	-
Plant 8	1,500,000	-	662,062	1,997,112	1,819,029	-
Plant 9	2,000,000	-	-	-	-	367,902
Plant 10	4,300,000	3,368,094	-	-	-	-
Plant 11	1,500,000	1,395,359	-	-	-	-
Sum	**22,100,000**					

The total design capacity of the 11 analyzed plants represents about 30% of the total design capacity of the whole sector. Plant number 1 was deleted from further analysis as it was identified as an outlier and the company could not verify the data.

[2] Data of the 1st quarter only of year 2014

4.1.2 Energy Consumption of Analyzed Companies

The following conversion factors were used to calculate the energy consumption of the analyzed companies.

Table 13: Conversion factors

Source	[3]Natural Gas (MJ/m^3)	Diesel (MJ/kg)	Mazout (MJ/kg)
IPCC 2006 Guidelines (Default Values)	37.74	43.00	40.40

4.1.2.1 Thermal Energy Consumption

The following tables represent the amount of thermal energy consumed and cement produced annually by the analyzed cement plants. All gathered data are along the range of years from 2010 to 2014. The common fuels that are used in the Egyptian cement industry are Natural Gas, Mazout and Diesel. It is worth mentioning that the available data for plants 10 and 11 were the production data and thermal energy consumption data only. During the quality control stage, data for plant 1 was identified as an outlier. The plant was contacted to verify the data but no reply was received. Therefore, the team decided to drop the data for this specific plant from further analysis.

[3] The NCVs obtained from IPCC 2006 Guidelines are the default values

Table 14: Thermal energy consumed by the analyzed cement plants

Plant No.	2010		2011		2012		2013		2014		Avg. Thermal Energy Consumption	Avg. SEC
	GJ/year	GJ/t	GJ/ year	GJ/t	GJ/ year	GJ/t	GJ/ year	GJ/t	GJ/ year	GJ/t	GJ/ year	GJ/t cement
Plant 2			4,691,483	4.30	4,692,602	4.22					4,692,043	4.26
Plant 3	6,854,263	4.61	8,488,971	2.58	13,566,285	3.13					9,636,506	3.17
Plant 4							3,721,398	3.68			3,721,398	3.68
Plant 5			6,976,426	3.85	7,684,069	3.43					7,330,248	3.62
Plant 6					4,880,558	3.50	5,218,428	3.43			5,049,493	3.46
Plant 7	2,616,173	3.60	2,607,391	3.33	2,628,153	3.06	2,488,604	2.93			2,585,080	3.21
Plant 8			4,328,834	6.54	6,688,882	3.35	5,874,705	3.23			5,630,807	3.77
Plant 9									1,359,803	3.70	1,359,803	3.70
Plant 10	13,827,989	4.11									13,827,989	4.11
Plant 11	5,749,285	4.12									5,749,285	4.12

Figure 4 illustrates the range of thermal SEC among the analyzed companies. The figure demonstrates that the specific thermal energy consumption of the analyzed companies falls within the average range of the developing countries, as described in chapter 2 of the study.

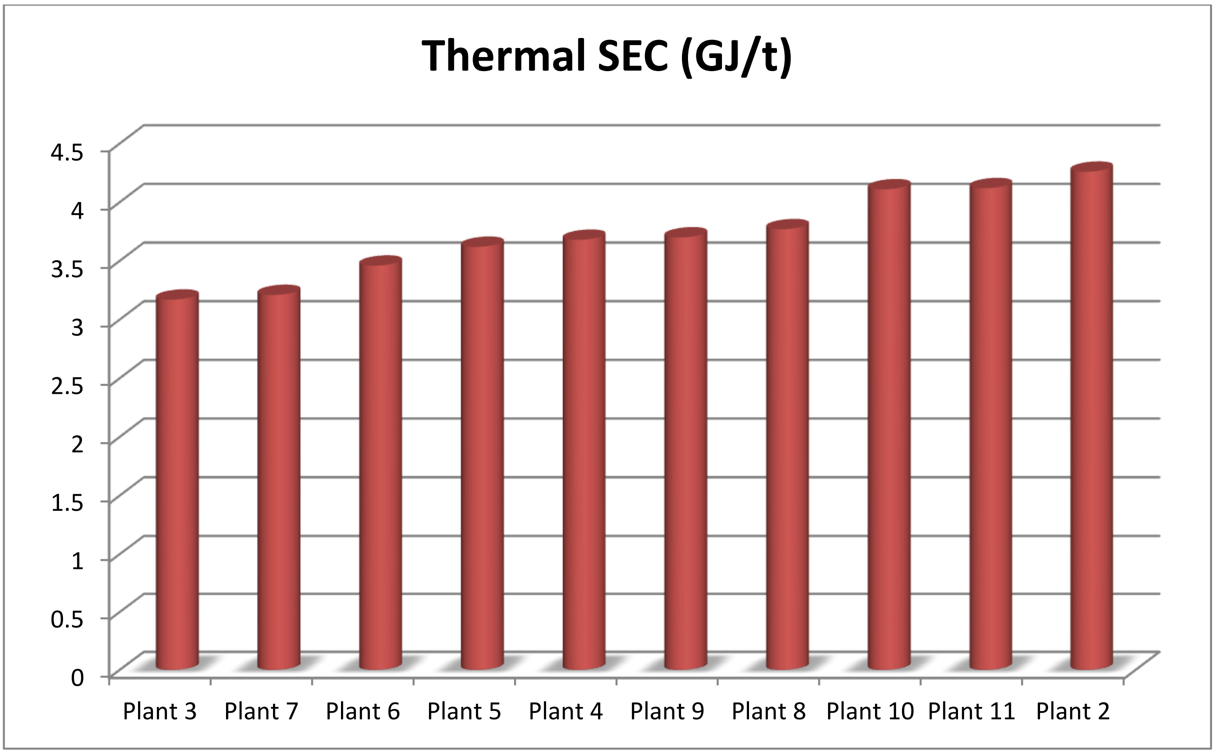


Figure 4: Range of Thermal SEC among the Analyzed Companies

4.1.2.2 Electrical Energy Consumption

Table 15 demonstrates the electrical energy consumed annually by the analyzed cement plants, gathered in the range of years from 2010 to 2014.

Table 15: Electric Energy Used by Each Plant

	2010 (kWh/year)	2011 (kWh/year)	2012 (kWh/year)	2013 (kWh/year)	2014 (kWh/year)	Average (kWh/year)	Average SEC (kWh/t)
Plant 2	-	67,424,993	136,629,642	-	-	102,027,318	92
Plant 3	179,943,000	318,603,000	373,710,000	-	-	290,752,000	101
Plant 4	-	-	-	102,025,459	-	102,025,459	101
Plant 5	-	165,431,980	177,582,450	-	-	171,507,215	85
Plant 6	-	-	136,689,400	145,216,400	-	140,952,900	97
Plant 7	83,593,500	90,052,475	98,611,580	97,840,965	-	92,524,630	115
Plant 8	-	85,332,880	165,135,050	138,866,720	-	129,778,217	91
Plant 9		-	-	--	85,322,000	85,322,000	232

Figure 5 illustrates the range of electrical SEC among the analyzed companies. The figure demonstrates that the specific electrical energy consumption for most of the analyzed companies (except for plant 9) falls within the average range of the developing countries, as described in chapter 2 of the study.

