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Energy Efficiency Indicators in Intensive Energy Consuming Industries (IECI) in the Arab Region

United Nations
Beirut, 2017

Note: The opinions expressed in this document are those of the authors and do not necessarily reflect the views of ESCWA.

17-00047

CONTENTS

Summary

This working paper reviews energy efficiency (EE) indicators in intensive energy consuming industries (IECI) in the Arab region in the general framework of the United Nations Secretary General's Sustainable Energy for All (SE4ALL) initiative and the 2030 Agenda for Sustainable Development, in particular Goals 7 (target 3), 9, 12 and 13.

In chapter I, the paper reviews the energy consumption indicators in the industrial sector worldwide and looks at the contribution of industry to gross domestic product (GDP) and added value in the Arab region. The chapter considers energy consumption patterns, the potential for saving energy and related priority areas, carbon dioxide (CO2) emissions and reductions due to EE improvements, and specific energy consumption (SEC).

Chapter II discusses the main characteristics of intensive energy consuming industries (IECI), energy consumption patterns and efficiency indicators. It also provides indicative values for potential energy savings in different IECI, and overviews the technologies and energy aspects in the most significant IECI (aluminum, cement, iron and steel, and chemicals, petrochemicals and fertilizers).

Chapter III presents calculations of energy consumption, energy saving, CO2 emissions and reductions, and potential revenue due to implementing net profit EE and CO2 abatement measures in 65 IECI in Arab countries. It also looks at priority areas, measures and policies for improving EE in IECI.

In conclusion, the paper discusses the components of a national EE programme in IECI and related actions to put them into effect, and also potential barriers to implementation in Arab counties. Work is needed in several areas, including: more data on end-use energy consumption among IECI, energy audits and the drafting of national EE strategies for IECI that reflect the goals of the 2030 Agenda.

ACRONYMS

BAT	best available technology
BF-BOF	blast furnace-basic oxygen furnace
BOF	basic oxygen furnaces
BPT	best practice technologies
CHP	combined heat and power
CO_2	carbon dioxide
DRI-EF	direct reduced iron with electric furnace
EAF	electric arc furnace
EE	energy efficiency
EP	energy productivity
exajoule (ej)	1,000,000,000,000,000,000 joules
gigajoule (gj)	1,000,000,000 joules
GCC	Gulf Cooperation Council
GDP	gross domestic product
Gt	gigatons
IEA	International Energy Agency
IECI	intensive energy consuming industries
ISIC	International Standard Industrial Classification of All Economic Activities
kgoe	kilogrammes of oil equivalent
kVA	kilovolt-amps
kW	kilowatt
MACC	marginal abatement cost curve
OHF	open hearth furnace
petajoule (pj)	Equivalent to 10^{15} joules
SEC	specific energy consumption
SE4ALL	Sustainable Energy For All
Toe/Mtoe	Tons of oil equivalent/Million tons of oil equivalent
WHR	waste heat recovery

I. ENERGY SITUATION IN THE INDUSTRIAL SECTOR

A. THE INDUSTRIAL SECTOR WORLDWIDE

The industrial sector supports economic and social development, providing strategic products and supporting other sectors, such as agriculture and services. It attracts foreign direct investment and contributes to boosting exports and GDP. It also creates, through value chains, a considerable number of decent jobs.

The industrial sector accounts for more than one third of global primary energy use;[1] in terms of end energy use, the figure is higher (about half the global total) due to non-fuel uses and conversion losses in the industrial sector.[2] Industry is also responsible for one third of energy-related carbon dioxide emissions.[3] Global industrial energy use is expected to double current levels by 2050 in the absence of new emission reduction measures. Even with the most ambitious reductions policy, energy use will still increase by at least 50 per cent.[4] Intensive energy consuming industries (IECI), especially chemicals and petrochemicals, and iron and steel, account for around half of total global industrial energy use.[5]

In 2014, industry accounted for 42.5 per cent of electricity, 38.6 per cent of natural gas, 8 per cent of oil and 79.8 per cent of coal consumption around the world. The rate of electricity, natural gas, oil and coal use in the industrial sector recorded annual rises between 1973 and 2014 of, respectively, 4.9 per cent, 1.2 per cent, -0.8 per cent, 2.6 per cent respectively, with total annual growth of energy consumption of 1.5 per cent.[6] On average, energy accounts for between 10 per cent and 20 per cent of the total production cost of industrial products.[7] In developing countries, the industrial sector consumes more than half of energy supply.[8] In the Arab region, it represents 29 per cent of total energy consumption in the industrial sector. Consumption between 2010 and 2014 grew by an average of 6.18 per cent, rising from 162.07 million tons of oil equivalent (Mtoe) to 229.89 Mtoe.[9,10]

The potential for global energy cost savings is estimated at $230 billion a year, including energy savings through improved operation and maintenance practices and equipment retrofits, but excluding modernization to adopt best available technologies (BAT). The developed world accounts for $65 billion of that total, and

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1 Aimee McKane and others, *Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies, Executive Summary*, United Nations Industrial Development Organization (UNIDO, Vienna, 2008). Available from https://www.unido.org/fileadmin/media/documents/pdf/Energy_Environment/ind_energy_efficiencyEbookv2.pdf.

2 See www.eia.gov/tools/faqs/faq.cfm?id=447&t=1.

3 McKane, *Policies*.

4 Tamaryn Brown and others, Reducing CO_2 emissions from heavy industry: a review of technologies and considerations for policy makers, briefing paper No. 7, Grantham Institute for Climate Change (London: Imperial College, February 2012). Available from https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Reducing-CO2-emissions-from-heavy-industry---Grantham-BP-7.pdf.

5 Rangan Banerjee and others, Energy End-Use: Industry, *Global Energy Assessment – Toward a Sustainable Future*, chap. 8 (Cambridge: Cambridge University Press, 2012). Available from www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter8_industry_hires.pdf.

6 International Energy Agency (IEA), Key world energy statistics (Paris: 2016). Available from www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf.

7 Deger Saygin and others, Global industrial energy efficiency benchmarking: an energy policy tool, working paper (UNIDO, November 2010). Available from https://www.unido.org/fileadmin/user_media/Services/Energy_and_Climate_Change/Energy_Efficiency/Benchmarking_%20Energy_%20Policy_Tool.pdf.

