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INDUSTRIAL ENERGY EFFICIENCY PROJECT

Benchmarking Report for the Fertilizer Sector

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الهيئة العامة للتنمية الصناعية
Industrial Development Authority

Industrial Energy Efficiency
Benchmarking Report for Fertilizer Sector

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Summary

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

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

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

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

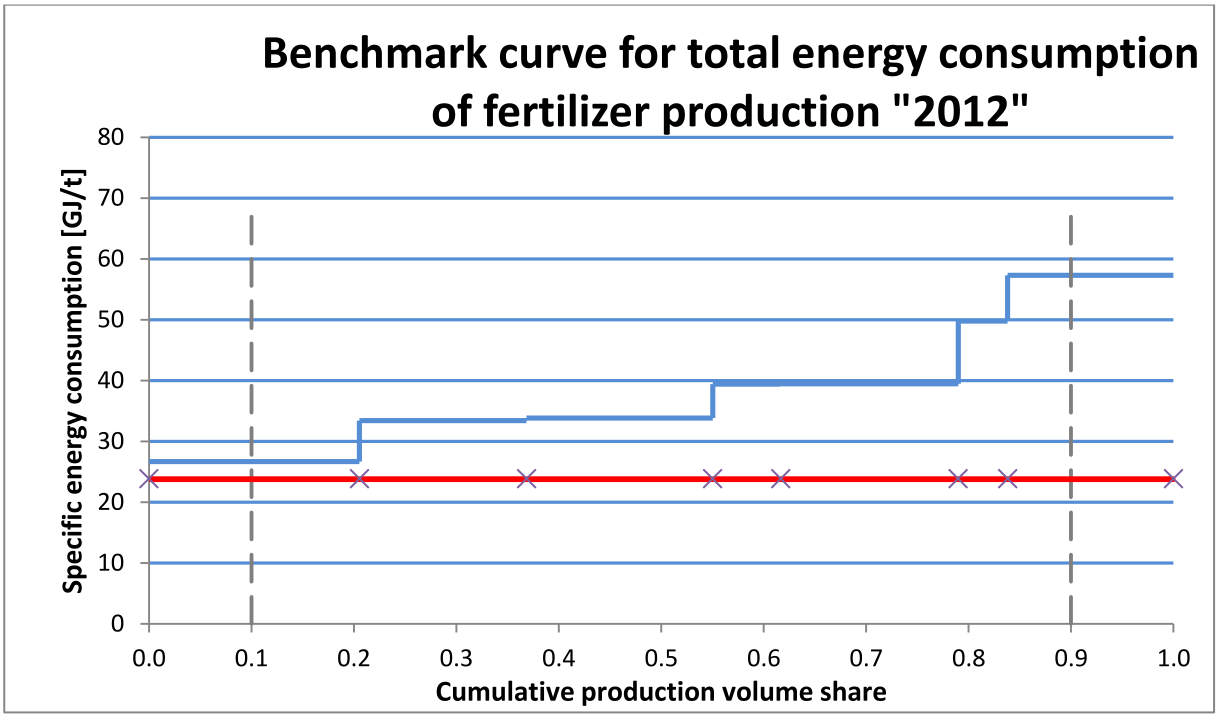
Chapter 3.3.4 describes the main drivers for energy consumption in the fertilizer industry. The main drivers for energy consumption are the ammonia and hydrogen production (if it is produced onsite) which are needed as semi-finished product within the production process of the different end products. In most cases the production of ammonia as a semi-finished product on site accounts for ~ 80-90 % of the energy use for the fertilizer end product. Also the consistency of the fertilizer end product is an energy driver. Main consistency forms are granulated, powdered, liquid and low-release fertilizers (various forms including fertilizer spiker, tabs, etc.)

For the fertilizer industry only international best available technology (BAT) benchmarks for Ammonia production (NH_3) in GJ/t NH_3 were found. The American Journal of Engineering Research (AJER) in 2013 shows the world BAT value with 23.8 GJ/t ammonia. The AJER BAT is the most current and transparent international BAT and is taken for the comparison with the fertilizer sector in Egypt. This value was used for calculating the saving potentials of the whole ammonia sector in Egypt.

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

Chapter 4 shows the results of the analysis of the data collected in Egyptian fertilizer plants. Of the nine companies (eleven plants) that were selected for on-site data collection, only five companies (with seven plants) were willing to cooperate within the project. These five companies have a share of 68 % of the total fertilizer 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 fertilizer industry for the total energy consumption. These types of benchmark curves show the specific energy consumption of the analyzed companies per ton of fertilizer produced (GJ/t) as a function of the production volume share. The most efficient plants of Egypt 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 (blue line).



The most efficient plant of the analyzed companies in Egypt has a specific total energy consumption of 26.7 GJ/t ammonia and a production volume share of 21 %. This value defines the national best available technology (BAT) value. The red line indicates the best international BAT value by AJER which corresponds to a specific total energy consumption of 23.8 GJ/t ammonia.

The second lowest specific energy consumption in this curve is defined as the national best practice technology (BPT) value. The national BPT value is 33.4 GJ/t. For this study, the BPT value was only applied for the saving scenarios in Chapter 4.7 in order to draw up the BPT scenario. It was defined that the lowest known BPT value, either on national or international level, would be applied for the scenario. For the fertilizer sector this is the national BPT value of 33.4 GJ/t in the year 2012.

In Chapter 4.6, energy saving potentials were calculated, on the one hand, for the 5 companies that participated on the benchmarking study and on the other hand, for the whole Egyptian fertilizer sector. The 5 companies have an energy saving potential of about 13.6 PJ/a. The total energy saving potential of the whole fertilizer industry sector in Egypt is about 36.5 PJ/a.

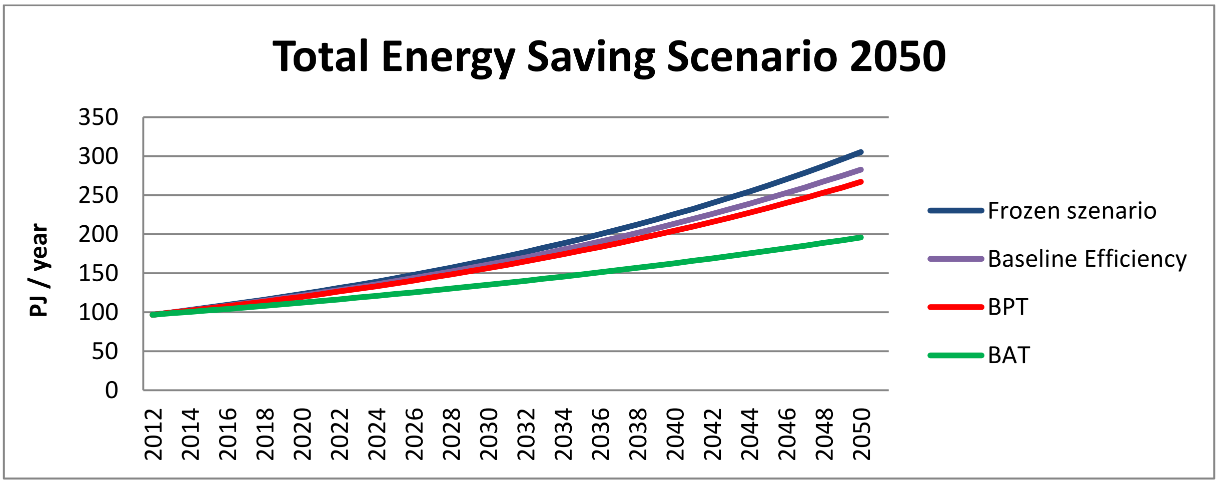
Furthermore, in Chapter 4.7 different energy saving scenarios until 2030 and 2050 were drawn. The scenarios correspond to the scenarios in the UNIDO Working Paper. The four scenarios are:

- **Frozen efficiency:** no additional energy efficiency savings are made. The current levels of energy efficiency are not improved upon.
- **Baseline efficiency:** energy efficiency improves at a rate of 0.2 % 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 0.33 % a year in the period 2012 to 2050. The BPT is the lowest BPT, either on national or international level. For the fertilizer sector this is the national BPT value of 33.4 GJ/t in the year 2012.
- **BAT scenario:** all plant is operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 0.99 % a year in the period 2012 to 2050. The BAT is the lowest BPT, either on national or international level. For the fertilizer sector this is the international BAT value of 23.8 GJ/t in the year 2012.

An important factor for drawing the scenarios is the rate of production growth. The production of the three sectors in 2050 will be about three times higher than today.

The following graph shows the four scenarios until 2050 for the growth of total energy consumption in the fertilizer industry. The basis for calculating these scenarios was the annual production volume of the whole sector according to the IDA which was 9,000,000 tons of ammonia for the year 2012. Multiplied with the weighted average total energy consumption of the analyzed companies which is 38.2 GJ/t fertilizer these two figures led to the total annual energy consumption of the fertilizer sector in Egypt in the year 2012. This total energy consumption of 96.7 PJ in the year 2012 was the basis for all 4 scenarios.

According to the frozen efficiency scenario, the annual total energy consumption in 2050 is about 305.1 PJ for the whole sector. The annual energy consumption in 2050 according to the BAT scenario is about 195.9 PJ. Comparing the frozen efficiency scenario and the BAT scenario, the annual saving potential would be about 109.2 PJ, which is 36 %.



The following table below shows the total annual energy consumption of the whole sector in 2012, 2030 and 2050 according to the four scenarios. Furthermore, the table shows the annual and cumulative energy saving potentials if all companies of the sector reach the BAT specific energy consumption in 2030 or 2050.

	Total Energy Consumtion of the Sector				Energy Savings of BAT Scenario vs. Frozen Scenario	Cumulative BAT Scenario (PJ)
	Frozen Scenario (PJ)	Baseline Scenario (PJ)	BPT Scenario (PJ)	BAT Scenario (PJ)	Energy Savings of BAT Scenario vs. Frozen Scenario	Cumulative BAT Scenario (PJ)
2012	96.7	96.7	96.7	96.7	-	
2030	129.4	119.9	113.1	80.6	48.8	453.7
2050	305.1	282.8	266.9	195.9	109.2	1,608.2

In Chapter 4.8, the sector-specific energy saving opportunities and measures are described. This study offers a solid basis for further energy efficiency projects for the Egyptian fertilizer sector. These projects should focus on supporting the companies in implementing energy efficiency measures and energy management systems in order to continually improve their energy efficiency.

Abstract

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

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

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

- **Frozen efficiency**: No additional energy efficiency savings are made.
- **Baseline efficiency**: Energy efficiency improves at a rate of 0.2 % 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 2012, 2030 and 2050 according to the four scenarios. Furthermore, the table shows the annual and cumulative energy saving potentials if all companies of the sector reach the BAT specific energy consumption in 2030 or 2050.

	Total Energy Consumtion of the Sector				Energy Savings of BAT Scenario vs. Frozen Scenario	Cumulative BAT Scenario (PJ)
	Frozen Scenario (PJ)	Baseline Scenario (PJ)	BPT Scenario (PJ)		Frozen Scenario (PJ)	Baseline Scenario (PJ)
2012	96.7	96.7	96.7	2012	96.7	96.7
2030	129.4	119.9	113.2	2030	129.4	119.9
2050	305.1	282.8	266.9	2050	305.1	282.8

Acknowledgement

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

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

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

Contents

1 Introduction

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

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

1.1 UNIDO Industrial Energy Efficiency Program

Energy efficiency in industry contributes to decoupling economic growth and environmental impact while reducing industrial energy intensity and improving competitiveness. Industry is responsible for more than one third of global primary energy consumption and energy-related carbon dioxide emissions. Industrial energy use is estimated to grow at an annual rate of between 1.8 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, 2010).

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

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

1.2 Aim of the Project

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

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

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

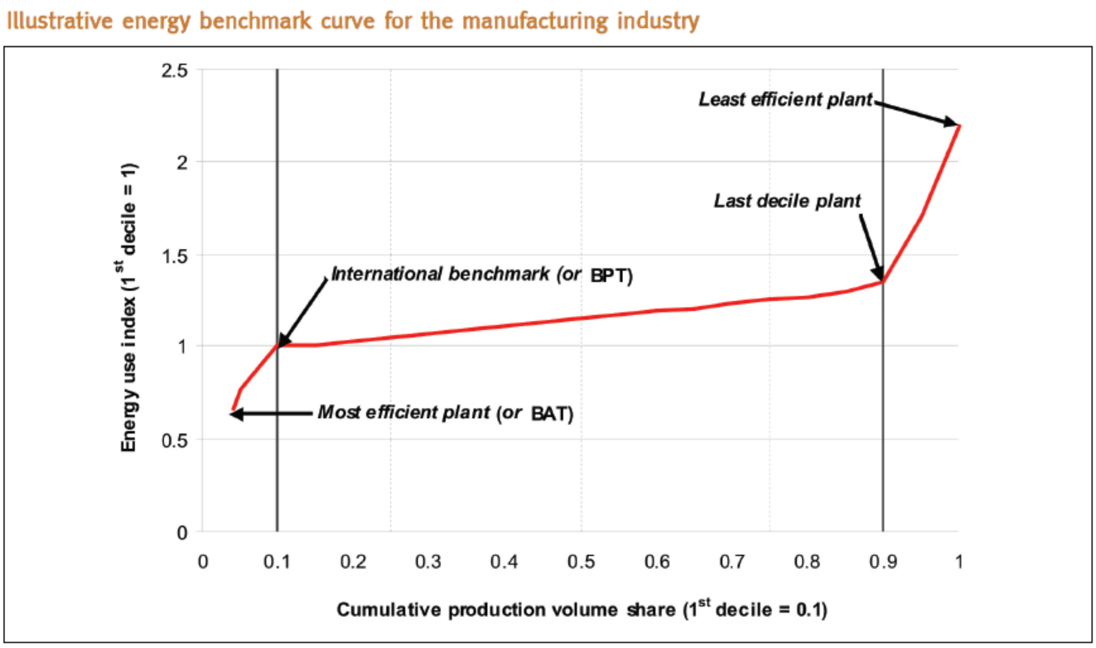
The preparation of IEE benchmarking reports for the Cement, Iron and Steel and Fertilizers sectors is part of Component 1 of the IEE project.

2 Methodology to Establish Benchmarking Studies

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



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 higher part of the curve. The shape of benchmark curves would vary for different sectors and regions. However, typically a few plants are very efficient and a few plants are very inefficient. This is generally represented by the steep slopes of the benchmark curve before the first decile and after the last decile respectively.”

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

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

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

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

Depending on the data availability either

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

is calculated in the UNIDO Working Paper.

2.2 Drawing the Benchmarking Curves for Egyptian Industry

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

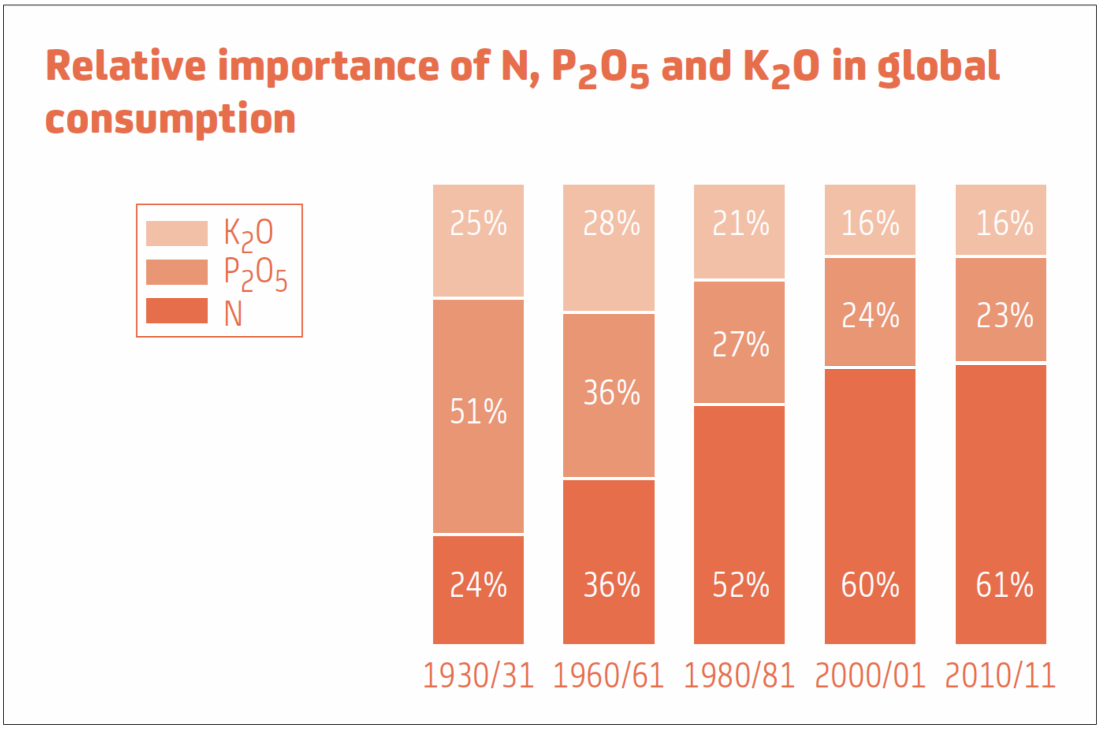
Therefore, the results of the benchmarking studies can be applied to support improving the national data collection on energy consumption and production volumes.

2.2.1 System Boundaries for Benchmarking

It is important to define the system boundaries for benchmarking in order to compare “apples to apples”. For comparison of national benchmarks with international ones the system boundaries have to be the same.

The three main types of fertilizers are nitrogen fertilizer, phosphate fertilizer and potassium fertilizer. As shown in the next table, within the worldwide share of fertilizers, nitrogen makes up the main part.