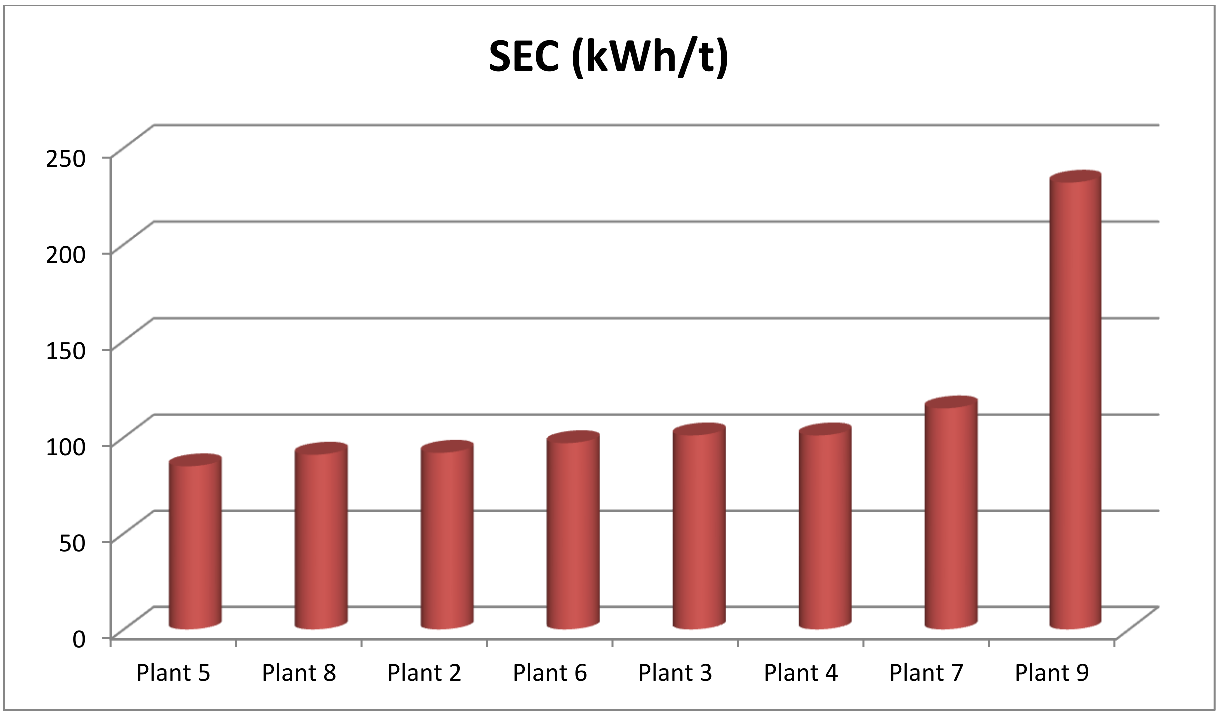


Figure 5: Range of Electrical SEC among the Analyzed Companies

4.1.2.3 Total Energy Consumption

The international BPT EPI (Worrel 2008, page 24) of 2.92 GJ/t cement contains the thermal (2.71 GJ/t cement) and electricity (0.21 GJ/t cement) consumption.

Table 16 demonstrates the total energy (thermal and electrical) consumed annually by the analyzed cement plants, gathered in the range of years from 2010 to 2014.

Table 16: Overview Energy Consumption and Specific Energy Consumption of Analyzed Plants: Thermal, Electrical and Total

Plant No.	Average Production (t/year)	Average Thermal Energy Consumption	Average electrical Energy Consumption	Average Total Energy Consumption	Specific Thermal Energy Consumption	Specific Electrical Energy Consumption	Specific Total Energy Consumption
		GJ/year	GJ/year	GJ/year	GJ/t	GJ/t	GJ/t
Plant 2	1,100,965	4,692,043	367,298	5,059,341	4.26	0.33	4.60
Plant 3	3,039,127	9.636.506	1,046,707	10,683,214	3.17	0.34	3.52
Plant 4	1,011,976	3,721,398	367,292	4,088,690	3.68	0.36	4.04
Plant 5	2,026,730	7,330,248	617,426	7,947,673	3.62	0.30	3.92
Plant 6	1,458,997	5,049,493	507,430	5,556,923	3.46	0.35	3.81
Plant 7	804,562	2,585,080	333,089	2,918,169	3.21	0.41	3.63
Plant 8	1,492,735	5,630,807	467,202	6,098,009	3.77	0.31	4.09
Plant 9	367,902	1,359,803	307,159	1,666,962	3.70	0.83	4.53
Plant 10	3,368,095	13,827,989	-	13,827,989	4.11	-	4.11
Plant 11	1,395,359	5,749,285	-	5,749,285	4.12	-	4.12
Weighted SEC of analyzed plants					**3.71**	**0.41**	**4.04**
International BAT					**2.71**	**0.21**	**2.92**

Figure 6 illustrates the range of the total SEC (thermal and electrical) among the analyzed companies. The figure demonstrates that the specific energy consumption of the analyzed companies falls within the average range of the developing countries, as described in chapter 2 of the study, however, above the BAT. Plant number 10 and 11 did not indicate the electrical consumption, for those plants the total consumption is corresponding to the thermal consumption.

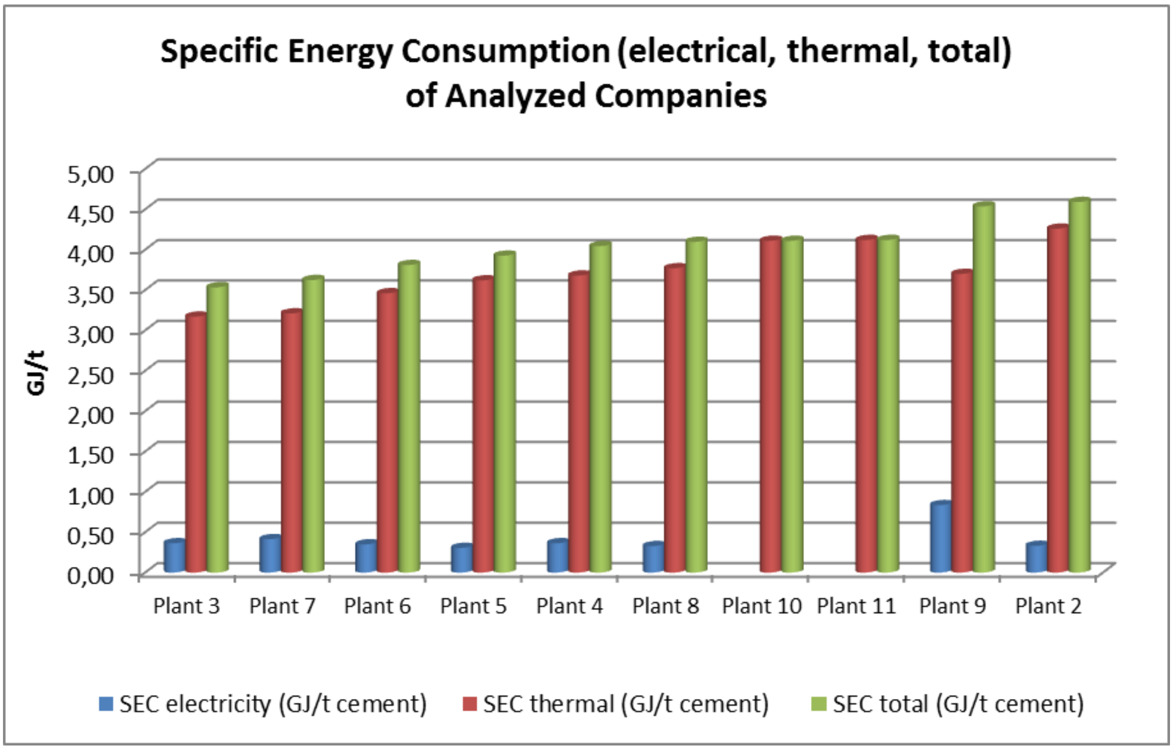


Figure 6: Range of SEC among the Analyzed Companies

4.1.2.4 Energy Costs of Analyzed Companies

The energy cost for each analyzed company was calculated based on the information regarding the energy consumption that was provided by each company. The energy cost calculations are based on the unit energy rates provided in the following table.