8 McKane, *Policies*.

9 Organization of Arab Petroleum Exporting Countries (OAPEC) – Tenth Arab Energy Conference, 2014.

10 ترشيد استخدام الطاقة في القطاع الصناعي في الدول العربية، مؤتمر الطاقة العربي الثامن، الأردن، أيار/مايو 2006.

developing countries and economies in transition the remainder.[11] Those savings represent about 2 per cent of current industrial value added worldwide. If developing countries implement the appropriate EE measures to meet specific energy consumption (SEC) in developed countries, total energy consumption in the industrial sector could fall by more than half.[12] Implementing BAT in the next 20 years could lead to energy savings of 34 per cent, with a yearly improvement rate of 1.7 per cent.[13]

B. The industrial sector in the Arab region

Characteristics: The industrial sector in Arab countries is characterized by: dependence on imported technology; use of fossil fuels, particularly oil and natural gas (some key industries are making the transition to natural gas); lack of investment needed for development; high cost of energy in non-oil producing countries; public and private ownership; low energy efficiency, mainly due to energy subsidies and use of old technologies; low labour productivity, due to the lack of skills and inadequate training. Development of the industrial sector in the Arab region is influenced by a range of factors, including: population growth; the rising consumption of individual industrial products; a shift to the services sector; the expansion of heavy industries; a trend towards the adoption of EE policies, especially the use of alternative energy sources and EE technologies.[14]

Contribution to GDP: Mining and quarrying contributed 40 per cent of GDP in the Arab countries in 2012 (see table 1 and figure 1). That contribution was as high as 60 per cent in oil-rich countries such as Iraq and Qatar, as little as 5 per cent in Jordan, and even less in Djibouti, Lebanon, Palestine, Somalia and the Sudan. On average, manufacturing accounted for 10 per cent of GDP across the region. That figure reached 16 per cent in non-oil rich countries like Egypt, Jordan and Tunisia, but was below 5 per cent in oil-rich countries such as Iraq and Kuwait.[15] The sharp decrease in the share of mining and quarrying in GDP in 2009 was mainly due to the drop in the price of oil from $94.10 a barrel in 2008 to $60.86 in 2009.[16] The added value (in millions of United States dollars) for manufacturing and mining and quarrying industries for the years (2010-2012) in ESCWA countries is given in table 2. Many Arab countries have made considerable efforts to boost the contribution of their industrial sectors to GDP. Several countries are working on diversifying income sources through industrial development, particularly in IECI, which will lead to an increase in industry energy consumption.

Output: Based on 2005 constant prices, output of mining and quarrying industries in Arab countries increased from $1,381 per capita in 2009 to $1,508 per capita in 2012 (annual average growth rate of 3.07 per cent). In ESCWA member countries, it increased from $1,475 per capita in 2009 to $1,628 in 2012 (annual average growth rate of 3.5 per cent). For manufacturing industries, output in Arab countries rose from $405 per capita to $440 between 2009 and 2012 (annual average growth rate of 2.9 per cent), and in ESCWA member countries from $456 per capita to $496 (annual average growth rate of 2.92 per cent).[17]

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[11] McKane, *Policies*.

[12] Ibid.

[13] Deger Saygin, *Global*.

[14] Ibid.

[15] E/ESCWA/SD/2015/2.

[16] See www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/.

[17] E/ESCWA/SD/2015/2.

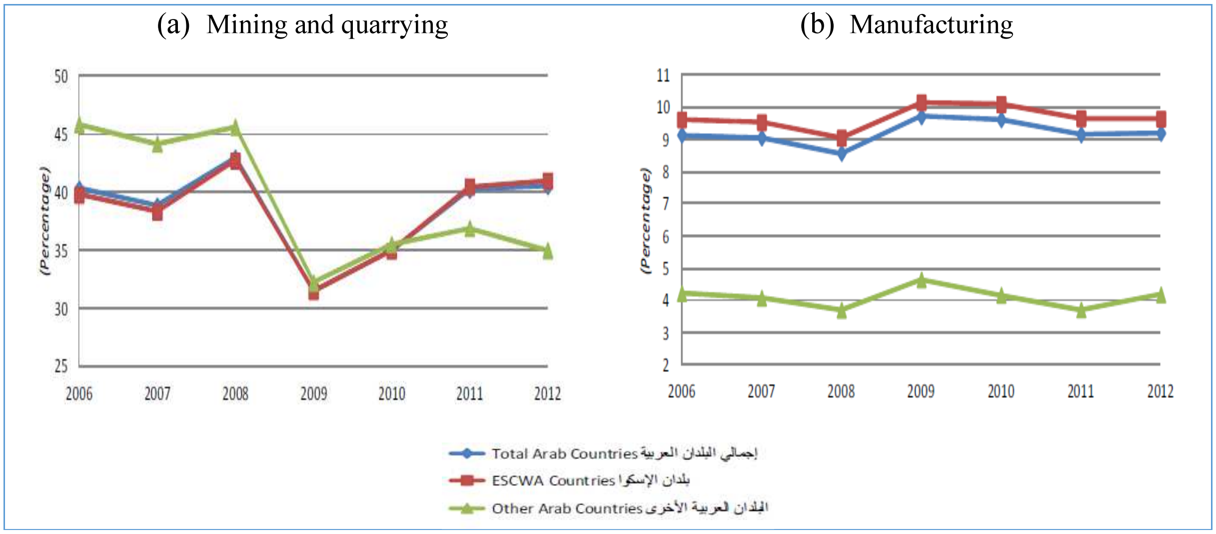
Table 1. GDP share in Arab countries (percentage), 2012

Country	Mining and quarrying	Manufacturing
Algeria	35.6	4.2
Bahrain	26.4	15.0
Djibouti	4.7	2.2
Egypt	16.4	15.5
Iraq	59.2	1.9
Jordan	5.5	16.5
Kuwait	64.0	5.4
Lebanon	-2.2*	7.4
Libya	54.4	4.6
Mauritania	22.0	6.2
Morocco	7.3	14.8
Oman	53.8	10.1
Palestine	2.2	10.8
Qatar	58.2	9.8
Saudi Arabia	48.1	10.1
Somalia	0.6	2.2
Sudan	2.4	9.7
Syrian Arab Republic	21.5	4.7
Tunisia	8.5	16.0
United Arab Emirates	42.6	9.0
Yemen	23.2	8.8
Total Arab countries	40.5	9.2
ESCWA member countries	41.0	9.6
Other Arab countries	35.0	4.2

Source: E/ESCWA/SD/2015/2.

* Electricity and water supply only, and including mining and quarrying.

Figure 1. Share of industries in GDP in Arab countries, 2006-2012



Source: E/ESCWA/SD/2015/2.

Table 2. Added value for manufacturing, mining and quarrying in ESCWA countries (millions of United States dollars)

Country	Manufacturing industries	Mining and quarrying	Total industry	Percentage of mining and quarrying from total industry	Year
Bahrain	3,349	5,527	8,876	62.3%	2010
Egypt	19,494	23,666	43,160	54.8%	2010
Iraq	1,655	NA	NA	NA	2012
Jordan	5,378	1,453	6,831	21.3%	2011
Kuwait	8,072	96,374	104,446	92.3%	2011
Lebanon	2,026	2	2,028	0.1%	2007
Morocco	11,307	NA	NA	NA	2010
Oman	6,157	NA	NA	NA	2010
Palestine	1,483	34	1,517	2.2%	2012
Qatar	8,801	61,396	70,197	87.5%	2010
Saudi Arabia	13,073	NA	NA	NA	2005
Sudan	1,658	NA	NA	NA	2007
Syria Arab Republic	3,256	12,938	16,194	79.9%	2010
Tunisia	7,092	2,484	9,576	25.9%	2007
United Arab Emirates	25,143	88,510	113,653	77.9%	2010
Yemen	2,884	7,361	10,245	71.8%	2012

Source: E/ESCWA/SD/2013/12.