Table 1: Share of Fertilizers (IFA, 2013)

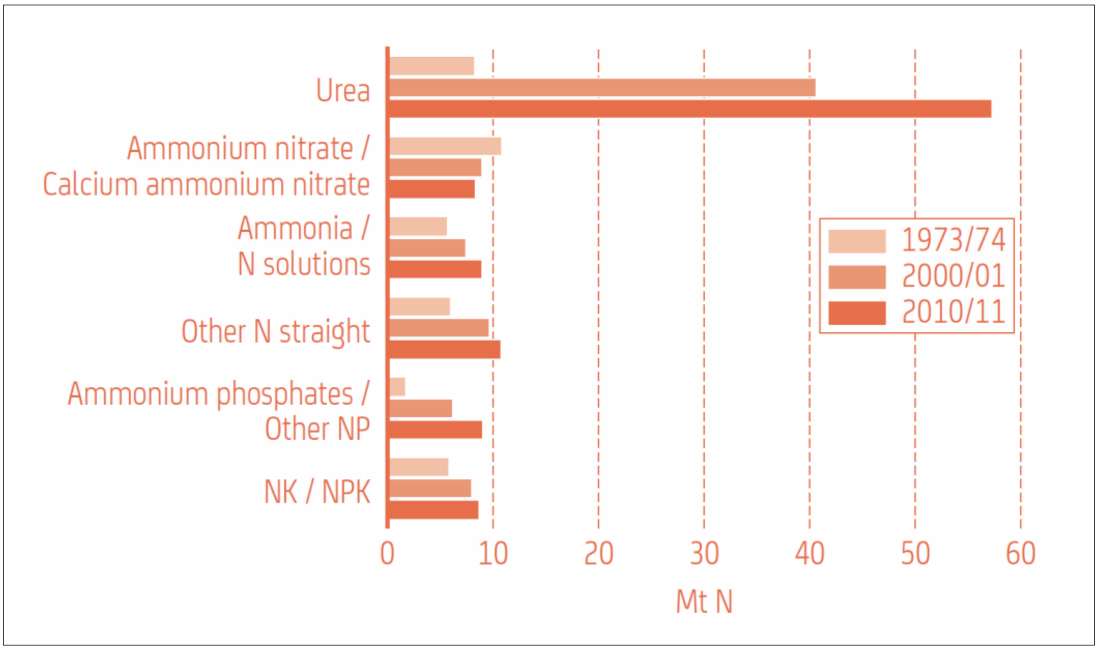


The main end products of nitrogen based fertilizers are:

- Urea ($(NH_2)_2CO$)
- Ammonium Nitrate (AN, NH_4NO_3)
- Calcium Ammonium Nitrate (CAN)
- Ammonia and Nitrogen solutions (UAN)
- Other N straight (ammonium sulphate (AP), $(NH_4)_2SO_4$)
- Ammonium phosphates (MAP, DAP, $(NH_4)_3PO_4$)
- Compound fertilizers and complex fertilizers (NK, NPK)

The following table shows the shares of the different end products in relation to the world production of nitrogen fertilizers.

Table 2: Nitrogen Fertilizers (IFA, 2013)



The global market and production share also reflects the Egyptian market. In Egypt, the main end products produced in the fertilizer sector are:

- Urea
- Ammonium Nitrate (AN)
- Calcium Ammonium Nitrate (CAN)
- Ammonia and Nitrogen solutions (UAN)

At the moment, there are no phosphate- and potassium-based products produced in Egypt and are therefore excluded from the scope of this study.

For the nitrogen line, ammonia is the main active ingredients of artificial fertilizers (90 % of all fertilizers are derived from ammonia). The production of ammonia is also the most energy-intensive production process. The Haber-Bosch process is the industrial implementation for the production of ammonia as a result of the reaction from nitrogen gas and hydrogen gas. The process is shown in the following flow diagram.

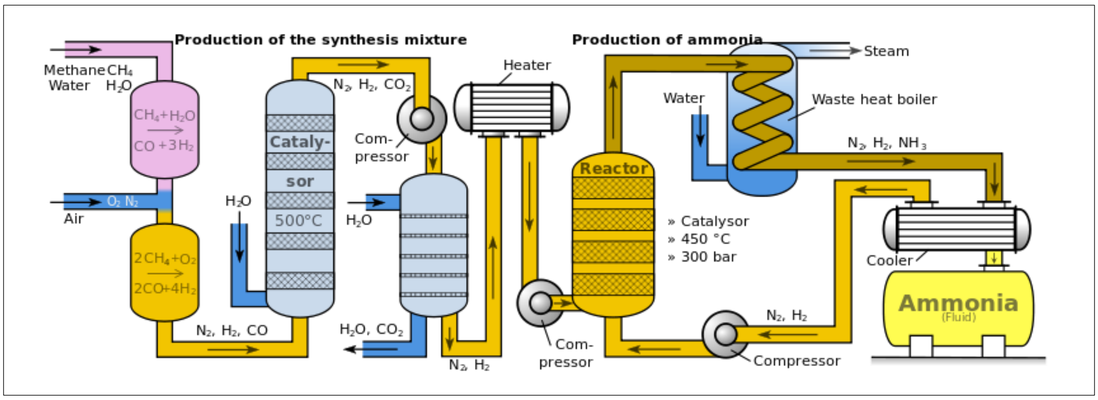


Figure 2: Flow Diagram Illustrating the Haber-Bosch Process.[1]

Under high temperatures (300–550 °C) and very high pressures (150–300 bar), hydrogen and nitrogen (from thin air) are combined to produce ammonia. The main energy consumption is based on the compressing and heating of the chemical nutrients.

The most important nutrient for the production of ammonia is hydrogen. For hydrogen, there are three main production processes:

- steam reforming,
- partial oxidation of oil and
- gasification of coal.

Steam reforming is the most common conversion technique. The major source for steam reforming is methane from natural gas.

Within this study, it was concluded that the energy used for ammonia and hydrogen production is within the system boundary due to its large share of the total energy consumption for producing nitrogen-based fertilizers.

An important question is how to deal with purchased ammonia?

For establishing the EPI of these plants the purchased tonnes of ammonia need to be subtracted from the total ammonia processed. The calculation method is as followed:

- Total energy corrected = total energy – energy consumed for purchased semi-finished products
- Total production corrected = total production of ammonia – purchased ammonia
- Energy consumed for purchased semi-finished products (ammonia) = total energy consumption * percentage of energy consumed for final product production (e.g. urea) * percentage of purchased ammonia

For establishing the benchmark curve the purchased semi-finished products need to be added to the „total production” (for cumulative production share).

[1] Wikimedia Commons, June 12, 2014

2.2.2 Approach for Data Collection in Companies

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

For the data collection, two different kinds of data collection sheets were developed:

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

The detailed collection file contains the following excel sheets:

- General information
  - Basic information of the company
  - Collected data: plant capacity and plant production [t], number of shifts, hours of operation per year, etc.
  - Resulting information: amount of produced end products [t], load shape of production
- Basic technical information
  - Detailed information about end products, semi-finished products and energy demanding production facilities
  - Collected data: type and amount of end products, type and amount of semi-finished products, boilers, compressors, etc.
  - Resulting information: type and amount of end products, type and amount of semi-finished products, energy consumption of most energy demanding production facilities
- Energy management
  - Information about implemented energy management systems
  - Collected data: responsible person for energy management, energy meters/sub-meters installed, energy efficiency targets available, planned energy saving measures, etc.
  - Resulting information: assessment of existing or possibility of establishing an energy management system
- Input data
  - Assessment of input flow
  - Collected information: primary energy input, conversion factors, raw materials and semi-products, clinker produced on-site, clinker imported, additives, gypsum, slags and others
- Output data
  - Assessment of output flow
  - Collected information: amount of produced end products per year
- Process information
  - Additional written information about the different production processes
  - Collected information: specific manufacturing process information
  - Resulting information: detailed information of production process

- Implemented energy efficiency measures
  - Written information of energy efficiency measures
  - Collected information: saving potential of realized and planned energy efficiency measures

2.2.3 Selection of the Companies for Data Collection

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

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

For the fertilizer sector, the following 9 plants were selected for data collection:

Table 3: Overview of Companies Selected for Data Collection

Number	Plant name	Location of the plant	Remarks
1	Abu Qir Fertilizer & Chemical Industries Co. (3 plants)	Alexandria Governorate Al Tabiya- Rasheed Road	
2	Egypt Basic Industries	Suez Governorate El Ain El Sokhna Industrial Zone	Non cooperative (pulled out after the second visit)
3	Alexandria Fertilizer Co. (Alexfert)	Alexandria Governorate Al Tabiya- Rasheed Road	Non cooperative (pulled out after the second visit)
4	Egyptian Chemical Industries KIMA ASWAN	Aswan Governorate – El Sad El Ally Road	Shut down due refurbishing
5	EL Delta Company for Fertilizers and Chemical	Daqahlia Governorate, Al Mansoura City, Talkha Industrial Area	
6	El Nasr Fertilizers and Chemicals Co. (SEMADCO)	Suez Governorate , Etaka	
7	Egyptian Fertilizers Co.	Suez Governorate El Ain El Sokhna Industrial Zone	Non cooperative (pulled out after the second visit)
8	Helwan Fertilizer Co.	Cairo Governorate, Helwan Industrial Zone	
9	Misr Fertilizer Production Co. S.A. (MOPCO)	Damietta Governorate, Free Zone	

2.2.4 Schedule for Data Collection

The following schedule for data collection on-site was stipulated:

Table 4: List of Companies and Schedule for Data Collection

Number	Plant name	Visit date	Remarks
1	Abu Qir Fertilizer & Chemical Industries Co. (3 plants)	25.032014, 15.06.2014	Cooperative
2	Egypt Basic Industries	25.03.2014	Non Cooperative
3	Alexandria Fertilizer Co. (Alexfert)	01.04.2014	Non Cooperative
4	Egyptian Chemical Industries KIMA ASWAN	Shutdown	Non Cooperative
5	EL Delta Company for Fertilizers and Chemical	19.04.2014	Cooperative
6	El Nasr Fertilizers and Chemicals Co. (SEMADCO)	16.06.2014	Cooperative
7	Egyptian Fertilizers Co.	19.03.2014	Non Cooperative
8	Helwan Fertilizer Co.	09.03.2014, 11.06.2014, 15.06.2014	Cooperative
9	Misr Fertilizer Production Co. S.A. (MOPCO)	The data sent by mail	Cooperative

2.2.5 Limitations of Data Collection and Barriers Encountered

Of the nine companies (eleven plants) that were selected for on-site data collection, only five companies (with seven plants) were willing to cooperate within the project. These five companies are:

1. Helwan Fertilizer Co.
2. Abu Qir Fertilizer & Chemical Industries Co:
    - Plant 1
    - Plant 2
    - Plant 3
3. El Nasr Fertilizers and Chemicals Co. (SEMADCO).
4. EL Delta Company for Fertilizers and Chemical.
5. Misr Fertilizer Production Co. S.A. (MOPCO).

Egyptian Fertilizers Co., Egypt Basic Industries and Alexandria Fertilizer Co. did not cooperate and pulled out after the second visit based on company policy of not to disclose information. While Egyptian Chemical Industries KIMA ASWAN was shut down for rehabilitation.

The following chart shows the share of production of the participating companies to the total sector production.

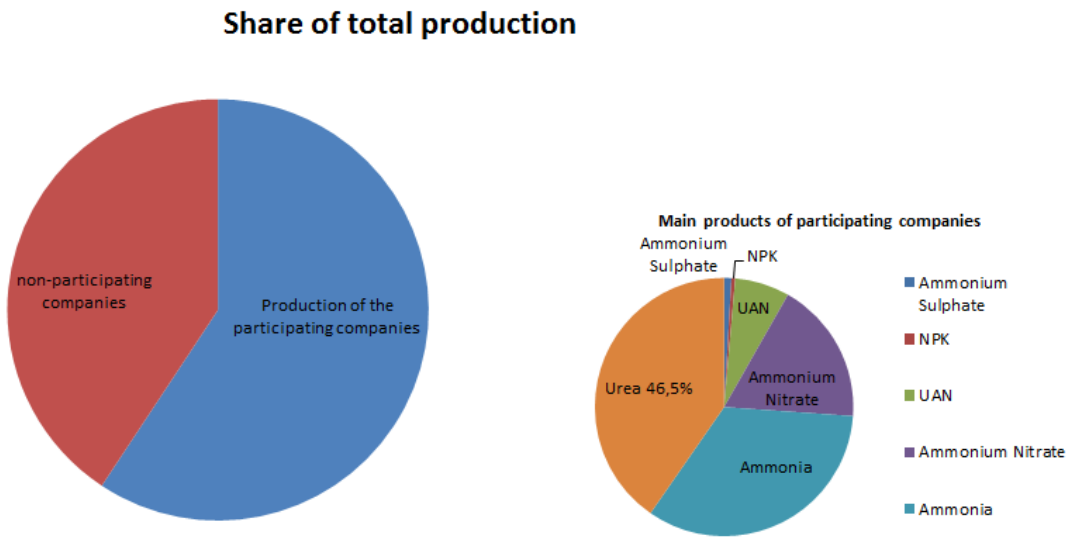


Figure 3: Share of total production

- NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium
- UAN combination of urea and ammonium nitrate

2.3 International Benchmarks for Comparison

For the fertilizer industry only BAT benchmarks for Ammonia production (NH_3) in GJ/t NH_3 were found. This is because the production of ammonia as a semi-finished product on site accounts for ~ 80-90% of the energy use for the fertilizer end product. In this chapter the international benchmarks - found in literature - are shown.

2.3.1 UNIDO Benchmarks

UNIDO Benchmark curve refers to the International Fertilizer Industry (IFA) benchmark curves of the years 2004 and 2007 as shown in the next Figure 4.

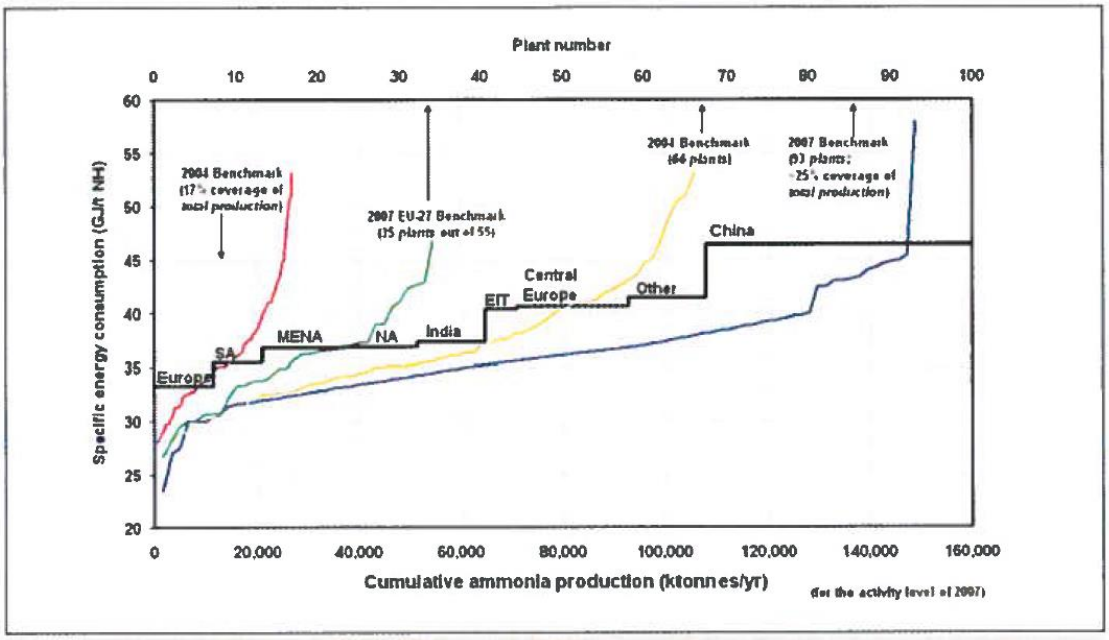


Figure 4: Benchmark Curves (2004 and 2007) and the Estimated Benchmark Curve (2007) for Ammonia Industry (IFA, 2009)

The following benchmarks were published by UNIDO:

Table 5: Benchmarks for Ammonia (UNIDO, 2010)

Benchmark	Selected industrial countries	Selected develop-ping countries	Global average	Best available technolo-gy (BAT)	Internatio nal BM (lowest EEI)	Last decile plant or region	Worst plant or region
GJ/t NH_3	33.2-36.2	35.9-46.5	41	23.5	31.5	43	58

2.3.2 International Fertilizer Industry (IFA) Benchmarks

The IFA has published benchmarks for ammonia (NH_3). The benchmarks are based on a survey conducted in 2008: 93 ammonia plants in 33 countries were interviewed to their energy efficiency. The definition of energy efficiency is:

Energy Efficiency = (Feed + Fuel + Other Energy) / NH_3 Production

Energy includes the required energy to produce ammonia as well as the energy used in operations, like shutdowns and startups.

Table 6: Benchmarks for Ammonia (IFA, 2009)

Net efficiency			
GJ/t NH_3	Average GJ/t NH_3	Top quartile GJ/t NH_3	Theoretical design efficiencies, (=optimum efficiency level, for a new plant) GJ/t
27.0-58.2	36.6	28-33	28-29

The next figure shows the increase of design efficiency from 1955 to 2005. The design efficiency is getting increasingly closer to the thermodynamic limit. It is not possible to fall with the energy efficiency below the thermodynamic limit.

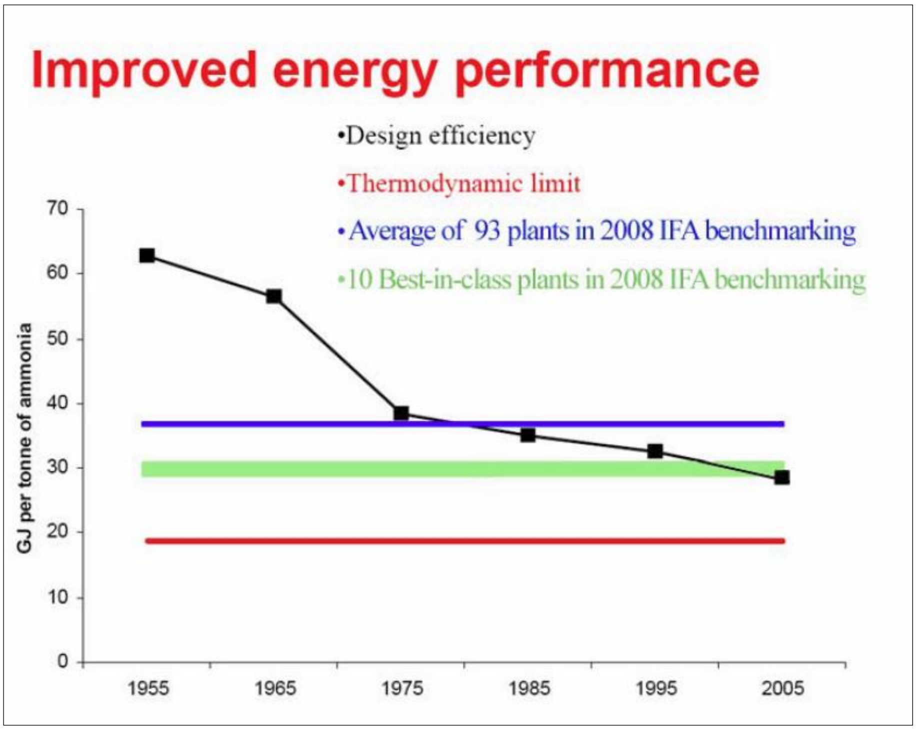


Figure 5: Increase of design efficiency (IFA, 2009)

2.3.3 International Energy Agency (IEA) Benchmarks

The International Energy Agency has published benchmarks for ammonia for different regions of the world. A benchmark for Africa was also published, namely 36 GJ/t NH_3.

