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Benchmarking Report of the Ceramics Sector

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Industrial Energy Efficiency Benchmarking Report of the Ceramics Sector

Prepared by

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Summary

One of the main purposes of the project “Industrial Energy Efficiency in Egypt” 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 key industrial sectors. This report covers the benchmarking study results for the ceramic tiles 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 were applied. This approach gives much more precise results than simply applying statistical data. The data were checked by the national experts and outliers were deleted.

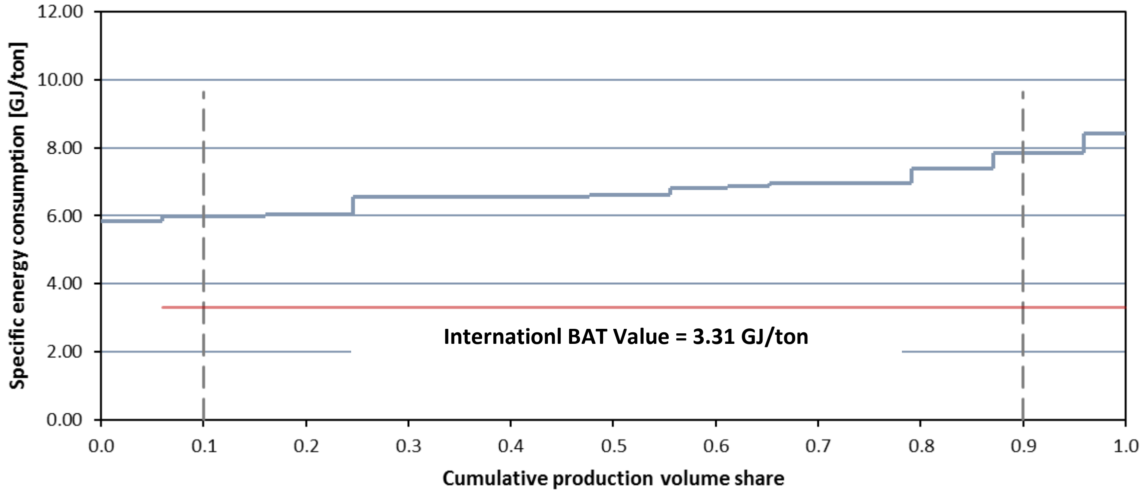
Chapter 3 contains the basic sector information, including the economic and legislative framework, the number of companies and ownership, production capacities, main products and markets. Furthermore, Chapter 3 shows the main drivers for energy consumption in the ceramic tiles industry and the energy 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 further describes the main drivers for energy consumption in the ceramic tiles industry. The energy consumption for ceramic tiles production is divided into thermal energy consumption, and electric energy consumption. The main drivers for thermal energy consumption are kiln firing process, drying and spray drying processes. On the other hand, the main drivers for electric energy consumption are grinding mills, pressing, in addition to drying and firing.

The “Best Available Techniques (BAT) Reference Document for the Production of Ceramic Manufacturing Industry” was used to obtain the world BAT value with of total specific energy consumption 3.31 GJ/t ceramic tiles. This value was used for calculating the saving potentials of the whole ceramic tiles sector in Egypt.

Chapter 4 shows the results of the analysis of the data collected in Egyptian ceramic tiles plants. From the 38 ceramic tiles plants operating in Egypt, 19 plants (representing 13 companies) were analyzed. These 13 plants have a share of 58% of the total energy consumption of the ceramic tiles sector in Egypt, which is quite a representative sample.

One important result of the study is the construction of energy efficiency benchmark curves. The graph below shows the benchmark curve for the ceramic tiles industry for the total energy consumption. These types of benchmark curves show the specific energy consumption of the analyzed companies per ton of ceramic tiles 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 5.66 GJ/t ceramic and a production volume share of 5.4%. This value defines the national BAT value. The red line indicates the international BAT value which corresponds to a specific total energy consumption of 3.31 GJ/t ceramic. The second lowest specific energy consumption in this curve is defined as the national best practice technology (BPT) value, which is 5.8 GJ/t ceramic. The international BPT value is 4.13 GJ/t based on literature review. The weighted average specific energy consumption of the ceramic tiles industry in Egypt is 6.76 GJ/ t ceramic.

For this study, the BPT value was only applied for the saving scenarios in Chapter 4 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 ceramic tiles industry, the international BPT for total energy consumption is 4.13 GJ/t ceramic, which is much lower than the national BPT value of 5.8 GJ/t ceramic.

In Chapter 4.5, energy saving potentials were calculated, on one hand, for the 13 companies that participated in the benchmarking study (one of them was considered an outlier) and on the other hand, for the whole Egyptian ceramic tiles sector. The 13 companies have an energy saving potential for thermal energy of about 2,387,444 GJ/yr. The saving potential for electrical energy of the 13 companies is about 1,128,553 GJ/yr. The potentials were calculated with the national BAT value in the following method:

Saving Potential of Company x = (SEC of Company x – BAT national) * Annual Production of Company x

The total energy saving potential of the whole ceramic tiles industry sector in Egypt is about 22,698,174 GJ/yr. The annual saving potential for the whole sector was calculated using the international BAT value in the following equation:

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

The production of the whole sector was taken from IDA data. The annual production of the whole ceramic tiles sector in Egypt is 366,006,561 square meters (Equivalent to 6,588,118 tons). As there is no reliable value for energy consumption of the whole sector on statistical basis, it was calculated with the weighted specific total energy consumption of the 13 analyzed ceramic tiles manufacturing companies. As the sample of benchmark companies is quite decent, this approach gives a good approximation of the total energy sector energy consumption.

Furthermore, in Chapter 4 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:

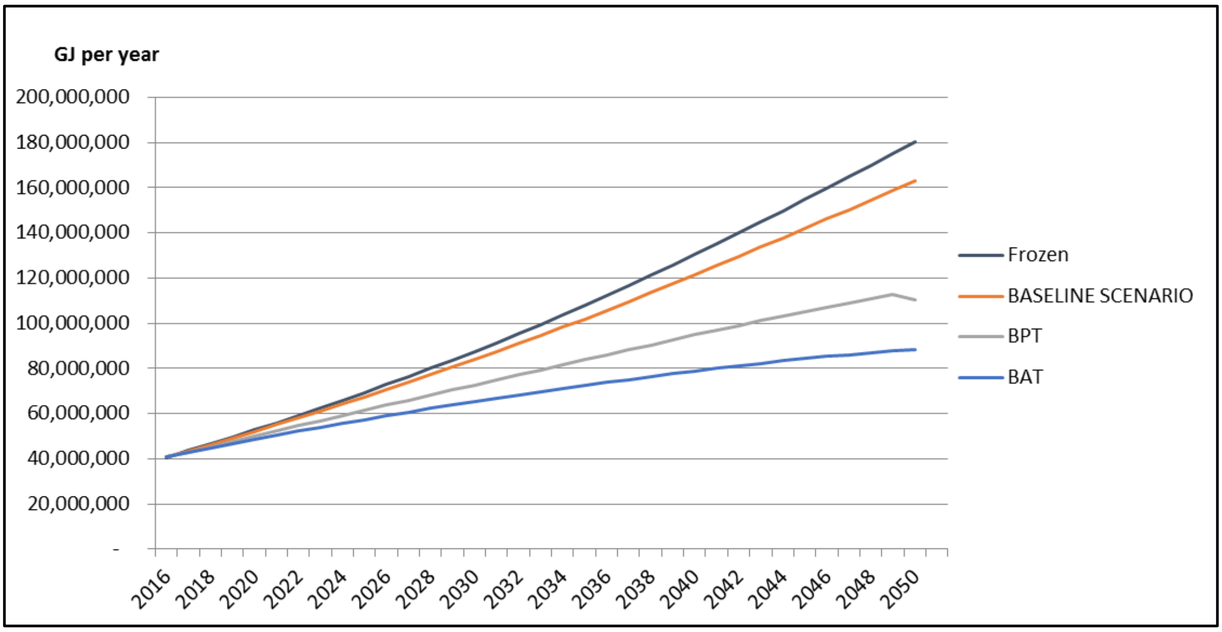
- **Frozen efficiency**: No additional energy efficiency savings are made. The current levels of energy efficiency are not improved upon.
- **Baseline efficiency**: Energy efficiency improves at a rate of 0.3% a year.
- **BPT scenario**: All plants are operating at the current levels of BPT by 2050. This is equivalent to an energy efficiency improvement of 1.32% a year in the period 2016 to 2050. The BPT is the lowest known BPT, either on international or on national level. For the ceramics sector the BPT value is the international BPT value 4.13 GJ/ton.
  All plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 3.46% a year in the period 2016 to 2030.

  The study also conducted this analysis on using national BPT value of 5.8 GJ/ton, and the results are shown in Chapter 4.
- **BAT scenario:** All plants are operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 2.08% a year in the period 2016 to 2050. The BAT is the lowest known BAT, either on international or on national level. For the ceramics sector the BAT value is the international BAT value 3.31 GJ/ton.
  All plants are operating at the current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 4.97% a year in the period 2016 to 2030.

  The study also conducted this analysis on using national BAT value of 5.66 GJ/ton, and the results are shown in Chapter 4.

An important factor for drawing the scenarios is the rate of production growth. Data on projections of ceramic tiles productivity is rare; hence, different approaches were used and illustrated in Chapter 4.6. The approach applied in this study takes in account the population growth until 2050, in addition to the ceramic productivity per capita. A relation was derived to obtain the factor for the increase in ceramic tiles productivity, which is 6.7 until 2050 and 3.3 until 2030.

The following graph shows the four scenarios until 2050 for the growth of total energy consumption in the ceramic tiles manufacturing industry using international BPT and BAT values. According to the frozen efficiency scenario, the annual total energy consumption in 2050 will reach about 180,497,714 GJ for the whole sector. The annual energy consumption in 2050 according to the international BAT scenario will be about 88,379,798 GJ. Comparing the frozen efficiency scenario and the BAT scenario, the total saving potential would be about 92,117,916 GJ, which is 51%.



The following table below shows the total annual energy consumption of the whole sector in 2016, 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 (GJ)	Baseline Scenario (GJ)	BPT Scenario (GJ)	BAT Scenario (GJ)	Savings Frozen - BAT Scenario (GJ)	Cumulative Savings BAT Scenario (GJ)
2016	40,653,114	40,653,114	40,653,114	40,653,114	-	
2030	87,522,231	83,975,264	53,451,462	42,884,511	44,637,721	300,998,149
2050	180,497,714	162,969,784	110,157,008	88,379,798	92,117,916	1,248,204,810

In Chapter 4, the sector-specific energy saving opportunities and measures are described. This study offers a basis for further energy efficiency projects for the Egyptian ceramic tiles sector. These projects should focus on implementation of energy management systems and identifying specific energy efficiency measures through detailed energy audits and assisting companies in implementation.

Abstract

The report contains the main results for the Egyptian ceramic tiles sector of the project "Industrial Energy Efficiency in Egypt", financed by the United Nations Industrial Development Organization (UNIDO) and the Global Environmental Facility (GEF).

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

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

- **Frozen efficiency**: No additional energy efficiency savings are made.
- **Baseline efficiency**: Energy efficiency improves at a rate of 0.3% 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 below shows the annual energy consumption of the whole sector in 2016, 2030 and 2050 according to the four scenarios using international BAT and BPT values. 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 (GJ)	Baseline Scenario (GJ)	BPT Scenario (GJ)	BAT Scenario (GJ)	Savings Frozen - BAT Scenario (GJ)	Cumulative Savings BAT Scenario (GJ)
2016	40,653,114	40,653,114	40,653,114	40,653,114	-	
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2050	180,497,714	162,969,784	110,157,008	88,379,798	92,117,916	1,248,204,810

Acknowledgement

This report is one of a series of benchmarking reports of energy intensive sectors in Egypt, namely; Ceramics, 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 Dr. Gihan Bayoumi and Ashraf Zeitoun. The Ceramics Sector Benchmarking Report was authored by Dr. Amr Osama and Dr. Fatheya Soliman.

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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 per cent and 3.1 per cent 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 per cent. 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 per cent and emissions by up to 32 per cent providing a striking 8.0 per cent and 12.4 per cent reduction in total global energy use and CO_2 emissions (IEA, 2012).

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.

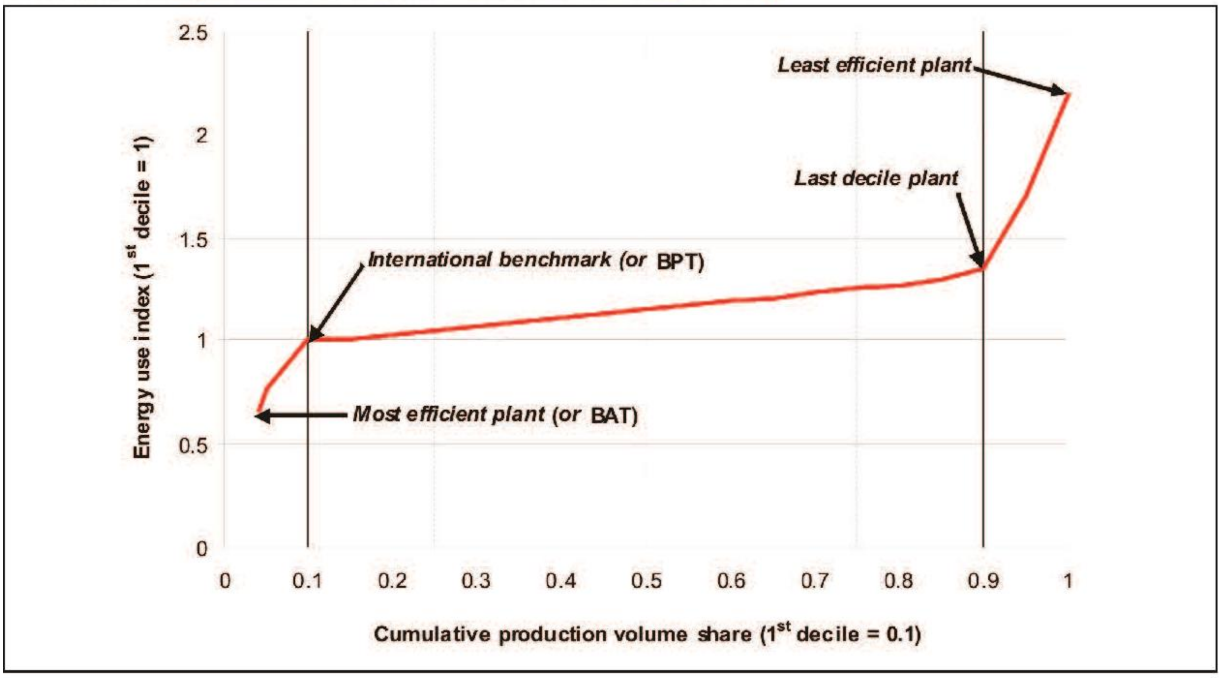
2 Methodology to Establish Benchmarking Studies

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.

In the UNIDO Working Paper, the first decile is defined as the BPT and as the international benchmark. While, 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 for a lot of industries. Since the UNIDO Working Paper did not present the benchmarks for the ceramic tiles industry, the BAT Reference Document (BREF) for Ceramic manufacturing industry published by the EU Commission was used in this report. The data for country-specific benchmarks were based on the collected data from the facilities.

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 were applied. This approach gives much more precise results. The data was checked by other national experts, system boundaries were kept and outliers were deleted. Therefore, the results of the benchmarking studies can be applied to support improving the national data collection on energy consumption and production volumes.

2.2.1 System Boundaries for Benchmarking

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

- Where is the boundary around the company? Is the 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? e.g. 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”.

The manufacture of ceramic products takes place in different types of kilns, with a wide range of raw materials and in numerous shapes, sizes and colors. The general process of manufacturing ceramic products, however, is rather uniform, and largely independent of the materials used and the final product (BREF Ceramics, 2007). In general, raw materials are mixed and cast, pressed or extruded into shape. Water is regularly used for a thorough mixing and shaping. This water is evaporated in dryers and the products are either placed by hand in the kiln (especially in the case of periodically operated kilns) or placed onto carriages that are transferred through continuously operated kilns. Figure 2 presents general overview of the typical ceramics manufacturing process.

As this report is specifically concerned with the manufacture of ceramic wall and floor tiles, more focus will be provided to the details of this industry. Figure 3 presents a schematic view of wall and floor tile manufacturing.The manufacturing process of ceramic wall and floor tiles starts with storage of raw materials, which are divided into two categories: clays and kaolins, and non-plastic raw materials such as quartz, chamotte, feldspars, calcium carbonate (calcite), talc, and dolomite. Afterwards, raw materials are prepared according to the type or form of body to be produced. Raw materials are milled in wet drum mills that can be batch or continuous mills. Also, an elutriation and homogenizing process takes place in large tanks, and suspension is pumped from those tanks to wet drum mills. This suspension is then processed either to ceramic powder and subjected to dust-pressing through a dry or wet process, or ceramic paste in a paste extrusion process. After shaping, drying is carried out at varied temperatures based on the used technology, e.g. temperature ranges between 300-350 °C in tunnel dryers, while in vertical dryers temperatures are within range of 200-220 °C. In order to prevent fissures and glazing errors from occurrence during the firing process, residual moisture content of less than one per cent is required. The firing process can be single, double or even triple in roller hearth kilns, tunnel kilns, or periodically operated kilns. In tunnel kilns, the temperature lies between 1050-1150 °C for a duration of 20-50 hours, while in modern hearth kilns it takes one to two hours. Glazing process takes place afterwards by watering or spraying, and glazed tiles are then placed at temperature of 1050-1300 °C in tunnel kilns or roller hearth kilns. Finally, some tiles can be ground or polished before being sorted manually or automatically, and then packed.