Table 17 : Unit Prices of Energy

Year	Electricity		Natural Gas		Diesel		Mazout	
	Unit Price		Unit Price		Unit Price		Unit Price	
2010	0.21	EGP/kWh	0.533	EGP/m³	1.1	EGP/litre	1,000	EGP/t
2011	0.23	EGP/kWh	0.533	EGP/m³	1.1	EGP/litre	1,000	EGP/t
2012	0.29	EGP/kWh	0.989	EGP/m³	1.1	EGP/litre	1,000	EGP/t
2013	0.30	EGP/kWh	0.989	EGP/m³	1.1	EGP/litre	1,500	EGP/t
2014[4]	0.30	EGP/kWh	0.989	EGP/m³	1.1	EGP/litre	1,500	EGP/t

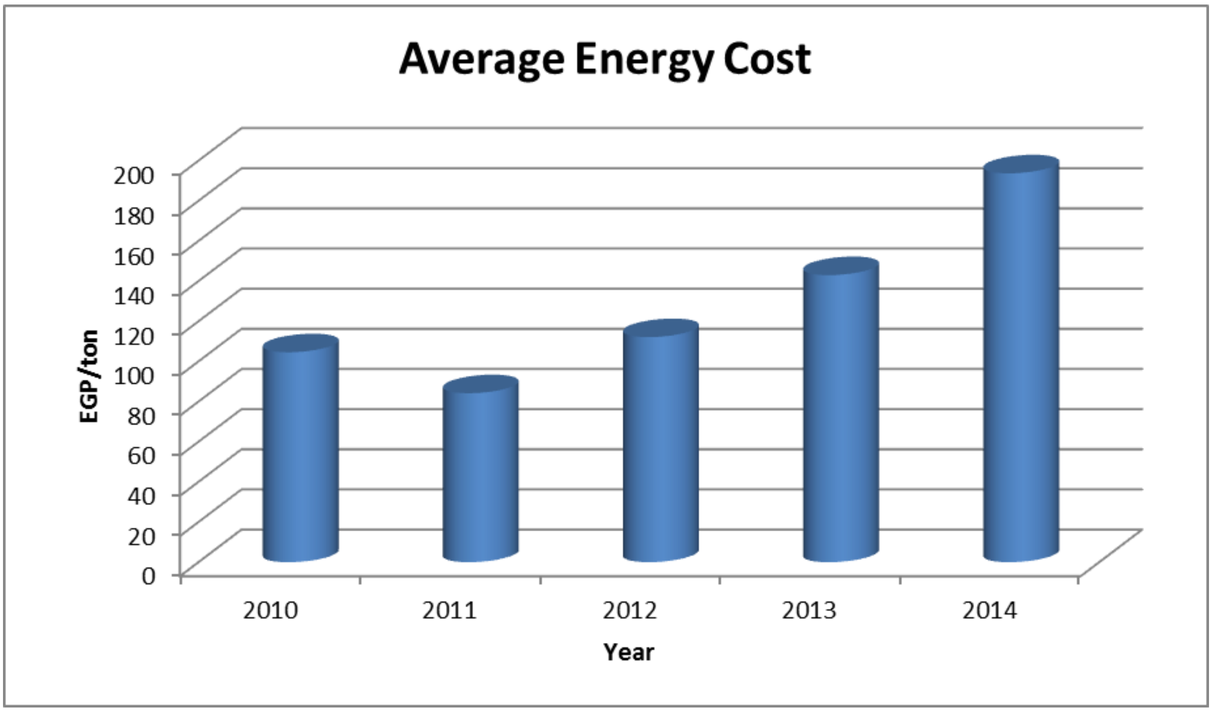


Figure 7: Energy Cost for Cement Production in the Analyzed Companies (2010 – 2014)

The energy cost of the analyzed plants in year 2010 ranged from 91 EGP/t to 118 EGP/t with an average of 104 EGP/t, while the energy cost of the analyzed plants in year 2011 ranged from 57 EGP/t to 115 EGP/t with an average of 84 EGP/t, and the energy cost of the analyzed plants in year 2012 ranged from 95 EGP/t to 146 EGP/t with an average of 112 EGP/t, followed by an increase in the Mazout price in year 2013 from 1,000 EGP/t to 1,500 EGP/t, to raise the energy cost range of the analyzed companies to range between 105 EGP/t to 167 EGP/t. It is worth mentioning that the only analyzed company in year 2014 generates its own electricity.

[4] The unit prices of energy for year 2014 are for the 1st quarter only, before the government issued the new energy tariffs.

4.1.3 Status of Energy Management System in Analyzed Companies

The following criteria have been defined in order to determine the status of energy management system implementation in each cement plant:

C1. Implementation of Management Systems
C2. Assigning of an Energy Manager
C3. Analysis of Energy Consumption
C4. Installation of Meters/Sub-meters
C5. Availability of Resources for EnMS implementation
C6. Consideration of energy efficiency in investment decisions
C7. Availability of energy efficiency targets
C8. Availability of previous energy audits
C9. Planning/Implementation of energy saving measures

Table 18 summarizes the status of energy management system implementation in the analyzed cement plants.

Table 18: Status of Energy Management System Implementation in the Analyzed Cement Plants

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Plant 1	No	Yes	Yes	No	No	No	Yes	No	No
Plant 2	No	Yes	Yes	No	No	No	Yes	No	No
Plant 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Plant 4	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Plant 5	No	Yes	Yes	Yes	No	Yes	No	No	Yes
Plant 6	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant 7	Yes	Yes	No	No	No	No	No	No	No
Plant 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Plant 9	No	No	Yes	No	No	Yes	No	No	No

4.2 Benchmark Clusters and/ or Adjustment Factors

All the analyzed cement plants utilize the same production process; dry production process with preheater/calciner. However, the number of preheating stages may differ from one plant to the other. In addition, types of raw mills may vary between the plants from vertical roller mills to horizontal mills. As shown in Table 8 the main product of the Egyptian cement plants is CEM I 42.5 thus there is no need to create a benchmark cluster based on the type of cement product.

4.3 Energy Performance Indicators of Analyzed Companies

4.3.1 Benchmark Curve on National Level

The energy performance indicators (EPIs) calculated for the analyzed companies in the cement sector are

- the specific thermal energy consumption (GJ/t cement)
- the specific electrical energy consumption (kWh/t cement) and
- the total specific energy consumption (GJ/t cement)

The EPIs were calculated as average values from the data collected for the years 2010 – 2014.

Table 19: Specific Thermal Energy Consumption of Analyzed Cement Plants (GJ/t)

Plant No	Average Cement Production[5] (t/year)	Production Share	Cumulative Production Share	Average Specific Thermal Energy Consumption (GJ/t cement)
Plant 3	3,039,127	0.19	0.19	**3.17**
Plant 7	804,562	0.05	0.24	**3.21**
Plant 6	1,458,997	0.09	0.33	3.46
Plant 5	2,026,730	0.13	0.46	3.62
Plant 4	1,011,976	0.06	0.52	3.68
Plant 9	367,902	0.02	0.54	3.7
Plant 8	1,492,735	0.09	0.63	3.77
Plant 10	3,368,095	0.21	0.84	4.11
Plant 11	1,395,359	0.09	0.93	4.12
Plant 2	1,100,965	0.07	1.00	4.26

[5] Average values for production and specific thermal energy consumption are taken for years 2010 – 2013 and year 2014 only for plant 9