Table 7: Benchmarks for Ammonia (IFA, 2009)

Region	Production [Mt Ammonia]	Energy intensity [GJ/t NH3]
Western Europe	12.2	35.0
North America	14.4	37.9
Africa	**4.0**	**36.0**
India	12.2	43.3
China	43.7	48.8
World	145.4	41.6

2.3.4 Benchmarks for the G8 States

Also the G8 states published benchmarks for NH_3, the specific energy consumption in ammonia production in 1995 and 2000. The dotted line in Figure 6 indicates the best practice level for ammonia production in 1995 and 2005 (these energy data are old).

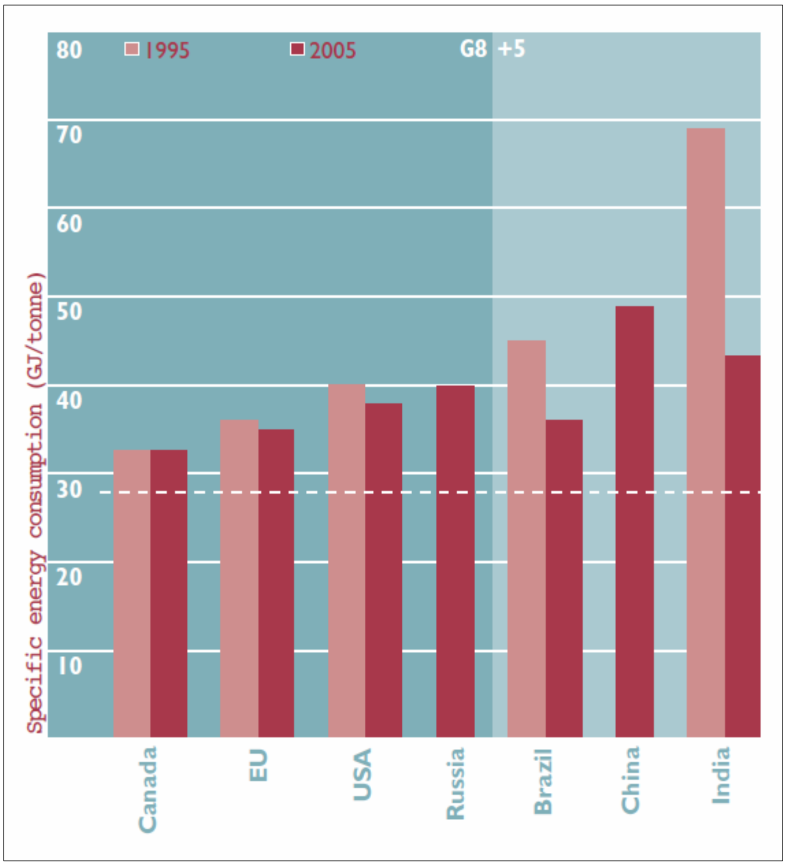


Figure 6: Best practice level in G8 states for specific energy consumption in ammonia production (IFA, 2009)

2.3.5 International Benchmarks - Worrell

The study “World Best Practice Energy Intensity Values for Selected Industrial Sectors” from the Berkeley National Laboratory provides world best practice EPIs for the production of different sectors. In the study by Ernst Worrell from 2008, some benchmarks for ammonia were published too (see Table 8). The theoretical minimum on energy required for ammonia production still depends on the composition of the natural gas feedstock, but it can be as low as 19.2 GJ/t ammonia or 23.3 GJ/t nitrogen.

Table 8: Best Practice Final Energy Benchmarks for Ammonia (Ernst Worrell, 2008)

Benchmark	Energy Intensity			
	GJ/t NH_3	GJ/t N	Kgce/t NH_3	Kgce/t N
Natural gas steam reforming	28	34	956	1,160
Coal	34.8	42.3	1,188	1,444

For Egypt, the relevant benchmarks are related to the natural gas steam reforming.

2.3.6 International Benchmarks – AJER

50 fertilizer plants were analyzed for the study “Indicators of Energy Efficiency in Ammonia Productions Plants” for the American Journal of Engineering Research (AJER) in 2013. These are the most current and transparent data that will be used for comparison within the fertilizer sector in Egypt.

Out of the 50 analyzed plants, 2 plants use high purity hydrogen as a feedstock, while 48 plants use natural gas or heavy oil. Plants with high purity hydrogen have a higher efficiency level.

In this study, the Energy Efficiency Indicator is determined as follows: $\eta = (R + Cf + Z)/MNH3$

- η = energy efficiency (GJ/t NH_3)
- R = the conversion of raw materials consumed in equivalent energy, assuming the lower calorific value
- Cf = the conversion of fuel used in the process in equivalent energy, assuming the lower calorific value
- Z = other energies involved in the process, such as electricity and steam imported, export credit for energy (steam) generation, and pumping water to supply boiler and cooling water MNH3 = ammonia production in metric tons

Figure 7 shows the variety of the energy intensity of the analyzed plants.

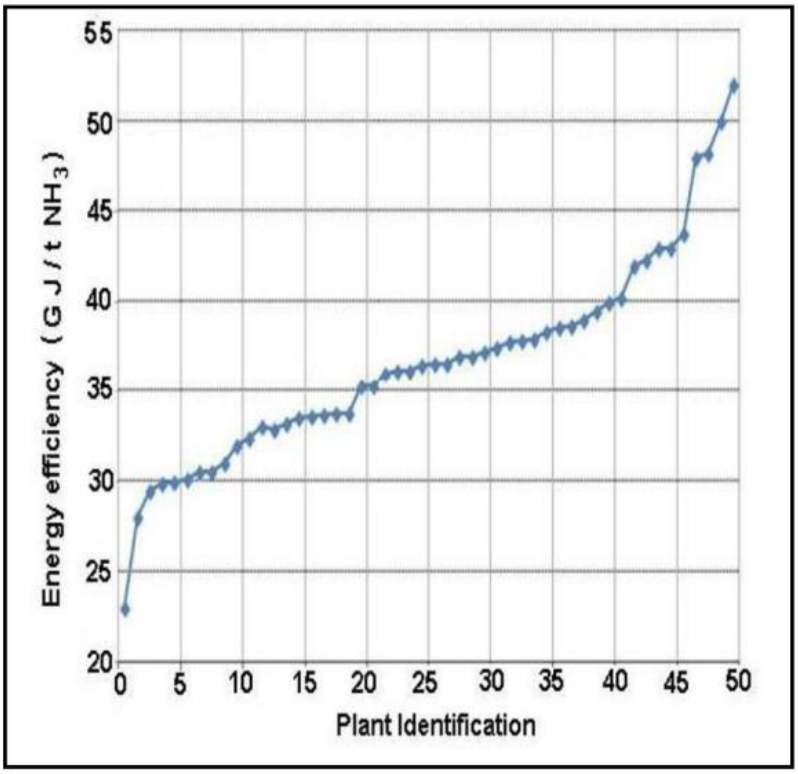


Figure 7: Energy Efficiency for Ammonia Production Plants (AJER, 2013)

The benchmark range of the analyzed ammonia productions are between 23.8 and 51.9 GJ/t NH_3.

Table 9: Range of Energy Efficiency Indicators for Ammonia Production Plants (AJER, 2013)

	Energy Efficiency indicator: GJ/t NH_3
Natural gas steam reforming	23.8-51.9

Figure 8 shows the relation between the capacity and the energy efficiency for the 48 conventional ammonia production plants.

There are not enough data to consider this clustering also for Egyptian fertilizer plants, they all have nearly the same capacity (large).

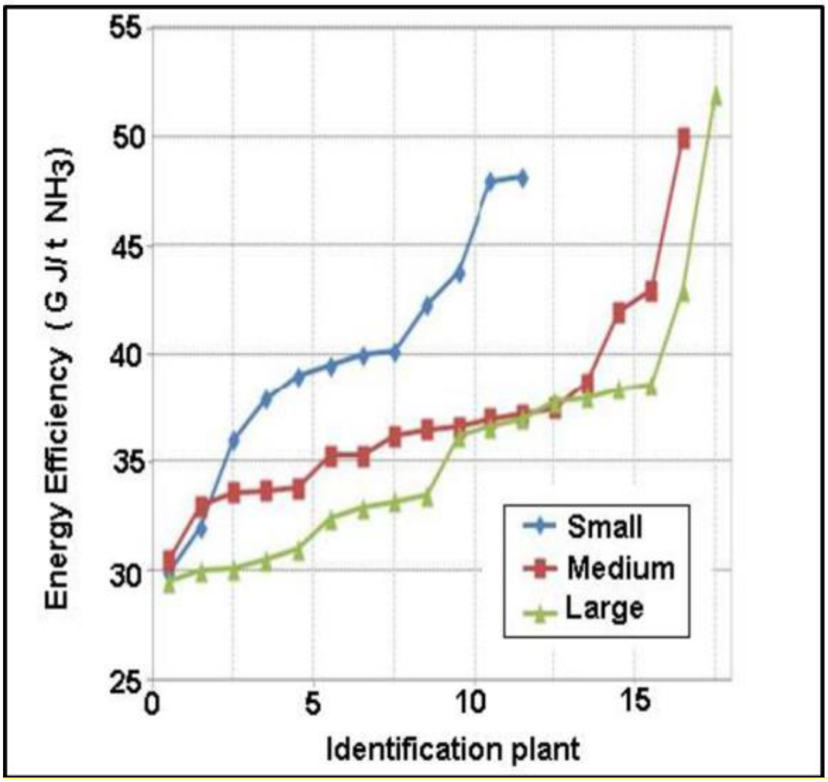


Figure 8: Relation Between the Capacity and the Energy Efficiency (AJER, 2013)

As the next table shows, the best plants of each group are in the range between 29.5 and 30.6 GJ/NH_3.

Table 10: Energy Efficiency Indicators for the Best Plants in Each Group (AJER, 2013)

Production process	Energy Efficiency indicator: GJ/t NH3 Best plants in each group
	29.5-30.6

The relation between the age of the plant and energy efficiency for the 48 conventional ammonia production plants are shown in Figure 9 and Table 11.

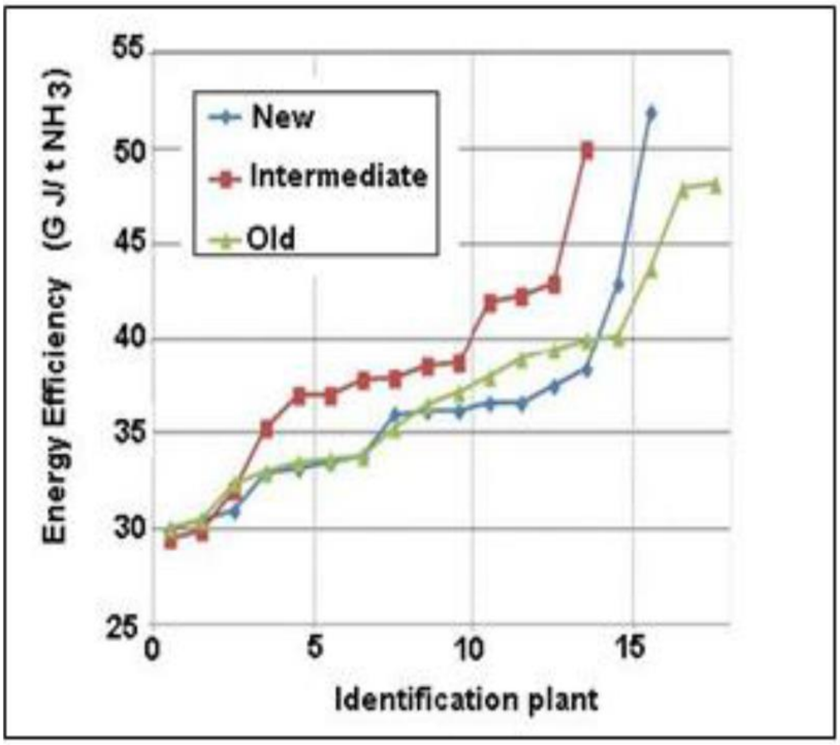


Figure 9: Relation between the Age of the Plant and Energy Efficiency (AJER, 2013)

Table 11: Relation Between the Age of the Plant and Energy Efficiency (AJER, 2013)

Energy Efficiency indicator: GJ/t NH_3 According to plant age in each group		
Average new	Average mid	Average old
36	37.7	37.4

2.4 Approach for Estimating Energy Saving Potentials

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

2.4.1 Saving Potential of Participating Companies

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

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

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

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

2.4.2 Saving Potential of the Whole Sector in Egypt

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

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

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

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

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

2.4.3 Saving Potentials for the BPT Scenario

In chapter 4.7 different saving scenarios are shown. For the BPT scenario also the lowest known BPT value was taken. This value can either be a national or an international one.

2.5 Possible Sources on National Level

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

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

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

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

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

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

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

2.5.2 Production Data on National Level (Top-Down)

For establishing benchmarks on national level, data on annual production of the whole fertilizer industry is also required. The Central Agency for Public Mobilization and Statistics (CAPMAS) collects production data on sector level. The national expert analyzed the CAPMAS data and came to the conclusion that this data is not reliable. Therefore this report does not contain a benchmark curve with national statistical data but with much more reliable data from individual companies.

2.6 Process to Check Reliability of Data

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

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

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

- Annual production hours in comparison to maximum annual hours

- Production capacity to production output
- Trend of energy consumption and production (3 years)
- Total energy consumption / production (EPI)
- Input / output balance (check semi-finished products, purchase of semi-finished etc.)
- Check of reported measures

3 Basic Sector Information

This chapter provides detailed information about the fertilizers sector in Egypt in particular nitrogen fertilizers since it is considered one of the more intensive energy consumer sectors.

3.1 Economic and Legislative Framework

Nitrogen fertilizers represent the most widely-used type of fertilizers in Egypt with a strong governmental contribution in that strategic industry. Large fertilizers production facilities owned by the public sector were established in the 1970’s. Many of these facilities use natural gas because it is cheap and widely available (Egypt is the second-largest producer of natural gas in Africa after Algeria). In spite of governmental efforts to organize the activities of the fertilizer sector, this industry faced many challenges in the past few years, as plants were forced to shut down and more questions were raised about the possible impacts of January 25th revolution on this sector.

About 80 % of natural gas is used in fertilizers as feedstock to produce ammonia for the nitrogen source in these types of fertilizers. 20 % of the natural gas acts as the energy source that is required for the fixation of atmospheric nitrogen to manufacture ammonia. Considerable energy is also required for the conversion of ammonia to urea. For the manufacture of ammonium nitrate; on the other hand, the conversion of ammonia to nitric acid provides a net energy gain which can be used to produce electrical energy via a steam turbine. The neutralization of ammonia with nitric acid to produce ammonium nitrate also releases energy.

The Egyptian fertilizers sector includes:

- Public sector: large companies established in the 1970 are using old technologies, which are the main suppliers to the local market.
- Private sector: companies established within the 2000’s, using the-state-of-the-art technology, which export most of their production.

Despite the Egyptian Government support that provides these companies with the subsidized natural gas, they suffer from the shortage of this gas due to the energy crisis that Egypt is undergoing. This has negatively affected the fertilizer sector on all spheres.

The data collection covered years 2010, 2011 and 2012, which are considered the last stable years in this sector. After that date, the sector has experiences a lot of problems due to the energy crisis that emerged due to the shortage of natural gas in the whole country.

Some fertilizer companies are working in the free zone, which is a special economic zone where fertilizers and other goods are manufactured and exported without the intervention of the customs authorities; no goods are moved to customers within the country. For example there are two newly established fertilizers plants located near the red sea ports at the Suez Free Zone.

3.2 Number of Companies and Ownership

Among several fertilizers companies in Egypt, the nitrogen (azotic) fertilizer sector includes nine companies as described in Table 12. One of these companies, which are the largest producer in Egypt, has three plants that produce ammonia.

The following table shows the company code, year of establishment and the ownership.

Table 12: Nitrogen Fertilizers Companies in Egypt – Number and Ownership

No.	Com-pany Code	Year of Establish-ment	Ownership	Remarks	Status from Project
1	**F1**	1976	Private (it was originally established as public) - Major shareholders are: National Investment Bank, Egyptian General Petroleum Corporation, Industrial Development Authority (IDA) and Al Ahli Capital.	It is the Largest producer of Nitrogen fertilizers in Egypt and directs part of its production to the local market as well as to export. cooperative	Cooperative
2	**F2**	2003	Private (Egyptian Joint Stock)	Exports large part of its production	Non Cooperative
3	**F3**	2009	Private (owned by a private company)	Located at a Free Zone. The plant has a direct link to the new bulk liquid export jetty via a dedicated pipeline. It is one of the largest Ammonia exporters.	Non Cooperative
4	**F4**	1987	Public	Ceased operations since 2009 for rehabilitation to operate with the natural gas (excluded from the study)	Non Cooperative
5	**F5**	1979	Public	Urea plant is shut down for overhauling. The second largest in Egypt it direct its product to the local market (mainly the government)	Cooperative
6	**F6**	1946	Public	Oldest company fertilizers in Egypt	Cooperative

No.	Com-pany Code	Year of Establish-ment	Ownership	Remarks	Status from Project
7	**F7**	2000	Private (owned by a private company)	Located at a Free Zone. The plant has a direct link to the new bulk liquid export jetty. It is one of the largest fertilizer exporters.	Non Cooperative
8	**F8**	2004	Shareholding Joint Stock Egyptian Company. Shareholders are: Holding Company for Metallurgical Industries, number of banks, insurance companies and the largest fertilizers company	Direct its production to the local market (Government) and to export.	Cooperative
9	**F9**	2009	Private: Owned by many companies	Exports its production as it exist in a free zone	Cooperative

3.3 Production Capacities

3.3.1 Main Products

In Table 13 are the main products of fertilizer products listed. Also the company's design and actual capacity of each product is shown for the years 2010 to 2012.