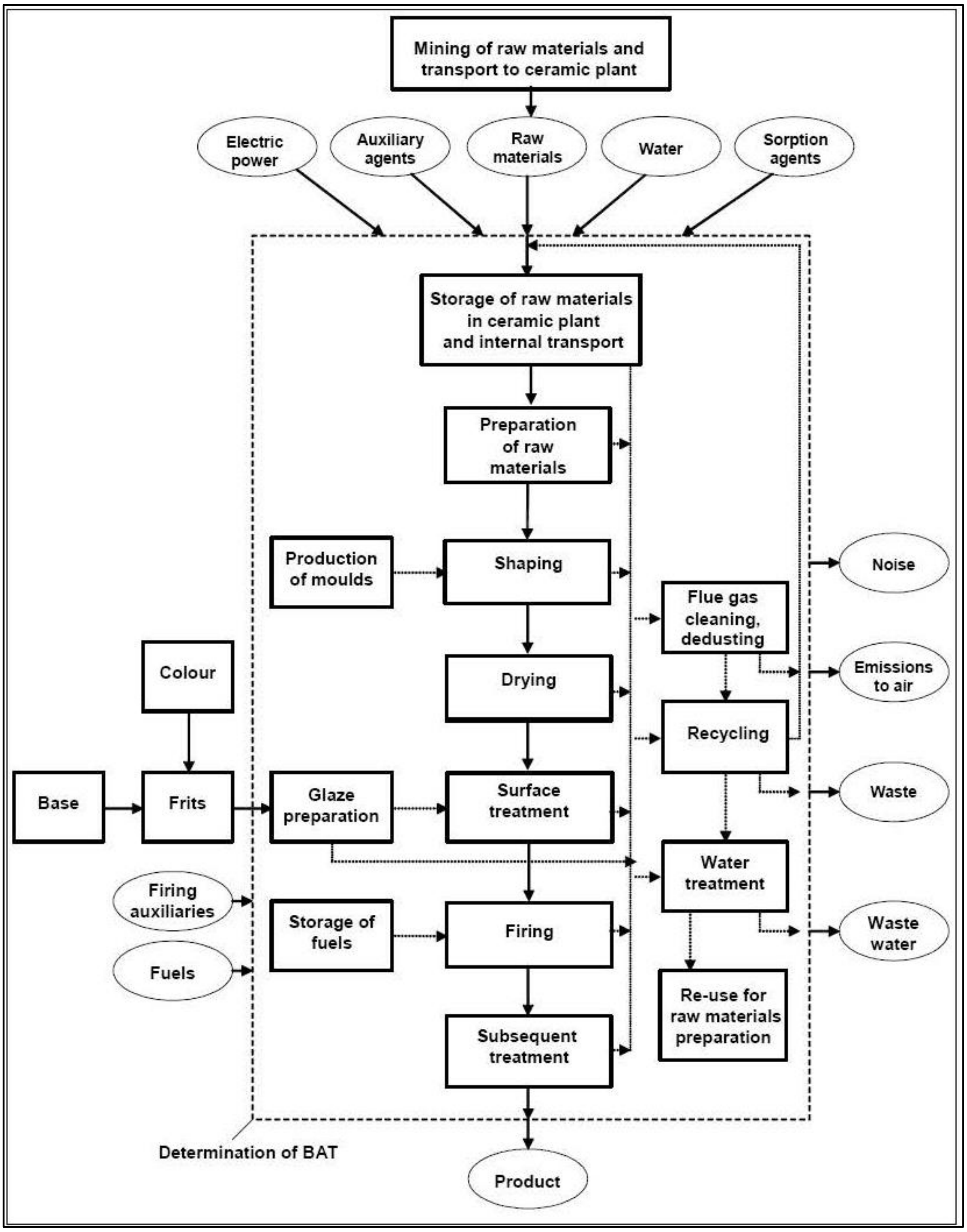


Figure 2: General overview of a ceramics manufacturing process, (BREF Ceramics, 2007)

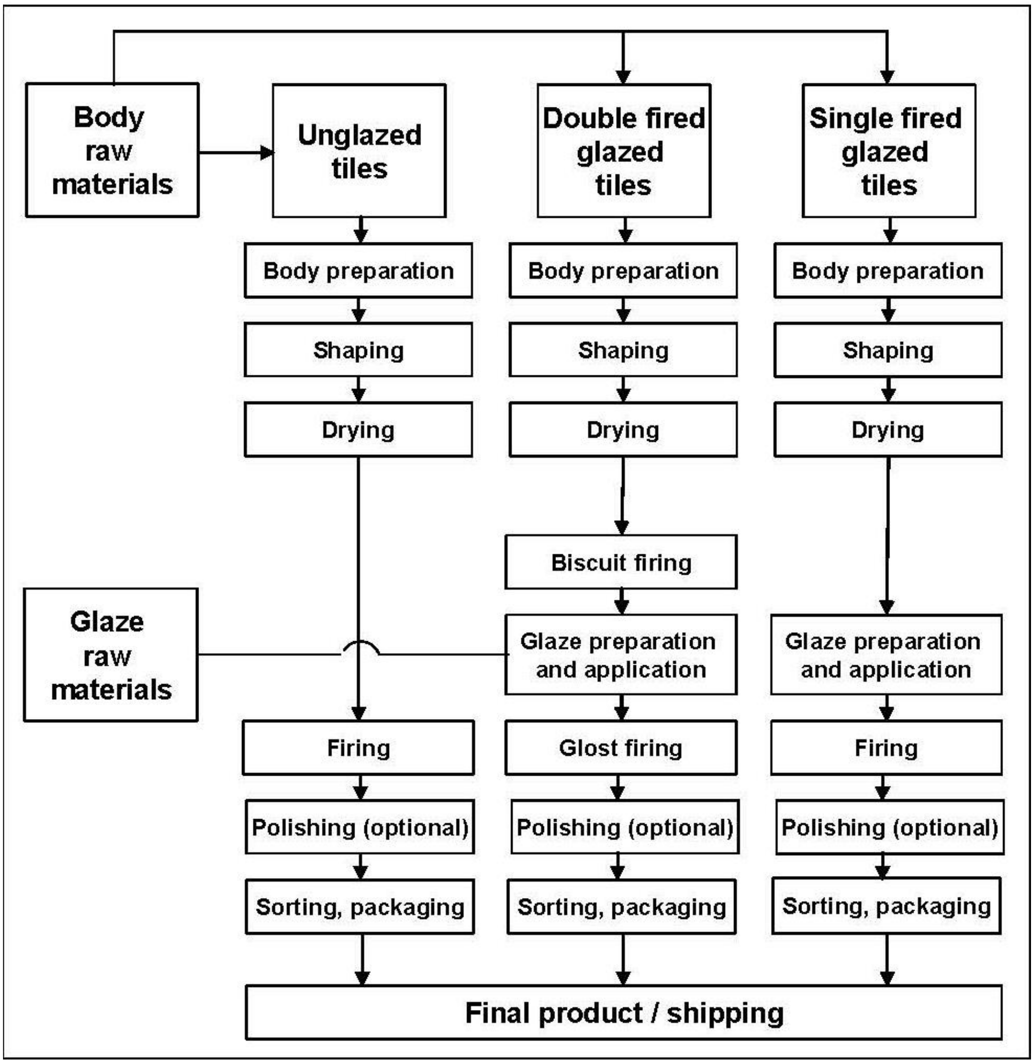


Figure 3: Schematic view of wall and floor tile manufacturing (BREF Ceramics, 2007)

The defined system boundary for the ceramics industry within this benchmarking study is (as shown in Figure 2) "the process from the raw materials storage in ceramic plant to the tiles packaging". The quarrying of raw materials, transporting them to the ceramic plant, and transportation of the final product (shipping, trucks) are not part of the system boundary, and hence the benchmarks.

2.2.2 Approach for Data Collection in Companies

Data from individual companies from the last available three years were 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 [m^2], number of shifts, hours of operation per year, etc.
- Resulting information: amount of produced end products [m^2], production capacity

- Basic technical information

- Detailed information about end products and energy demanding production facilities
- Collected data: type and amount of end products, boilers, compressors, etc.
- Resulting information: type and amount of end 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 energy sources 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/technology 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

According to IDA, the ceramics sector in Egypt include 38 industrial plants. The sector is designed to produce 366,006,561 m^2/year of ceramic tiles (Wall, floor and porcelain tiles). The following table overviews the industrial plants producing ceramic tiles in Egypt.

Table 1: Overview of Ceramic tiles plants in Egypt

#	Plant Name	Location
1	Lecico Egypt	Alexandria Governorate
2	The International Ceramics Company	Alexandria Governorate

3	Eldorado company for manufacturing of ceramics	Ain Sokhna - Suez
4	Ceramica Fancy	Ain Sokhna - Suez
5	El Alamia company (ceramica rock)	Ain Sokhna - Suez
6	Cleopatra company (cleopatra Galaria)	Ain Sokhna - Suez
7	The Egyptian Italian company	Suez Governorate
8	Karas for manufacturing of ceramics and porcelain (ceramica orient)	Suez Governorate
9	Ceramica Glamour	Suez Governorate
10	Ceramica Cleopatra	10th of Ramadan
11	Ceramica Cleopatra Group	10th of Ramadan
12	Ceramica EL-Amir	10th of Ramadan
13	Ceramica Cleopatra	10th of Ramadan
14	ceramica laboteh	10th of Ramadan
15	Venous Ceramics	10th of Ramadan
16	Porcelain Majestic	10th of Ramadan
17	El Ragaa for clay products (Ceramica Venus Egypt , omega and pyramids)	10th of Ramadan
18	Porcelain and ceramic EL-Amir	10th of Ramadan
19	The Arabic company for ceramics - Aracemco	El Obour City
20	Royal company for manufacturing ceramics and porcelain	El Obour City
21	Sheeni	Qalubiya
22	EL-Ezz company for ceramics - Gemma	El Sadat City- Menoufiya
23	EL-Ezz company for ceramics and porcelain - Gemma	El Sadat City- Menoufiya
24	ceramica Prima (EJMY)	El Sadat City- Menoufiya
25	ceramica Granito	El Sadat City- Menoufiya
26	EL-Ezz for ceramics and porcelain-Gemma	El Sadat City- Menoufiya
27	Ceramica Misr	Quesna- Minufya
28	EL-Ahlia company for ceramics	6th of October- Giza
29	Alfa group	6th of October- Giza
30	Venezia group	6th of October- Giza
31	New Alfa	6th of October- Giza
32	Ceramica Gloria	Beni Suef Governorate
33	Ceramica Mayorka	Beni Suef Governorate
34	EL-Amal company	Fayoum Governorate
35	Pharaos company for ceramics	Fayoum Governorate
36	Pharaos company for porcelain	Fayoum Governorate
37	Pharaos Style for manufacturing of ceramics and porcelain	Fayoum Governorate

2.2.4 Schedule for Data Collection

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

Table 2: Schedule for data collection

Plant Number	Visit date		Remarks
	1st Round	2nd Round	
1	10/02/2016	12/04/2016	Cooperative
2	18/01/2016		Cooperative
3	01/02/2016		Cooperative
4	01/02/2016		Non Cooperative
5	01/02/2016		Non Cooperative
6	15/02/2016	21/04/2016	Cooperative
7	08/02/2016	10/05/2016	Cooperative
8	13/01/2016	02/06/2016	Cooperative
9	11/01/2016	02/06/2016	Cooperative
10	11/01/2016	02/06/2016	Cooperative
11	11/01/2016	02/06/2016	Cooperative
12	15/02/2016	21/04/2016	Cooperative
13	28/01/2016	28/04/2016	Cooperative
14	28/01/2016	28/04/2016	Cooperative
15	28/01/2016	28/04/2016	Non Cooperative
16	15/02/2016		Non Cooperative
17	21/01/2016	18/05/2016	Cooperative
18	21/01/2016	18/05/2016	Non Cooperative

2.2.5 Limitations of Data Collection and Barriers Encountered

Of the 38 plants in Egypt, 19 plants (13 companies) were willing to cooperate in the project. According to the design capacity data, the 13 companies included in the study produce 211,931,561 m^2/year of ceramic tiles, which cover 58% of the sector as shown in the following figure. After analyzing the data, one company Company 11, was removed because it was considered an outlier. Most of the other companies were unwilling to share their data, and few others claimed that their data will not be respresentative since they have production-related problems.

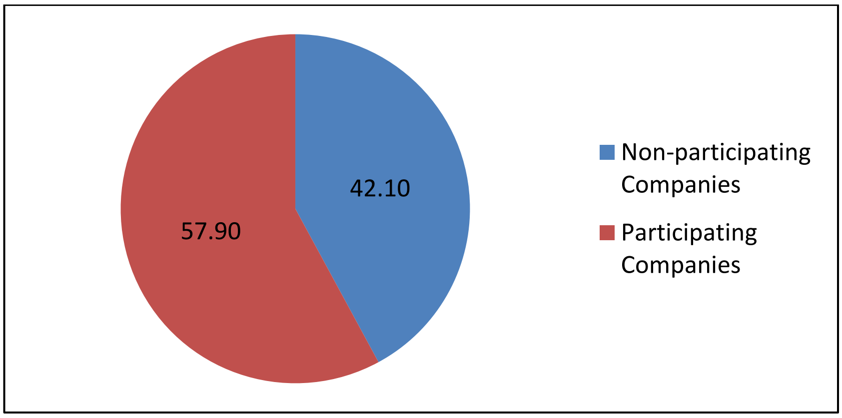


Figure 4 Production share of the participating companies

2.3 International Benchmarks for Comparison

Most of the studies relevant to the energy consumption in the ceramic tiles industry refers to the "Best Available Techniques (BAT) Reference Document for the Ceramic Manufacturing Industry", published in 2007. The study "World Best Practice Energy Intensity Values for Selected Industrial Sectors" does not include the ceramic tiles. Moreover, the UNIDO Working Paper "Global Industrial Energy Efficiency Benchmarking – An Energy Policy Tool, 2010" just focuses on the ceramic bricks without any relevant content about the ceramic tiles.

2.3.1 International Best Practice

Spain and Brazil are two of the world's biggest ceramic tile producers. Recent studies have been published for both countries focusing on specific thermal energy consumption (Monfort, E et al, 2012). The following table presents the minimum, maximum and average values for both countries, in addition to the BAT value. The average specific thermal energy consumption values in two countries are low compared to many other countries. It is to be noted that there are many factors that affect the specific thermal energy consumption of ceramic tiles manufacturing. These include the type of kiln (tunnel versus rotary hearth), type of firing (single versus double firing), type of raw materials, and the provision of energy recovery.

Table 3: Specific thermal energy consumption of ceramic tiles in Spain and Brazil compared to BAT

Benchmark (BM)	Spain		Brazil		Best Available Technology (BAT)
	Range	Average	Range	Average	BAT
GJ/t (thermal)	3.82-7.1	5.14	3.98-6.35	4.98	3.13

For calculating the energy saving scenarios in section 4.6, the international BPT value for themal energy consumption was taken as 3.82 GJ/t ceramic.

2.3.2 International Best Available Techniques (BAT)

The “Best Available Techniques (BAT) Reference Document for the Production of Ceramic Manufacturing Industry” published in 2007 indicates BAT-associated energy consumption levels for the different processing steps in the ceramic tiles manufacture as shown in the table below.

Table 4: BAT-Associated Energy Consumption Levels in different processing steps

Process	Unit	Industry Benchmark
Thermal energy: Spray drying process	GJ/t	0.98–2.2
Thermal energy: Drying process	GJ/t	0.25–0.75
Thermal energy: Firing: single-fired tiles (Tunnel kilns)	GJ/t	5.42–6.3
Thermal energy: Firing: double-fired tiles (Tunnel kilns)	GJ/t	5.92–7.3
Thermal energy: Firing: single-fired tiles (Roller hearth kilns)	GJ/t	1.9–4.8
Thermal energy: Firing: double-fired tiles (Roller hearth kilns)	GJ/t	3.4–4.62
Electric energy: Dry grinding	GJ/t	0.04–0.07
Electric energy: Wet grinding	GJ/t	0.05–0.35
Electric energy: Spray drying	GJ/t	0.01–0.07
Electric energy: Pressing	GJ/t	0.05–0.15
Electric energy: Drying	GJ/t	0.01–0.04
Electric energy: Firing	GJ/t	0.02–0.15

By adding the lower ends of the different processes, it can be concluded that the thermal BAT value is 3.13 GJ/t ceramic, while the electric BAT value is 0.18 GJ/t ceramic.