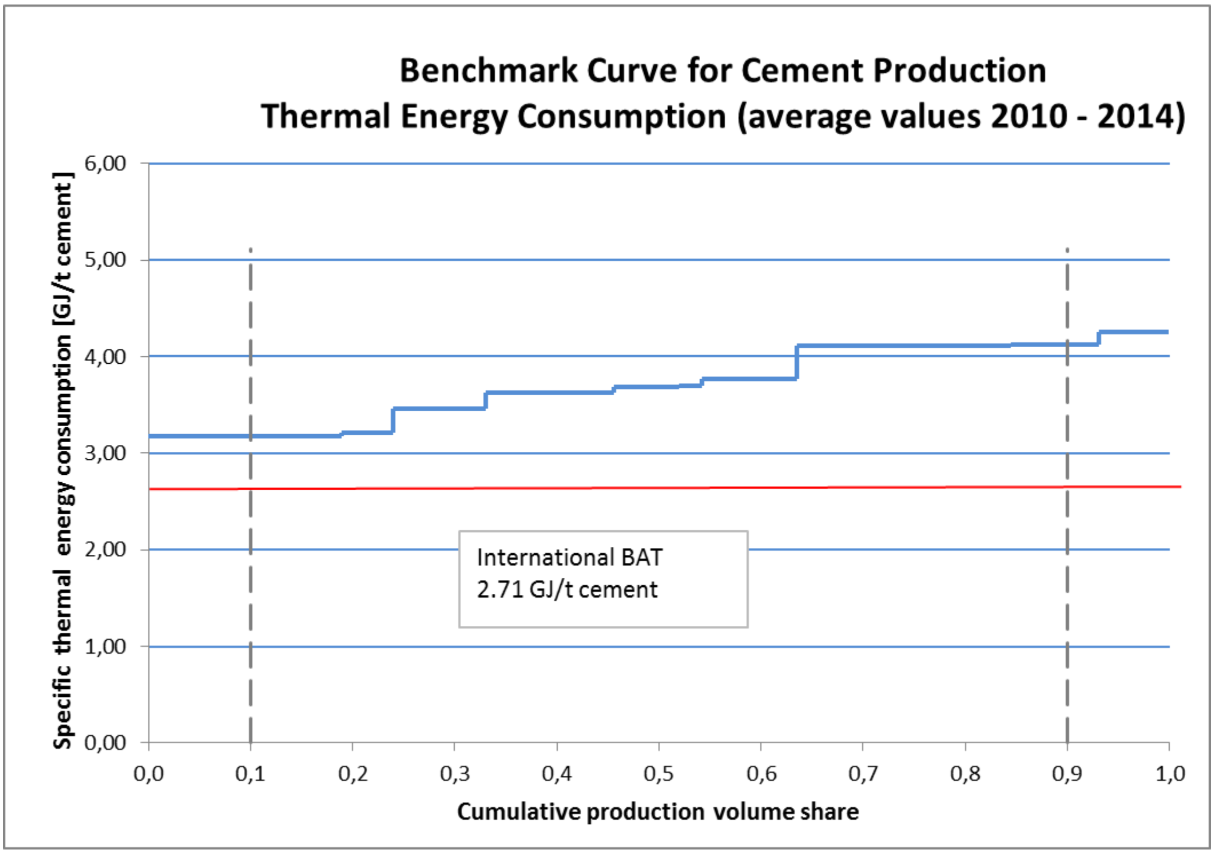


Figure 8: Specific Thermal Energy Consumption Benchmark Curve for Cement Production

- The thermal energy consumption EPI corresponding to the national BAT value = 3.17 GJ/t cement
- The thermal energy consumption EPI corresponding to the national BPT value = 3.21 GJ/t cement
- The thermal energy consumption EPI corresponding to the international BAT value = 2.71 GJ/t cement

Table 20: Specific Electrical Energy Consumption of Analyzed Cement Plants (kWh/t)

Plant No	Average Cement Production[6] (t/year)	Production Share	Cumulative Production Share	Average Specific Electrical Energy Consumption (kWh/t cement)
Plant 5	2,026,730	0.15	0.15	**85**
Plant 8	1,492,735	0.11	0.27	**91**
Plant 2	1,100,965	0.08	0.35	92
Plant 6	1,458,997	0.11	0.46	97
Plant 3	3,039,127	0.23	0.69	101
Plant 4	1,011,976	0.08	0.77	101
Plant 7	804,562	0.06	0.83	115
Plant 9	367,902	0.03	1.00	232

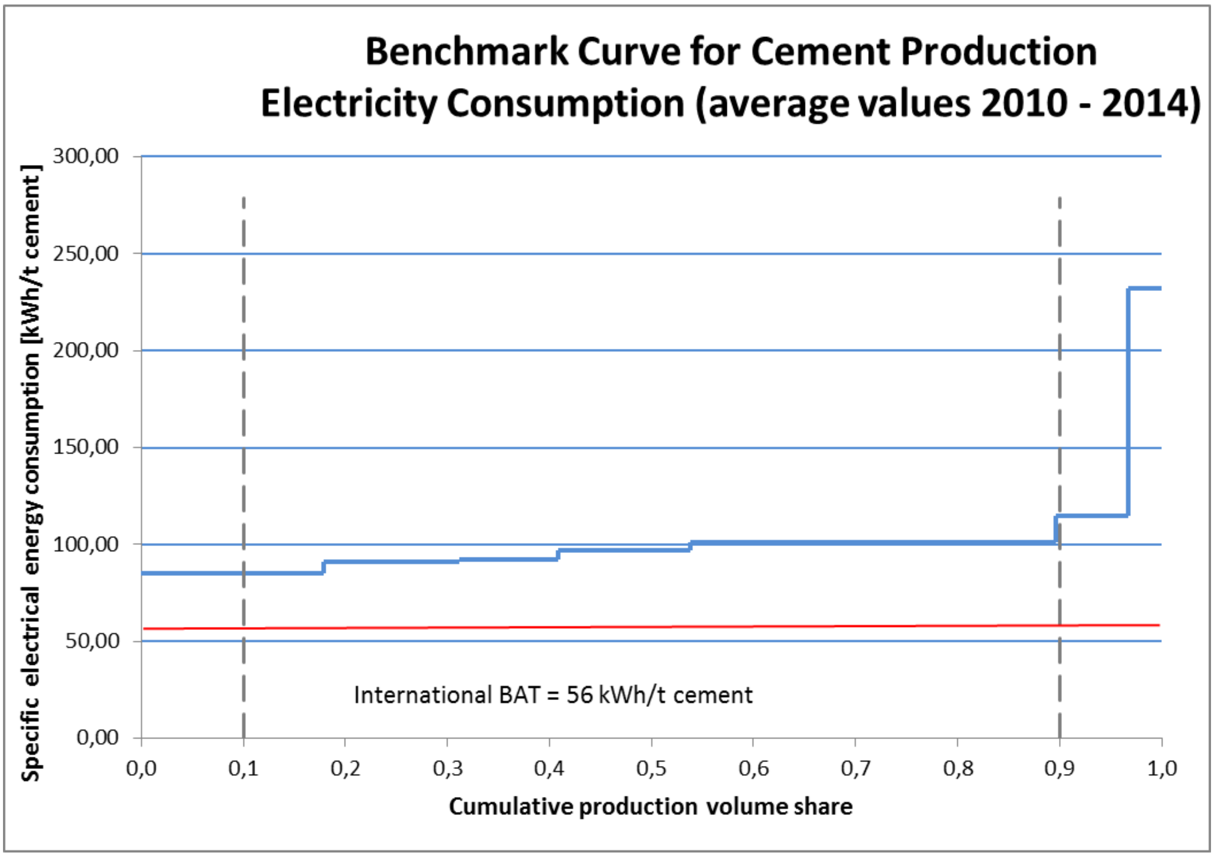


Figure 9: Specific Electricity Consumption Benchmark Curve for Cement Production

[6] Average values for production and specific thermal energy consumption are taken for years 2010 – 2013 and year 2014 only for plant 9.

- The electrical energy consumption EPI corresponding to the national BAT value = 85 kWh/t cement
- The electrical energy consumption EPI corresponding to the national BPT value = 91 kWh/t cement
- The electrical energy consumption EPI corresponding to the international BAT value = 56 kWh/t cement

The most important benchmark curve is shown in figure 10 representing the total specific energy consumption.