Table 13: Main Products and Total Production of the 5 Participating Companies with 7 Plants

No.	Product	Nominal Production from IDA in Mt/year[2]	Annual Production in 2010 in Mt /year[3]	Annual Production in 2011 in Mt /year[4]	Annual Production in 2012 in Mt /year[5]
1	Ammonia	2,531,054	2,301,953	2,300,099	2,072,677
2	Urea 46,5%	2,115,480	2,913,772	2,871,572	2,492,736
3	Ammonium Nitrate	884,867	1,116,736	1,035,266	1,104,620
6	Urea and ammonia nitrate (UAN)	300,000	224,311	266,764	422,423
7	NPK*	200,000	142,868	134,262	297,580
8	Ammonium Sulphate	31,101	3,998	52,253	56,278
Total Production		**6,095,202**	**6,703,638**	**6,660,216**	**6,446,314**

*…NPK: NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium.

[2] IDA data for the 5 companies which delivered data for this study
[3] Data are from the 5 companies with 7 plants
[4] Data are from the 5 companies with 7 plants
[5] Data are from the 5 companies with 7 plants

According to IDA, the sector is designed to produce 4,071,914 Mt/year of ammonia and a total of about 9,000,000 Mt/year of different products including all companies: also the companies, which did not contribute to the study (4 companies). According to the collected data, the seven plants produce 2,531,054 Mt/year of ammonia and total about 6,095,202 Mt/year. However, slight increase in the production rate was recorded due to an increase in demand especially in the local market. This was achieved by extra working hours (some companies were working around the clock) to meet certain target of production, especially under the difficult conditions that they suffered due to the natural gas shortage that started in 2012 after the January 25th revolution.

The following figure shows the production variation of ammonia, urea and other products from 2010 to 2012 which collected from analyzed companies as compared to the nominal design value which obtained from IDA.

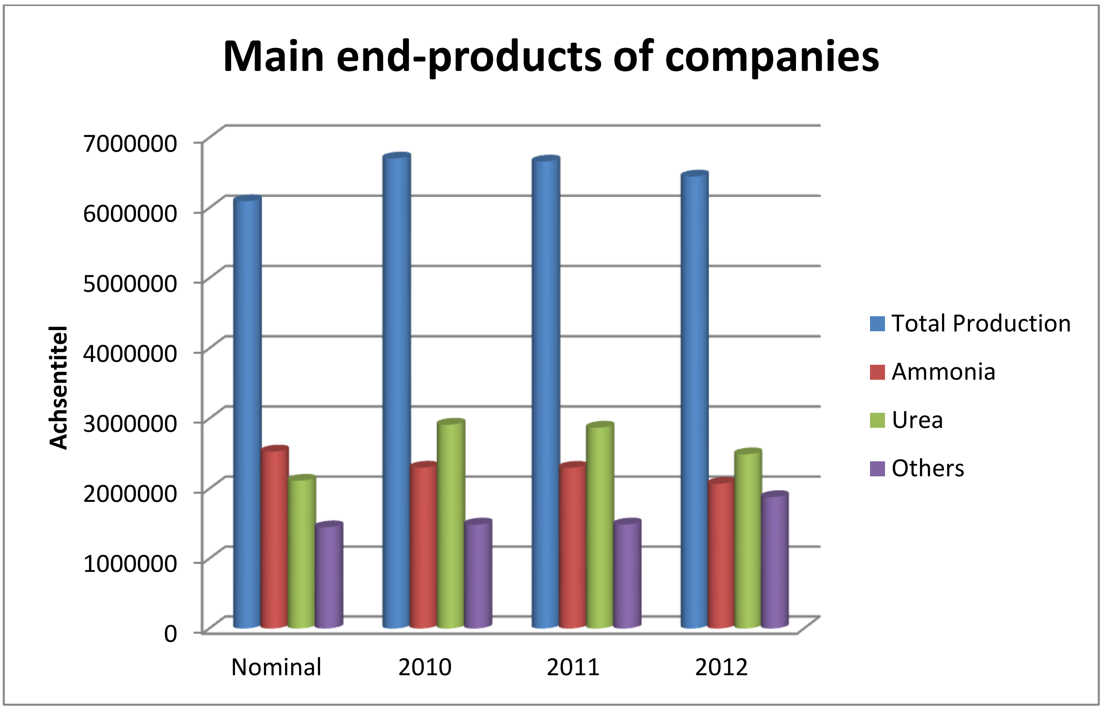


Figure 10: Variation of Egypt's Nitrogen Fertilizers from 2010 to 2012 from analyzed companies

A slight increase over the design production of the sector is shown due to extra urea production especially in 2012. This increase reached about 6 % in 2010 and 2011 and dropped to 3 % in 2012.

The predominant production sector is the private sector for both ammonia and total fertilizers including urea as shown in Figure 11 and Figure 12.

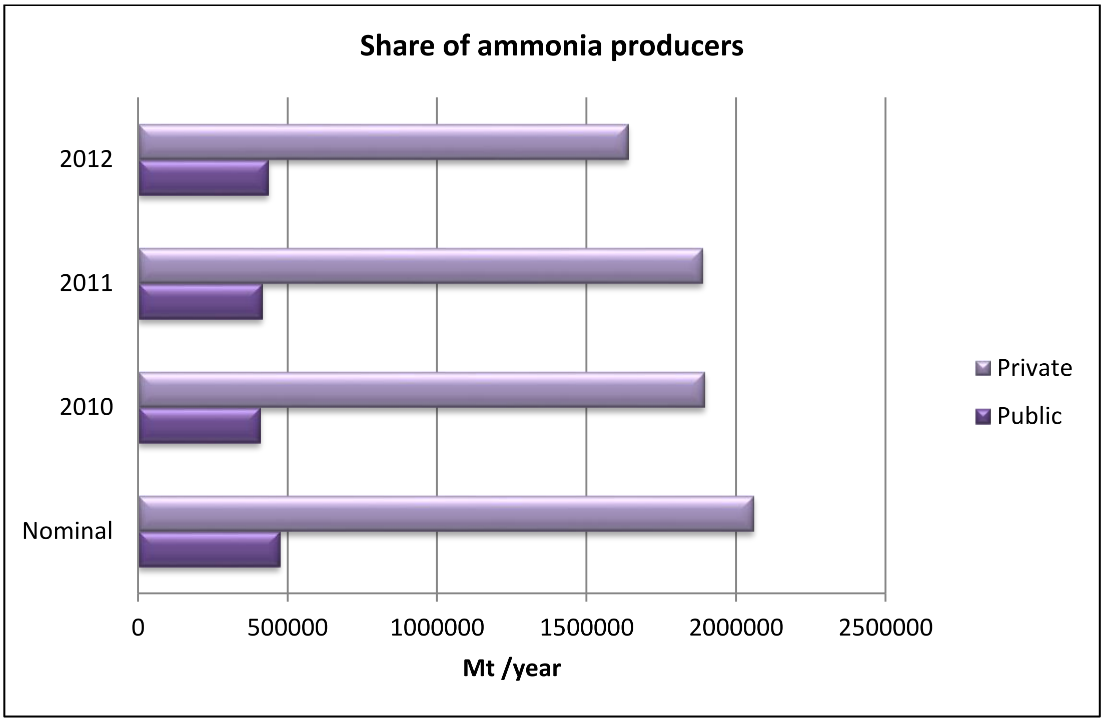


Figure 11: Share of Private and Public fertilizer producers of Ammonia from 2010 to 2012

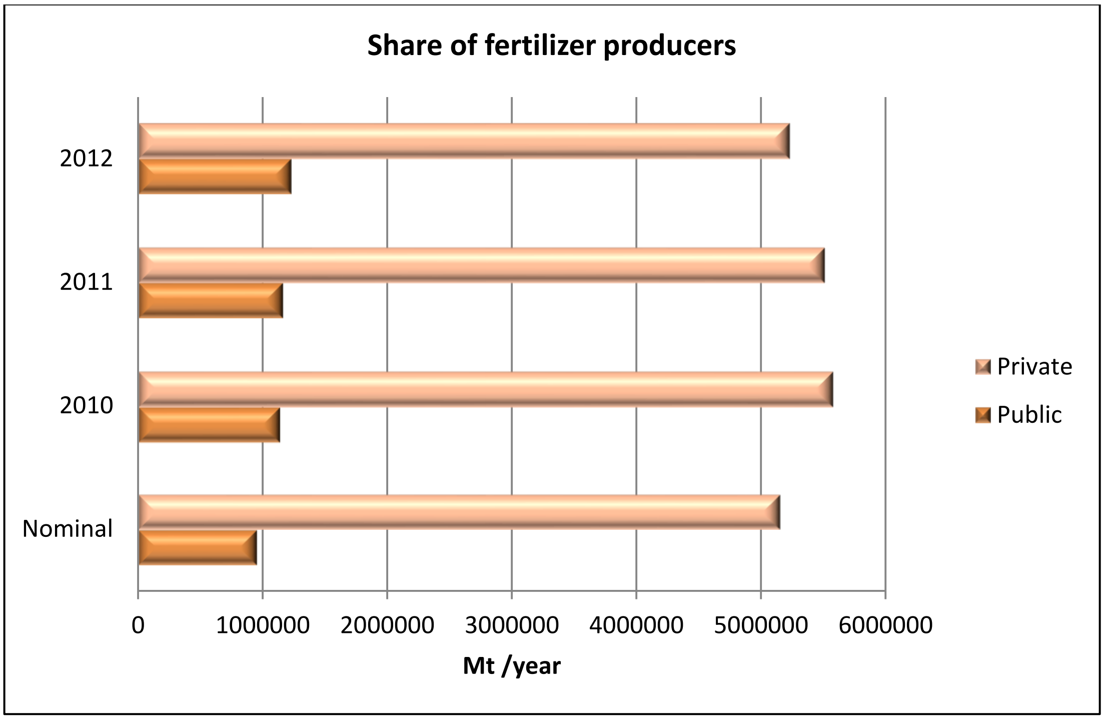


Figure 12: Share of Private and Public fertilizer producers of all fertilizers from 2010 to 2012

3.3.2 Annual Turnover

It is not possible to obtain the annual turnover on company level. Both, local and international prices for nitrogen fertilizers continuously rose in the last few years as a response to the increasing demand. However, there has been always a divergence between local and international prices as global prices usually record higher levels.

The last few years have witnessed a dramatic increase for Egyptian exports, rising from USD 138.5 million in 2005/2006 to USD 1135.7 million in 2010/2011 with a lower rate of increase in imports resulting in a surplus, which amounted to USD 850.7 million in 2010/2011 against only USD 13.1 million in 2005/2006[6].

However, exports retrieved during the first quarter 2011/2012 posting USD 209.4 million compared the corresponding period of the previous year due to challenges facing producers after the 25 Revolution and yet they achieved a surplus amounted to USD 140.4 million.

3.3.3 Main Markets

The fertilizer market dynamics in Egypt were investigated[6]. The research included the local international demand and prices for major types of fertilizers, as well as the exports and imports of the market's key players.

The study revealed that local consumption for nitrogen fertilizers increased through the past few years by 14.3 % in 2007/2008 compared to 2003/2004. The annual consumption for nitrogen fertilizers in 2011/2012 ranges from 8 to 9 million metric tons of azotic fertilizers and 3 main cereal crops (rice - wheat - maize) that consume most of the available fertilizer quantities.

The export is dominated by the private sector fertilizer producers. The private sector currently represents the largest producer of fertilizers in Egypt with more than 90 % shares of nitrogen fertilizer production. Many producers exist in the free zones that facilitate the export of their production. It is worth noting that companies coded as F1/P1, F1/P2 and F1/P3 (see table 14) contribute with the highest share of the private sector's production directed to the local market.

The export policy has been changed in Egypt at the beginning of 2012: the government demanded that companies first fulfill the needs of the local market before exporting. This is shown in the next figure, where the exported amount of fertilizers decreased in favor of the local market by 23.6% due to the increase of the local market demand.

[6] Sectorial Survey, Fertilizers Industry in Egypt, Economic Research Alex Bank, May 2012.

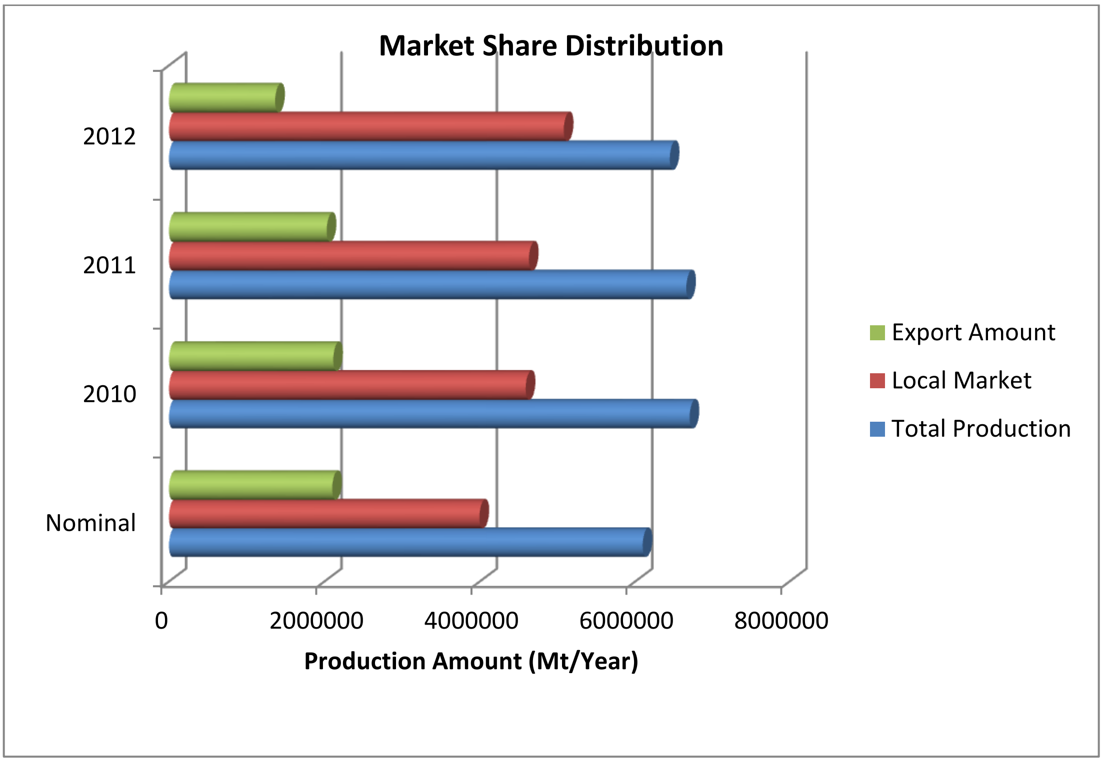


Figure 13: Local/Export Market Share Distribution

An overview of the role of each company in the local market and in the export market is presented herein.

Table 14: Contribution of Each Company to the Local and to the International Markets

Company	Local Market Share Market	Export Share	Remarks
Private Sector Producers			
F1	Directs most of its production to the local market	Limited	Most important producer in Egypt
F8	Directs most of its production to the local market	Limited	
Free Zones Producers			
F2	Limited as and their products entering the local market are considered as imports,	Exports more than 50% of their production	Exempted from exporting restrictions as they are obliged by law to export more than 50% of their production and their products entering the local market are considered as import
F3	Part of its Ammonia production goes to other Companies in the free zone	Exports more than 50% of its production	Exempted from exporting restrictions as they are obliged by law to export more than 50% of their production and their products entering the local market are considered as imports

Company	Local Market Share Market	Export Share	Remarks
F7	None	Exports all its production	Exempted from exporting restrictions as they are obliged by law to export more than 50% of their production and their products entering the local market are considered as imports
F9	None	Exports all its production	Exempted from exporting restrictions as they are obliged by law to export more than 50% of their production and their products entering the local market are considered as imports
Public Sector Producers			
F4	Directs most of its production to the local market	Limited	Shutdown from (2010 – till now) for rehabilitation
F5	Directs most of its production to the local market	Limited	
F6	Directs most of its production to the local market	Limited	

3.3.4 Main Drivers for Energy Consumption

For the fertilizer industry the main drivers for energy consumption are:

- Ammonia and hydrogen production onsite
- Consistency of end product: granulated, powdered, liquid, low-release fertilizers (various forms including fertilizer spiker, tabs, etc.)

3.4 Energy Data of the Whole Sector

The following conversion factors were used in the calculations.

Table 15: Conversion factors (IPCC, 2006)

Source	Natural Gas (MJ/m3)	Diesel (MJ/kg)	Mazot* (MJ/kg)
IPCC 2006 Guidelines (Default Values)	37.74	43	40.4

*…Mazot: gasoline

3.4.1 Thermal Energy Consumption of the Whole Sector

Previously, the commonly used fuels in the Egyptian fertilizer sector is natural gas. The Egyptian fertilizer sector consumes around 1,879 Million m3/year natural gas (IDA) for the analyzed companies, and consumes around 3,666 Million m3/year natural gas (IDA) for the whole sector.

3.4.2 Electricity Consumption of the Whole Sector

The total electrical energy consumption of the analyzed companies is estimated to be 575,761 MWh/year (IDA) for the analyzed companies, and is estimated to be 1,041,288 MWh/year (IDA) for the whole Egyptian fertilizer sector.

3.4.3 Energy Costs

The energy cost calculations are based on the unit energy rates provided in the following table.