2.4 Approach for Estimating Energy Saving Potentials

The following chapter describes the methods used for calculating energy saving potentials for the ceramics sector in Egypt. The results are shown in chapter 4.5

2.4.1 Saving Potential of Participating Companies

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

Assumption for saving potential of companies that participated on the benchmarking study:
All participating companies achieve the SEC of the company with the lowest SEC (BAT).

Saving Potential of Company x = (SEC of Company x- BAT national) * 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 the whole 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 companies participating in the benchmarking study (SEC_y) as SEC of the whole sector. This assumption is eligible as the companies that participated the benchmark studies represent 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 = (Weighted SEC of the Analyzed Companies – International BAT) * 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. For the ceramics sector in Egypt, the international BAT is lower than the national BAT.

2.4.3 Saving Potentials for the BPT Scenario

In chapter 4.6, 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. For the ceramic tiles sector in Egypt, the international BPT is lower than the national BPT.

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 ceramics 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. Plausibility checks of data filled into the excel sheets included the following comparisons and evaluation:

- 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

3 Basic Sector Information

3.1 Economic and Legislative Framework

Egypt is one of the top 15 manufacturing countries in the ceramic tiles industry with a production rate of 200 million squared meters in 2012, which comprised 1.8% of the total world's production by then (Stock, 2013).

The ceramics industry in Egypt was initiated in the late 50s through “SHINI”, a public sector company that started by manufacturing ceramic tiles, sanitary wares and pottery. Many reasons have encouraged Egyptian investors to invest in this industry. This includes the harmonization of the Egyptian consumers requirements with the ceramic tiles properties such as easy maintenance, easy to clean, suitable to hot weather, and reasonable cost. The increase of the domestic consumption due to the population growth and the availability of the body raw materials (feldspar, kaolin, clay, and quartz) are other reasons that encouraged investors. In the late 60s, LECICO started to produce ceramic tiles and sanitary ware as the first private company. Later in the 70s, a joint venture company of ARACEMCO and private companies of ALAHLIA for tiles and GRAVENA for sanitary wares followed in the same field. Egypt then stopped being a net importer in the late 80s and has become a player in the international markets with the introduction of new private companies like CERAMICA CLEOPATRA that was established in 1987. As the per capita consumption increased, the domestic sector tried to satisfy this development. In the late 90s, the production capacity has increased due to new investments of some companies; however, they were still focused on the domestic market whereas LECICO started to export sanitary ware to Europe through a European multi-brand group (SANITEC). Most of the ceramic companies have been established in the new industrial cities around Cairo and Alexandria. Consequently, the main governing laws are law No. 8 of 1997 concerning investment guarantees and incentives in addition to law No. 159 of 1981 concerning the new industrial cities (IMC, 2005).

There are various major sectors that depend on the ceramic products such as wall and floor tiles, refractory products, sanitary ware, bricks and roof tiles, technical ceramics, vitrified clay pipes, expanded clay aggregates, and inorganic bonded abrasive. However, the main focus of this report is the ceramic wall and floor tiles. According to IDA, there are 38 ceramic tiles industrial plants in Egypt with a total design capacity of 366 Million squared meters. The data presented in this report was collected from 19 ceramic tiles plants (representing 13 companies), which represents about 58% of Egypt's production.

Generally, ceramic products are made of inorganic materials with the possibility of containing some organic materials. Ceramic products can have a small fraction of clay or none at all, and they can be glazed or unglazed, porous or vitrified. Properties of ceramic products include high strength, long service life, chemical inertness, wear resistance, non-toxicity, resistance to heat and fire, and usually electric resistance (European Commission, 2007). The manufacturing process of the ceramic products is independent of the type of used kilns, and the used raw materials, which can be different in shape, size, or color. The main steps of the ceramics manufacturing process are: mining/quarrying of raw materials, transport to the ceramic plant, storage of raw materials, preparation of raw materials, shaping, drying, surface treatment, firing, and subsequent treatment, as shown above in Figure 2. However, the firing process is often of multiple stages when used for manufacturing wall and floor tiles.

Specifically, the manufacturing process of ceramic wall and floor tiles starts with storage of raw materials, which are divided into two categories: plastic raw materials like clays and kaolins, and non-plastic raw materials such as quartz, chamotte, feldspars, calcium carbonate (calcite), talc, and dolomite. Afterwards, raw materials are proportioned gravimetrically considering the moisture content of those materials. Raw materials are milled in wet drum mills that can be batch or continuous mills. Also, an elutriation and homogenizing process takes place in large tanks, and suspension is pumped from those tanks to wet drum mills. This suspension is then processed either to ceramic powder and subjected to dust-pressing through a dry or wet process, or ceramic paste in a paste extrusion process. After shaping, drying is carried out at varied temperatures based on the used technology, e.g. temperature ranges between 300-350 °C in tunnel dryers, while in vertical dryers temperatures are within a range of 200-220 °C. Glazing process is taking place afterwards by watering or spraying, and glazed tiles are then placed at temperature of 1050-1300 °C in tunnel kilns or roller hearth kilns. In order to prevent fissures and glazing errors from occurrence during the firing process, residual moisture content of less than one per cent is required. The firing process can be single, double or even triple in roller hearth kilns, tunnel kilns, or periodically operated kilns. In tunnel kilns, the temperature lies between 1050-1150 °C for a duration of 20-50 hours, while in modern hearth kilns it takes one to two hours. For specially formed tiles, they are fired in shuttle kilns or tunnel kilns at temperature up to 1100 °C. Finally, some tiles can be ground or polished before being sorted manually or automatically, and then packed.

The best available technique for ceramic tiles attains a total specific energy consumption of 3.31 GJ/t. In order to reduce the energy consumption of the ceramic tiles industry, the general BAT that should be applied can be summarized in improving the design of kilns and dryers, recovery of excess heat from kilns especially from the cooling zone, modification of ceramic bodies, and cogeneration/combined heat and power plants.

3.2 Production Capacities

As of today, there are 38 ceramics factories in Egypt with a total design capacity of around 366 million square meters of tiles, according to the Industrial Development Authority. The available data in this report are obtained from 19 ceramics plants (representing 13 companies) that represent 58% of Egypt's production capacity. The following table demonstrates the name and the design capacity of the different ceramic tiles industrial plants in Egypt. Most of these companies belong to the private sector.

Table 5: Number of Ceramic Tiles Plants in Egypt (Source: IDA)

Factory	Design Capacity (Million m^2/yr)
1. Pharaohs	6.0
2. Royal	16.5
3. Gloria	12.0
4. Granito	45.0
5. Masr Ceramics M.I.C.C	14.0
6. Ceramica Cleopatra Group	16.0
7. Eldorado - Cleopatra	12.5
8.Fancy - Cleopatra	8.0

Factory	Design Capacity (Million m^2/yr)
9. Galaria 1,2	23.0
10. El-Ezz Company for Ceramics - Gemma	3.2
11. Alfa	10.0
112.1112. New Alfa	0.3
13. Venus	6.5
14. Lecico Egypt	24.0
15. ElAlamia Company (ceramica rock)	10.0
16. The Egyptian Italian Company	4.0
17. Karas for manufacturing of ceramics and porcelain (ceramic orient)	4.0
18. Ceramica Glamour	6.0
19. Ceramica Cleopatra 1	2.9
20. Ceramica Cleopatra 2	4.0
21. Ceramica El-Amir	4.9
22. Ceramica Laboteh	17.5
23. Porcelain Majestic	3.0
24. El Ragaa for clay products (Ceramica Venus Egypt, Omega, and Pyramids)	14.0
25. Porcelain and Ceramic El-Amir	7.5
26. The Arabic company for ceramics - Aracemco	20.0
27. Sheeni	2.8
28. El-Ezz company for ceramics and porcelain – Gemma 1	11.0
29. Ceramica Prima (EJMY)	8.1

Factory	Design Capacity (Million m^2/yr)
30. El-Ezz company for ceramics and porcelain – Gemma 2	6.0
31. Ceramica Misr	15.0
32. El-Ahlia company for ceramics	2.7
33. Venezia Group	11.0
34. Ceramica Art	9.0
35. Ceramica Mayorka	3.6
36. El-Amal Company	4.4
37. Pharaohs company for ceramics	3.0
38. Pharaohs Style for manufacturing of ceramics and porcelain	3.0
Total	374.4

3.3 Economics of the Sector

3.3.1 Main Products

The ceramic tiles industry in Egypt focuses on three main categories based on the price, which are:

- Low price products: price of the low price products ranges between 16-18 EGP (price as of 2005).
- Medium price products: price of the medium products varies from 19 to 24 EGP (price as of 2005).
- High price products: price of this category ranges between 25-30 EGP (price as of 2005).

Common wall tiles dimensions are 10*10, 20*20, 20*30, and 20*35 cm^2. On the other hand, common floor tiles dimensions are 30*30, 30*35, 42*42, and 50*50 cm^2. All these dimensions are available as low price, medium price and high price products. In a survey conducted in 2004, 42% of the manufacturers work on the low price products, 40% on the medium price products, and the rest work in the high price products. Generally, the price of the three categories is deemed cheap compared to the international prices in Europe and worldwide. Those inexpensive prices can be an advantage for exporting, but it can also limit the Egyptian products to cheap products category that might be difficult to change later (IMC, 2005). All the Egyptian products are abiding by the Egyptian standards No.3168-1, 2, 3, 4, 5, 6/2000. These standards are based on ISO 13006 standards for dry-pressed ceramic tiles.

3.3.2 Annual Turnover

As of 2004, the ceramic tiles and sanitary ware industry in Egypt contributed to the Egyptian macroeconomic total turnover with approximately 300 million dollars, which is almost 0.4% of the country's GDP. Also, the export turnover was about 60 million dollars, which accounts as 20% of the total ceramic tiles and sanitaryware sector's turnover and about 0.35% of the total Egyptian exports. Moreover, around 25,000 persons were employed directly in the sector, which represented about 0.5% of the total industrial manpower in Egypt. More recent data about the turnover of the ceramic tiles is scarce in the literature. However, the above-mentioned values have of course increased significantly (may be more than doubled) since the Egyptian production capacity increased from 90 million m^2 in 2004 to 220 million m^2 in 2010 (IMC, 2005). In addition, and according to a study conducted by the ceramic division in the Federation of Egyptian Industries (FEI), the Egyptian exports amounted to 391 million dollars in 2012 and 178 million dollars in 2015. This decline started to take place due to the devaluation of the Egyptian pound that led to massive increase in the production cost, which in return impacted the competitive price of Egyptian products in the region e.g. Iran, Saudi Arabia, Turkey, and UAE (Daily News Egypt, 2016) .

3.3.3 Main Markets

According to the Central Agency for Public Mobilization and Statistics in Egypt (CAPMAS), the main market for the Egyptian ceramic products is the local market. Therefore, low percentage of about 20-25% of the production is exported to foreign markets. It is also obvious that the final destination markets are generally the neighboring markets in the MENA region specifically Libya, Sudan, Syria, Palestine, and Yemen, except for the two market leaders, which are able to export to Europe.

3.3.4 Main Drivers for Energy Consumption

The energy consumption for ceramic tiles production is divided into thermal energy consumption, and electric energy consumption. The main drivers for thermal energy consumption are kiln firing process, drying and spray drying processes. On the other hand, the main drivers for electric energy consumption are grinding mills, pressing, in addition to drying and firing. The following table shows the different energy inputs for each production process.

Table 6: Overview of Specific Energy Consumption of Different Production Processes for ceramic tile manufacturing (EU BREF, 2005)

Production Process	Type of input energy	Unit	Industry Benchmark
Spray drying process	Thermal energy	GJ/ton	0.98-2.20
Drying process	Thermal energy	GJ/ton	0.25-0.75
Firing: single-fired tiles (Tunnel kilns)	Thermal energy	GJ/ton	5.4-6.3
Firing: double-fired tiles (Tunnel kilns)	Thermal energy	GJ/ton	6.0-7.3
Firing: single-fired tiles (Roller hearth kilns)	Thermal energy	GJ/ton	1.9-4.8
Firing: double-fired tiles (Roller hearth kilns)	Thermal energy	GJ/ton	3.4-4.6
Pressing	Electric energy	GJ/ton	0.05-0.15

Drying	Electric energy	GJ/ton	0.01-0.04
Firing	Electric energy	GJ/ton	0.02-0.15

3.4 Energy Data of the whole sector

The following conversion factors were used in the calculations.

Table 7: Conversion factors

Source	Natural Gas (MJ/m^3)
IPCC 2006 Guidelines (Default Values)	37.74
Source	**Natural Gas (m^2→ ton)**
IDA	0.018

3.4.1 Thermal Energy Consumption of the Whole Sector

Generally, the commonly used fuels in the ceramic tiles sector are Natural Gas, Diesel, LPG, Mazout as well as solid fuels, LNG and biogas/biomass. According to IDA, the Egyptian ceramic tiles sector consumption is approximately 687 Million m^3/year of natural gas for the 38 plants.

3.4.2 Electricity Consumption of the Whole Sector

The total electrical energy consumption of the Egyptian ceramic tiles sector is estimated to be 781,000 MWh/year of electricity from the 38 ceramic tiles plants, according to IDA.

3.4.3 Energy Costs

For studying the financial efficiency in the ceramic tiles production, the energy cost per m^2 of tiles was calculated for each factory along the plant's year of operation. The energy costs varied from one year to another in each plant due to the increase in energy prices. Average energy costs per m^2 of ceramic tiles ranged from 2.59 EGP/ m^2 in 2013 to 6.83 EGP/ m^2 in 2015.

3.5 Energy Efficiency Measures Implemented and/or Planned

All factories participated in this study have energy saving measures planned. Most of the plants consider energy efficiency in investment decisions and have energy efficiency targets. The energy efficiency plans can include the design of kilns and dryers, recovery of excess heat from kilns, cogeneration/combined heat and power plants, and modification of ceramic bodies.

4 Analysis of Results

All companies in the Egyptian ceramics sector were contacted to participate in the benchmarking study. A total of 38 companies were invited to cooperate. After conducting site visits to 18 companies, only 13 companies were willing to cooperate and participate in the project. That's because some of the private sector companies were afraid to share their production data and numbers publicly (data confidentiality), while others claimed they have problems with their plants and production lines, that will make them unable to participate.

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 ceramic tiles production capacities of the 19 analyzed plants out of the 38 plants represent around 58% of the total production capacity of the Egyptian ceramic tiles industry.

4.1 Achieved Data Sets for Analysis

This subsection describes the data regarding ceramic tiles production and energy consumption of the analyzed companies. These data were gathered for years 2013, 2014 and 2015.

4.1.1 Production Volume of Analyzed Companies

The following table represents the ceramic tiles production volume of the analyzed companies for years 2013, 2014 and 2015. As mentioned before, and after the analysis of data, Company 11 was considered an outlier, and hence its data will not be used in the upcoming sections.

Table 8: Production Volume of Analyzed Companies

	Design Capacity (sq. m/yr)	2013 (sq. m/yr)	2014 (sq. m/yr)	2015 (sq. m/yr)
Company 1	12,000,000	22,798,548	24,140,534	26,357,737
Company 2	16,500,000	14,343,304	12,699,076	10,620,453
Company 3	12,000,000	8,612,483	11,048,089	8,745,422
Company 4	45,000,000	15,396,268	16,639,183	15,540,688
Company 5	15,000,000	14,893,560	15,028,245	10,372,882
Company 6	22,897,000	12,740,472	14,003,536	14,996,856
Company 7	12,500,000	5,030,249	6,711,166	7,570,508
Company 8	8,527,000	6,468,810	5,854,897	6,837,090
Company 9	23,000,000	19,947,240	21,998,047	23,693,646
Company 10	20,240,000	13,766,803	12,680,944	9,287,661
Company 12	267,561	5,634,147	8,656,915	11,984,116
Company 13	14,000,000	12,600,000	12,600,000	12,600,000

The design capacity of the 12 analyzed companies (201,931,561 sq. m/year) represents about 55% of the total design capacity.

4.1.2 Energy Consumption of Analyzed Companies

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

Table 9: Conversion factors

Source	Natural Gas (MJ/m^3)
IPCC 2006 Guidelines (Default Values)	37.74
Source	Natural Gas (m^2→ ton)
IDA	0.018

4.1.2.1 Thermal Energy Consumption

The following table represents the amount of thermal energy consumed and ceramic tiles produced annually by the analyzed ceramic companies. All gathered data are along the range of years from 2013 to 2015. The main fuel that is used in the Egyptian ceramic industry is Natural Gas.