Table 21: Specific Total Energy Consumption (Thermal & Electrical) of the Analyzed Cement Plants (GJ/t)

	Average Cement Production[7] (t/year)	Production Share	Cumulative Production Share	Average Specific Energy Consumption (GJ/t cement)
Plant 3	3,039,127	0.27	0.27	**3.53**
Plant 7	804,562	0.07	0.34	**3.62**
Plant 6	1,458,997	0.13	0.47	3.81
Plant 5	2,026,730	0.18	0.65	3.93
Plant 4	1,011,976	0.09	0.74	4.04
Plant 8	1,492,735	0.13	0.87	4.10
Plant 9	367,902	0.03	0.90	4.53
Plant 2	1,100,965	0.10	1.00	4.59

- The total energy consumption EPI corresponding to the national BAT value = 3.53 GJ/t cement
- The total energy consumption EPI corresponding to the national BPT value = 3.62 GJ/t cement
- The total energy consumption EPI corresponding to the international BAT value = 2.92 GJ/t cement

For two analyzed companies the electrical energy consumption was not available. Therefore the benchmark curve for the total consumption contains only eight data sets.

The international benchmarks (Table 22) for cement industry are available for specific thermal energy consumption, specific electrical energy consumption and the total specific energy consumption.

[7] Average values for production and specific thermal energy consumption are taken for years 2010 – 2013 and year 2014 only for plant 9.

Table 22: International BAT for Thermal, Electrical and Total Energy Consumption

Production Process		Portland Cement (GJ/t)
Raw Materials Preparation:	Electricity	0.07
Clinker Making	Fuel	2.79
	Electricity	0.08
Finish Grinding 325 Cement	Electricity	0.06
Total Thermal Energy Use (GJ/t Cement)		**2.71**
Total Electricity Energy Use (GJ/t Cement)		**0.21**
Total Energy Use (GJ/t Cement)		**2.92**

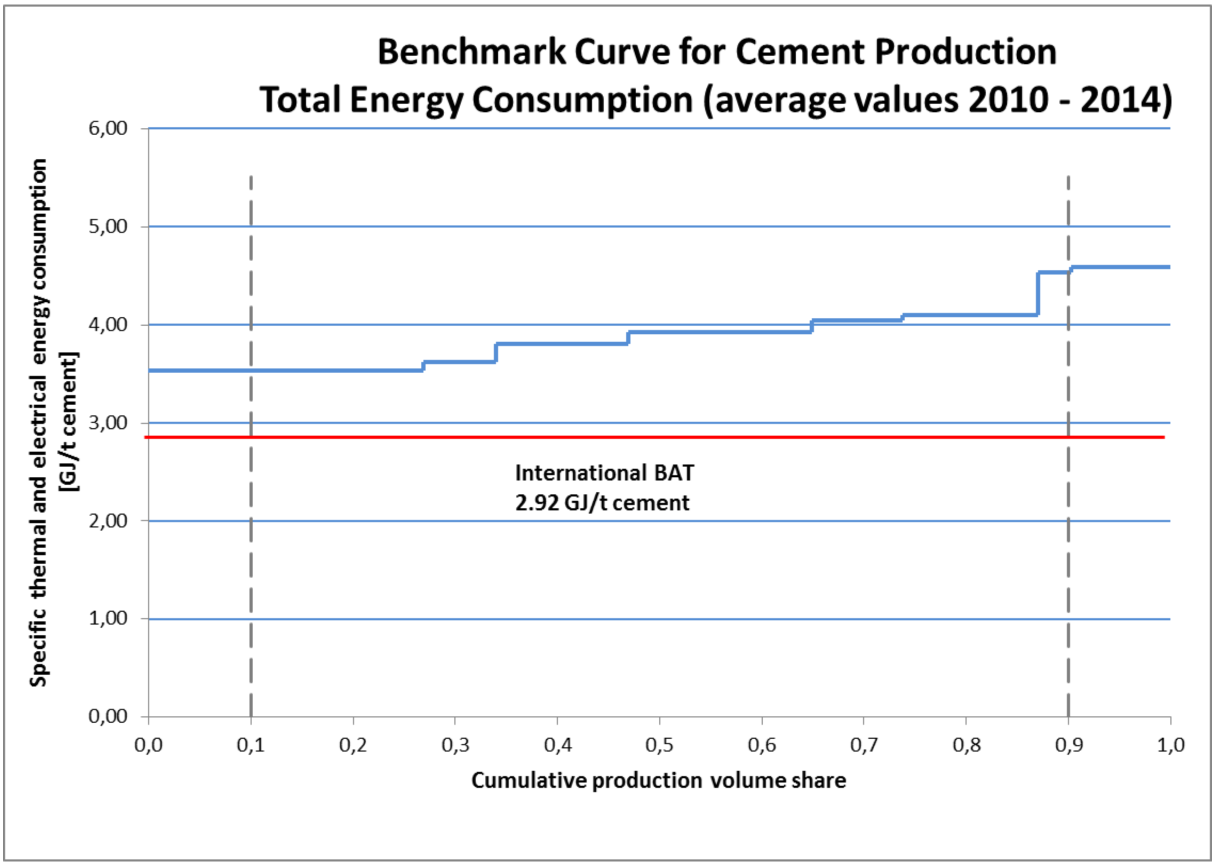


Figure 10: Total Specific Energy Consumption Benchmark Curve for Cement Sector

The most efficient plant produces 27% of the production of all analyzed companies shown in Figure 10. The specific energy consumption of the most efficient plant represents the national BAT value and is 3.53 GJ/t cement. The international BAT value is 2.92 GJ/t cement.

4.4 Share of Energy Costs of Turnover

Only one plant among the analyzed companies has published data; reporting the company's annual revenues. For this specific plant, the total energy consumption (thermal and electrical) was estimated to be 10,683,213 GJ/year with a net profit of 399,368,311 EGP/year. The ratio of energy consumption to the net profit of this company is estimated to be (MJ/EGP) is 26.75 MJ/EGP.

4.5 Energy Cost Benchmark Curve for Egyptian Companies

Energy Tariffs as per the Egyptian Ministerial Decrees in the cement sector are fixed through the period from 2010 to 2012, followed by an increase in the Mazout and electricity prices in year 2013.

Table 23: Energy Cost per Ton of Cement for the Examined Sample Plants

Plant No	2010 (EGP/t)	2011 (EGP/t)	2012 (EGP/t)	2013 (EGP/t)	2014 (EGP/t)	Average (EGP/t)
Plant 2	-	75	146	-	-	111
Plant 3	91	59	107	-	-	86
Plant 4	-	-	-	167	-	167
Plant 5	-	75	112	-	-	94
Plant 6	-	-	115	156	-	136
Plant 7	118	111	109	143	-	120
Plant 8	-	95	101	106	-	101
Plant 9	-	-	-	-	194	194