Table 16 : Unit Prices of Energy

Year	Electricity		Natural Gas	
	Unit Price[7]		Unit Price[8]	
2010	0.263	EGP/kWh	0.675	EGP/m3
2011	0.263	EGP/kWh	0.675	EGP/m3
2012	0.263	EGP/kWh	0.675	EGP/m3
2013	0.263	EGP/kWh	0.675	EGP/m3

[7] Ministerial decree no 2130/2010 and 1257/2014
[8] Ministerial decree no 1953/2010 and 1162/2014

Year	Electricity		Natural Gas	
	Unit Price[7]		Unit Price[8]	
2014	0.388	EGP/kWh	1.0125	EGP/m3

3.5 Energy Efficiency Measures Implemented and/or Planned

Most of the companies have no energy management system implemented; most of the companies have just set single measures in the area of energy.

4 Analysis of Results

The data collection procedure targeted 9 companies with 11 production plants as included in the previous table. A meeting was held at IDA to schedule the site visits; at least one senior and one junior member from IDA accompanied the Egyptian UNIDO team at the site visits. A simple questionnaire form was prepared and sent to the companies before the site visit. Seven companies and 10 plants contributed, and one company (KIMA) was not subject to the study since it was shut down. The UNIDO team visited those plants; the approach was to present in details the project activities and methodology as well as the benefits gained from the project. During the visit, the main data collection sheet and the confidentiality agreement signed by the UNIDO Representative and Director of Regional Office at Cairo were handed over to each company. About 65 % of the actual data in relation to the total sector production was collected through seven (5 companies) out of eleven (nine companies).

After the visits, daily communication was maintained with the companies in order to answer their queries and to help processing the data through the excel sheets. Revisiting companies occurred in many cases to enhance the data collection process.

4.1 Achieved Data Sets for Analysis

This subsection describes the data regarding fertilizer production and energy consumption of the analyzed companies. These data were gathered for years 2010, 2011 and 2012. The most representative year for the fertilizer sector in Egypt is 2012.

4.1.1 Production Volume of Analyzed Companies

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

Table 17: Details of Production volume of analyzed companies

No.	Company Code	Products in M t/year	Design Capacity* in Mt/year	Production in 2010 in Mt/year	Production in 2011 in Mt/year	Production in 2012 in Mt/year
1	**F1/P1**	Ammonia	1,242,620/3	330,430	360,490	359,266
		Urea 46,5%	537,000/2	530,214	567,481	545,526
2	**F1/P2**	Ammonia	1,242,620/3	365,452	335,569	338,222
		Ammonium Nitrate	768,000	852,934	770,529	815,276
		NPK	200,000	142,868	134,262	297,580
	F1/P3	Ammonia	1,242,620/3	401,769	412,860	425,864
		Urea 46,5%	537,000/2	610,018	629,340	654,078
		UAN	300,000	224,311	266,764	422,423

No.	Company Code	Products in M t/year	Design Capacity* in Mt/year	Production in 2010 in Mt/year	Production in 2011 in Mt/year	Production in 2012 in Mt/year
2	**F2******	Ammonia	422,800	----	----	----
		Urea	660,000	----	----	----
3	**F3****	Ammonia	660,000	----	----	----
4	**F4*****	Ammonium Nitrate	-----	----	----	----
5	**F5**	Ammonia	443,232	345,673	359,026	33,5257
		Purchased Ammonia	**NA**	**19,405**	**13,899**	**3,447**
		Ammonium Nitrate	102,246	143,745	200,532	15,8758
		Nitric Acid	32,700	NA	NA	NA
		Urea	293,480	456,650	423,730	44,1330
6	**F6**	Ammonia	29,902	61,880	54,489	99,960
		Purchased Ammonia	**NA**	**11,463**	**7,609**	**24**
		Ammonium Nitrate	14,621	120,057	64,205	130,586
		Ammonium Sulphate	31,101	3,998	52,253	56,278
7	**F7****	Ammonia	395,560	----	----	----
		Urea	682,000	----	----	----
8	**F8**	Ammonia	407,000	387,771	430,570	376,498
		Urea	650,000	643,200	693,565	615,565
9	**F9**	Ammonia	408,300	408,678	347,149	137,610
		Urea	635,000	673,690	557,456	236,237

*Design Data obtained from Industrial Development Authority (IDA) and collected in 2010.

** Excluded from the study due to company policy (assuming it is working at full capacity)

*** Excluded from the study due to shut down for rehabilitation

****Data not received

4.1.2 Energy Consumption of Analyzed Companies

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

Table 18: Conversion factors (IPCC, 2006)

Source	[9]Natural Gas (MJ/m3)	Diesel (MJ/kg)	Mazot (MJ/kg)
IPCC 2006 Guidelines (Default Values)	37.74	43	40.4

4.1.2.1 Thermal Energy Consumption

The thermal energy consumption for the analyzed companies can be found below. The main fuel used is natural gas, which is used as a feedstock and as an energy source for production processes and for utilities to produce steam.

Table 19: Natural Gas (NG) Total Consumption for the Analyzed Companies (5 companies "7 plants") (Feedstock and Power Generation)

No.	Company	Total NG consumption (Design Figure from IDA) in Mm^3/Y	Total NG consumption in 2010 Mm^3/Y	Total NG consumption in 2011 Mm^3/Y	Total NG consumption in 2012 Mm^3/Y
1	F1/P1		460	500	469
2	F1/P2	634	392	373	373
3	F1/P3		477	492	496
4	F5	337	657	656	621
5	F6	83	108	109	150
6	F8	396	433	453	410
7	F9	429	206,53	171,23	71,714
Total NG Consumption of the Sector analyzed companies		**1,879**	**3,024**	**2,880**	**2,574**

The natural gas consumption varies over the years in relation to the annual production, which is exceeds the nominal design (from IDA) shown in figures 14 and 15.

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

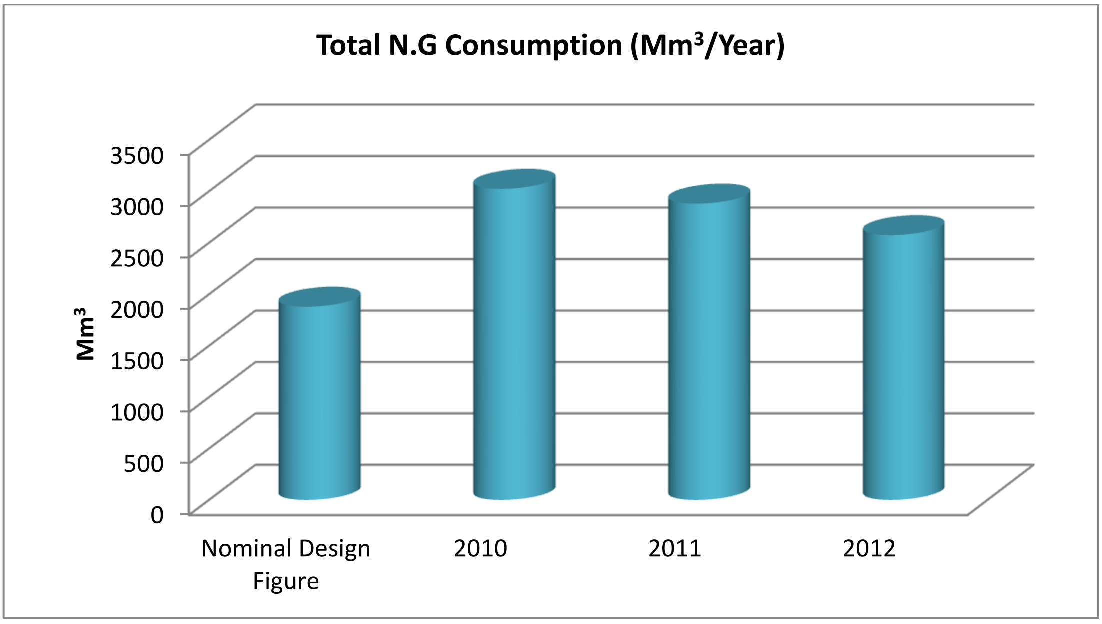


Figure 14: Total Natural Gas Consumption for Analyzed Companies

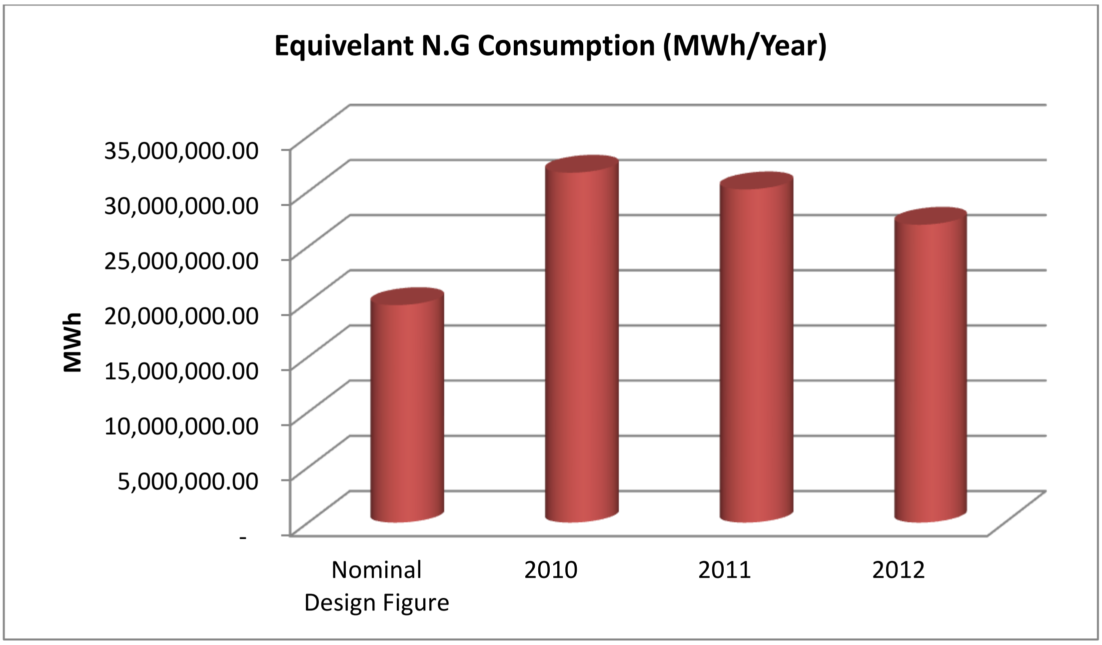


Figure 15: Total Natural Gas Consumption of the Whole Sector Between 2010 through 2012 as Compared to the Design Value (obtained from IDA)

4.1.2.2 Electrical Energy Consumption

Table 20 demonstrates the electrical energy consumed annually by the analyzed fertilizer plants, gathered in the range of years from 2010 to 2012.

Table 20: Electrical Energy Consumption for the analysed companies (Purchased and Self-Generated)

No.	Company	Total Electricity consumption (Design Figure from IDA) in MWh/a	Total Electricity consumption in 2010MWh/a			Total Electricity consumption in 2011 MWh/a			Total Electricity consumption in 2012 MWh/a		
		Purchased	Purchased	Self-Generated	Total	Purchased	Self-Generated	Total	Purchased	Self-Generated	Total
1	**F1/P1***				11,855.7			9,921.6			9,878
2	**F1/P2***	266,000			11,985.6			13,350			14,174.4
3	**F1/P3***				37,237.6			22,968.2			34,821
4	F5	65,400	80,202	115,444	195,646	65,595	119,107	184,703	42,336	124,763	167,099
5	F6	21,432	NA	NA	93,025	NA	NA	121,839	NA	NA	156,054
6	F8	129,600	16,182	105,183	121,365	17,520	113,880	131,400	16,539	107,503	124,042
7	F9	93,329	NA	NA	20,020.9	NA	NA	17,390	NA	NA	10,202.4
Total Energy for the 5 companies		**575,761**			**491,135.8**			**501,571.9**			**516,270.9**

* Plant belong to Company F1 – The Company incorporates three plants

In the figure below the total electrical power consumption for the analysed companies in comparison to the nominal design figure of IDA is shown.

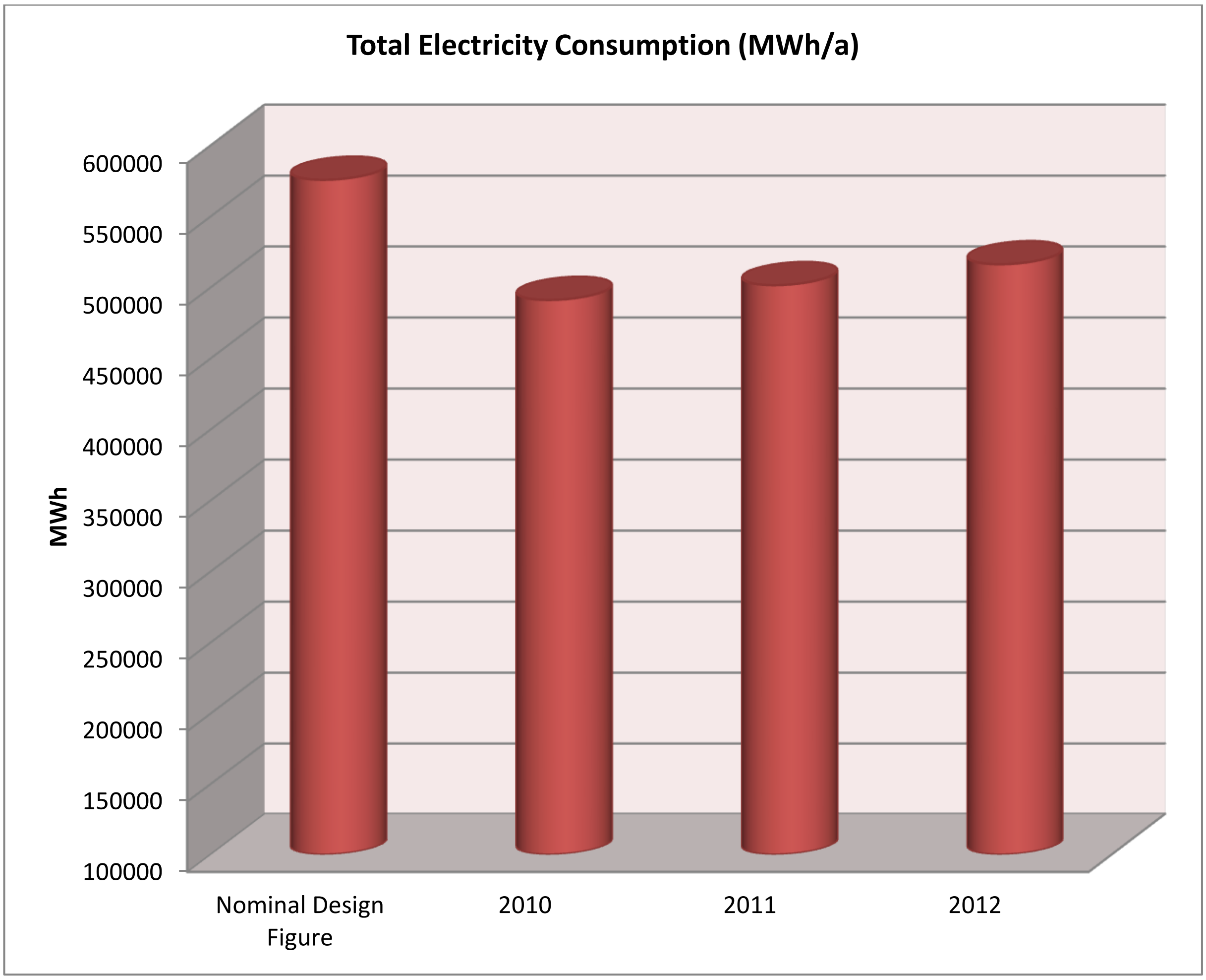


Figure 16: Total Electrical Power Consumption of the Whole Sector between 2010 through 2012 As Compared to the Design Value (IDA, 2010 and 2012)

4.1.2.3 Total Energy Consumption

Table 21 demonstrates the total energy (thermal and electrical) consumed annually by the analyzed fertilizer plants, gathered in the range of years from 2010 to 2012.

Table 21: Total Energy Consumption for seven plants (Electricity + Natural Gas including Feedstock)

Company Code	Nominal Design Figure		2010		2011		2012	
	Total Energy Consumption [MWh]	NH_3 Production Consumption [MWh]	Total Energy Consumption [MWh]	NH_3 Production Consumption [MWh]	Total Energy Consumption [MWh]	NH_3 Production Consumption [MWh]	Total Energy Consumption [MWh]	NH_3 Production Consumption [MWh]
F1	6,912,412.2	5,529,929.8	13,990,239.6	11,192,191.7	13,111,576.7	10,489,261.4	12,792,057.4	10,233,645.9
F1-P1	---	---	4,834,173.7	3,867,339.0	5,251,571.6	4,201,257.3	4,921,304.1	3,937,043.2
F1-P2	---	---	4,118,294.2	3,294,635.4	3,925,193.4	3,140,154.7	3,925,053.3	3,140,042.7
F1-P3	---	---	5,037,771.7	4,030,217.4	3,934,811.7	3,147,849.4	3,945,700.0	3,156,560.0
F5	3,598,272.1	2,878,617.7	7,083,174.1	5,649,815.7	7,061,747.8	5,637,768.3	6,677,228.3	5,338,792.4
F6	891,545.9	713,236.7	1,225,221.4	970,191.2	1,264,518.7	1,003,028.9	1,728,549.0	1,382,816.7
F8	4,280,986.8	3,424,789.4	4,660,633.9	3,728,507.1	4,880,334.9	3,904,267.9	4,422,195.0	3,537,8
F9	4,590,664.7	3,672,531.8	5,236,511.0	4,189,208.8	4,378,442.8	3,502,754.3	1,882,519.8	1,506,015.8
TOTAL	**20,273,881.7**	**16,219,105.4**	**32,195,778.0**	**25,729,914.6**	**30,696,620.9**	**24,537,080.7**	**27,502,549.5**	**21,999,026.8**

In the next figure the total energy consumption for the analysed companies in comparison to the nominal design figure of IDA is shown.