Energy: In the Arab region, industry accounts for consumption of 20 per cent of oil, 22 per cent of natural gas, 3.5 per cent of electricity and 0.2 per cent of coal.[18] Table 3 shows estimated annual overall energy consumption (in Mtoe) in the industrial sector in 17 Arab countries between 2010 and 2014.[19] Total consumption in that sector rose from 162.07 Mtoe in 2010 to 230 Mtoe in 2014 (annual average growth rate of 6.18 per cent). Industry accounts for 29 per cent of total consumption, but the figure varies considerably from one country to another (from 10.7 per cent in Morocco to 56 per cent in the United Arab Emirates). Within the industrial sector, manufacturing accounts for 61 per cent of total energy consumption in the Arab countries, while mining and quarrying represent 29 per cent.

Table 3. Energy consumption in the industrial sector (Mtoe/year)[*]

Country	2010	2011	2012	2013	2014	Annual growth rate (2010-2014)	Share of industrial sector in total energy consumption (2010-2014)
Algeria	7.0	7.4	7.9	8.4	8.9	3.9%	16.0%
Bahrain	3.3	3.6	3.8	4.1	4.4	3.8%	28.5%
Egypt	19.7	20.5	21.4	22.4	23.4	2.4%	25.2%
Iraq	8.6	8.9	9.2	9.6	9.9	-3.3%	23.6%
Jordan	1.3	1.3	1.4	1.5	1.6	3.4%	18.0%
Kuwait	4.8	5.0	5.2	5.3	5.5	6.7%	19.3%
Lebanon	0.8	1.0	1.2	1.4	1.7	25.6%	19.8%
Libya	4.4	4.5	4.6	4.7	4.9	16.9%	21.1%
Morocco	1.2	1.5	1.8	2.3	2.9	18.6%	10.7%
Oman	4.7	6.4	8.8	12.0	16.5	23.5%	38.7%
Qatar	11.8	13.0	14.3	15.7	17.3	7.0%	20.9%
Saudi Arabia	51.8	55.3	59.0	62.9	67.1	2.0%	31.1%
Sudan	0.8	0.8	0.9	1.0	1.0	18.4%	15.7%
Syria Arab Republic	5.7	5.9	6.2	6.5	6.7	14.2%	28.2%
Tunisia	1.9	1.9	2.0	2.0	2.1	1.3%	24.3%
United Arab Emirates	31.4	35.7	40.7	46.3	52.8	8.4%	56.0%
Yemen	3.1	3.2	3.2	3.3	3.4	0.1%	42.0%
Total	162.07	175.88	191.52	209.36	229.89	6.18%	28.8%

[*] Estimates based on annual growth rate from 1980 to 2009.

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18 مؤتمر الطاقة العربي العاشر، فرص ترشيد استهلاك الطاقة في الدول العربية، أبو ظبي 21-23 كانون أول/ديسمبر 2014.

19 Organization of Arab Petroleum Exporting Countries (OAPEC) – Tenth Arab Energy Conference, 2014.

II. INTENSIVE ENERGY CONSUMING INDUSTRIES (IECI): CHARACTERISTICS, ENERGY CONSUMPTION AND POTENTIAL EFFICIENCY GAINS

A. IECI CHARACTERISTICS

Industries are classified by three categories in terms of energy consumption:[20] Intensive energy consuming industries (IECI), such as cement, glass, iron and steel, aluminum, and chemicals and petrochemicals; medium energy consuming industries (MECI), such as furniture, tobacco, printing, leather and textiles; and low energy consuming industries (LECI), such as cars, computers, appliances, electrical and electronic, equipment and machinery industries.

Energy in IECI is used in industrial processes for heating/cooling, power and electricity generation, and in some cases as a raw material "feed stock", such as natural gas in the petrochemicals/fertilizer industry and coal in the steel industry. IECI are characterized by:

- High SEC. Smaller and older IECI plants are typically high SEC and inefficient. A plant that operates below capacity has a higher SEC compared with a plant that operates at nameplate capacity;
- High proportion of industrial sector energy consumption. For example, the chemical and petrochemical and iron and steel industries account for approximately half of all industrial sector energy used worldwide;[21] in Egypt, the figure is more than 60 per cent;
- High potential for energy saving. Approximately two thirds of the total savings potential in the industrial sector can be found in IECI. Such savings could reduce total production costs by between 3 and 4 per cent;[22]
- High portion of energy cost in total production cost (20 to 50 per cent for the chemicals industry,[23] 15 to 20 per cent for the steel industry, 20 to 40 per cent for the cement industry,[24] 14 per cent for the glass industry in the United States of America);[25]
- Heavy impact on the environment because of the type of fuels and raw materials used. The iron and steel industry accounts for 25 per cent of direct global industrial CO_2 emissions, followed by chemicals and petrochemicals, with for 16 per cent;[26]
- High possibility of using alternative energy sources. In the steel industry, for instance, by-product gases from coke ovens, blast furnaces and basic oxygen furnaces (BOF) can be fully reused. Waste heat from sulfur units in the fertilizer industry can be recovered, and waste chemicals, wood waste, used tires and biomass in the cement industry can be used;
- Use of energy in major processes, including the extraction of natural resources and their conversion into raw materials, and in the manufacture of finished products.

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[20] E/ESCWA/ENR/2001/14.

[21] Deger Saygin, *Global*.

[22] Ibid.

[23] Ibid.

[24] See www.climatetechwiki.org/technology/energy-saving-cement.

[25] See www.energystar.gov/ia/business/industry/Glass-Guide.pdf.

[26] IEA, Tracking industrial energy efficiency and CO_2 emissions (Paris, 2007). Available from https://www.iea.org/publications/freepublications/publication/tracking_emissions.pdf.

The presence of IECI is generally either steady or in decline in industrialized countries. In developing countries where infrastructure and buildings are being constructed, the presence of IECI is growing and in many cases they account for more than half of the industrial sector's energy consumption.[27] There are IECI in many Arab countries (figure 2).