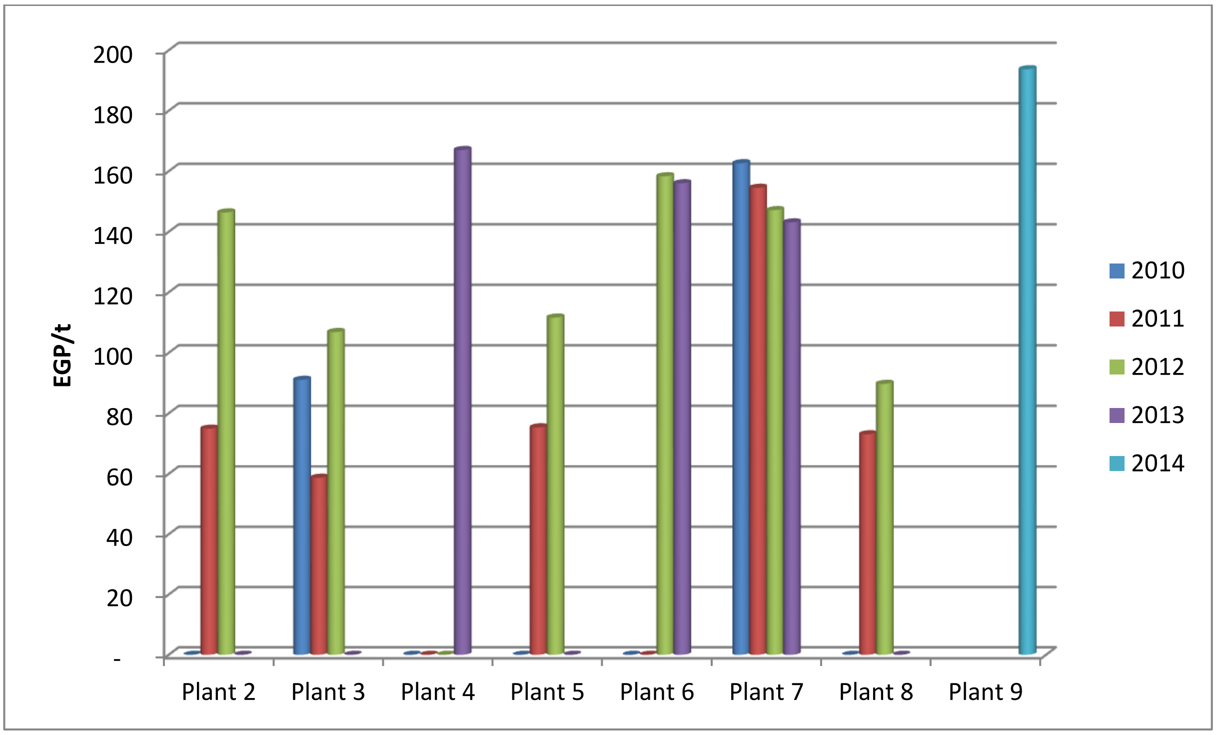


Figure 11: Energy Cost Benchmark Curve for the Cement Sector

Plant number 9 started its operation at the end of the year 2013 therefore they could only report data from the first quarter of 2014. This plant generates its own electricity and does not purchase electricity from the national network.

4.6 Annual Saving Potential

4.6.1 Annual Saving Potential for Each Plant

On the national level, the annual saving potential for each cement plant was calculated by the following equation:

Potential of company x = (SEC of company x - BAT national) * production of company x

The potential savings calculated by applying only the specific thermal energy or electricity consumption is only a theoretical value. The most important and realistic saving potential is the one corresponding to the total energy consumption.

The national BAT for total energy consumption is 3.53 GJ/t. The annual saving potential of the analyzed companies in comparison to “plant 3” is 6,920,611 GJ or 11%.

Table 24: Potential Savings Calculated with Specific Total Energy Consumption

(EGP/t)	Average Production (t/year)	SEC (GJ/t)	Saving Potential (%)	Saving Potential (GJ/year)
Plant 2	1,100,965	4.59	30%	1,164,381
Plant 3	3,039,127	**3.53**	0%	-
Plant 4	1,011,976	4.04	14%	516,108
Plant 5	2,026,730	3.93	11%	795,289
Plant 6	1,458,997	3.81	8%	402,100
Plant 7	804,562	3.62	3%	72,732
Plant 8	1,492,735	4.10	16%	841,903
Plant 9	367,902	4.54	28%	368,491
Plant 10	3,368,095	4.11	16%	1,941,370
Plant 11	1,395,359	4.12	17%	818,239
SUM				**6,920,613**

Comparing the thermal and electrical BAT brings not the same results as the calculation with the total specific energy consumption BAT. This is caused by the fact, that a company which has the lowest thermal energy consumption does not necessarily have to have also the lowest consumption in electrical energy.

Table 25: Potential Savings in Thermal Energy

(EGP/t)	Average Production (t/year)	SEC (GJ/t)	Saving Potential (%)	Saving Potential (GJ)
Plant 2	1,100,965	4.26	34%	1,200,052
Plant 3	3,039,127	**3.17**	0%	-
Plant 4	1,011,976	3.68	16%	516,108
Plant 5	2,026,730	3.62	14%	912,029
Plant 6	1,458,997	3.46	9%	423,109
Plant 7	804,562	3.21	1%	32,182
Plant 8	1,492,735	3.77	19%	895,641
Plant 9	367,902	3.7	17%	194,988
Plant 10	3,368,095	4.11	30%	3,166,009
Plant 11	1,395,359	4.12	30%	1,325,591
SUM				**8,665,709**

The lowest thermal SEC (GJ/t) was found to be in plant 3 (3.17 GJ/t).

Table 26: Potential Savings in Electrical Energy

(EGP/t)	Average Production (t/year)	SEC (kWh/t)	Saving Potential (%)	Saving Potential (MWh)
Plant 2	1,100,965	92	8%	7,707
Plant 3	3,039,127	101	19%	48,626
Plant 4	1,011,976	101	19%	16,192
Plant 5	2,026,730	**85**	0%	-
Plant 6	1,458,997	97	14%	17,508
Plant 7	804,562	115	35%	24,137
Plant 8	1,492,735	91	7%	8,956
Plant 9	367,902	232	173%	54,082
SUM				**177,207**

The lowest electrical SEC (kWh/t) was found to be in plant 5 (85 kWh/t).

4.6.2 Annual Saving Potential for the Whole Sector

The annual saving potential for the whole sector was calculated using the international BAT values for electricity, thermal and total energy use in the following equation:

Potential of whole sector = (BAT international – weighted SEC of analyzed companies) * production of the whole sector

Table 27: Annual Total Energy Saving Potential for the Whole Sector

Annual Production	Current Total Specific Energy (weighted average)	BAT Benchmark	Percent Reduction	Total Technical Potential
t/year	GJ/t	GJ/t	%	GJ/year
46,500,000	4.04	2.92	-38%	52,080,000

Table 28: Annual Thermal Energy Saving Potential for the Whole Sector

Annual Production	Current Thermal Specific Energy (weighted average)	BAT Benchmark	Percent Reduction	Total Technical Potential
t/year	GJ/t	GJ/t	%	GJ/year
46,500,000	3.71	2.71	-37%	46,500,000

Table 29: Annual Electrical Energy Saving Potential for the Whole Sector

Annual Production	Current Electrical Specific Energy (weighted average)	BAT Benchmark	Percent Reduction	Total Technical Potential
t/year	GJ/t	GJ/t	%	GJ/year
46,500,000	0.407	0.21	-94%	9,160,500

As the weighted specific electricity consumption was only calculated with data of 8 analyzed plants and the weighted specific thermal energy consumption was calculated with data of all 10 analyzed plants, the total energy saving potential differs a bit from the sum of electrical and thermal potential.

4.7 Saving Scenarios until 2030 and 2050

Within this benchmark study four different saving scenarios have been drawn until 2030 and 2050. The scenarios correspond to the scenarios in the UNIDO Working Paper. The four scenarios are:

- **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 0.3% a year.
- **BPT scenario**: All plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 1.65% a year in the period 2012 to 2030. The BPT is the lowest known BPT, either on international or on national level. For the cement sector the international BPT value was chosen (3.02 GJ/t cement).
  All plants are operating at the current levels of BPT by 2050. This is equivalent to an energy efficiency improvement of 0.78% a year in the period 2012 to 2050.
- **BAT scenario:** All plants are operating at the current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 1.84% a year in the period 2012 to 2030. The BAT is the lowest known BAT, either on international or on national level. For the cement sector the international BAT value was chosen (2.92 GJ/t cement).
  All plants are operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 0.87% a year in the period 2012 to 2050.