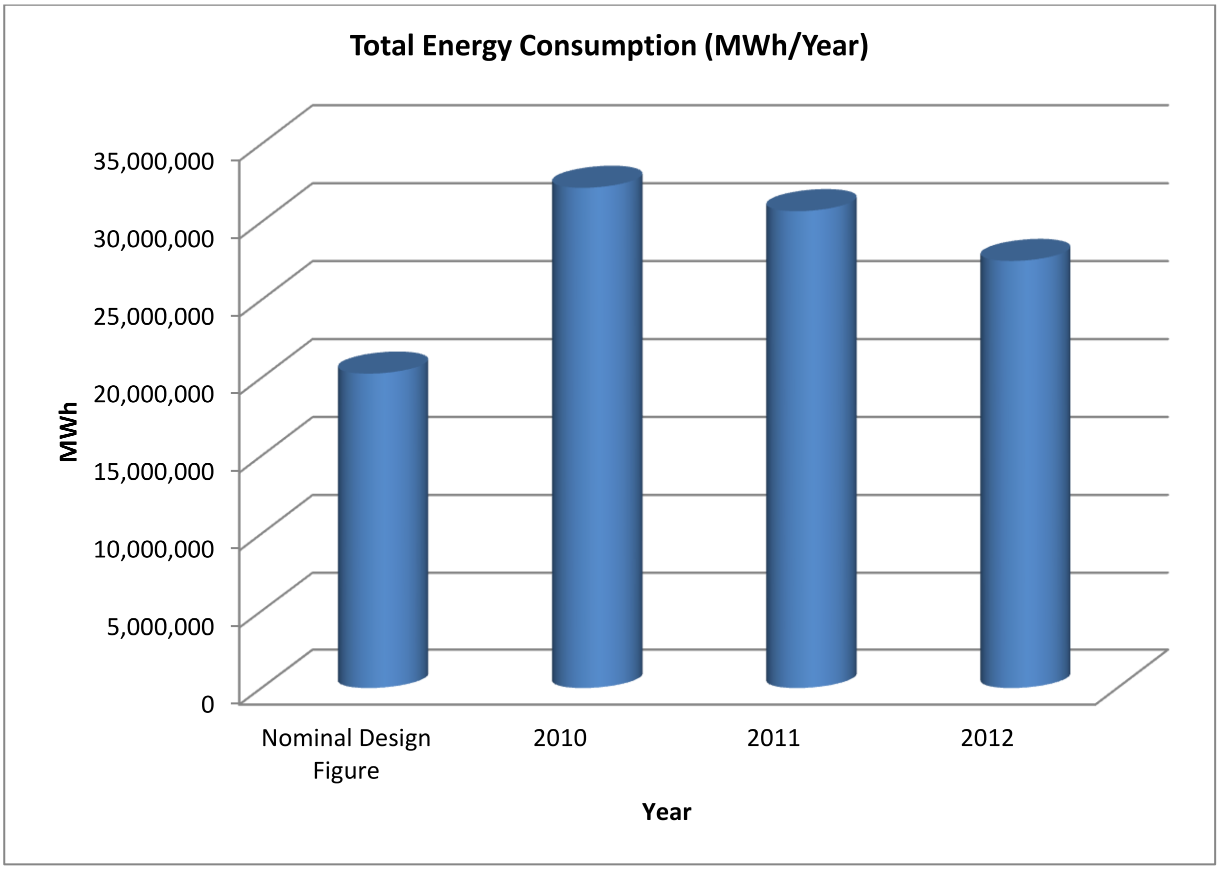


Figure 17: Total Energy Consumption (Including Feedstock) of the Whole Sector between 2010 through 2012 as Compared to the Design Value (IDA 2010 and 2012)

Table 22 illustrates the range of SEC (thermal and electrical) for ammonia among the analyzed companies. The figure demonstrates that the specific energy consumption of the analyzed companies falls within the average range of the developing countries, as described in chapter 2 of the study, however, above the BAT.

Table 22: Specific Energy Consumption for Ammonia Production

	Ammonia Production (t)	Total Energy Consumption (GJ)	SEC (GJ/t)
Nominal Design Figure from IDA	2,531,054	58,388,779	23.07
2010	2,301,953	92,627,692	40.24
2011	2,300,099	88,333,491	38.40
2012	2,072,677	79,196,496	38.21

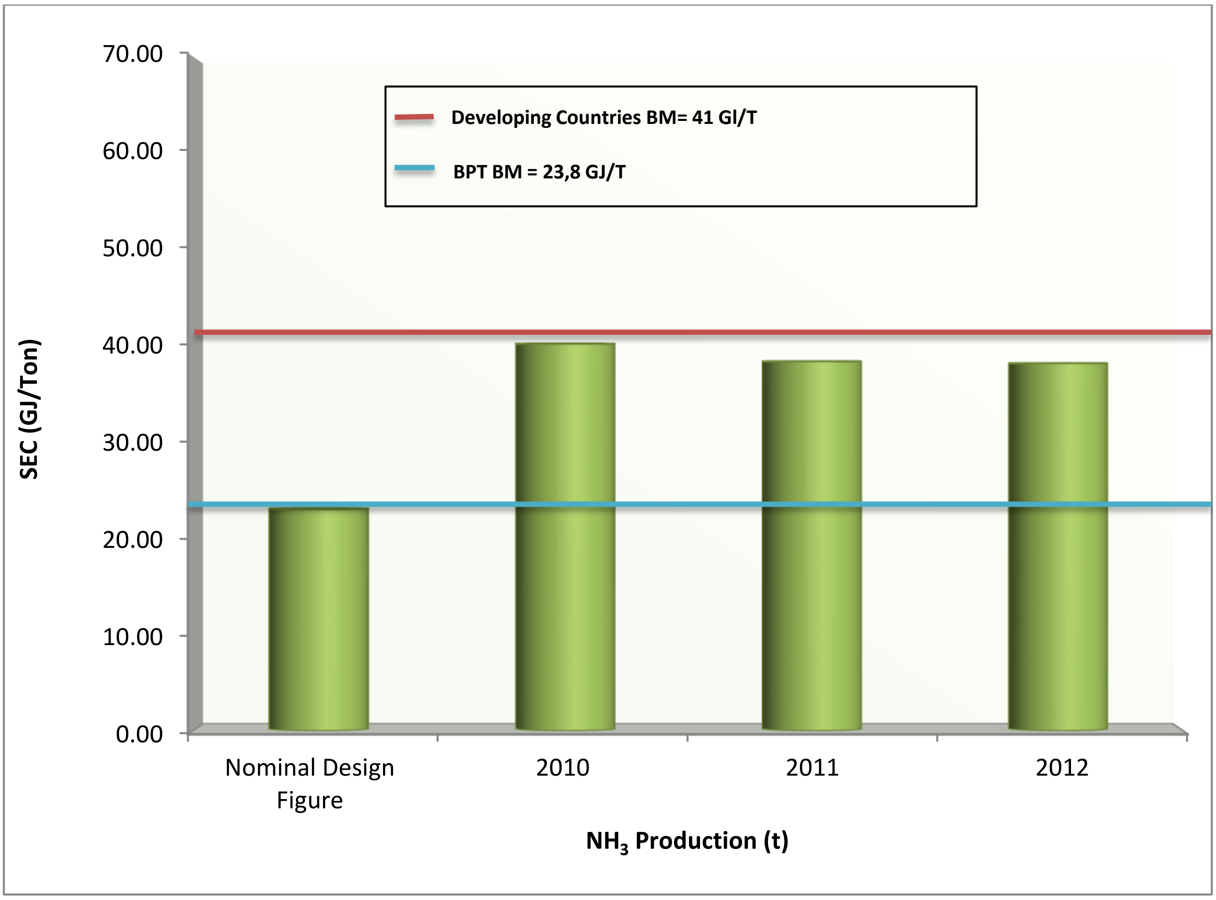


Figure 18: Specific Energy Consumption for Ammonia Production as Compared to AJER Figures

As shown in the figure above the specific energy consumption (SEC)[10] is lower than the average of the developing countries. This could be attributed to the old technology used in many companies in the sector. As will as many companies working under full capacities.

4.1.2.4 Energy Costs of Analyzed Companies

The energy costs for each analyzed company were calculated based on the information regarding to the energy consumption that was provided by each company. The energy costs of each year are shown in the following table.

[10] (AJER, 2013)

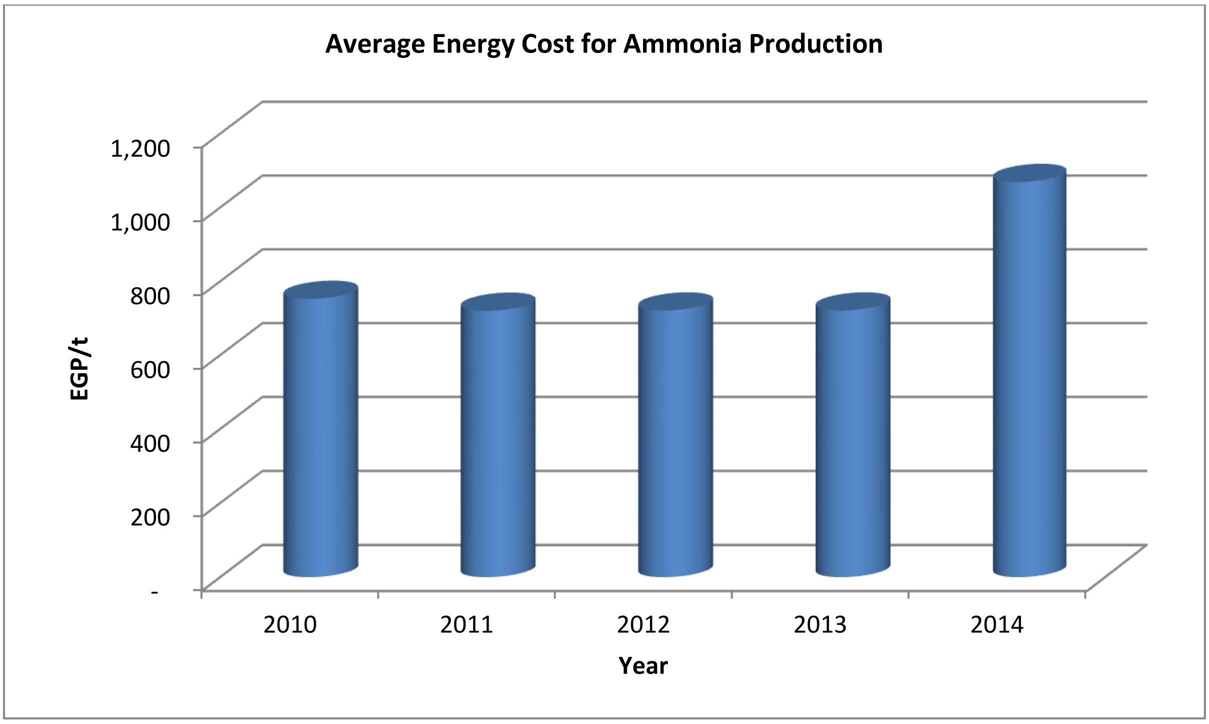


Figure 19: Energy Costs for Ammonia Production in the Analyzed Companies (2010 – 2014)

The energy costs for the ammonia production of the analyzed companies over the years 2010 through to 2012 are presented in table 23 and table 24. The calculated values in the next table are based on the information collected from the companies (the purchased electric energy from the main grid is about 20 % of the total electric energy consumption while the self-produced may reach 80 % of that consumption).

Table 23: Energy Cost for the 5 companies with 7 plants

	Cost in 2010 (EGP)	Cost in 2011 (EGP)	Cost in 2012 (EGP)	Cost in 2013 (EGP)*	Cost in 2014 (EGP)*
Purchased Electrical Power	25,833,743	26,382,682	27,155,849	27,155,849	40,062,622
Self-Generated Power	98,227,160	100,314,380	103,254,180	103,254,180	123,905,016
Total Electric Power Consumption	124,060,903	126,697,062	130,410,029	130,410,029	163,967,638
Cost of Natural Gas	2,041,402,500	1,944,202,500	1,737,595,800	1,737,595,800	2,606,393,700
Cost of Natural Gas consumed in NH_3 Production	1,633,122,000	1,555,362,000	1,390,076,640	1,390,076,640	2,085,114,960
Cost of Electricity Consumed in NH_3 Production	99,248,722	101,357,650	104,328,023	104,328,023	131,174,110
Energy Cost for Ammonia Production (EGP/t)	753	720	721	721	1,069

*Assume the production and consumption for 2013 and 2014 as the same in 2012 to elaborate the raising up in Energy cost

Table 24 : Energy Cost for Ammonia Production for each plant in Egypt

	Energy Cost for Ammonia Production for each plant in 2010 (EGP/t)	Energy Cost for Ammonia Production for each plant in 2011 (EGP/t)	Energy Cost for Ammonia Production for each plant in 2012 (EGP/t)
F1/P1	751.76	748.99	704.19
F5	1,026.46	986.77	1,000.35
F6	942.77	1,080.67	810.64
F1/P2	578.79	600.48	595.63
F1/P3	641.13	488.14	473.06
F8	603.05	568.19	588.12
F9	657.02	647.11	700.87

4.1.3 Status of the Implementation of Energy Management Systems (EnMS) in Analyzed Companies

The following criteria have been defined in order to determine the status of EnMS implementation in each fertilizer plant:

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

Table 25 summarizes the status of energy management system implementation in the analyzed fertilizer plants.

Table 25: Energy Management System Questionnaire

Availabilty of Energy Management System									
Criteria	F1-P1	F1-P2	F1-P3	F5	F6	F8	F9	% Yes	% No
Responsible person for energy?	Yes	Yes	Yes	No	Yes	No	No	57%	43%
Do you analyze your energy consumption?	Yes	Yes	Yes	No	No	No	Yes	57%	43%
Energy meters/sub-meters ?installed	Yes	Yes	Yes	Yes	No	Yes	Yes	86%	14%
Resources available for Energy management?	Yes	Yes	Yes	Yes	Yes	No	Yes	86%	14%
Energy efficiency considered in investment decisions?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
Energy Efficiency Targets available?	Yes	Yes	Yes	No	Yes	No	Yes	71%	29%
Previous Energy Audits Available? If yes date of audit?	No	No	No	No	No	No	No	0%	100%
Energy saving measures planned?	Yes	Yes	Yes	No	Yes	No	No	57%	43%
Maintenance executed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
Average for sector								68 %	32 %

As same from the previous table, most of the companies have no energy management systems except few that have incomplete and scattered measures that not constitute full system. Accordingly, most of these companies should obtain ISO 50001 EnMS; this should start as soon as possible since energy tariff shall go up very soon, as the government subsidy will cease.

4.2 Benchmark Clusters and/or Adjustment Factors

Although two companies do not produce completely the Ammonia on site no clusters were necessary for the companies because the usage of correction factors was eligible. In two of the analyzed Egyptian plants, a small part of the Ammonia (< 10%) is purchased. For establishing the EPI of these plants the purchased tonnes of ammonia need to be subtracted from the total ammonia processed. The calculation method is as followed:

- Total energy corrected = total energy – energy consumed for purchased semi-finished products
- Total production corrected = total production of ammonia – purchased ammonia
- Energy consumed for purchased semi-finished products (ammonia) = total energy consumption * percentage of energy consumed for final product production (e.g. urea) * percentage of purchased ammonia

For establishing the benchmark curve the purchased semi-finished products need to be added to the „total production“ (for cumulative production share).

4.3 Energy Performance Indicators of Analyzed Companies

4.3.1 Benchmark Curve on National Level

Table 26 Energy performance indicators of analyzed companies in 2010

	Ammonia Production (t)	Production Share	Cumulative energy production volume share	Total Energy Consumption (GJ)	SEC (GJ/t)	SEC (KWh/t)
F1/P2	365,452	0.16	0.16	11,860,687.32	32.45	9,015
F8	387,771	0.17	0.33	13,422,625.63	34.61	9,615
F1/P3	401,769	0.17	0.50	14,508,782.5	36.11	10,031
F9	408,978	0.18	0.68	15,081,151.62	36.88	10,243
F1/P1	330,430	0.14	0.82	13,922,420.26	42.13	11,704
F6	61,880	0.03	0.85	3,492,688.272	56.44	15,679
F5	345,673	0.15	1.00	20,339,336.62	58.84	16,344

The benchmark curves in the next figure for the three consecutive years are constructed from the actual collected data. The most efficient plants are represented to the left and lower part of the curve, and the least efficient plants to the right and higher part of the curve. However, typically a few plants are very efficient and a few plants are very inefficient. The most efficient plants are located within the 1st decile while the inefficient ones within the last decile. As shown from the figure, 5 plants out of 7 (70% of the sector) are included in the core of the curve. This exercise has been repeated for 2010, 2011 and 2012.