Table 10: Thermal energy consumed by the analyzed ceramic companies

Plant No.	2013		2014		2015		Avg. Thermal Energy Consumption	Avg. SEC
	GJ/Year	GJ/ton	GJ/Year	GJ/ton	GJ/Year	GJ/ton	(GJ/year)	(GJ/ton)
Company 1	2,464,800	6.006	2,755,211	6.341	2,713,543	5.719	2,644,518	6.022
Company2	1,381,673	5.352	1,380,953	6.041	1,255,744	6.569	1,339,457	5.987
Company3	785,307	5.066	1,045,472	5.257	853,525	5.422	894,768	5.248
Company4	1,552,529	5.602	1,587,119	5.299	1,480,380	5.292	1,540,009	5.398
Company5	1,461,411	5.451	1,474,627	5.451	1,056,973	5.661	1,331,003	5.521
Company6	1,602,956	6.990	1,747,030	6.931	1,917,267	7.102	1,755,751	7.008
Company7	608,608	6.722	721,737	5.975	773,969	5.680	701,438	6.125
Company8	839,108	7.206	770,799	7.314	830,542	6.749	813,483	7.090
Company9	2,380,103	6.629	2,480,680	6.265	2,425,278	5.687	2,428,687	6.193
Company10	1,303,716	5.261	1,269,927	5.564	1,072,723	6.417	1,215,455	5.747
Company12	803,923	7.927	890,486	5.715	1,303,363	6.042	999,257	6.561
Company13	1,426,567	6.290	1,521,672	6.709	1,616,776	7.129	1,521,672	6.709

Figure 5 illustrates the range of thermal SEC among the analyzed companies. The figure demonstrates that the specific thermal energy consumption of the analyzed companies is close to the higher end values for plants operating in Brazil and Spain presented in chapter 2 of the study.

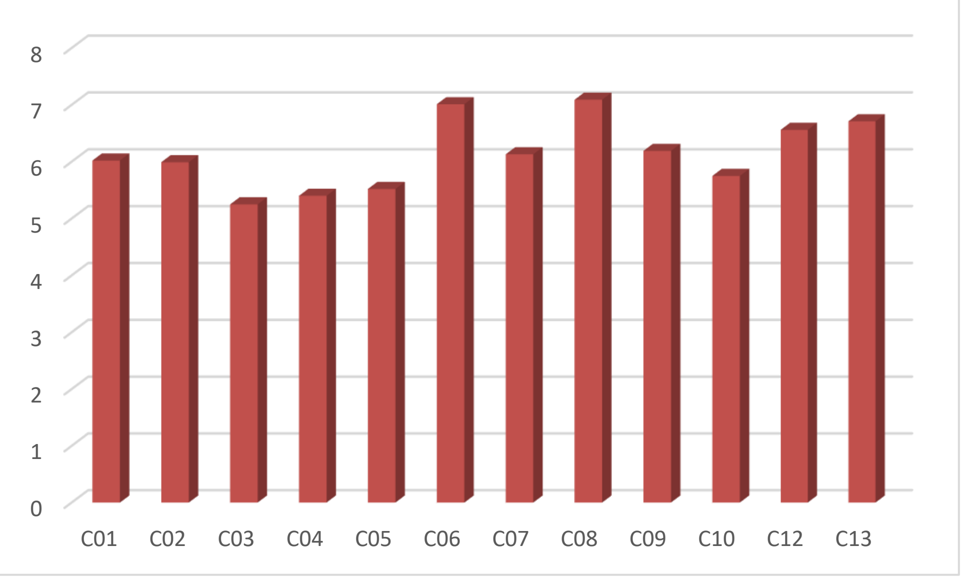


Figure 5: Range of Thermal SEC among the Analyzed Companies in GJ/ton

4.1.2.2 Electrical Energy Consumption

Table 11 demonstrates the electrical energy consumed annually by the analyzed ceramic plants, gathered in the range of years from 2013 to 2015.

Table 11: Electric Energy Used by the analyzed ceramics companies

	2013 (MWh/Year)	2014 (MWh/Year)	2015 (MWh/Year)	Average (MWh/year)	Average SEC (GJ/ton)
Company 1	63,194	62,185	70,807	65,395	0.54
Company 2	40,412	38,631	36,377	38,473	0.62
Company 3	25,555	29,715	29,780	28,350	0.60
Company 4	40,686	47,679	48,505	45,623	0.58
Company 5	37,234	37,571	26,969	33,925	0.51
Company 6	55,427	59,251	59,968	58,215	0.84
Company 7	20,379	23,811	26,689	23,626	0.74
Company 8	42,770	39,965	43,623	42,119	1.32
Company 9	80,352	84,118	86,378	83,616	0.77
Company 10	52,549	47,550	43,253	47,784	0.81
Company 12	7,463	12,716	14,673	11,617	0.27
Company 13	48,227	40,197	42,197	43,540	0.69

Figure 6 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 is close to the higher end values of the BAT industry benchmark described in chapter 2 of the study.

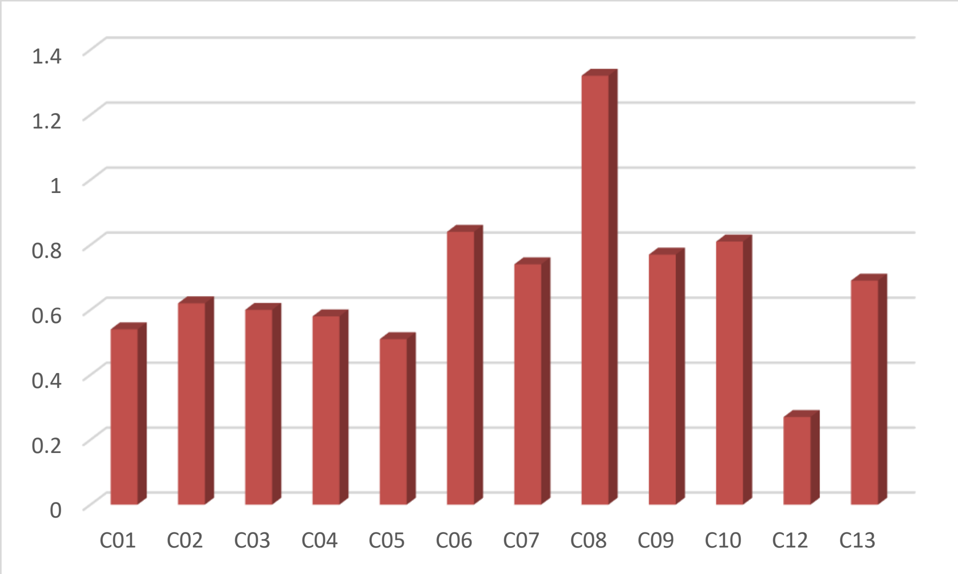


Figure 6: Range of Electrical SEC among the Analyzed Companies in GJ/ton

4.1.2.3 Total Energy Consumption

Table 12 demonstrates the total energy (thermal and electrical) consumed annually by the analyzed ceramic companies, gathered in the range of years from 2013 to 2015.

Table 12: Overview Energy Consumption and Specific Energy Consumption of Analyzed Plants: Thermal, Electrical and Total

Company No.	Average Production (Sq. m/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**
Company 1	24,432,273.00	2,644,518	235,422	2,879,940	6.02	0.54	6.56
Company 2	12,554,277.67	1,339,457	138,504	1,477,961	5.99	0.62	6.61
Company 3	9,468,664.67	894,768	102,060	996,828	5.25	0.60	5.85
Company 4	15,858,713.00	1,540,009	164,244	1,704,253	5.40	0.58	5.97
Company 5	13,431,562.33	1,331,003	122,129	1,453,132	5.52	0.51	6.03
Company 6	13,913,621.33	1,755,751	209,575	1,965,326	7.01	0.84	7.85
Company 7	6,437,307.67	701,438	85,055	786,493	6.13	0.74	6.87
Company 8	6,386,932.33	813,483	151,630	965,113	7.09	1.32	8.41
Company 9	21,879,644.33	2,428,687	301,018	2,729,705	6.19	0.77	6.96
Company 10	11,911,802.67	1,215,455	172,023	1,387,478	5.75	0.81	6.56
Company 12	8,758,392.67	999,257	41,822	1,041,079	6.56	0.27	6.83
Company 13	12,600,000.00	1,521,672	156,744	1,678,416	6.71	0.69	7.40
Weighted SEC of analyzed companies					**6.09**	**0.67**	**6.76**
National BAT					**5.066**	**0.24**	**5.66**
International BAT					**3.13**	**0.18**	**3.31**

Figure 7 illustrates the range of the total SEC (thermal and electrical) among the analyzed companies.

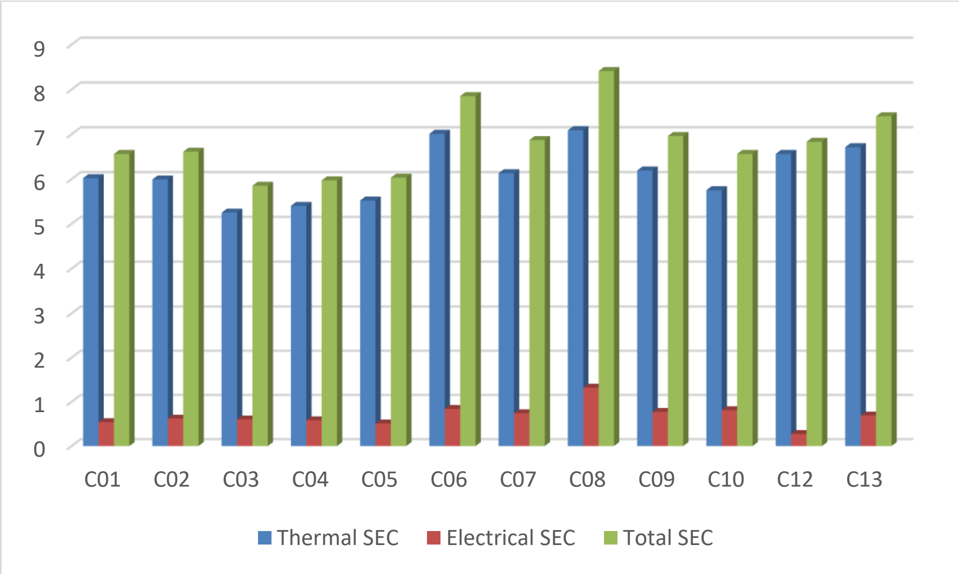


Figure 7: Range of SEC among the Analyzed Companies in GJ/ton

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 13 : Unit Prices of Energy (IDA)

Year	Electricity		Natural Gas	
	Unit Price		Unit Price	
201٣	0.263	EGP/kWh	0.569	EGP/m³
201٤	0.3	EGP/kWh	1.769	EGP/m³
201٥	0.38	EGP/kWh	1.885	EGP/m³

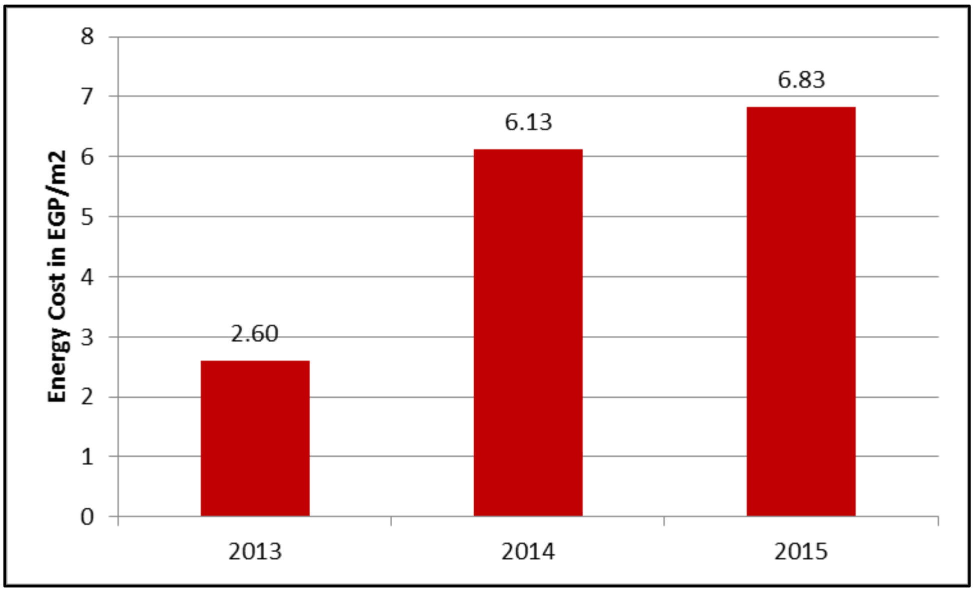


Figure 8: Energy Cost for Ceramics Production in the Analyzed Companies (2013 – 2015) in EGP/m²

The energy cost of the analyzed plants in year 2013 ranged from 2.1 EGP/m2 to 3.7 EGP/m2 with an average of 2.6 EGP/m2. The energy cost of the analyzed plants in year 2014 ranged from 5.25 EGP/m2 to 8.2 EGP/m2 with an average of 6.13 EGP/m2, and the energy cost of the analyzed plants in year 2015 ranged from 5.9 EGP/m2 to 8.5 EGP/m2 with an average of 6.8 EGP/m2. These values reflect the significant effect of increasing energy prices on the production cost of Egyptian ceramic tiles.

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 plant:

- C1. Assigning of an Energy Manager
- C2. Analysis of Energy Consumption
- C3. Installation of Meters/Sub-meters
- C4. Availability of Resources for EnMS implementation
- C5. Consideration of energy efficiency in investment decisions
- C6. Availability of energy efficiency targets

C7. Availability of previous energy audits
C8. Planning/Implementation of energy saving measures
C9. Execution of regular maintenance

Table 14 summarizes the status of energy management system implementation in the analyzed ceramics companies.

Table 14: Status of Energy Management System Implementation in the Analyzed Ceramic Companies

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
Company 1	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Company 2	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes
Company 3	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Company 4	No	Yes	No	Yes	Yes	No	No	Yes	Yes
Company 5	No	Yes	Yes	No	Yes	No	No	Yes	Yes
Company 6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Company 7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Company 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Company 9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Company 10	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Company 12	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Company 13	No	No	No	No	Yes	Yes	No	Yes	No

4.2 Energy Performance Indicators of Analyzed Companies

4.2.1 Benchmark Curve on National Level

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

- Specific thermal energy consumption (GJ/ton)
- Specific electrical energy consumption (GJ/ton) and
- Total specific energy consumption (GJ/ton)

4.2.1.1 Specific Thermal Energy Consumption

Table 15: Specific Thermal Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2013

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Thermal Energy Consumption (GJ/ton)
Company 3	8,612,483	0.057	0.06	5.07
Company 10	13,766,803	0.090	0.15	5.26
Company 2	14,343,304	0.094	0.24	5.35
Company 5	14,893,560	0.098	0.34	5.45
Company 4	15,396,268	0.101	0.44	5.60
Company 1	22,798,548	0.150	0.59	6.01
Company 13	12,600,000	0.083	0.67	6.29
Company 9	19,947,240	0.131	0.80	6.63
Company 7	5,030,249	0.033	0.84	6.72
Company 6	12,740,472	0.084	0.92	6.99
Company 8	6,468,810	0.042	0.96	7.21
Company 12	5,634,147	0.037	1.00	7.93

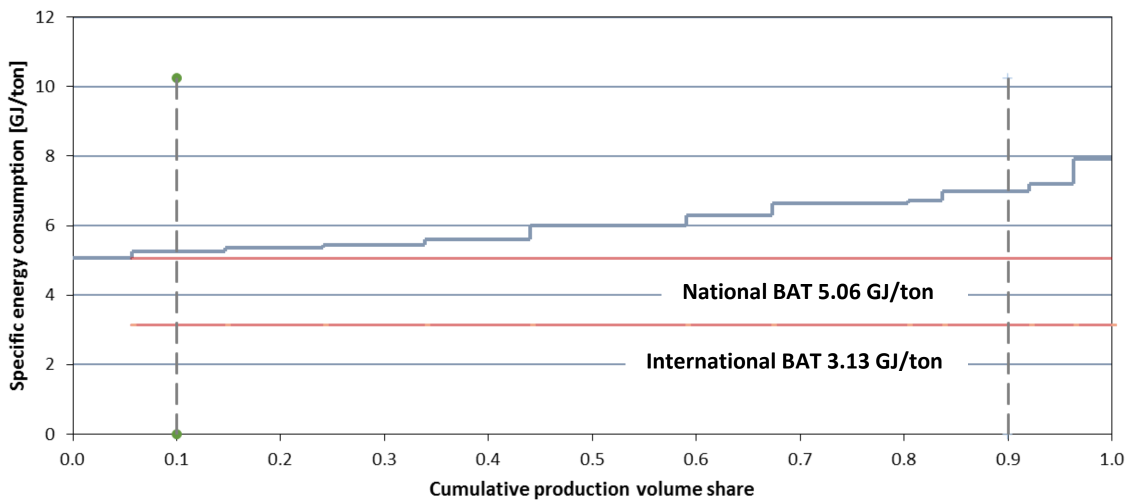


Figure 9: Specific Thermal Energy Consumption Benchmark Curve for 2013

- The specific thermal energy consumption EPI corresponding to the national BAT value in 2013 = 5.07 GJ/t ceramic

- The specific thermal energy consumption EPI corresponding to the international BPT value in 2013 = 3.82 GJ/t ceramic
- The specific thermal energy consumption EPI corresponding to the international BAT value in 2013 = 3.13 GJ/t ceramic

Table 16: Specific Thermal Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2014