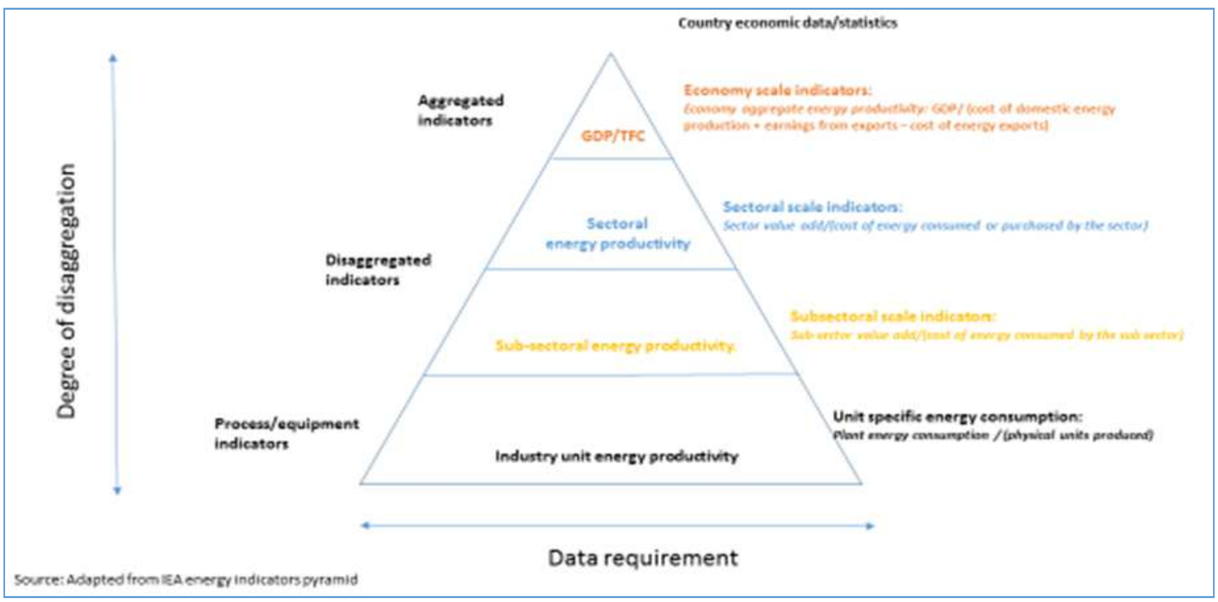
Figure 2. Main IECI in the Arab countries

Iron and steel	Aluminum	Cement	Fertilizers	Petrochemicals	Glass
• Algeria • Egypt • Iraq • Saudi Arabia • United Arab Emirates	• Bahrain • Egypt • Jordan • Qatar • Saudi Arabia • United Arab Emirates	• All Arab countries	• Algeria • Egypt • Jordan • Qatar • Morocco • Saudi Arabia	• Algeria • Egypt • Jordan • Qatar • Morocco • Saudi Arabia	• Almost all Arab countries

B. Energy efficiency indicators in IECI

EE indicators provide a crucial guide for energy policy and are essential for tracking progress in the implementation of energy efficiency strategies. The International Energy Agency (IEA) uses a pyramid of energy productivity (EP) indicators, divided into four levels (figure 3).

Figure 3. Industrial EP indicators



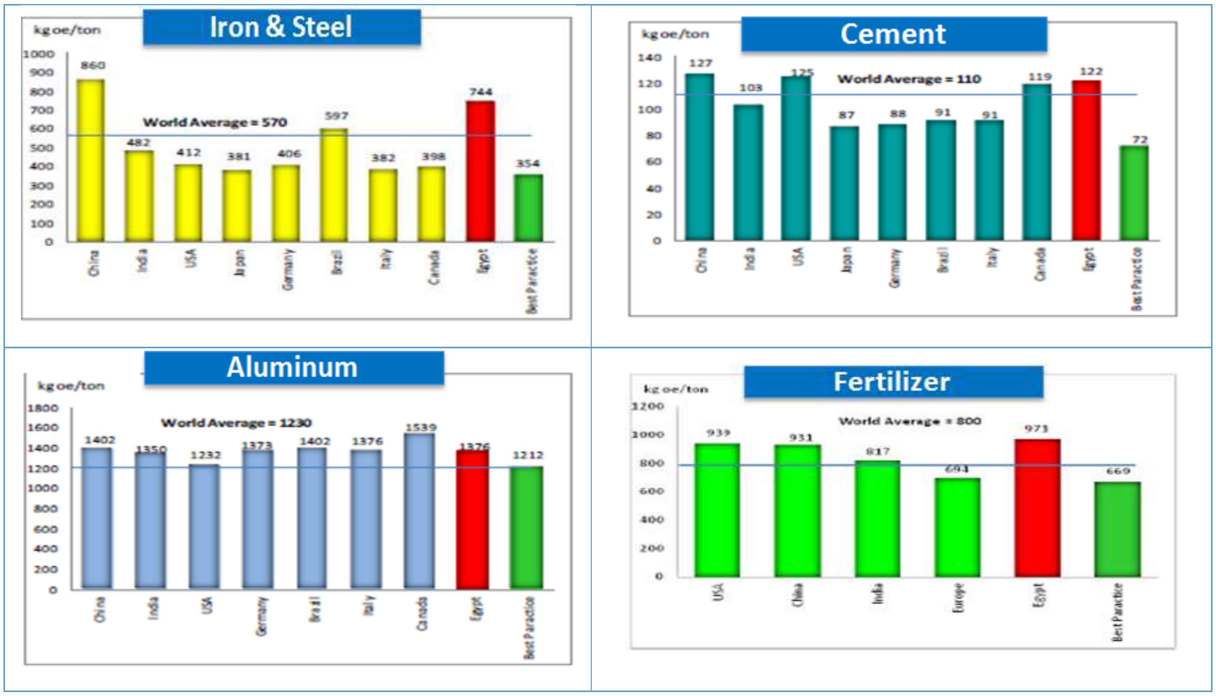
In order to obtain an overall picture with regard to IECI energy efficiency, EE indicators are needed at various levels, starting with plant equipment and moving up through the levels of facility, subsector, sector and, finally, the national level. Each level has its own specific indicators.

The EE indicator measures the ratio between energy consumption (in energy units) and activity data (in physical units). In IECI, they can measure energy consumption per ton of product or per United States dollar

[27] McKane, *Policies*.

of added value. Average SEC for the cement, fertilizer, iron and steel, and aluminum industries in some countries is given in figure 4. The only consolidated case study on EE in IECI for an Arab country comes from Egypt, conducted in the framework of the United Nations Industrial Development Organization (UNIDO) Industrial Energy Efficiency Project.