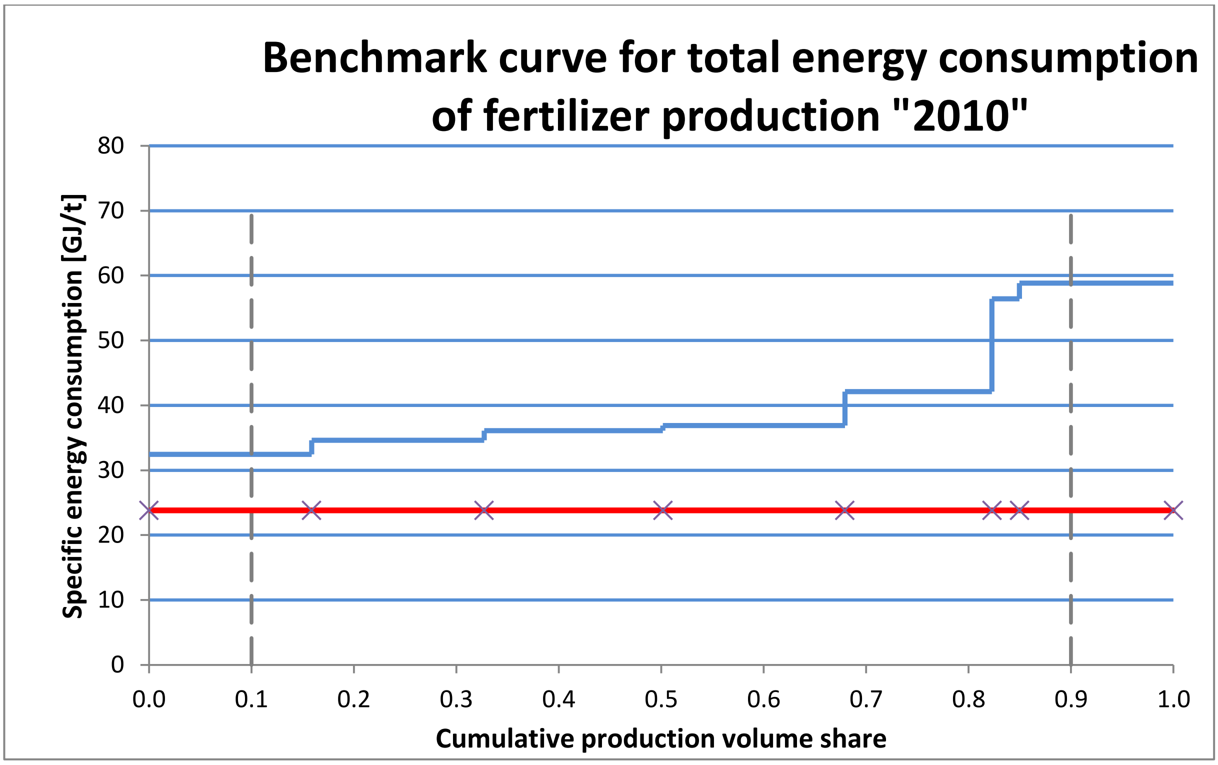


Figure 20: Benchmark Curve for Beverage Production of 2010 for Analyzed Companies

- The EPI corresponding to the national BAT value = 32,45 GJ/t ammonia
- The EPI corresponding to the national BPT value = 34,61 GJ/t ammonia
- The EPI corresponding to the international BAT value = 23.8 GJ/t ammonia

Table 27: Energy performance indicators of analyzed companies in 2011

	Ammonia Production (t)	Production Share	Cumulative energy production volume share	Total Energy Consumption (GJ)	SEC (GJ/t)	SEC (kWh/t)
F1/P3	412,806	0.18	0.18	11,332,257.68	27.45	7,625.49
F8	430,570	0.19	0.37	14,055,364.51	32.64	9,067.67
F1/P2	335,569	0.15	0.51	11,304,556.98	33.69	9,357.70
F9	347,149	0.15	0.66	12,609,915.26	36.32	10,090.06
F1/P1	360,490	0.16	0.82	15,124,526.21	41.96	11,654.30
F5	359,026	0.16	0.98	20,295,965.84	56.53	15,702.95
F6	54,489	0.02	1.00	3,610,904.10	66.27	18,407.92

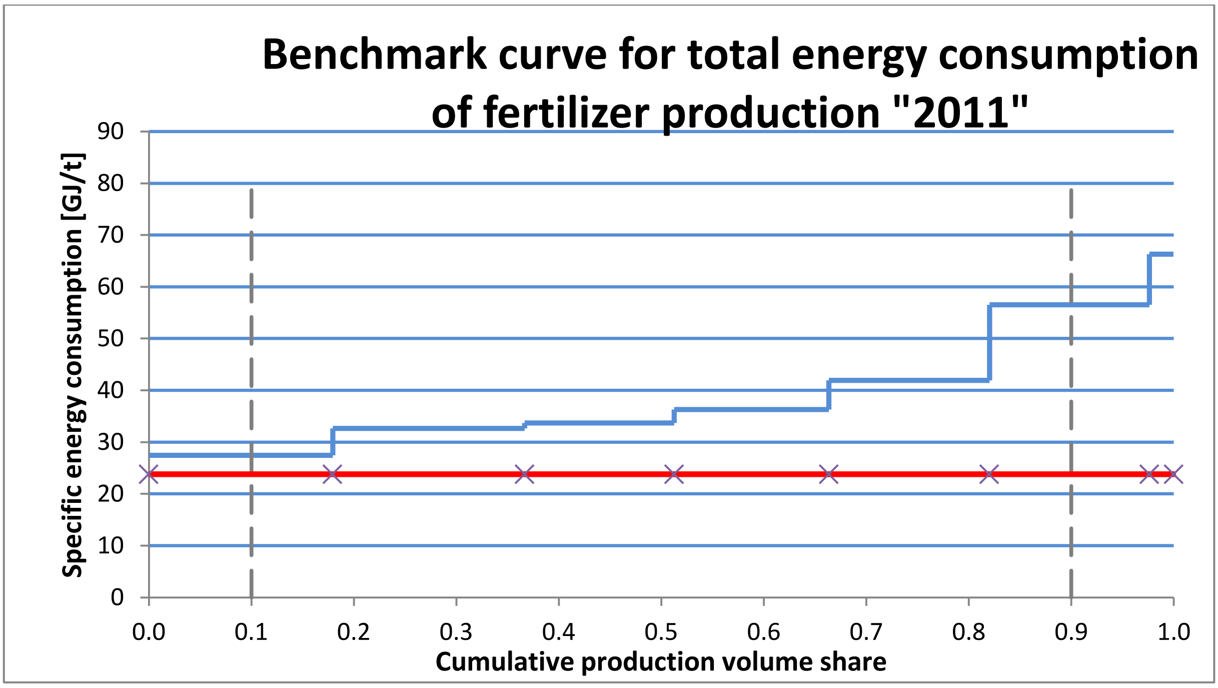


Figure 21: Benchmark Curve for Beverage Production of 2011 for Analyzed Companies

- The EPI corresponding to the national BAT value = 27.45 GJ/t ammonia
- The EPI corresponding to the national BPT value = 32.64 GJ/t ammonia
- The EPI corresponding to the international BAT value = 23.8 GJ/t ammonia

Table 28: Energy performance indicators of analyzed companies in 2012

	Ammonia Production (t)	Production Share	Cumulative energy production volume share	Total Energy Consumption (GJ)	SEC (GJ/t)	SEC (kWh/t)
F1/P3	425,864	0.21	0.21	11,363,616.09	26.68	7,412.13
F1/P2	338,222	0.16	0.37	11,304,153.59	33.42	9,283.97
F8	376,498	0.18	0.55	12,735,921.6	33.83	9,396.48
F9	137,610	0.07	0.62	5,421,656.966	39.40	10,944.09
F1/P1	359,266	0.17	0.79	14,173,355.66	39.45	10,958.57
F5	99,960	0.05	0.84	4,978,139.965	49.80	13,833.70
F6	335,257	0.16	1.00	19,219,652.55	57.33	15,924.48

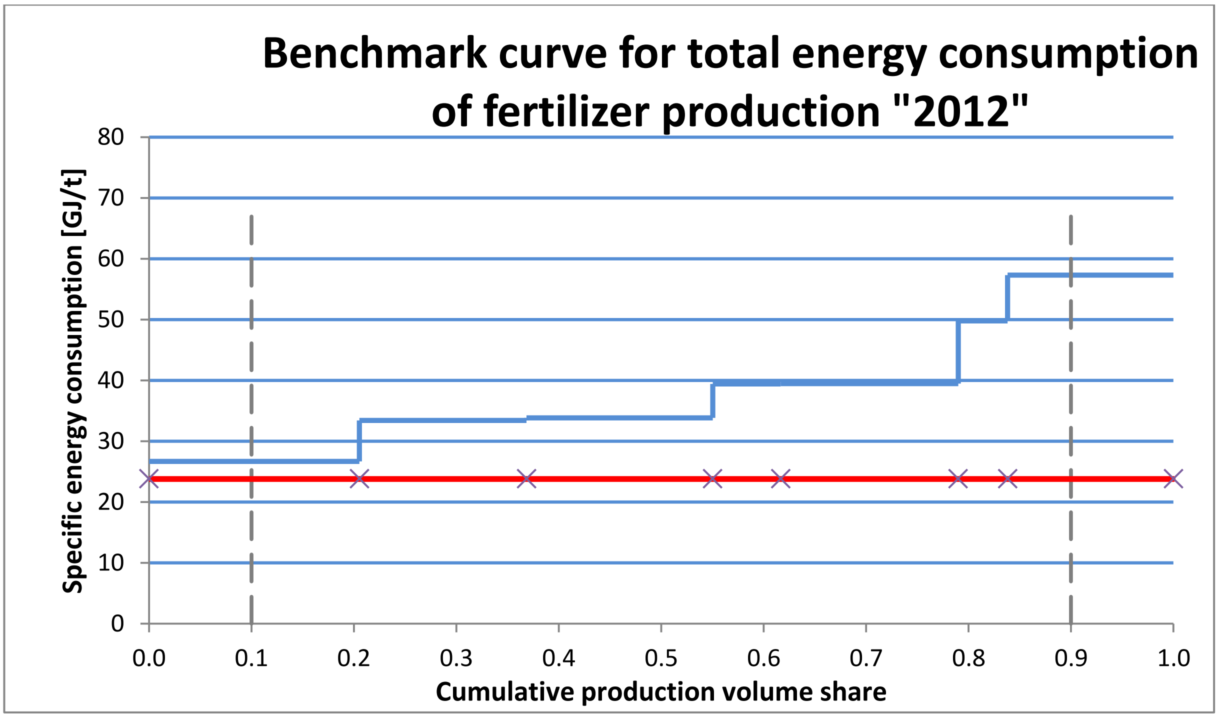


Figure 22: Benchmark Curve for Beverage Production of 2012 for Analyzed Companies

The comparison between the three curves shows that the energy performance indicator for the sector has been improved over the years. This will be shown in the calculation of the potential energy saving of the sector over the three years.

- The EPI corresponding to the national BAT value = 26.68 GJ/t ammonia
- The EPI corresponding to the national BPT value = 33.42 GJ/t ammonia
- The EPI corresponding to the international BAT value = 23.8 GJ/t ammonia

4.4 Share of Energy Costs of Turnover

The following table shows the annual turnover of each company contributed in the study.

Table 29: Annual Turnover for each plant through 2010, 2011 and 2012.

Company Code	Annual Turnover					
	2010		2011		2012	
	Urea (USD300/t)	Ammonium Nitrate (USD297/t)	Urea (USD300/t)	Ammonium Nitrate (USD297/t)	Urea (USD400/t)	Ammonium Nitrate (USD390/t)
F1/P1	159,064,200	-	170,244,300	-	218,210,400	-
F1/P2	-	253,321,398	-	228,847,113	-	317,957,640
F1/P3	183,005,400	-	188,802,000	-	261,631,200	-
F5	136,995,000	42,692,265	127,119,000	59,558,004	176,532,000	61,915,620
F6	-	35,656,929	-	19,068,885	-	50,928,540
F8	192,960,000	-	208,069,500	-	246,226,000	-
F9	202,107,000	-	167,236,800	-	94,494,800	-
Total	**874,131,600**	**331,670,592**	**861,471,600**	**307,474,002**	**997,094,400**	**430,801,800**
		1,205,802,192		**1,168,945,602**		**1,427,896,200**

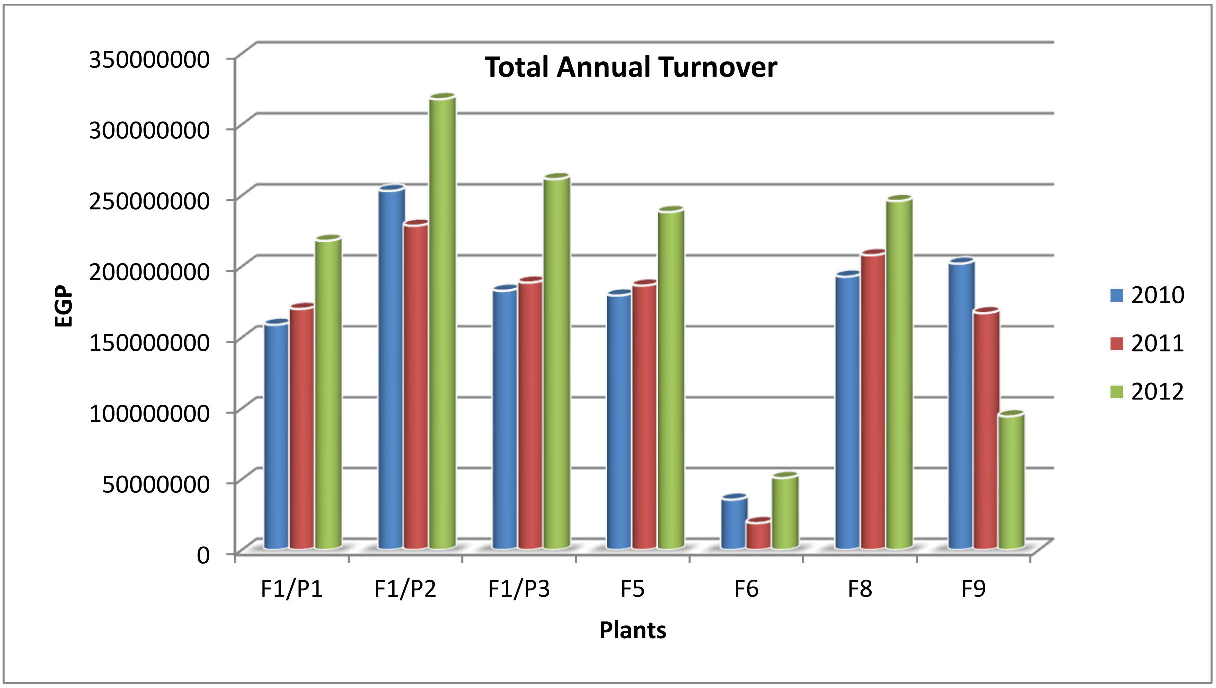


Figure 23: Total annual turnover for the analyzed companies

Figure 24: USD Vs EGP analysis through 5 years, Source (www.xe.com)

The calculation of the energy share against the total turnover is based on the variation of the US Dollar against the Egyptian Pound shown in the previous graph. This variation shows dramatic increase in the dollar exchange rate. This approach is adapted as the fertilizers price per ton is always calculated in US Dollar. The price of Urea and Ammonium Nitrate has increased in 2012 by 100 US Dollar per ton while the energy cost did not exhibit any increase during this period. This is reflected in the following Table as the share of energy cost as compared to the turnover has dropped dramatically (from 33 -30 % to 22 %) due to:

- Increase in the US Dollar exchange rate.
- Increase of the selling price of the ton of product.
- No change in the energy cost.

Table 30: Percentage of energy costs on the total turnover

Share of Energy Cost of Turnover	
Year	Share Percentage
2010	33 %
2011	30 %
2012	22 %

4.5 Energy Cost Benchmark Curve for Egyptian Companies

Tariffs for energy in fertilizers sector fixed according to a ministerial decree through the period from 2010 to 2012.

Table 31: Energy Cost for Ammonia Production for Egyptian Companies through 2010, 2011 and 2012.

	Energy Cost for Ammonia Production for each plant in 2010 (EGP/t)	Energy Cost for Ammonia Production for each plant in 2011 (EGP/t)	Energy Cost for Ammonia Production for each plant in 2012 (EGP/t)
F1/P1	751.75	748.99	704.19
F5	1026.46	986.77	1000.35
F6	942.77	1080.67	810.64
F1/P2	578.79	600.48	595.63
F1/P3	641.13	488.14	473.06
F8	603.05	568.19	588.12
F9	657.02	647.11	700.87

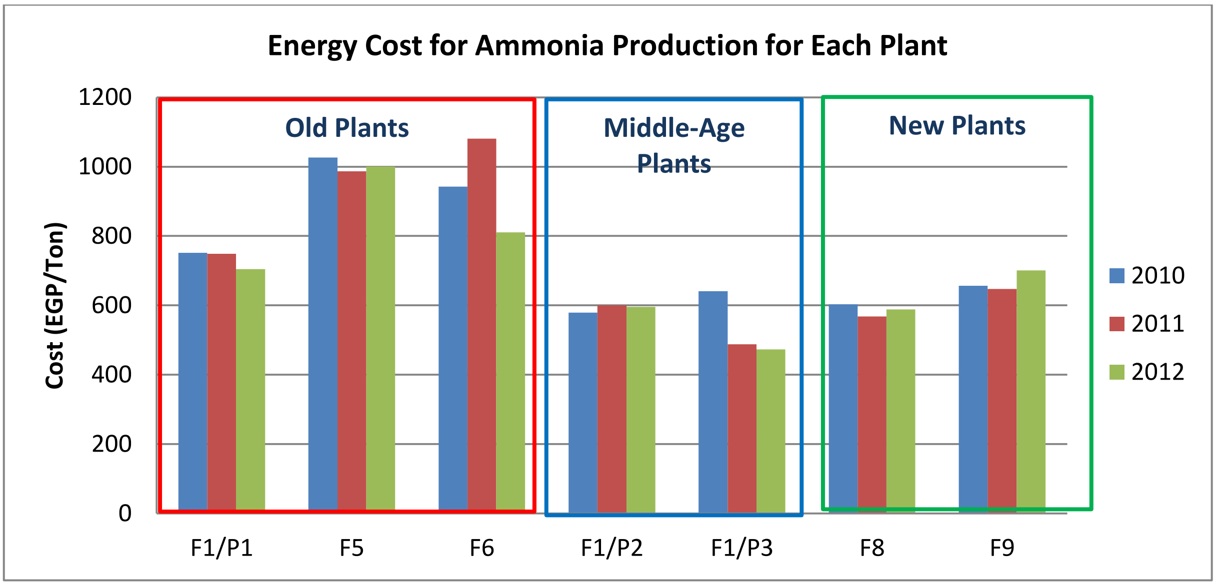


Figure 25: Energy Cost Benchmark Curve for Ammonia Production for Egyptian Companies

The pervious figure shows that the energy cost per ton of ammonia production for the old plants is much higher than both middle age and new plants; however, new plants produce at cost near the middle age plants; this is attributed to the energy crises.

4.6 Annual Saving Potential

4.6.1 Annual Saving Potential for Each Plant

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

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

The SEC lowest was for F1/P2 in 2010 = 32.45 GJ/t.