An important factor for drawing the scenarios is the rate of production growth. The production of the cement sector in 2050 will be about three times higher than today. For deriving the production values for the cement sector in 2050 the following approach was chosen:

- In the IEA publication Energy Technology Transitions for Industry (IEA/OECD, 2009) the demand for cement is projected. The cement demand is projected for the low- and high demand cases from 2005 to 2050, with additional projection for 2015 and 2030.
- The cement demand is shown as “per capita (kg/cap)” for the regions “South Africa” and “Other Africa”.
- For the saving scenarios the value for “Other Africa” was chosen and corrected to get the value for 2012 and the corresponding increase to 2030 and 2050.
- Furthermore the average between high and low demand was chosen. For cement demand it is 1.86.
- 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 and 2050 for Egypt was taken. This factor is 1.51.
- To get the factor for the increase in the demand between 2012 and 2050 those two factors are multiplied. For cement the factor is 2.8 until 2050 and 1.7 until 2030.

The factor for the increase in the demand between 2012 and 2030 is for cement 1.70.

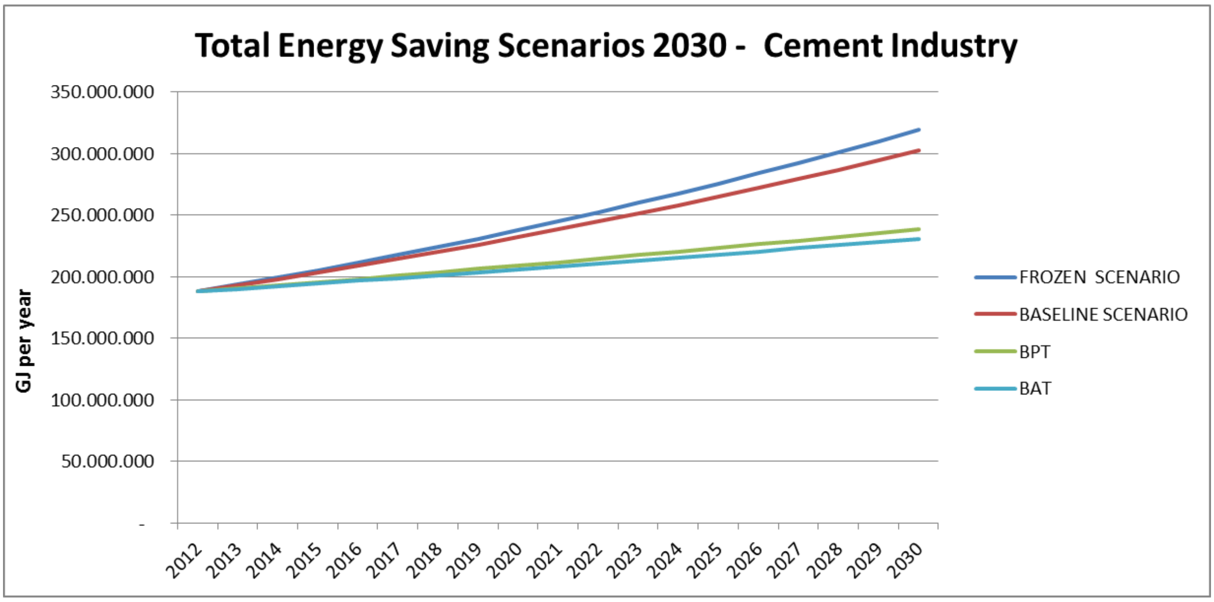


Figure 12: Total Energy Consumption in Egyptian Cement Industry, Four Scenarios 2012-2030

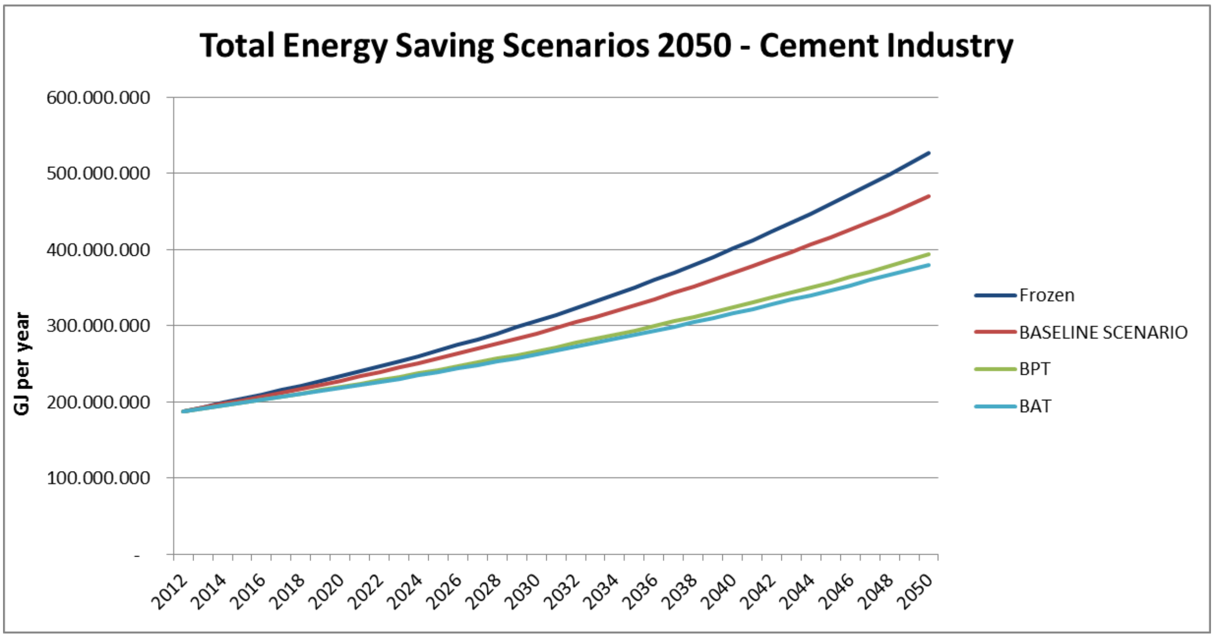


Figure 13: Total Energy Consumption in Egyptian Cement Industry, Four Scenarios 2012-2050

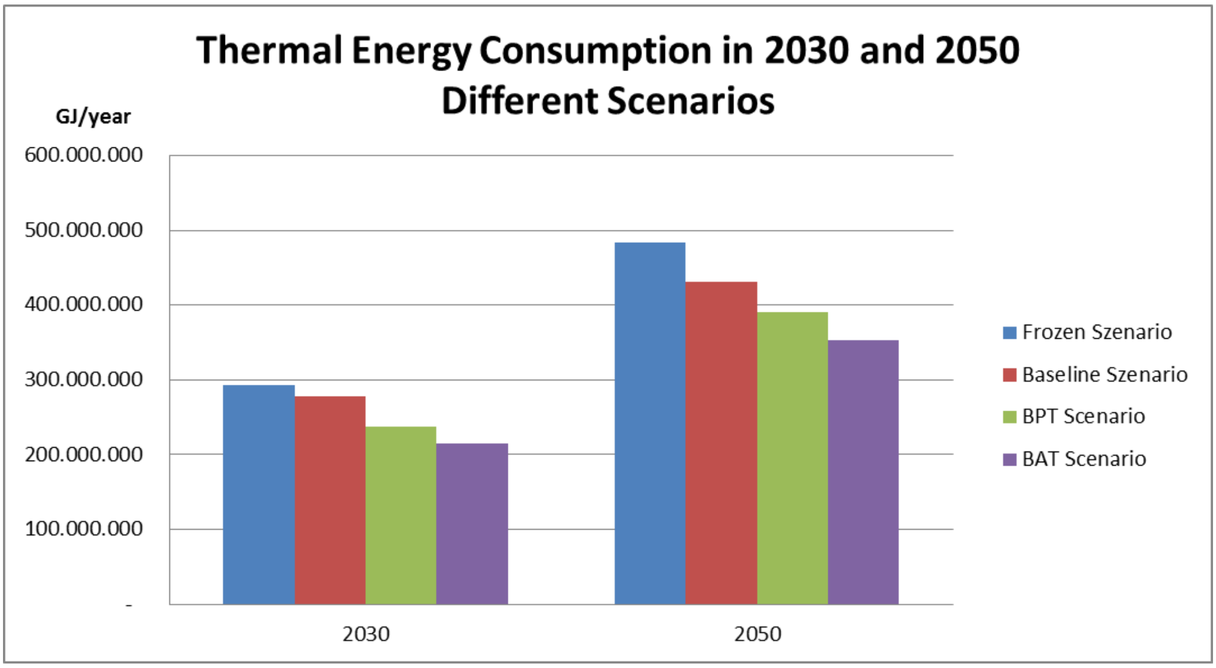


Figure 14: Total Energy Consumption in Egyptian Cement Industry in 2030 and 2050 according to the four Scenarios