Figure 4. Average SEC of IECI in selected countries



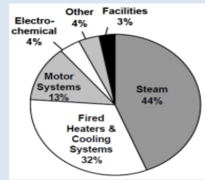
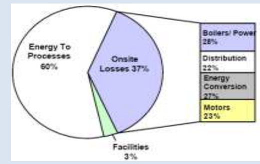
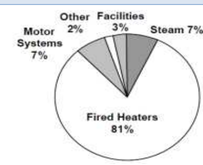
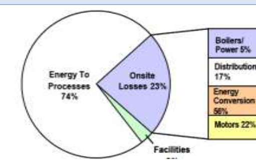
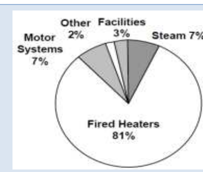
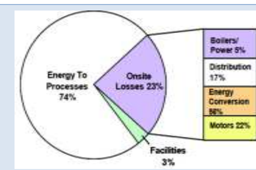
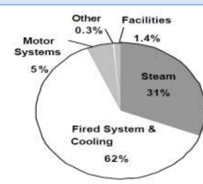
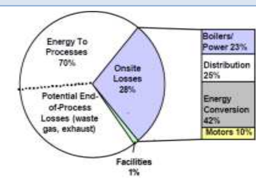
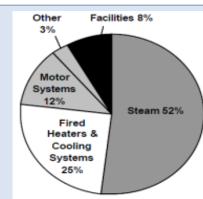
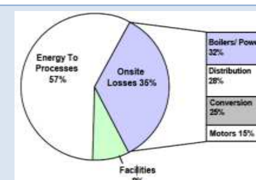
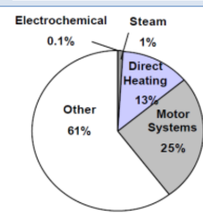
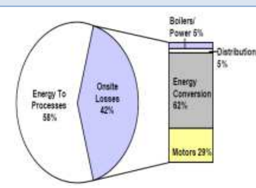
Source: UNIDO and others, *Industrial Energy Efficiency Baseline Assessment Report: Industrial Energy Efficiency Project in Egypt* (2014). Available from http://ieeegypt.net/wp-content/uploads/2016/04/IEE_Activity_Final.pdf.

C. Energy consumption and potential savings in IECI

1. *Consumption patterns*

Patterns of energy consumption and losses, whether thermal or electrical, vary from one industry to another, as does the percentage of energy use and losses. For example, in the United States of America, according to one study, steam generation is the main source of energy in the chemical and food industries, while furnaces predominate in the aluminum and iron and steel sectors (table 4). Determining the type and indicative percentages of energy end use and onsite energy losses in different industries helps to identify the direction of EE efforts and rank priority areas by industry.

Table 4. Share of fuels and electricity, energy end-use distribution and onsite energy losses for selected industries (indicative values) in the United States of America

Industries		Thermal/fuel share (percentage)	Electricity share* (percentage)	Energy end use distribution (percentage)	Onsite energy losses (percentage)
IECI	Chemicals (including fertilizers)	84%	16%		
	Aluminum	44%	56%		
	Iron and steel mills	90%	10%		
	Cement	89%	11%	NA	NA
	Glass and glass products	79%	21%	NA	NA
	Petroleum refining	96%	4%		
Non-IECI	Food and beverage	79%	21%		
	Mining	68%	32%		
	Textile	61%	39%	NA	NA
	Plastics and rubber	44%	56%	NA	NA
	Fabricated metal	60%	40%	NA	NA
	Transported equipment	60%	40%	NA	NA
	Foundries	73%	27%	NA	NA

Source: Energetics, Incorporated and E3M, Energy Use, Loss and Opportunities Analysis, U.S. Manufacturing and Mining (December 2014).

* Based on equivalence of electrical energy with thermal energy.

2. *Saving potential*

IECI can increase EE by: upgrading inefficient equipment and technologies; improving operational and maintenance practices; adopting energy management policies at the company level, and implementing energy management systems like ISO 50001. The broad adoption of best practice technologies (BPT) would could bring about significant reductions in energy consumption.[28] Efforts in the past 40 years have brought a global reduction in SEC of 50 per cent, but the cost of energy still represents a considerable portion of total production cost in IECI. There is still great potential for short-term energy savings in selected IECI, in particular in developing countries (table 5).

Table 5. Energy savings potential in selected IECI in industrialized and developing countries

Industry		Short-term energy savings (percentage)	
		Industrialized countries	Developing countries
Iron and steel		10%	30%
Cement		20%	25%
Glass		30-35%	40%
Aluminum	Alumina production	35%	50%
	Aluminum smelters	5-10%	5%
Chemicals and petrochemicals	Steam cracking (excluding feedstock)	20-25%	25-30%
	Ammonia	11%	25%
	Methanol	9%	14%
Petroleum refineries		10-25%	40-45%

Source: Deger Saygin and others, Global industrial energy efficiency benchmarking: an energy policy tool, working paper (UNIDO, November 2010). Available from https://www.unido.org/fileadmin/user_media/Services/Energy_and_Climate_Change/Energy_Efficiency/Benchmarking_%20Energy_%20Policy_Tool.pdf.

D. IECI TECHNOLOGIES AND ENERGY USE IN SELECTED INDUSTRIES

1. *Cement*

The cement industry, with simple processes, well defined system boundaries and a uniform product, is well suited to EE indicator analysis enabling comparison of performance between plants in various regions and countries. Cement manufacturing is the third largest energy-consuming and CO_2 emitting sector globally, with an estimated 1.9Gt of CO_2 emissions from thermal energy consumption and production processes (about 5 per cent of all CO_2 emissions) in 2006. Some of the key energy intensity indicators include: total primary energy consumption per ton of clinker produced; thermal energy consumption per ton of clinker produced; electricity consumption per ton of clinker produced; clinker-to-cement ratio; CO_2 emissions per ton of cement.

[28] Deger Saygin, *Global*.

Moreover, over half of CO_2 emissions related to cement production are due to chemical reactions, especially in the production of lime (the key element in cement).[29]

Limestone (calcium carbonate/CaCO3), clay and sand are used to produce cement. The raw materials are milled, mixed and fed in to a kiln system. Inside the pre-heaters, the raw material is heated to around 900°C.[30] Cement is produced using either wet or dry technology. The former is characterized by low energy efficiency, which can be improved by optimizing preheating and combustion systems, adapting to semi-wet conversion, and enhancing heat recovery in clinker coolers. Wet processes tend to be the preserve of old plants built in the 1960s and 1970s, most of which have been phased out in Arab countries. The dry process, which eliminates the need for water evaporation, is less energy intense. The other major difference lies in the use of the more efficient rotary kilns, rather than vertical shaft kilns. EE gains in the dry process could be made in terms of preheating, heat recovery and cogeneration.