Table 32: Annual Saving Potential for Egyptian Companies 2010

	Ammonia Production (t)	Total Energy Consumption (GJ)	SEC (GJ/Ton)	Potential Saving (%)	Potential Saving (GJ)
F1/P2	365,452	11,860,687.32	32.45	0.00%	0
F8	387,771	13,422,625.63	34.61	6.24%	837,579
F1/P3	401,769	14,508,782.5	36.11	10.13%	1,469,433
F9	408,978	15,081,151.62	36.88	11.99%	1,807,835
F1/P1	330,430	13,922,420.26	42.13	22.97%	3,198,366
F6	61,880	3,492,688.272	56.44	42.50%	1,484,383
F5	345,673	20,339,336.62	58.84	44.84%	9,120,574
Sum					17,081,428

The SEC_{lowest} was for F1/P3 in 2011 = 27.45 GJ/t

Table 33: Annual Saving Potential for Egyptian Companies 2011

	Ammonia Production (t)	Total Energy Consumption (GJ)	SEC (GJ/t)	Potential Saving (%)	Potential Saving (GJ)
F1/P3	412,806	11,332,257.68	27.45	0.00%	0
F8	430,570	14,055,364.51	32.64	15.90%	2,235,456
F1/P2	335,569	11,304,556.98	33.69	18.51%	2,092,594
F9	347,149	12,609,915.26	36.32	24.43%	3,080,061
F1/P1	360,490	15,124,526.21	41.96	34.57%	5,228,438
F5	359,026	20,295,965.84	56.53	51.44%	10,440,067
F6	54,489	3,610,904.1	66.27	58.57%	2,115,085
Sum					25,191,701

The SEC_{lowest} was for F1/P3 in 2012 = 26.68/t

Table 34: Annual Saving Potential for Egyptian Companies 2012

	Ammonia Production (t)	Total Energy Consumption (GJ)	SEC (GJ/t)	Potential Saving (%)	Potential Saving (GJ)
F1/P3	425,864	11,363,616.09	26.68	0.00%	0
F1/P2	338,222	11,304,153.59	33.42	20.16%	2,279,148
F8	376,498	12,735,921.60	33.83	21.12%	2,689,572
F9	137,610	5,421,656.97	39.40	32.27%	1,749,717
F1/P1	359,266	14,173,355.66	39.45	32.36%	4,586,819
F5	99,960	4,978,139.96	49.80	46.42%	2,310,840
F6	335,257	19,219,652.55	57.33	53.45%	10,273,764
Sum					13,616,096

4.6.2 Annual Saving Potential for the Whole Sector

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

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

Table 35: Annual Saving Potential for Egyptian Fertilizers Sector through 2010, 2011 and 2012

	Ammonia Production (Ton)	Weighted SEC (GJ/Ton)	Potential Saving (%)	Potential Saving(GJ)
2010	2,301,953	40.24	40.85%	37,841,211
2011	2,300,099	38.40	38.02%	33,591,134
2012	2,072,677	38.21	37.71%	29,866,784

4.7 Saving Scenarios until 2030 and until 2050

In this chapter different energy saving scenarios until 2030 and 2050 were drawn. The scenarios correspond to the scenarios in the UNIDO Working Paper.

4.7.1 Energy Savings in 2050

In this chapter different energy saving scenarios until 2050 is 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 0.2 % 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 0.33 % a year in the period 2012 to 2050. The BPT is the lowest BPT, either on national or international level. For the fertilizer sector this is the national BPT value of 33.42 GJ/Ton in the year 2012.

BAT scenario: all plant is operating at current levels of BAT by 2050. This is equivalent to an energy efficiency improvement of 0.99 % a year in the period 2012 to 2050. The BAT is the lowest BPT, either on national or international level. For the fertilizer sector this is the international BAT value of 23.80 GJ/Ton in the year 2012.

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

- In the IEA publication Energy Technology Transitions for Industry (IEA/OECD, 2009) the demands for ammonia are projected.
- The ammonia demand is shown as "per capita (kg/cap)" for the regions "South Africa" and "Other Africa".
- For the saving scenarios the value for "Other Africa" was chosen and corrected to get the value for 2012 and the corresponding increase to 2030 and 2050.
- Furthermore the average between high and low demand was chosen. For ammonia demand it is 2.04 for 2050 and 1,3 for 2030. This means that the average per capita demand increases by approximately the factor of 1,3 until 2030 and 2,0 until 2050.
- In addition the population growth for Egypt for this period was taken from the United Nations, World Population Prospects: The 2012 Revision, available on: http://esa.un.org/wpp/unpp/panel_population.htm
- From this source the factor for the population growth between 2012 and 2050 for Egypt was taken. This factor is 1.51 for 2050 and 1,27 for 2030.

To get the factor for the increase in the demand between 2012 and 2050 the factors are multiplied:

- Ammonia: 3.07

This means that until 2050 the demand for fertilizers increases by a factor bigger than 3.

The factor for the increase in the demand between 2012 and 2030 is:

- Ammonia: 1.63

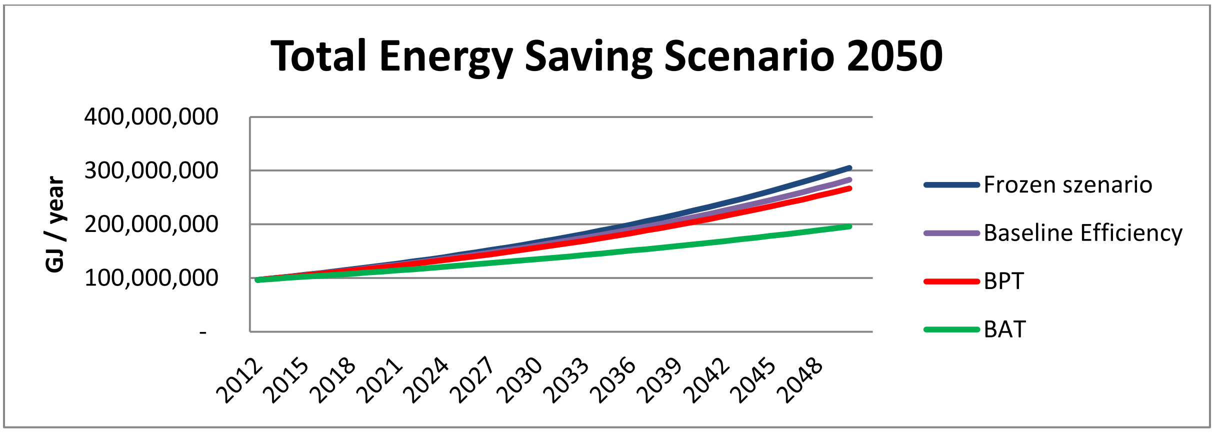


Figure 26: Total Energy Saving Scenario 2050

4.7.2 Energy Savings in 2030

In this chapter different energy saving scenarios until 2030 is 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 0.2 % a year

BPT scenario: all plants are operating at the current levels of BPT by 2030. This is equivalent to an energy efficiency improvement of 0.69 % a year in the period 2012 to 2030. The BPT is the lowest BPT, either on national or international level. For the fertilizer sector this is the national BPT value of 33.42 GJ/Ton in the year 2012.

BAT scenario: all plant is operating at current levels of BAT by 2030. This is equivalent to an energy efficiency improvement of 2.09 % a year in the period 2012 to 2030. The BAT is the lowest BPT, either on national or international level. For the fertilizer sector this is the international BAT value of 23.80 GJ/Ton in the year 2012.

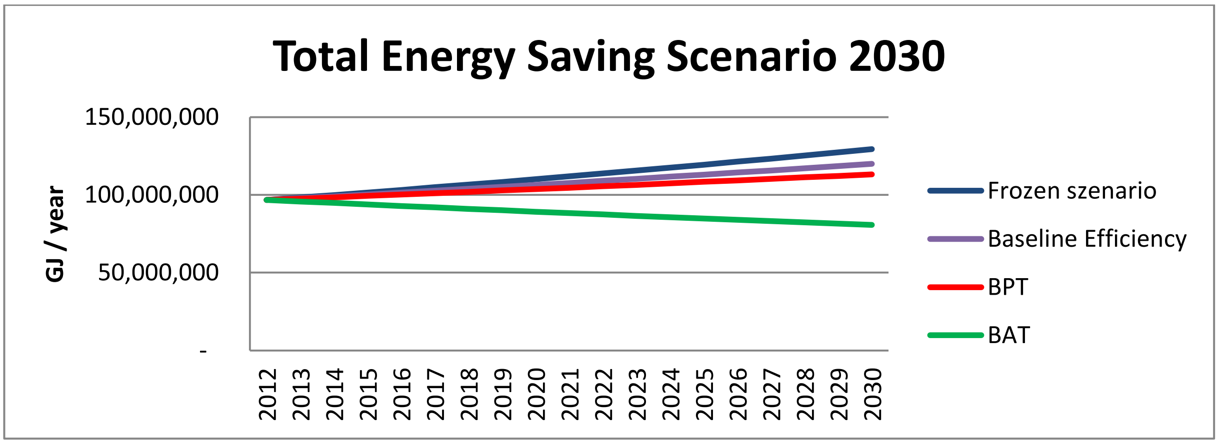


Figure 27: Total Energy Saving Scenario 2030

4.7.3 Energy Savings in 2030 and 2050

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

Table 36: Energy Savings in 2030 and 2050

	Total Energy Consumtion of the Sector				Energy Savings of BAT Scenario vs. Frozen Scenario	Cumulative BAT Scenario (GJ)
	Frozen Scenario (GJ)	Baseline Scenario (GJ)	BPT Scenario (GJ)	BAT Scenario (GJ)	Energy Savings of BAT Scenario vs. Frozen Scenario	Cumulative BAT Scenario (GJ)
2012	96,709,790	96,709,790	96,709,790	96,709,790	-	
2030	129,379,390	119,920,017	113,162,496	80,588,492	48,790,898	453,709,413
2050	305,138,445	282,828,722	266,891,256	195,901,217	109,237,228	1,608,183,733

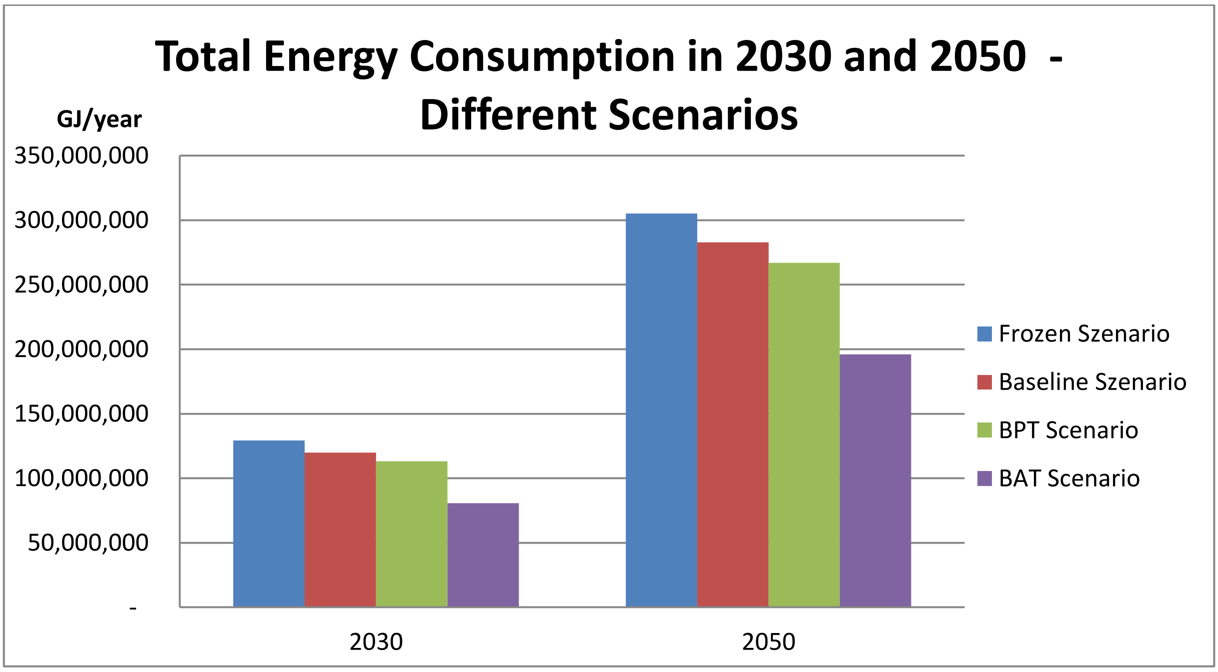


Figure 28: Energy Savings in 2030 and 2050

4.8 Saving Opportunities

The following table shows the recommended options for energy savings in the companies subject to the study as presented in the BREF[11]. The options are divided to:

[11] BREF: http://eippcb.jrc.ec.europa.eu/reference/lvic-aaf.html

- “No-Cost” option: Implemented at no cost such as improving behaviors, control of resources, etc.
- “Low-Cost” option: These options are implemented at reduced cost.
- Investment: In such case equipment may be installed.

In reference to the collected data sheets, some companies have already implemented certain measures as shown in the following table; also the percentage of implementation is recorded in the next table.

Table 37: Energy Saving Measures

#	Measures*		Investment Cost	F1-P1	F1-P2	F1-P3	F5	F6	F8	F9	% Yes	% No
1	**Ammonia**											
1.01	Increasing the temperatures of the mixed feed and process air in line with the current limits		Medium	Yes	Yes	Yes	Yes	Yes	No	Yes	**86%**	**14%**
1.02	Utilizing the recovered heat after the secondary reformer to raise and superheat steam		Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**100%**	**0%**
1.03	Applying improved designs of high temperature shift reactors for lower steam to carbon ratio		High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**100%**	**0%**
1.04	Utilizing ammonia converter designs which use small size catalysts for higher conversions		High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**100%**	**0%**
1.05	Ensuring the efficient recovery of a large proportion of reaction heat energy from the ammonia synthesis		Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**100%**	**0%**
1.06	Applying a highly efficient ammonia condensation and refrigeration system.		High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**100%**	**0%**
2	**Urea**											
2.01	CO_2 and NH_3 separation Reactor Conditions	NH3/CO2 ratio 4:1	No cost	No	No	No	No	**Non-Producer for Urea**	No	No	**0%**	**100%**
		Conversion 65 – 67 % of CO2 input	No cost	No	No	No	No		No	No	**0%**	**100%**
		Pressure 200 bar	No cost	No	No	No	No		No	No	**0%**	**100%**
2.02	Total recycling CO_2 stripping process Conditions	NH3/CO2 ratio 2.8, CO2 is fed via the HP stripper	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**
		Temperature 180 ºC	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**
		Pressure 140 bar	No cost	Yes	Yes	Yes	Yes		No	Yes	**83%**	**17%**
2.03	Total recycling NH_3 stripping process Conditions	NH3/CO2 ratio 3.5	No cost	No	No	No	No		No	No	**0%**	**100%**
		Temperature 170 ºC	No cost	No	No	No	No		No	No	**0%**	**100%**
		Pressure 150 bar	No cost	No	No	No	No		No	No	**0%**	**100%**
2.04	almost complete raw material	40% of the ammonia is fed to the carbamate condenser. The remainder goes directly to the reactor to control the	High	No	No	No	No		Yes	No	**17%**	**83%**

#	Measures*		Investment Cost	F1-P1	F1-P2	F1-P3	F5	F6	F8	F9	% Yes	% No
	recovery	temperature.										
2.05	Safe NH3 washing from inert	the availability on site of flammable gas at the right pressure	High	No	No	No	No		No	No	**0%**	**100%**
		the availability of the NH3 recovery system	High	Yes	Yes	Yes	No		No	Yes	**67%**	**33%**
		The possibility of using the resulting gas stream as a fuel, e.g. for a boiler.	High	Yes	Yes	Yes	No		No	No	**50%**	**50%**
2.06	Redirecting fines to the concentrated urea solution	solidification process is applied	High	No	No	No	No		Yes	Yes	**33%**	**67%**
2.07	Revamping conventional plants with stripping technology		High	No	No	No	No		Yes	No	**17%**	**83%**
2.08	Combined condensation and reaction in one vessel		High	No	No	No	No		Yes	No	**17%**	**83%**
2.09	Minimization of NH3 emissions from granulation		Medium	No	No	No	No		Yes	Yes	**33%**	**67%**
2.10	Treatment of exhaust gas from prilling/granulation		Medium	No	No	No	No		Yes	Yes	**33%**	**67%**
2.11	Monitoring of key performance parameters	Feedstock	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**
		Utilities consumed	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**
		Utilities generated	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**
		Products	No cost	Yes	Yes	Yes	Yes		Yes	Yes	**100%**	**0%**

*..The measures are determined by the national experts

5 Recommendations

5.1 Strengthening the Statistical Data Collection Process in Egypt

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

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

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

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

5.2 Implementing Support Programmes for Industry

The fertilizers sector includes both new and old technologies used in the production lines. All new companies are using BAT and follow the recommendations of the technology suppliers; this is obvious from the specific electricity consumption, which is not too far from the BAT (according to AJER); however, no complete energy management systems are applied neither in the new nor in the olds companies. Accordingly, the following recommendations are to be taken into consideration to support the energy management in all companies:

- Creation of energy management systems in all companies
- Application of preventive maintenance program rather than corrective, which is currently applied
- The old companies are ultimately think of replacing the current used technologies with the-state –of - the- art at least on the medium term
- Implementation of heat recovery systems
- Review the boilers performance (air to fuel ratios, temperature of feed water, etc.) to save energy
- insulate steam networks, to minimize the loss especially in that the recovered steam is used in power generation

It is worth noting that the major problem in the fertilizers sector is the natural gas shortage (as feed stock), which is reflected on the company performance; this could not be accounted as energy deficiency. This problem started in 2013. This problem is affecting the equipment as it is running idle for long periods. This problem should be radically solved with the Government of Egypt.

5.2.1 Energy Management Programmes

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

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

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

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

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

Benefits of Energy Management Programmes

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

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

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

5.2.2 Energy Audit Programmes

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

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

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

6 Literature

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7 Abbreviations

AEA	Austrian Energy Agency
BAT	Best Available Technology
BPT	Best Practice Technology
CAPMAS	Central Agency for Public Mobilization and Statistics
CHP	Combined Heat and Power
EE	Energy Efficiency
EEI	Energy Efficiency Index
EPI	Energy Performance Indicator
IEA	International Energy Agency
IDA	Industrial Development Authority
IEE	Industrial Energy Efficiency
PV	Photovoltaic
SEC	Specific Energy Consumption
SME	Small and Medium Sized Enterprise
TFEU	Total Final Energy Use

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