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Thermal Energy Consumption (GJ/ton)
Company 03	11,048,089	0.07	0.07	5.26
Company 04	16,639,183	0.10	0.17	5.30
Company 05	15,028,245	0.09	0.26	5.45
Company 10	12,680,944	0.08	0.34	5.56
Company 12	8,656,915	0.05	0.40	5.71
Company 07	6,711,166	0.04	0.44	5.97
Company 02	12,699,076	0.08	0.52	6.04
Company 09	21,998,047	0.14	0.65	6.26
Company 01	24,140,534	0.15	0.80	6.34
Company 13	12,600,000	0.08	0.88	6.71
Company 06	14,003,536	0.09	0.96	6.93
Company 08	5,854,897	0.04	1.00	7.31

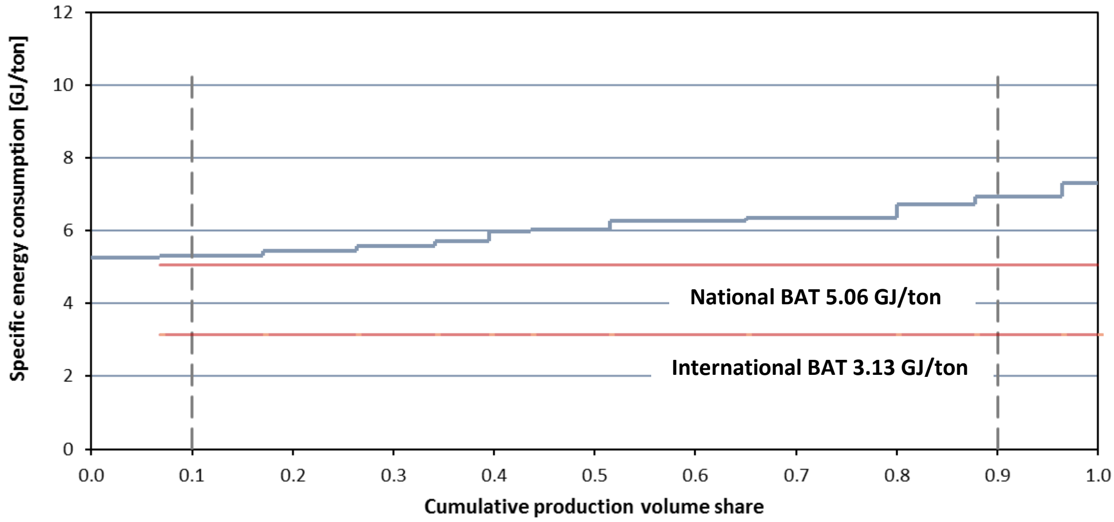


Figure 10: Specific Thermal Energy Consumption Benchmark Curve for 2014

- The specific thermal energy consumption EPI corresponding to the national BAT value in 2014 = 5.26 GJ/t ceramic
- The specific thermal energy consumption EPI corresponding to the international BPT value in 2014 = 3.82 GJ/t ceramic
- The specific thermal energy consumption EPI corresponding to the international BAT value in 2014 = 3.13 GJ/t ceramic

Table 17: Specific Thermal Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2015

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Thermal Energy Consumption (GJ/ton)
Company 04	15,540,688	0.10	0.10	5.29
Company 03	8,745,422	0.06	0.15	5.42
Company 05	10,372,882	0.07	0.22	5.66
Company 07	7,570,508	0.05	0.27	5.68
Company 09	23,693,646	0.15	0.42	5.69
Company 01	26,357,737	0.17	0.58	5.72
Company 12	11,984,116	0.08	0.66	6.04
Company 10	9,287,661	0.06	0.72	6.42
Company 02	10,620,453	0.07	0.78	6.57

Company 08	6,837,090	0.04	0.83	6.75
Company 06	14,996,856	0.09	0.92	7.10
Company 13	12,600,000	0.08	1.00	7.13

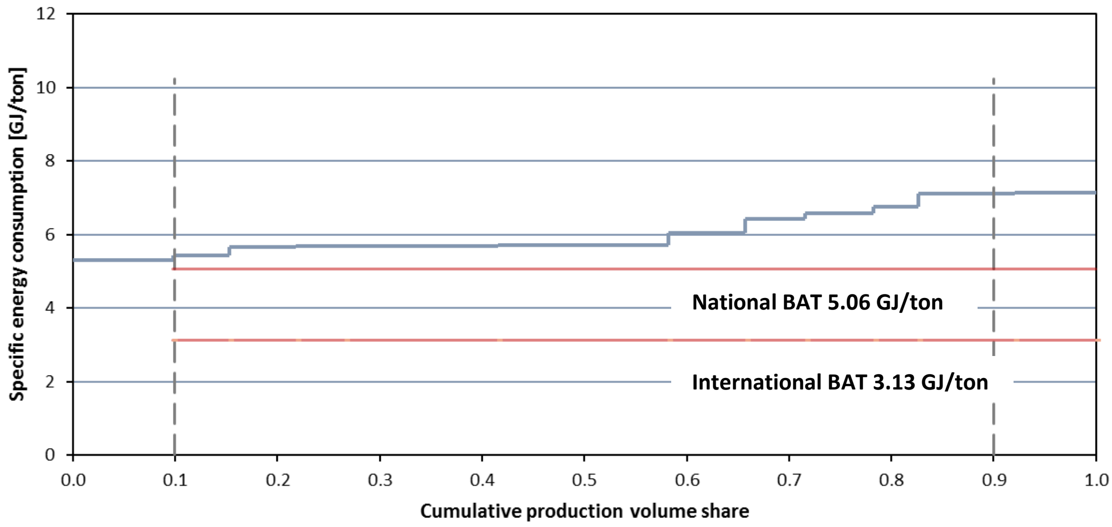


Figure 11: Specific Thermal Energy Consumption Benchmark Curve for 2015

- The specific thermal energy consumption EPI corresponding to the national BAT value in 2015 = 5.29 GJ/t ceramic
- The specific thermal energy consumption EPI corresponding to the international BPT value in 2015 = 3.82 GJ/t ceramic
- The specific thermal energy consumption EPI corresponding to the international BAT value in 2015 = 3.13 GJ/t ceramic

4.2.1.2 Specific Electrical Energy Consumption

Table 18: Specific Electrical Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2013

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Electrical Energy Consumption (GJ/ton)
Company 12	5,634,147	0.04	0.04	0.26
Company 5	14,893,560	0.10	0.13	0.50
Company 4	15,396,268	0.10	0.24	0.53
Company 1	22,798,548	0.15	0.39	0.55
Company 2	14,343,304	0.09	0.48	0.56

Company 3	8,612,483	0.06	0.54	0.59
Company 10	13,766,803	0.09	0.63	0.76
Company 13	12,600,000	0.08	0.71	0.77
Company 9	19,947,240	0.13	0.84	0.81
Company 7	5,030,249	0.03	0.87	0.81
Company 6	12,740,472	0.08	0.96	0.87
Company 8	6,468,810	0.04	1.00	1.32

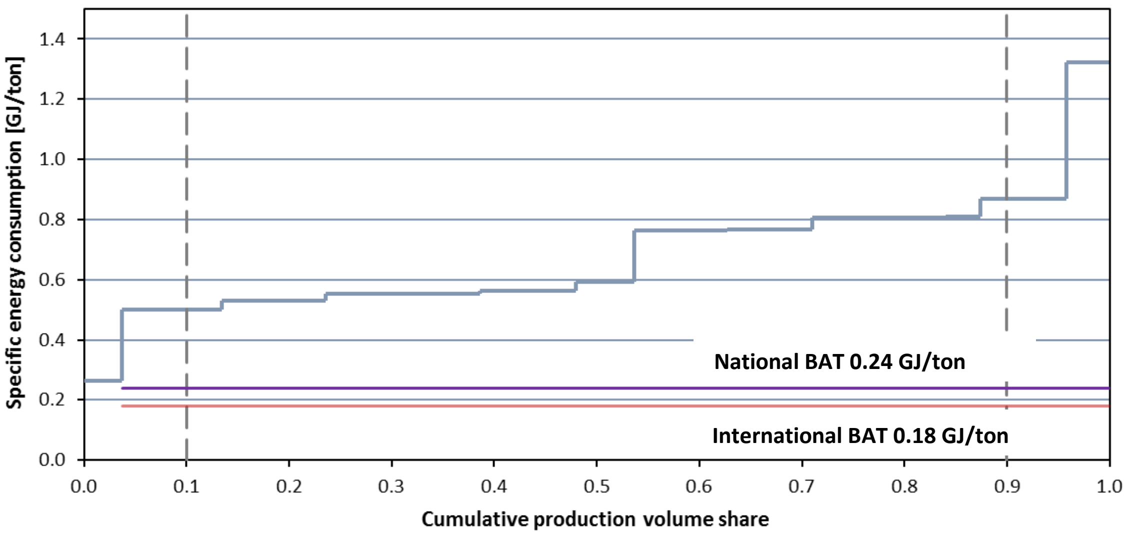


Figure 12: Specific Electrical Energy Consumption Benchmark Curve for 2013

- The specific electrical energy consumption EPI corresponding to the national BAT value in 2013 = 0.26 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BPT value in 2013 = 0.31 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BAT value in 2013 = 0.18 GJ/t ceramic

Table 19: Specific Electrical Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2014

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Electrical Energy Consumption (GJ/ton)
Company 12	8,656,915	0.05	0.05	0.29
Company 05	15,028,245	0.09	0.15	0.50

Company 01	24,140,534	0.15	0.30	0.52
Company 03	11,048,089	0.07	0.36	0.54
Company 04	16,639,183	0.10	0.47	0.57
Company 02	12,699,076	0.08	0.54	0.61
Company 13	12,600,000	0.08	0.62	0.64
Company 07	6,711,166	0.04	0.66	0.71
Company 10	12,680,944	0.08	0.74	0.75
Company 09	21,998,047	0.14	0.88	0.76
Company 06	14,003,536	0.09	0.96	0.85
Company 08	5,854,897	0.04	1.00	1.37

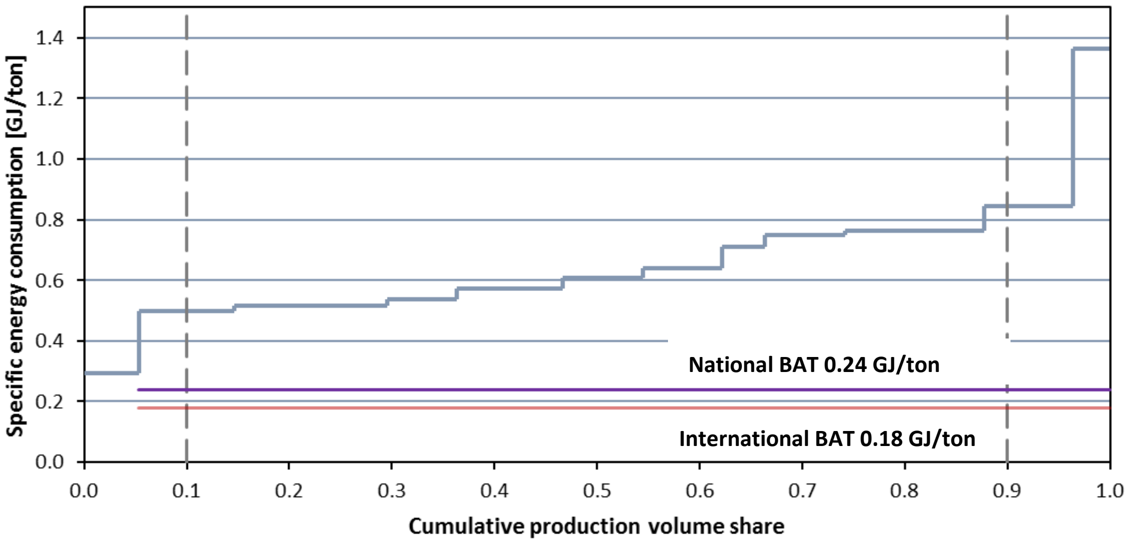


Figure 13: Specific Electrical Energy Consumption Benchmark Curve for 2014

- The specific electrical energy consumption EPI corresponding to the national BAT value in 2014 = 0.29 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BPT value in 2014 = 0.31 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BAT value in 2014 = 0.18 GJ/t ceramic

Table 20: Specific Electrical Energy Consumption of the Analyzed Ceramic Plants (GJ/ton) for the year 2015

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Electrical Energy Consumption (GJ/ton)
Company 12	11,984,116	0.08	0.08	0.24
Company 05	10,372,882	0.07	0.14	0.52
Company 01	26,357,737	0.17	0.31	0.54
Company 04	15,540,688	0.10	0.41	0.62
Company 13	12,600,000	0.08	0.48	0.67
Company 03	8,745,422	0.06	0.54	0.68
Company 02	10,620,453	0.07	0.61	0.69
Company 07	7,570,508	0.05	0.65	0.71
Company 09	23,693,646	0.15	0.80	0.73
Company 06	14,996,856	0.09	0.90	0.80
Company 10	9,287,661	0.06	0.96	0.93
Company 08	6,837,090	0.04	1.00	1.28

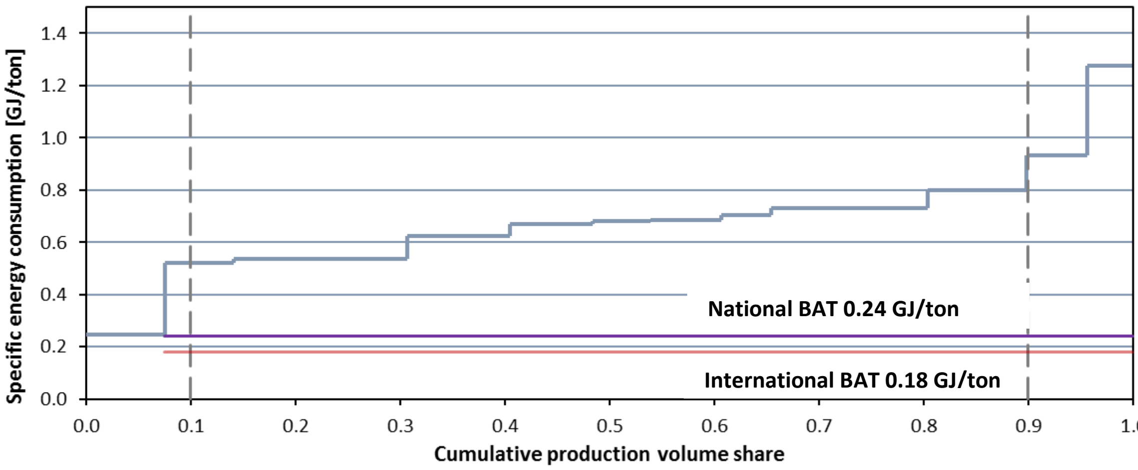


Figure 14: Specific Electrical Energy Consumption Benchmark Curve for 2015

- The specific electrical energy consumption EPI corresponding to the national BAT value in 2015 = 0.24 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BPT value in 2015 = 0.31 GJ/t ceramic
- The specific electrical energy consumption EPI corresponding to the international BAT value in 2015 = 0.18 GJ/t ceramic

4.2.1.3 Total Specific Energy Consumption

Table 21: Specific Total Energy Consumption (Thermal & Electrical) of the Analyzed Ceramic Plants (GJ/ton) for the year 2013

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Total Energy Consumption (GJ/ton)
Company 3	8,612,483	0.057	0.06	5.66
Company 2	14,343,304	0.094	0.15	5.92
Company 5	14,893,560	0.098	0.25	5.95
Company 10	13,766,803	0.090	0.34	6.02
Company 4	15,396,268	0.101	0.44	6.13
Company 1	22,798,548	0.150	0.59	6.56
Company 13	12,600,000	0.083	0.67	7.06
Company 9	19,947,240	0.131	0.80	7.43
Company 7	5,030,249	0.033	0.84	7.53
Company 6	12,740,472	0.084	0.92	7.86
Company 12	5,634,147	0.037	0.96	8.19
Company 8	6,468,810	0.042	1.00	8.53