Energy is consumed mainly in fire and steam systems and motor drives, and above all in the heating (which accounts for about 74 per cent of energy consumption[31]), calcining and sintering of blended and ground materials to form clinker. About 30 per cent of electrical energy is consumed in grinding, 30 per cent in the clinker burning process (mainly used for the fans), and 24 per cent in mills.[32]

EE gains and reductions in CO_2 emissions in the cement industry can be achieved in three main ways: by changing production processes, with a focus on energy systems; adjusting the chemical composition of cement; and using more energy efficient technologies.[33] This could involve increasing the ratio of clinker substitutes in order to reduce process emissions from calcination,phasing out old kilns and adding pre-heaters and a pre-calciner to modern rotary kilns, and using advanced milling and grinding equipment.[34] The high cost of energy in the cement industry should serve as an incentive to improve EE and reduce energy consumption.[35]

Worldwide, the cement industry consumes 2.7 Mtoe of biomass and 0.8 Mtoe of waste per year, making up less than 2 per cent of total fuel use in the industry. Tires, wood, chemicals, plastics and other types of waste could be used "in large quantities" as co-combustion in kilns. In some countries (Belgium, France, Germany, the Netherlands and Switzerland) kilns are fired using 30 to 70 per cent alternative fuels. In the United States, the cement industry burns 53 million used tires (0.39 million tons, with an energy equivalent of 15pj).[36] In some Arab countries, alternative fuels used include solid and liquid waste, coke oil and shale oil. The national cement company in the United Arab Emirates uses tires with fuel oil; 5 per cent of the fuel mix used in cement factories in Jordan is olive peat.[37]

29 See www.climatetechwiki.org/technology/energy-saving-cement.

30 Brown and others, Reducing CO_2 emissions.

31 See www.climatetechwiki.org/technology/energy-saving-cement.

32 See www.energyefficiencyasia.org/docs/IndustrySectorsCement_draftMay05.pdf.

33 See www.climatetechwiki.org/technology/energy-saving-cement.

34 Brown and others, Reducing CO_2 emissions.

35 See www.climatetechwiki.org/technology/energy-saving-cement.

36 Ibid.

37 مجلة المختار للعلوم الاقتصادية، المجلد الأول العدد الأول السنة الأولى، حزيران/يونيو 2012، تحسين كفاءة الطاقة في الصناعات كثيفة الاستهلاك في الدول العربية، د. فلاح خلف علي الربيعي. http://www.omu.edu.ly/articles/OMU%20Journal/forms/No%201.pdf.

2. *Chemical and petrochemical sector and fertilizers*

The chemical and petrochemical industry converts raw materials such as natural gas, oil, water, air, metals and minerals into thousands of products, such as fertilizers, industrial gases, plastics, fibres and resins, which in turn are essential for manufacturing many consumer goods and materials needed in other industries.

Fossil fuels are used in the chemical and petrochemical industry sector as a source of thermal energy for heating, cooling, steam generation and the like. More than half are also used as "feed stock" in many chemical processes. The sector accounts for more than 30 per cent of total industrial energy usage around the world.[38]

The main types of fertilizer are potassium (K), phosphorus (P) and nitrogen (N). Ammonia (NH3) is the main active element and 90 per cent of fertilizers are produced from it. Its production, particularly the compression and heating processes, is highly energy intensive. In the Haber-Bosch process, ammonia is produced by combining hydrogen and nitrogen at high temperatures (300-550°C) and under high pressure (150-300 bar).[39]

Considerable energy savings can be made in the chemical and petrochemical sector. For example, in olefins and aromatics, savings could range from 10 per cent in polyvinyl chloride to 40 per cent in various types of polypropylene. Application of the best available technology to ammonia production could bring savings of about 20 per cent.[40]

In the Arab region, the petrochemicals industry is a key mover of economic development. Saudi Arabia accounts for 60 per cent of production in the region, followed by: Libya (11 per cent), Qatar (7 per cent), Kuwait (6.8 per cent), Egypt (5.5 per cent), Algeria (4.4 per cent), Iraq (2.9 per cent), Bahrain (2 per cent) and Jordan, Morocco, Oman, the Syrian Arab Republic and the United Arab Emirates (the remaining 0.4 per cent). As for fertilizers, the Arab region has about 70 per cent of the world's reserves of phosphate rock and 30 per cent of natural gas reserves, as well as generous stocks of sulfur and potash.

Gulf Cooperation Council (GCC) countries are considered a hub for the chemical and petrochemical industry, with an annual growth rate of 12 per cent. The chemical industry is the second largest manufacturing sector in GCC countries and represents 2.9 per cent of GDP, with annual revenues of $97.3 billion. The industry employs more than 148,700 people directly and for every job creates on average of three additional jobs in related industries.

3. *Iron and steel*

Between 2003 and 2013, global crude steel production rose from 927 million tons to 1,606 million tons, 48.5 per cent of it produced in China. By 2050, world output is expected to grow by 1.5 times that of 2013.[41] Steel is essential for many sectors, including infrastructure and construction (bridges, buildings), transport (railways, automobiles), utilities (power stations and municipal water systems), and manufacturing (including military hardware, energy and food storage equipment, appliances and tools). The construction sector accounts

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[38] Energy Information Administration, Manufacturing energy consumption survey (MECS): Chemical industry analysis brief. Available from www.eia.gov/consumption/manufacturing/briefs/chemical/index.cfm.

[39] UNIDO, Industrial energy efficiency project: benchmarking report for the fertilizer sector (Vienna, 2014). Available from https://open.unido.org/api/documents/4677044/download/Industrial%20Energy%20Efficiency%20Benchmarking%20Report%20for%20the%20Fertilizer%20Sector.

[40] IEA, Tracking industrial energy efficiency.

[41] World Steel Association, Energy use in the steel industry fact sheet. Available from https://www.worldsteel.org/publications/fact-sheets.html.

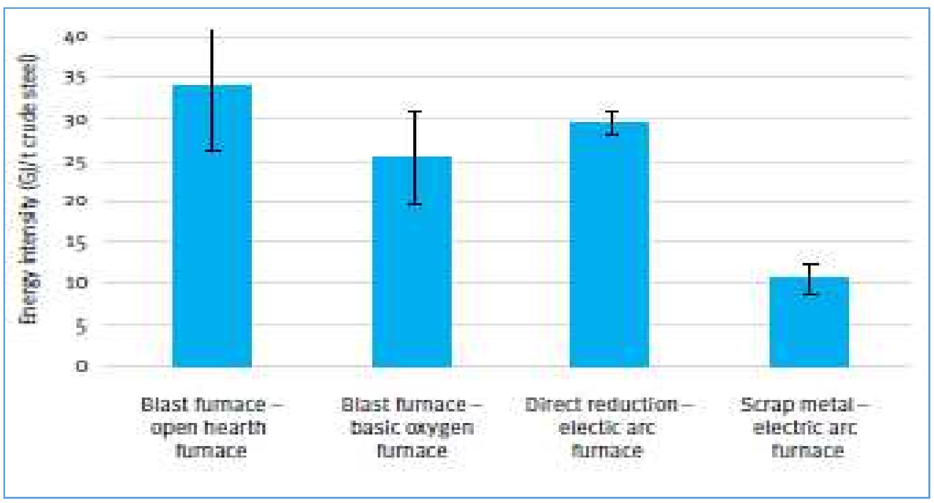
for 50 per cent of world steel consumption followed by transport (16 per cent), machinery (14 per cent), metal products (14 per cent), domestic appliances (3 per cent) and electrical equipment (3 per cent).[42]

The steel industry accounts for 5 to 10 per cent of CO_2 emissions worldwide. Given growth predictions, per unit emissions would have to be cut by half in order to stabilize emissions by 2050 at current levels.[43]

Primary steel production relies on coal, iron ore and limestone, and sometimes uses recycled steel, and consumes excessive energy per ton. Secondary production uses recycled steel. There are various industrial processes: direct reduction of iron ore; the manufacture of pig iron in molten or solid form; the conversion of pig iron into steel; the making of steel; the manufacture of shapes (such as bars, plates, rods, sheets, strips and wire); and the production of tubes and pipes.