In order to reach the saving of 88,536,000 GJ in 2030 the sector would need to implement energy saving measures of about 4,900,000 GJ per year. Per company this means annual savings of about 224,000 GJ. To reach the saving of 145,824,000 GJ in 2050 the sector would need to implement energy saving measures of about 3,800,000 GJ per year. Per company this means annual savings of about 174,000 GJ.

4.7.1 Energy Savings in 2030 and 2050

The following table shows the energy saving of all cement plants in Egypt in the year 2030 and 2050 if all companies reach the BAT value. Furthermore it shows the cumulated energy savings from 2012 to 2030 or 2050.

Table 30: Energy Savings in 2030 and 2050 and Cumulative Savings until 2030 and 2050

Year	Frozen Scenario (GJ)	Baseline Scenario (GJ)	BPT Scenario (GJ)	BAT Scenario (GJ)	Savings Frozen - BAT Scenario (GJ)	Cumulative Savings BAT Scenario (GJ)
2012	187,860,000	187,860,000	187,860,000	187,860,000		
2030	319,362,000	302,549,000	238,731,000	230,826,000	88,536,000	750,459,000
2050	526,008,000	469,254,000	393,204,000	380,184,000	145,824,000	10,651,332,000

4.8 Saving Opportunities

Since most of the investigated cement plants are relatively new, several energy efficiency measures were already implemented in their facilities. The following table describes the status of implementation of energy efficiency measures at some of the analyzed companies in addition to the investment cost of each energy efficiency measure.

The cost of energy efficiency measures have been classified as follows:

- Low cost energy efficiency measures: Energy efficiency measures with capital cost ranging from 0 – 1 US$/t cement
- Medium cost energy efficiency measures: Energy efficiency measures with capital cost ranging from 1 – 3 US$/t cement
- High cost energy efficiency measures: Energy efficiency measures with capital cost > 3 US$/t cement.

As shown in the below table, the cost of some energy efficiency measures may range between low-medium or medium-high cost; depending on the size of retrofit and the amount of energy saving achieved.

Table 31: Status of Energy Efficiency Measures Implementation

Energy Efficiency Measure	Investment Cost	Plant 3	Plant 4	Plant 6	Plant 8	Plant 9
1. Raw Meal Preparation						
Efficient Transport System	Medium cost	Yes	Yes	Yes	No	Yes
Raw Meal Blending	High cost	Yes	Yes	Yes	No	Yes
Process Control Vertical Mill	Low cost	Yes	Yes	Yes	Yes	Yes
High-Efficiency Roller Mill	High cost	Yes	Yes	Yes	No	Yes
High-Efficiency Classifiers	Medium cost	Yes	Yes	Yes	Yes	Yes
Roller Mills for Fuel Preparation	High cost	No	No	Yes	No	No
2. Clinker Production						
Improved refractories	Low cost	Yes	Yes	N/A, the plant is new	Yes	Yes
Kiln shell heat loss reduction	Low cost	Yes	Yes	N/A, the plant is new	No	Yes
Energy management & process control	Low cost	Yes	No	N/A, the plant is new	Yes	Yes
Adjustable speed drive for kiln fan	Low cost	Yes	Yes	N/A, the plant is new	Yes	Yes

Energy Efficiency Measure	Investment Cost	Plant 3	Plant 4	Plant 6	Plant 8	Plant 9
3. Preheater kiln upgrade to precalciner kiln	High cost	N/A, the plant is new	Yes	N/A, the plant is new	Yes	No
4. Long dry kiln upgrade to preheater/precalciner kiln	High cost	N/A, the plant is new	No	N/A, the plant is new	Yes	No
5. Older dry kiln upgrade to multi-stage preheater kiln	High cost	N/A, the plant is new	No	N/A, the plant is new	Yes	No
6. Convert to reciprocating grate cooler	Medium	N/A, the plant is new	No	N/A, the plant is new	Yes	No
7. Kiln combustion system improvements	Low cost	N/A, the plant is new	No	N/A, the plant is new	Yes	No
8. Indirect Firing	High cost	N/A, the plant is new	No	N/A, the plant is new	No	No
9. Optimize heat recovery/upgrade clinker cooler	Low cost	N/A, the plant is new	No	N/A, the plant is new	Yes	No
10. Seal replacement	Low cost	N/A, the plant is new	No	N/A, the plant is new	Yes	No
11. Low temperature heat recovery for power (capital costs given in $/kW)	Medium-High cost	N/A, the plant is new	No	N/A, the plant is new	No	No
12. High temperature heat recovery for power	High cost	N/A, the plant is new	No	N/A, the plant is new	No	In progress
13. Low pressure drop cyclones	Medium cost	Yes	No	N/A, the plant is new	Yes	Yes

Energy Efficiency Measure	Investment Cost	Plant 3	Plant 4	Plant 6	Plant 8	Plant 9
14. Efficient kiln drives	Low cost	Yes	Yes	N/A, the plant is new	Yes	Yes
15. Energy Efficiency Measures for Final Grinding of Products in Cement Plants.						
• Energy Management & Process Control	Low cost	Yes	No	Yes	Yes	Yes
• High Pressure Roller Press	High cost	No	No	Yes	Yes	No
• High-Efficiency Classifiers	Medium cost	Yes	No	Yes	Yes	Yes
• Improved Grinding Media in Ball Mills	Low cost	Yes	No	No	No	Yes
16. Plant Wide Measures in Cement Plants.						
Preventative Maintenance	Low cost	yes	Yes	Yes	Yes	Yes
High Efficiency Motors	Low cost	In progress	Yes	Yes		Yes
Adjustable Speed Drives	Low cost	yes	Yes	Yes	Yes	Yes
Optimization of Compressed Air Systems	Low cost	yes	No	Yes	Yes	Yes
Efficient Lighting	Low cost	yes	No	Yes	Yes	Yes

Energy Efficiency Measure	Investment Cost	Plant 3	Plant 4	Plant 6	Plant 8	Plant 9
17. Product and Feedstock Changes to Improve the Energy Efficiency of Clinker Production						
Blended cements	Low cost	Yes	No	No	No	No
Use of waste-derived fuels	Low-Medium cost	No	No	No	No	No
Limestone cement	Low cost	No	No	No	No	No
Low alkali cement (rotary only)	Low cost	Yes	No	No		No
Use of steel slag in kiln	Low cost	No	Yes	No	No	No

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.

6 Literature

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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
EE	Energy Efficiency
EEI	Energy Efficiency Index
EPI	Energy Performance Indicator
IEA	International Energy Agency
IDA	Industrial Development Authority
IEE	Industrial Energy Efficiency
PV	Photovoltaic
SEC	Specific Energy Consumption
SME	Small and Medium Sized Enterprise
TFEU	Total Final Energy Use

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