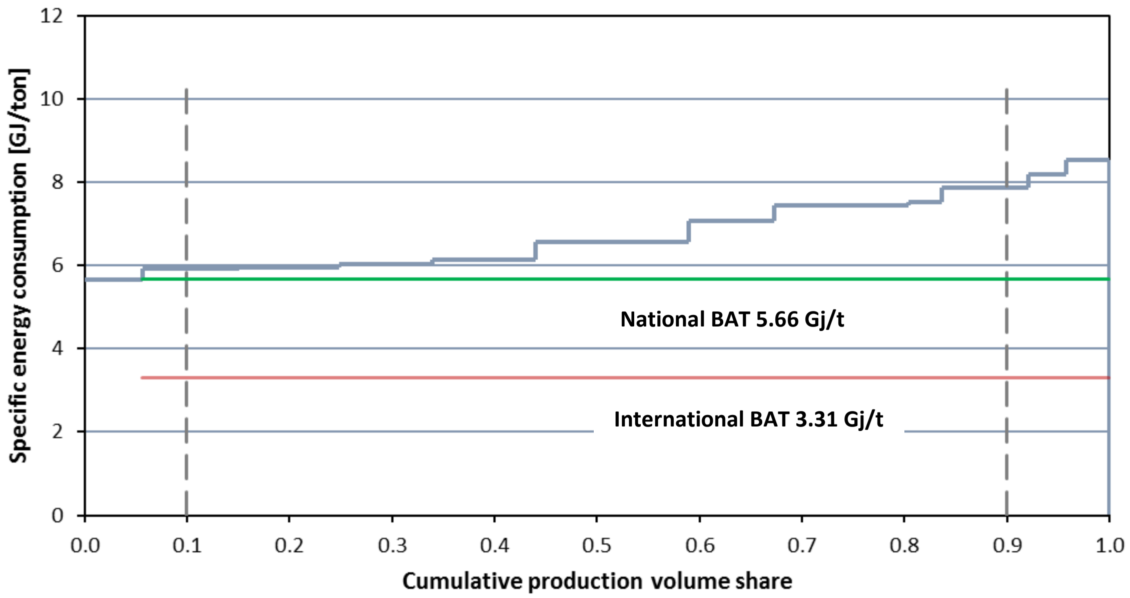


Figure 15: Specific Total Energy Consumption Benchmark Curve for 2013

- The specific total energy consumption EPI corresponding to the national BAT value in 2013 = 5.66 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BPT value in 2013 = 4.13 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BAT value in 2013 = 3.31 GJ/t ceramic

Table 22: Specific Total Energy Consumption (Thermal & Electrical) of the Analyzed Ceramic Plants (GJ/ton) for the year 2014

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Total Energy Consumption (GJ/ton)
Company 03	11,048,089	0.07	0.07	5.80
Company 04	16,639,183	0.10	0.17	5.87
Company 05	15,028,245	0.09	0.26	5.95
Company 12	8,656,915	0.05	0.32	6.01
Company 10	12,680,944	0.08	0.40	6.31
Company 02	12,699,076	0.08	0.47	6.65
Company 07	6,711,166	0.04	0.52	6.68
Company 01	24,140,534	0.15	0.66	6.86
Company 09	21,998,047	0.14	0.80	7.03
Company 13	12,600,000	0.08	0.88	7.35
Company 06	14,003,536	0.09	0.96	7.78
Company 08	5,854,897	0.04	1.00	8.68

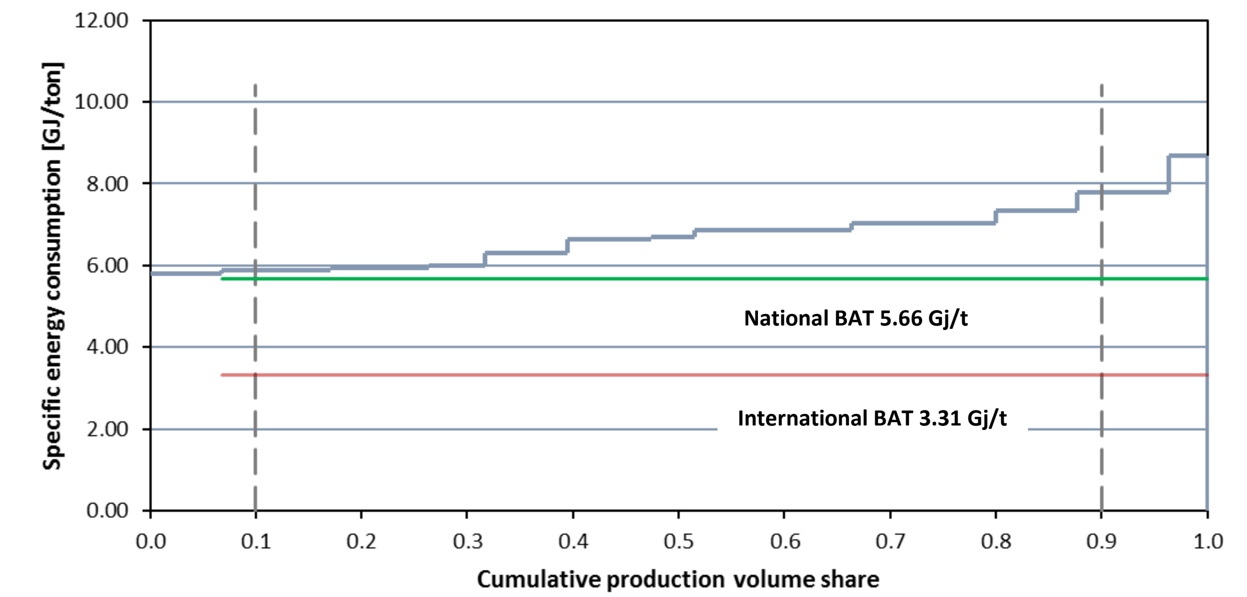


Figure 16: Specific Total Electricity Consumption Benchmark Curve for 2014

- The specific total energy consumption EPI corresponding to the national BAT value in 2014 = 5.8 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BPT value in 2014 = 4.13 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BAT value in 2014 = 3.31 GJ/t ceramic

Table 23: Specific Total Energy Consumption (Thermal & Electrical) of the Analyzed Ceramic Plants (GJ/ton) for the year 2015

	Ceramics Production (Sq. m/year)	Production Share	Cumulative Production Share	Specific Total Energy Consumption (GJ/ton)
Company 04	15,540,688	0.10	0.10	5.92
Company 03	8,745,422	0.06	0.15	6.10
Company 05	10,372,882	0.07	0.22	6.18
Company 01	26,357,737	0.17	0.38	6.26
Company 12	11,984,116	0.08	0.46	6.29
Company 07	7,570,508	0.05	0.51	6.38
Company 09	23,693,646	0.15	0.66	6.42
Company 02	10,620,453	0.07	0.72	7.25
Company 10	9,287,661	0.06	0.78	7.35
Company 13	12,600,000	0.08	0.86	7.80
Company 06	14,996,856	0.09	0.96	7.90
Company 08	6,837,090	0.04	1.00	8.02

- The specific total energy consumption EPI corresponding to the national BAT value in 2015 = 5.92 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BPT value in 2015 = 4.13 GJ/t ceramic
- The specific total energy consumption EPI corresponding to the international BAT value in 2015 = 3.31 GJ/t ceramic

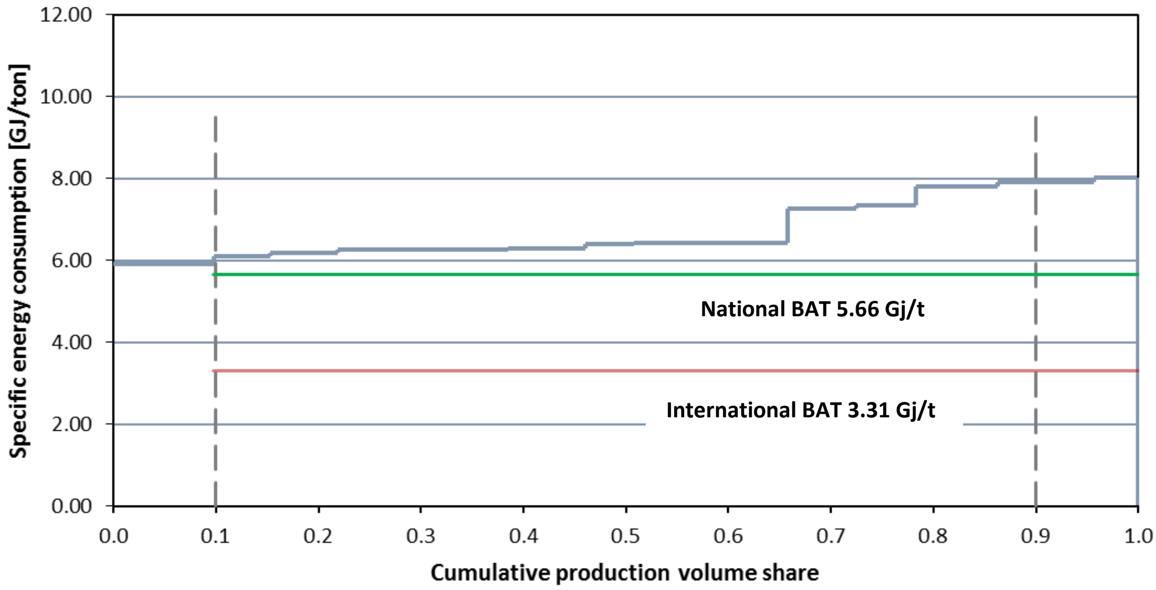


Figure 17: Specific Total Energy Consumption Benchmark Curve for 2015

The comparison between the previous three curves shows that this energy performance indicator for the sector shows ups and downs indicating that there are no real actions towards enhancing energy efficiency in the sector. The following figure shows the average total energy consumption benchmark between 2013 and 2015.

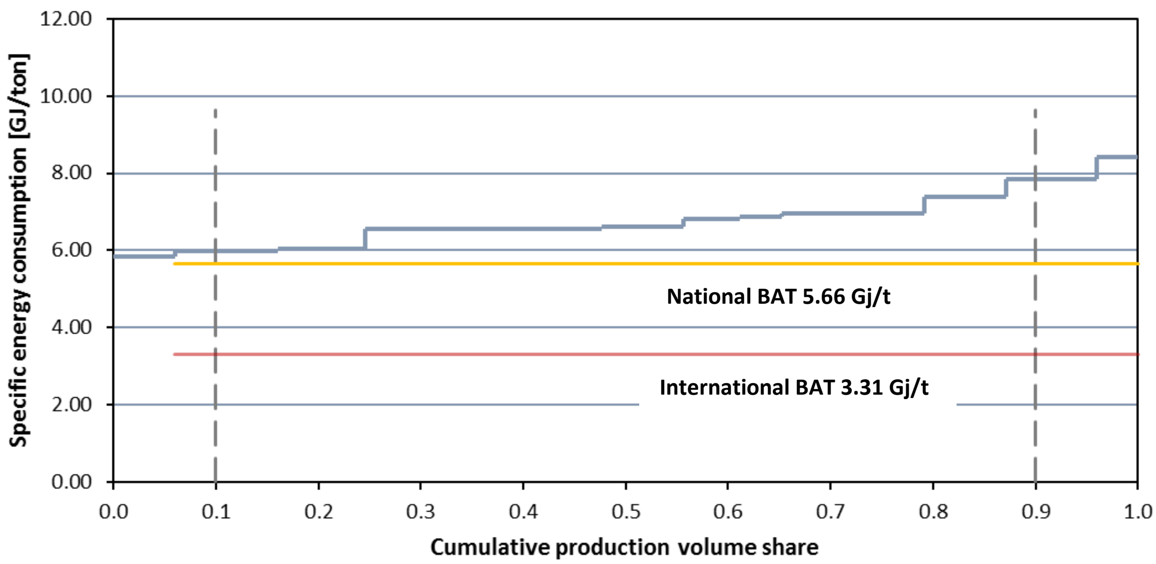


Figure 18 Average Specific Total Energy Consumption Benchmark Curve between 2013 and 2015

4.3 Share of Energy Costs of Turnover

There is no available data on the sector’s profits, neither any company revenues.

4.4 Energy Cost Benchmark Curve for Egyptian Companies

Energy Tariffs as per the Egyptian Ministerial Decrees in the ceramics sector were changed in 2013, 2014 and 2015 as presented above in Table 13. The following table presents the energy costs per unit product of ceramic tiles in the sampled companies.

Table 24: Energy Cost per unit product of Ceramic tiles for the Examined Sample companies

	2013		2014		2015		Average	
	(EGP/m2)	(EGP/ton)	(EGP/m2)	(EGP/ton)	(EGP/m2)	(EGP/ton)	(EGP/m2)	(EGP/ton)
Company 1	2.36	131.04	6.12	340.07	6.16	342.35	4.88	271.15
Company 2	2.19	121.84	6.01	333.81	7.21	400.37	5.14	285.34
Company 3	2.15	119.72	5.24	291.19	6.17	342.68	4.52	251.19
Company 4	2.22	123.06	5.33	296.08	5.94	330.19	4.50	249.78
Company 5	2.14	118.70	5.35	297.12	6.08	337.61	4.52	251.15
Company 6	3.04	168.93	7.12	395.31	7.90	439.13	6.02	334.46
Company 7	2.89	160.52	6.10	339.11	6.45	358.08	5.15	285.90
Company 8	3.69	205.24	8.22	456.51	8.49	471.74	6.80	377.83
Company 9	2.86	158.78	6.43	357.31	6.50	360.97	5.26	292.35
Company 10	2.43	135.08	5.82	323.21	7.54	418.78	5.26	292.36
Company 12	2.50	138.85	5.26	292.28	5.90	327.60	4.55	252.91
Company 13	2.71	150.74	6.62	367.58	7.68	426.72	5.67	315.01

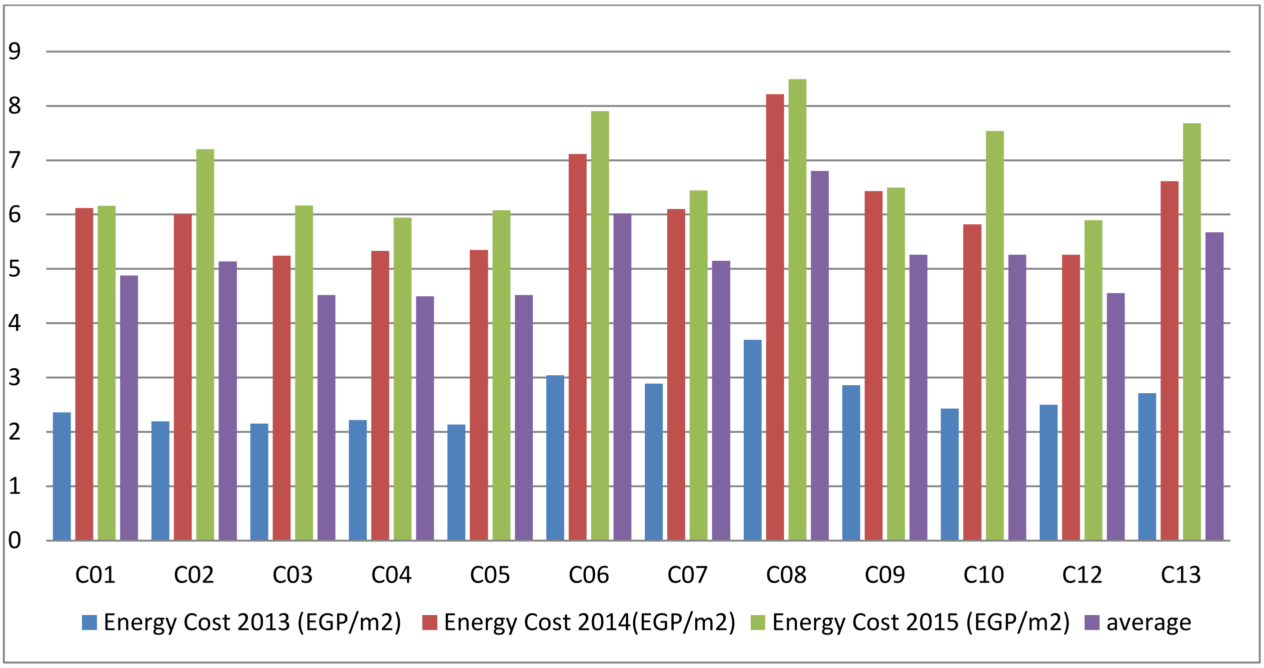


Figure 19: Energy Cost Benchmark Curve for the Ceramics Sector

The increased prices of natural gas and electricity have clear and direct effect on the energy cost of the companies as shown in Figure 19. However, it's worth noting that some companies which have worked to reduce their specific energy consumption were less affected by such energy price increase (e.g. C01, C08 and C09).

4.5 Annual Saving Potential

4.5.1 Annual Saving Potential for Each Plant

On the national level, the annual saving potential for each ceramic 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.

Using the average values of 2013, 2014 and 2015, the annual saving potential of the analyzed companies in comparison to "Company 3" which has the least SEC is 2,561,829 GJ.

Table 25: Potential Savings Calculated with Specific Total Energy Consumption

	Average Production (tons/year)	SEC (GJ/ton)	Saving Potential (%)	Saving Potential (GJ/year)
Company 1	439,781	6.56	10.76%	310,176
Company 2	225,977	6.61	11.41%	170,339
Company 3	170,436	5.85	0.00%	-
Company 4	285,457	5.97	2.02%	34,435
Company 5	241,768	6.03	2.91%	42,414
Company 6	250,445	7.85	25.41%	499,381
Company 7	115,872	6.87	14.77%	117,554
Company 8	114,965	8.41	30.42%	294,130
Company 9	393,834	6.96	15.91%	436,193
Company 10	214,412	6.56	10.81%	152,148
Company 12	157,651	6.83	14.30%	153,977
Company 13	226,800	7.40	20.92%	351,083
SUM				**2,561,829**

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

Table 26: Potential Savings in Thermal Energy

(EGP/ton)	Average Production (tons/year)	SEC (GJ/ton)	Saving Potential (%)	Saving Potential (GJ/year)
Company 1	439,781	6.02	12.85%	340,313
Company 2	225,977	5.99	12.34%	166,984
Company 3	170,436	5.25	0.00%	-
Company 4	285,457	5.40	2.77%	42,672
Company 5	241,768	5.52	4.94%	65,979
Company 6	250,445	7.01	25.11%	440,638
Company 7	115,872	6.13	14.32%	101,621
Company 8	114,965	7.09	25.97%	211,693
Company 9	393,834	6.19	15.26%	372,243
Company 10	214,412	5.75	8.68%	106,952
Company 12	157,651	6.56	20.01%	206,993
Company 13	226,800	6.71	21.78%	331,357
SUM				**2,387,444**

Using the average values of 2013, 2014 and 2015, the lowest thermal SEC (GJ/ton) was found to be in company 3.