Blast furnace-basic oxygen furnace (BF-BOF) processes account for about 70 per cent of global steel production. Some 29 per cent of steel is made in electric arc furnaces (EAF), whereby electricity is used to melt recycled steel. Only 1 per cent of steel is produced in open hearth furnaces (OHF), which are very energy intensive (see figure 5).[44] Replacing OHF with BOF could decrease SEC by 8 Gj/ton of steel; switching from BOF to scrap-EAF could decrease SEC by 20 Gj/ton of steel.[45] Another alternative is the direct reduced iron (DRI) process, which accounts for almost half of the total steel capacity of 25 million tons per annum in GCC countries. In that process, iron ore is reduced in its solid state, unlike the BF process, in which a liquid metal is formed during reduction. DRI can be transformed into steel in EAF. Steel production using DRI has expanded rapidly over the past decade in Bahrain, Qatar, Saudi Arabia and the United Arab Emirates.

Figure 5. Steel manufacturing SEC



Source: Brown and others, Reducing CO_2 emissions.

EE gains of up to 24 per cent could be made in the global iron and steel sector using existing technologies. Advanced technologies would be more effective still, taking energy savings to 29 per cent by

[42] Peter Wooders, Energy-Intensive Industries: Decision making for a low-carbon future: The Case of Steel (Winnipeg, Canada: International Institute for Sustainable Development (IISD), November 2012). Available from hwww.iisd.org/pdf/2012/tricc_energy_intensive_industries_steel.pdf.

[43] Ibid.

[44] World Steel Association, Energy use.

45 Brown and others, Reducing CO_2 emissions.

2020.[46] Although SEC in iron and steel has fallen by 60 per cent since 1960, energy still represents 20 to 40 cent of the total cost of steel production. Further improvement could come through: switching to more efficient processing methods (such as by phasing out OHF and using more scrap-AEF); increasing waste heat recovery (WHR) from hot gases and using a heat integration approach in blast furnaces and BOF; and implementing efficient methods in final steel production and finishing. There is great WHR potential through by-product gases emitted from the coke oven, blast furnace and basic oxygen furnace; more than 90 per cent of coke oven gas can be recovered in integrated steel plants.[47]

Steel is the most recycled material in the world. About 650 million tons of steel can be recycled annually. Recycling makes a significant contribution to in energy and raw materials savings: more than 1,400kg of iron ore, 740kg of coal, and 120kg of limestone can be saved for every recycled ton of steel.[48] SEC in steel production using recycled steel requires 8 GJ/ton of steel, as opposed to 20.6 GJ/ton when producing from iron ore.[49]

4. *Aluminum*

Alumina (Al_2O_3) is used to produce aluminum (or aluminium) and is obtained by grinding raw bauxite. Refinement starts with “digesting”, the chemical process to dissolve the alumina, followed by settling/precipitation, mainly using gravity with some chemicals, and then calcination, whereby water is removed from the alumina hydrate by heating it to 1,100°C in the kiln. The alumina is then transformed into aluminum at a metal plant in a process requiring electricity, carbon and aluminum oxide. The result is liquid aluminum, which is then cast for use in manufacturing.[50]

Aluminum is one of the most produced and used metals in the world. In 2012, around 49 million metric tons of primary aluminum and over 100 million metric tons of alumina were produced worldwide.[51] The key aluminum producers are Australia, Brazil, Canada, China, India, Norway and the Russian Federation.[52] China accounts for 23 per cent of world production, followed by the Russian Federation, with 12 per cent.[53] Annual global demand of aluminum is projected to increase to 70 million metric tons by 2020, 40 per cent of it from GCC countries.

In 2014, GCC countries produced 4.7 million tons of aluminum (8.8 per cent of global production). The Gulf aluminum industry is growing by 8.4 per cent annually, while the average annual global growth is about 3.5 per cent. The United Arab Emirates produces more than half of the Gulf's aluminum.

Aluminum production is energy-intensive and time-consuming. However, once made, it can be recycled over and over without any loss in quality. Energy accounts for 20 to 40 per cent of aluminum production cost. Roughly 14,000 kilowatt-hours (kWh) of electricity are required to produce one ton of aluminum (table 6).

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[46] McKane, *Policies*.

[47] World Steel Association, Energy use.

[48] World Steel Association, World steel in figures 2014. Available from https://www.worldsteel.org/en/dam/jcr:17354f46-9851-45c2-a1b6-a896c2e68f37/World+Steel+in+Figures+2014+Final.pdf.

[49] Saygin and others, Global.

[50] See also www.hydro.com/en/About-aluminium/How-its-made.

[51] Statista, Global aluminum demand and supply growth rates. Available from: www.statista.com/statistics/242777/aluminum-demand-and-supply-growth-rates/.

[52] Banerjee, Energy End-Use.

[53] McKane, *Policies*.

Table 6. SEC for aluminum production by region, 2014

Region	SEC (kWh/ton) (AC))
Africa	14,569
Asia (except China)	14,714
China	13,596
Europe	15,513
GCC Countries	14,889
North America	14,870
Oceania	14,770
South America	15,038
Average World	14,289

Source: World Aluminium, Primary aluminium smelting energy intensity. Available from www.world-aluminium.org/statistics/primary-aluminium-smelting-energy-intensity. Accessed 20 July 2015.

Note: AC value refers to the power consumed by facilities for the smelting process including rectification from AC to DC and normal smelter auxiliaries (including pollution control equipment) up to the point where the liquid aluminum is tapped from the pots. It excludes power used in casting and carbon plants.

Aluminum is a unique lightweight metal characterized by its flexibility, high electrical conductivity, strength, high resistance to corrosion and endless recyclability. About 75 per cent of all aluminum produced is still in use; recycling of aluminum saves 84 million tons of greenhouse gases every year.[54] Due to its lightness, aluminum is used extensively in car manufacturing (which accounts for 39 per cent of aluminum produced in Europe). The amount of aluminum used per car produced in Europe has tripled since 1990, reaching 140kg. The use of aluminum in car manufacture reduces fuel consumption by an annual average of 65 litres,[55] and reduces CO_2 emissions (a car containing 10 per cent aluminum emits 6.8 per cent less CO_2 than the same vehicle without aluminum).