Table 27: Potential Savings in Electrical Energy

(EGP/ton)	Average Production (tons/year)	SEC (GJ/ton)	Saving Potential (%)	Saving Potential (GJ/year)
Company 1	439,781	0.54	50.0%	117,754
Company 2	225,977	0.62	56.7%	79,347
Company 3	170,436	0.60	55.7%	57,315
Company 4	285,457	0.58	53.4%	87,757
Company 5	241,768	0.51	47.1%	57,737
Company 6	250,445	0.84	68.1%	142,963
Company 7	115,872	0.74	63.9%	54,898
Company 8	114,965	1.32	79.7%	121,098
Company 9	393,834	0.77	65.1%	196,390
Company 10	214,412	0.81	67.1%	117,299
Company 12	157,651	0.27	0.0%	-
Company 13	226,800	0.69	61.2%	95,995
SUM				**1,128,553**

Using the average values of 2013, 2014 and 2015, the lowest electrical SEC was found to be in plant 12 .

4.5.2 Annual Saving Potential for the Whole Sector

4.5.2.1 Annual Saving Potential for the Whole Sector using International BAT

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

Table 28: Annual Total Energy Saving Potential for the Whole Sector Compared to International BAT

Annual Production (t/year)	Current Total Specific Energy (weighted average) (GJ/t)	BAT Benchmark (GJ/t)	Percent Reduction (%)	Total Technical Potential (GJ/yr)
6,588,118	6.76	3.31	51%	22,698,174

Table 29: Annual Thermal Energy Saving Potential for the Whole Sector Compared to International BAT

Annual Production (t/year)	Current Thermal Specific Energy (weighted average) (GJ/t)	BAT Benchmark (GJ/t)	Percent Reduction (%)	Total Technical Potential (GJ/yr)
6,588,118	6.090	3.13	49%	19,499,010

Table 30: Annual Electrical Energy Saving Potential for the Whole Sector Compared to International BAT

Annual Production (t/year)	Current Electrical Specific Energy (weighted average) GJ/t	BAT Benchmark GJ/t	Percent Reduction (%)	Total Technical Potential GJ/a
6,588,118	0.666	0.180	73%	3,199,164

4.5.2.2 Annual Saving Potential for the Whole Sector using National BAT

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

Potential of whole sector = (Weighted SEC of analyzed companies – BAT national) * production of the whole sector

Table 31: Annual Total Energy Saving Potential for the Whole Sector Compared to National BAT

Annual Production (t/year)	Current Total Specific Energy (weighted average) (GJ/t)	BAT National Benchmark (GJ/t)	Percent Reduction (%)	Total Technical Potential (GJ/yr)
6,588,118	6.76	5.66	16%	7,216,096

Table 32: Annual Thermal Energy Saving Potential for the Whole Sector Compared to National BAT

Annual Production (t/year)	Current Thermal Specific Energy (weighted average) (GJ/t)	BAT National Benchmark (GJ/t)	Percent Reduction (%)	Total Technical Potential (GJ/yr)
6,588,118	6.090	5.066	17%	6,744,414

Table 33: Annual Electrical Energy Saving Potential for the Whole Sector Compared to National BAT

Annual Production (t/year)	Current Electrical Specific Energy (weighted average) GJ/t	BAT National Benchmark GJ/t	Percent Reduction (%)	Total Technical Potential GJ/a
6,588,118	0.666	0.24	64%	2,803,876

It worth noting again that comparing the thermal and electrical BAT does not bring the same results as the calculation with the total specific energy consumption BAT. This is caused by the fact, that a company with the lowest thermal energy consumption does not necessarily correspond to the lowest consumption in electrical energy.

4.6 Saving Scenarios until 2050 and until 2030

4.6.1 Saving Scenarios until 2050, 2030 (using International BAT and BPT)

Within this benchmark study four different saving scenarios have been drawn until 2050 and until 2030. 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 2050. This is equivalent to an energy efficiency improvement of 1.32% a year in the period 2016 to 2050. The BPT is the lowest known BPT, either on international or on national level. For the ceramics sector the BPT value is the international BPT value 4.13 GJ/ton.
  All plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 3.46% a year in the period 2016 to 2030.
- **BAT scenario:** All plants are operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 2.08% a year in the period 2016 to 2050. The BAT is the lowest known BAT, either on international or on national level. For the ceramics sector the BAT value is the international BAT value 3.31 GJ/ton.
  All plants are operating at the current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 4.97% a year in the period 2016 to 2030.

Regarding the significant differences between the average total specific energy consumption in the Egyptian ceramic tiles companies and the corresponding BAT and BPT values, and as shown in the above bullet points, huge annual energy efficiency improvement is required. This may be difficult to be achieved unless focused efforts are exerted by the national authorities.

An important factor for drawing the scenarios is the rate of production growth. Data on projections of ceramic tiles productivity is rare. Therefore, different approaches to project the production rates were tried as shown below.

1) Approach 1:

- Historical data for ceramic tiles productivity in Egypt between 1999 and 2010 in addition to the population in the same period were used to estimate "Per-capita" value at each year. Rate of "per capita" development within this period was estimated, and a straight line with high R^2 value was obtained as shown in the following figure. It was assumed that the same relation will continue till 2030 and 2050.

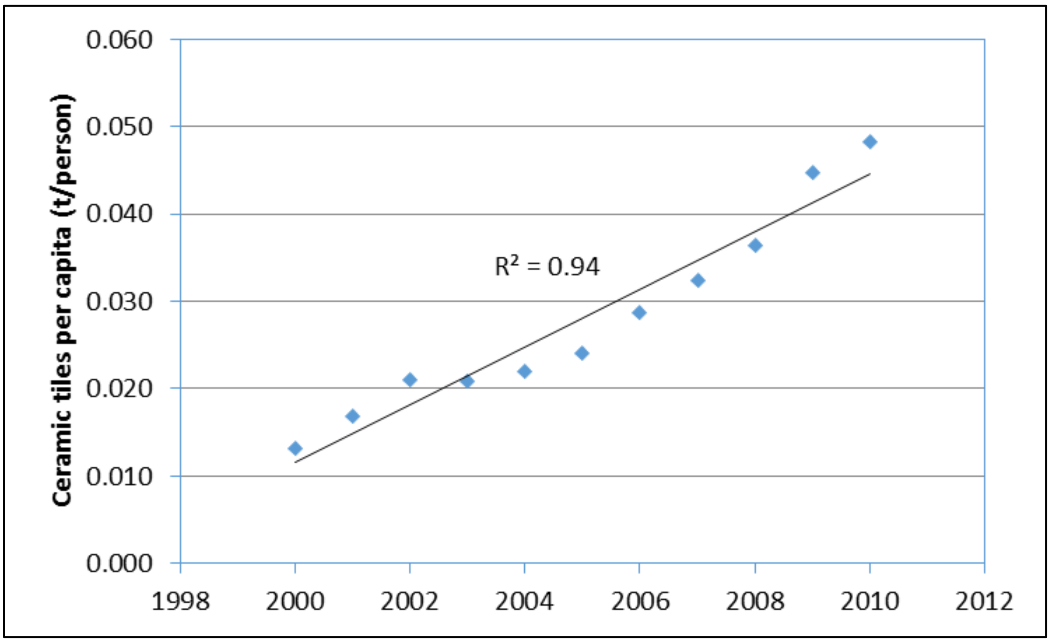


Figure 20 Development of Ceramic tiles per capita in Egypt

- In addition, the population growth for Egypt for this period was taken from the United Nations, World Population Prospects: The 2015 Revision, available on: http://esa.un.org/wpp/unpp/panel_population.htm
- From this source, the factor for the population growth of 1.84 between 2010 and 2050 for Egypt was used.
- To get the factor for the increase in the productivity between 2010 and 2050 those two factors are multiplied. For ceramic tiles, the factor is 6.7 until 2050 and 3.3 until 2030.

2) Approach 2:

- Historical data for ceramic tiles and cement productivity in Egypt between 1999 and 2010 were used, and ratio between their productivities was estimated in each year. A straight line with good R^2 value was obtained, as shown in the following figure. It was assumed that the same relation will continue till 2030 and 2050. Linking the ceramic tiles production to the cement production is reasonable regarding their interconnected consumption in buildings.

- The projection of cement productivity in Egypt in 2030 and 2050 was sourced from the "UNIDO Benchmarking Report for the Cement Sector in Egypt".

- Using the equation relating ceramic tiles and cement productivity in addition to the projected cement productivity, the increase in the ceramic tiles productivity between 2010 and 2050 was estimated to be 8.6, while it was estimated to be 3.4 until 2030.

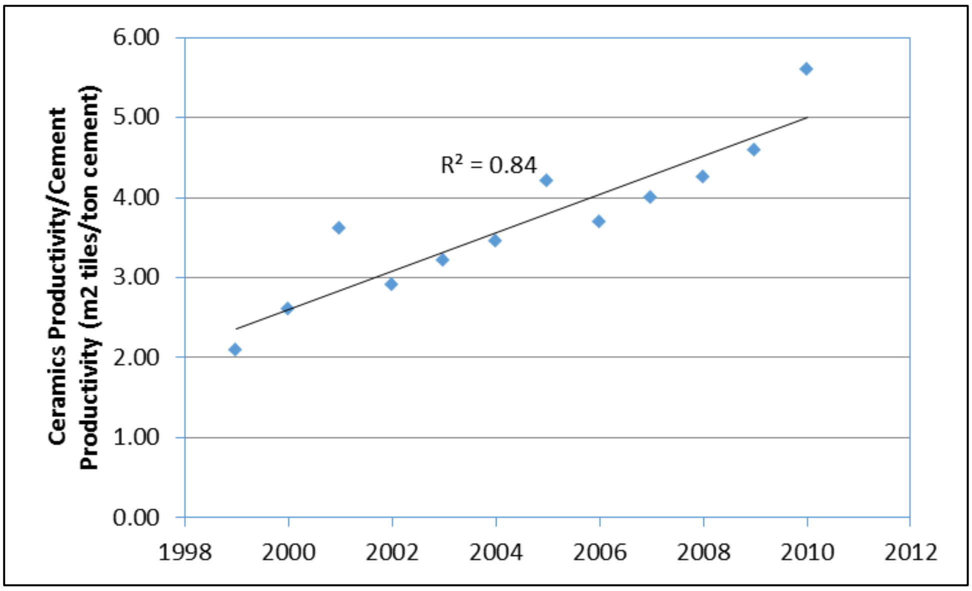


Figure 21 Development of (Ceramic tiles/Cement) productivity ratio in Egypt

Approach 1 is the most recommended since it entails the least magnitude of uncertainties. Therefore, it was applied in deriving the results of the different scenarios.

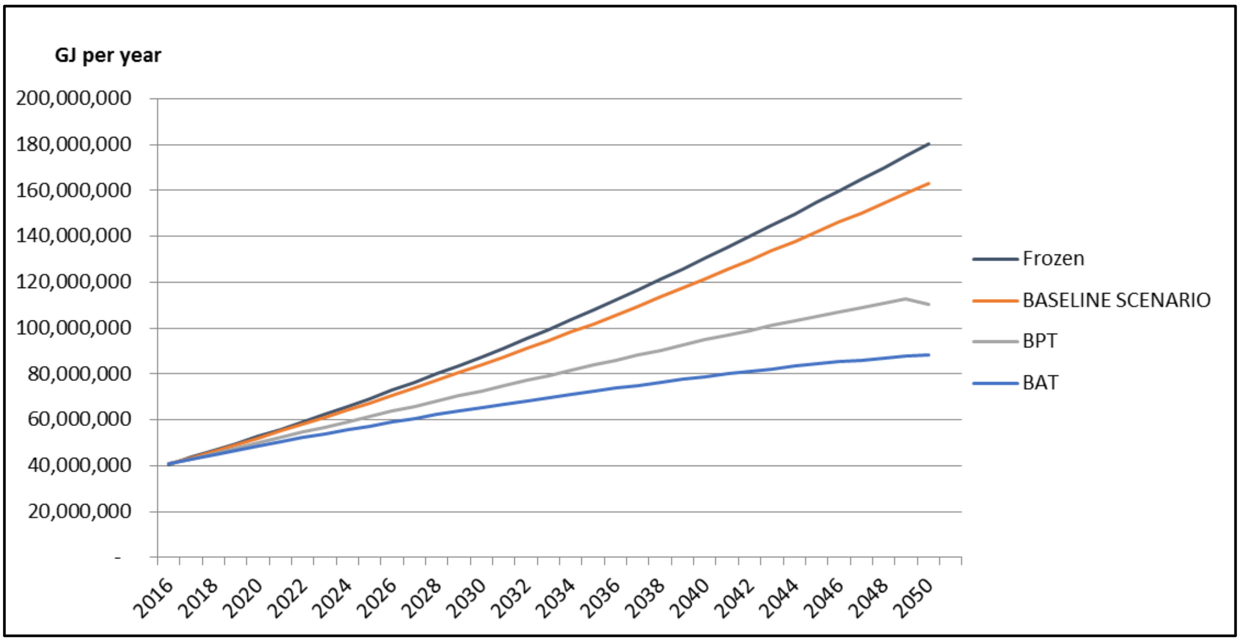


Figure 22: Total Energy Consumption in Egyptian Ceramics Industry, Four Scenarios 2016-2050 using International BAP and BPT

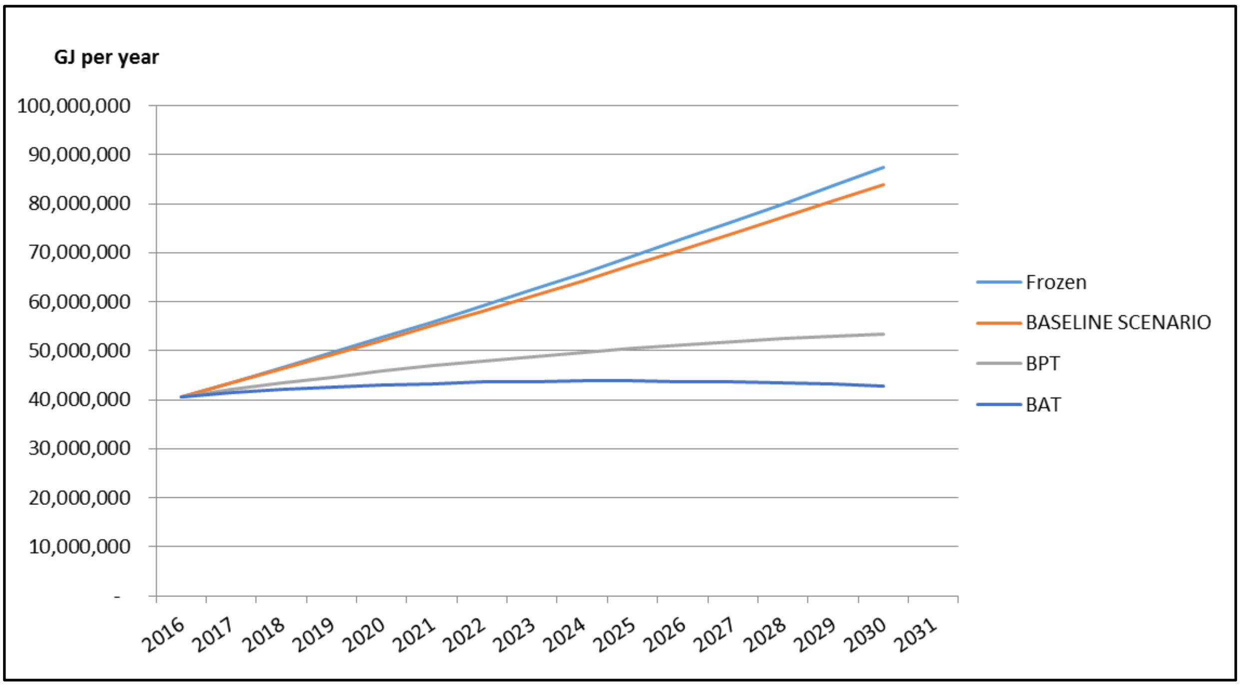


Figure 23: Total Energy Consumption in Egyptian Ceramics Industry, Four Scenarios 2016-2030 using International BAP and BPT

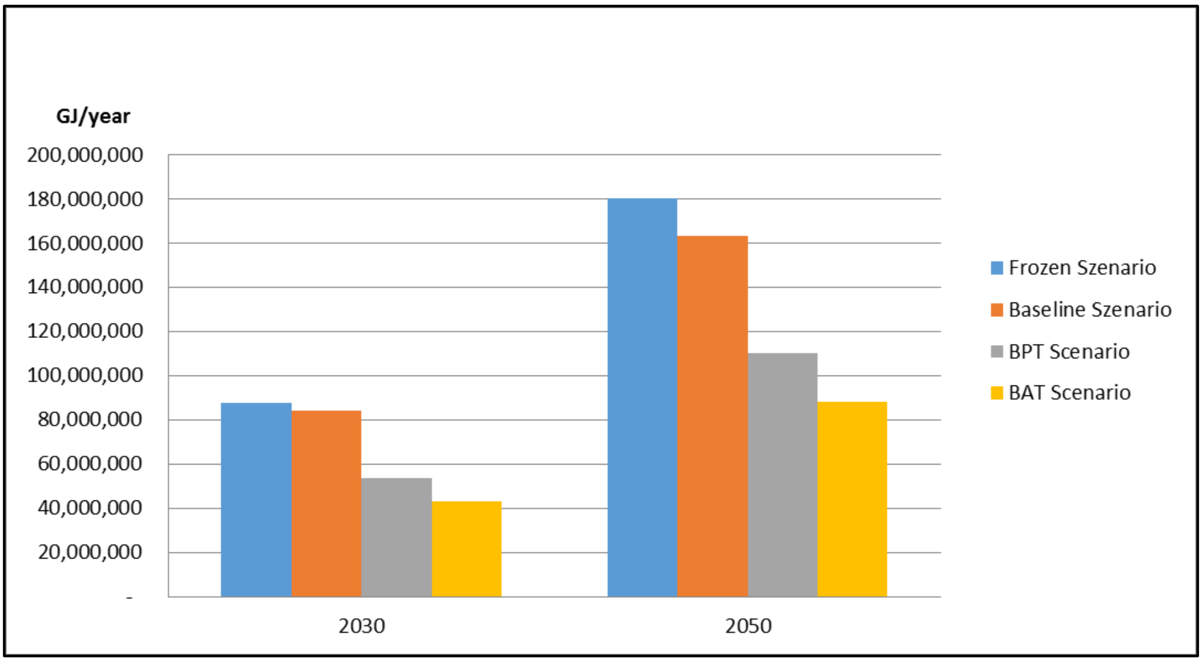


Figure 24: Total Energy Consumption in Egyptian Ceramics Industry in 2030 and 2050 according to the four Scenarios using International BAP and BPT

To reach the saving of 92,117,916 GJ in 2050, the sector would need to implement energy saving measures of about 2,631,940 GJ per year. To reach the saving of 44,637,721 GJ in 2030, the sector would need to implement energy saving measures of about 2,975,848 GJ per year.

4.6.2 Energy Savings in 2030 and 2050

The following table shows the energy saving of ceramics plants in Egypt in the year 2030 and 2050 if all companies reach the international BAT value. Furthermore it shows the cumulated energy savings from 2016 to 2030 or 2050.

Table 34: Energy Savings in 2030 and 2050 and Cumulative Savings until 2030 and 2050 (International BAT)

Year	Frozen Scenario (GJ/a)	Baseline Scenario (GJ/a)	BPT Scenario (GJ/a)	BAT Scenario (GJ/a)	Savings Frozen – BAT Scenario (GJ/a)	Cumulative Savings (Frozen-BAT) (GJ)
2016	40,653,114	40,653,114	40,653,114	40,653,114	-	
2030	87,522,231	83,975,264	53,451,462	42,884,511	44,637,721	300,998,149
2050	180,497,714	162,969,784	110,157,008	88,379,798	92,117,916	1,248,204,810

4.6.3 Saving Scenarios until 2050, 2030 (using National BAT and BPT)

In this section, the four saving scenarios were calculated by comparing to the national BAT and BPT until 2050, and 2030. The four scenarios are:

- **Frozen efficiency**: No additional energy efficiency savings are made. The current levels of energy efficiency are not improved upon.
- **Baselines 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 2050. This is equivalent to an energy efficiency improvement of 0.45% a year in the period 2016 to 2050. The BPT here is the lowest known national BPT. For the ceramics sector, the national BPT value is 5.85 GJ/ton.
  All plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 1.08% a year in the period 2016 to 2030.
- **BAT scenario:** All plants are operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 0.52% a year in the period 2016 to 2050. The BAT here is the lowest known national BAT. For the ceramics sector the national BAT value is 5.66 GJ/ton.
  All plants are operating at the current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 1.26% a year in the period 2016 to 2030.

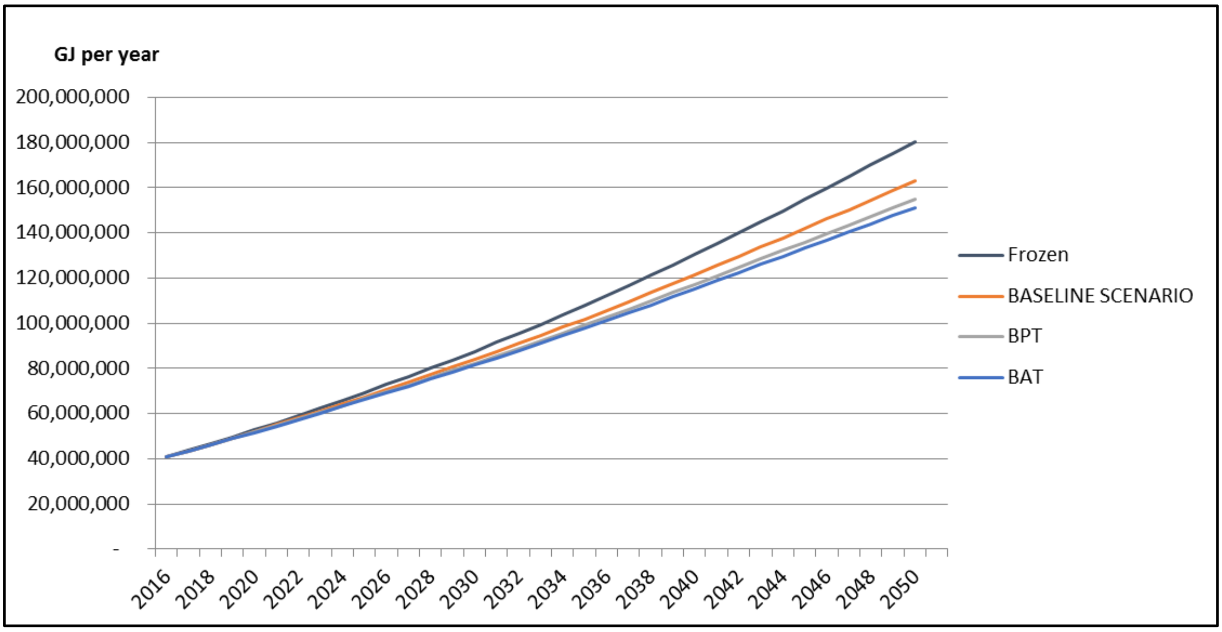


Figure 25: Total Energy Consumption in Egyptian Ceramics Industry, Four Scenarios 2016-2050 using National BAP and BPT

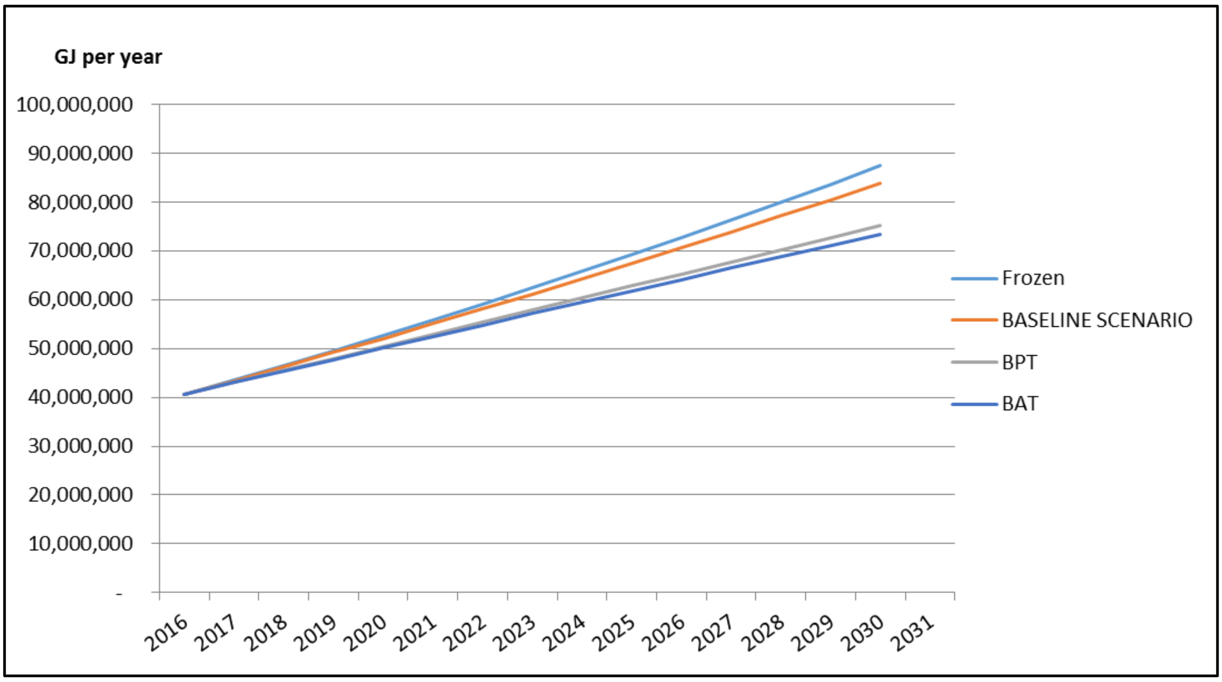


Figure 26: Total Energy Consumption in Egyptian Ceramics Industry, Four Scenarios 2016-2030 using National BAP and BPT

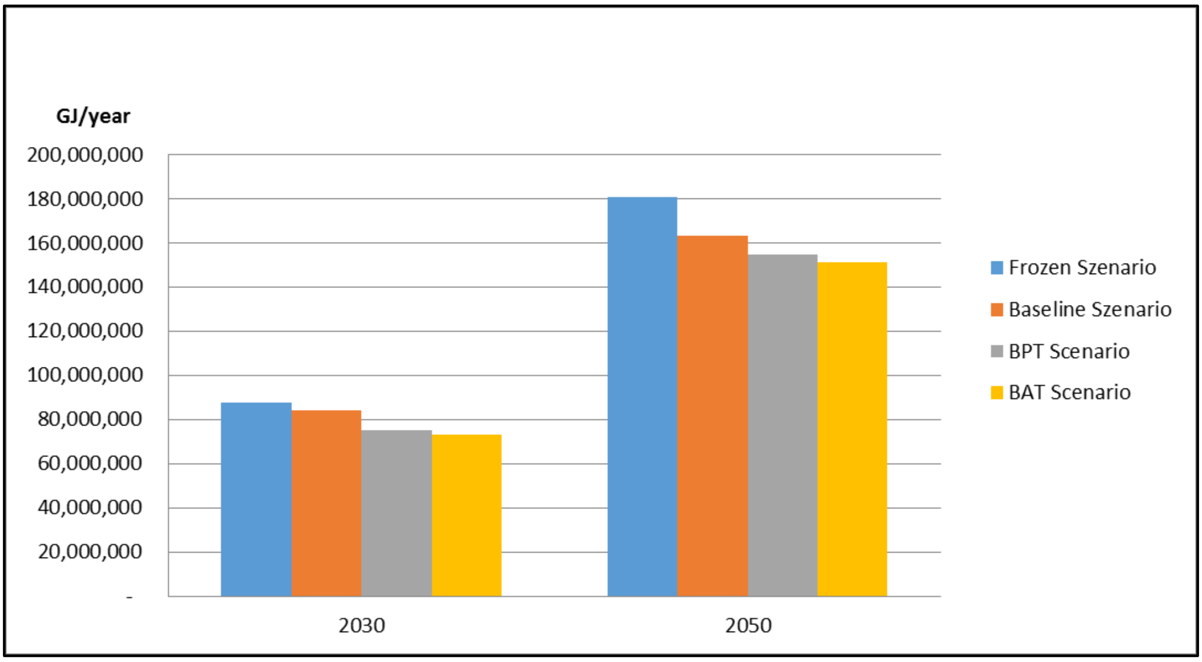


Figure 27: Total Energy Consumption in Egyptian Ceramics Industry in 2030 and 2050 according to the four Scenarios using National BAP and BPT

To reach the saving of 29,370,930 GJ in 2050, the sector would need to implement energy saving measures of about 839,169 GJ per year. To reach the saving of 14,251,650 GJ in 2030, the sector would need to implement energy saving measures of about 950,110 GJ per year.

4.6.4 Energy Savings in 2030 and 2050

The following table shows the energy saving of ceramics plants in Egypt in the year 2030 and 2050 if all companies reach the national BAT value. Furthermore it shows the cumulated energy savings from 2013 to 2030 or 2050.

Table 35: Energy Savings in 2030 and 2050 and Cumulative Savings until 2030 and 2050 (National BAT)

Year	Frozen Scenario (GJ/a)	Baseline Scenario (GJ/a)	BPT Scenario (GJ/a)	BAT Scenario (GJ/a)	Savings Frozen – BAT Scenario (GJ/a)	Cumulative Savings (Frozen-BAT) (GJ)
2016	40,653,114	40,653,114	40,653,114	40,653,114	-	
2030	87,582,868	83,975,264	75,145,064	73,331,218	14,251,650	89,738,418
2050	180,497,714	162,969,784	154,864,903	151,126,785	29,370,930	372,584,913

4.7 Saving Opportunities

All factories participated in this study do have energy saving measures planned and most of them consider energy efficiency in investment decisions and have energy efficiency targets. The energy efficiency plans can include improving the design of kilns and dryers, recovery of excess heat from kilns, cogeneration/combined heat and power plants, and modification of ceramic bodies.

The table below shows the energy efficiency measures in the ceramics sector and the companies that have applied them.

Table 36: Status of Energy Efficiency Measures Implementation

Energy Efficiency Measure	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13
Measures Related to Drying Process													
Lighter products	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Suitable initial moisture content (6% in Tiles)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Homogeneity in initial moisture content	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable ambient temperature	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Suitable ambient relative humidity	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No
Suitable flow of air	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Using Pure waste air From Tunnel Kilns	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No
Use a specified burner	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Choose better insulation with low density	No	No	Yes	No	No	No	No	No	No	Yes	No	No	No
Measures Related to Firing Process													
Exhaust gas temperature should be kept as low as possible	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Use better insulator which can bear higher temperature	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No

Energy Efficiency Measure	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13
Recovering the cooling air	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Air ratio should be 2:1 (air: gas) for the burner to ensure a good combustion	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Firing management (heat curve, temperature distribution in the kiln, kiln pressure, atmosphere)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Loading pattern on the kiln car	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Clearance between the kiln wall and kiln car	No	No	Yes	No	No	No	No	No	No	No	No	No	Yes
Sand seal	No	No	No	No	No	No	No	No	No	No	No	No	Yes
Kiln car pushing speed	No	No	Yes	No	No	No	No	No	No	Yes	No	No	Yes
Measures Related to Housekeeping													
Purchasing the right materials to reduce energy	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Storing any material costs money and uses energy in some way. Even bulk outside storage costs money in terms of the inventory cost	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Fit interlocks or sensors to conveyors or link them to machine start-up/shutdown	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Energy Efficiency Measure	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13
switches so that they only operate when the machines are operating.													
Fit time delay switches to all grinding and milling machines to turn them off if no material is being processed	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Large motors with high use on grinders and mills will benefit from being replaced by high efficiency motors	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reducing materials content should be an ongoing process. Define the product in terms of a performance specification and adjust the materials content to meet the specification.	Yes	No	No	Yes	Yes	No	No	No	No	No	No	No	No
Motors run most efficiently close to their design output – a large motor at part load is less efficient than a small one at full load.	No	Yes	No	No	No	No	No	No	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 e.g. 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 investment and execution planning.

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

- Implementation tools like the legislative framework, the subsidy /financial scheme and other incentives/promotion and marketing activities.
- Administration of the program and interaction of the key players: the administrator (very often a government level body), the operating agent (e.g. an energy agency), 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 training and/or authorization of auditors and the quality control (checking of the reports).
- In addition, audit tools should be made available.

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7 Abbreviations

BAT	Best Available Technology
BPT	Best Practice Technology
BREF	Reference Document on Best Available Techniques in the Industry
CAPMAS	Central Agency for Public Mobilization and Statistics
CHP	Combined Heat and Power
EE	Energy Efficiency
EEI	Energy Efficiency Index
EPI	Energy Performance Indicator
FEI	Federation of Egyptian Industries
IDA	Industrial Development Authority
IEA	International Energy Agency
IEE	Industrial Energy Efficiency
MOIFT	Ministry of Industry and Foreign Trade
PV	Photovoltaic
SEC	Specific Energy Consumption
SME	Small and Medium Sized Enterprise

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