III. IECI ENERGY EFFICIENCY AND THE 2030 AGENDA IN THE ARAB REGION

A. SELECTED IECI IN ARAB COUNTRIES

Measuring energy consumption in IECI is the key to calculating EE potential and indicators. Owing to a lack of such data in Arab countries, consumption is estimated on the basis of production and SEC. Annual energy consumption for specific IECI can be estimated by multiplying production (table 7) by SEC (table 8). Given the lack of national SEC data for the region, average world values have been used in this study. Similarly, national IECI production data are hard to come by. Data has thus been collected from a variety of sources for selected IECI in up to 17 Arab countries (table 9). Calculations were then performed for energy

[54] See https://unfccc.int/files/meetings/workshops/other_meetings/application/vnd.ms-powerpoint/marx.pps.

[55] European Aluminium Association, Sustainable development indicators for the aluminium industry in Europe: 2012 key facts and figures (Brussels, November 2013). Available from http://alucan.cat/wp-content/uploads/2015/06/EAA-leaflet.pdf.

consumption, energy saving, CO_2 emissions and reduction, and revenues due to implementing the net profit EE and CO_2 abatement measures in those IECI. The results appear in the following sections.

Table 7. Annual production of selected IECI in Arab countries (1,000 ton/year), 2013

			Fertilizers			
Country	Crude steel	Cement	Ammonia	Urea	Phosphate	Aluminum
Algeria	440	18,500	509	NA	1,496	NA
Bahrain	NA	1,200	562	652	NA	930
Egypt	6,754	50,000	3,200	1,813	512	340
Iraq	NA	3,657	1,295	1,970	NA	NA
Jordan	150	5,000		678		NA
Kuwait	1,500	2,250	799	910	NA	NA
Lebanon	NA	5,831	NA	NA	370	NA
Libya	715	2,000	359	221	NA	NA
Morocco	558	14,900	NA	NA	2,175	NA
Oman	160	4,472	1,100	1,000	NA	354
Qatar	2,236	5,335	2,985	4,737	NA	610
Saudi Arabia	5,471	57,000	4,004	4,858	3,810	500
Sudan	NA	3,500	NA	NA	NA	NA
Syrian Arab Republic	NA	10,800	238	330	207	NA
Tunisia	109	7,504	131	NA	2,309	NA
United Arab Emirates	2,878	21,000	702	618	NA	2,400
Yemen	NA	3,000	NA	NA	NA	NA
Total	20,971	215,949	16,562	17,109	10,879	5,134

Sources: E/ESCWA/SD/2013/12; E/ESCWA/SDPD/2005/1(Part I); FAO Resource Statistics - Fertilizers, 2015 (https://knoema.com/FAORSF2015/fao-resource-statistics-fertilizers); www.statista.com/statistics/264624/global-production-of-aluminum-by-country; USGS 2013 Minerals Yearbook (https://minerals.usgs.gov/minerals); The Tenth Arab Energy Conference, 2014.

Note: Where 2013 data is unavailable, production is estimated on the basis of growth in previous years, considering a 4 per cent annual production growth rate.

Table 8. Average world and latest technology SEC (kgoe/ton product) and energy saving potential for selected IECI

	Crude Steel	Cement	Fertilizer			Aluminum
			Ammonia	Urea	Phosphate	
Average World	570	110	941	660	80	1230
Latest technology	425	93	685	458	69	1131
Energy saving potential	25.4%	15.5%	27.2%	30.6%	13.8%	8%

Sources: Saygin, Global (see table 5); IEA, Tracking industrial energy efficiency and CO_2 emissions (Paris, 2007; available from https://www.iea.org/publications/freepublications/publication/tracking_emissions.pdf); The Tenth Arab Energy Conference, 2014.

Note: Energy saving potential is the difference between average world and latest technology SEC.

Table 9. Selected IECI

			Fertilizers			
Countries	Crude steel	Cement	Ammonia	Urea	Phosphate	Aluminum
Algeria	✓	✓	✓		✓	
Bahrain		✓	✓	✓		✓
Egypt	✓	✓	✓	✓	✓	✓
Iraq		✓	✓	✓		
Jordan	✓	✓	✓	✓	✓	
Kuwait	✓	✓	✓	✓		
Lebanon		✓			✓	
Libya	✓	✓	✓	✓		
Morocco	✓	✓			✓	
Oman	✓	✓	✓	✓		✓
Qatar	✓	✓	✓	✓		✓
Saudi Arabia	✓	✓	✓	✓	✓	✓
Sudan		✓				
Syrian Arab Republic		✓	✓	✓	✓	
Tunisia	✓	✓		✓	✓	
United Arab Emirates	✓	✓	✓	✓		✓
Yemen		✓				
Total	11	17	12	12	8	6

B. Energy consumption in selected IECI

On the basis of the above mentioned calculations, energy consumption for production crude steel, cement, fertilizer (ammonia, urea, and phosphate) and aluminum in 2013 reached 11.9, 23.7, 26.1, and 6.3 Mtoe respectively, representing 32.54 per cent of total energy consumption in the industrial sector in Arab countries (table 10 and figure 6).

Table 10. Energy consumption in selected IECI in Arab countries (Mtoe), 2013

Country	Total industrial energy consumption	IECI energy consumption					
		Crude steel	Cement	Fertilizers	Aluminum	Total selected IECI	Selected IECI as portion of industry (%)
Algeria	8.38	0.25	2.04	0.60	NA	2.88	34.42%
Bahrain	4.09	NA	0.13	0.96	1.14	2.24	54.66%
Egypt	22.37	3.85	5.50	4.25	0.42	14.02	62.66%
Iraq	9.58	NA	0.40	2.52	NA	2.92	30.49%
Jordan	1.50	0.09	0.55	0.38	NA	1.02	67.69%
Kuwait	5.33	0.86	0.25	1.35	NA	2.45	46.06%
Lebanon	1.41	NA	0.64	0.03	NA	0.67	47.59%
Libya	4.74	0.41	0.22	0.15	NA	0.77	16.32%
Morocco	2.29	0.32	1.64	0.17	NA	2.13	93.06%
Oman	12.00	0.09	0.49	0.66	0.44	1.68	13.99%
Qatar	15.73	1.28	0.59	5.94	0.75	8.55	54.34%
Saudi Arabia	62.90	3.12	6.27	7.28	0.62	17.28	27.48%
Sudan	0.96	NA	0.39	NA	NA	0.39	40.10%
Syrian Arab Republic	6.45	NA	1.19	0.46	NA	1.65	25.52%
Tunisia	2.02	0.06	0.83	0.31	NA	1.2	59.19%
United Arab Emirates	46.33	1.64	2.31	1.07	2.95	7.97	17.20%
Yemen	3.30	NA	0.33	NA	NA	0.33	10.00%
Total	209.38	11.953	23.754	26.116	6.315	68.14	32.54%

Energy consumption in IECI = Production (table 7) x SEC (table 8).

Figure 6. Distribution of energy consumption in selected IECI in Arab countries, 2013

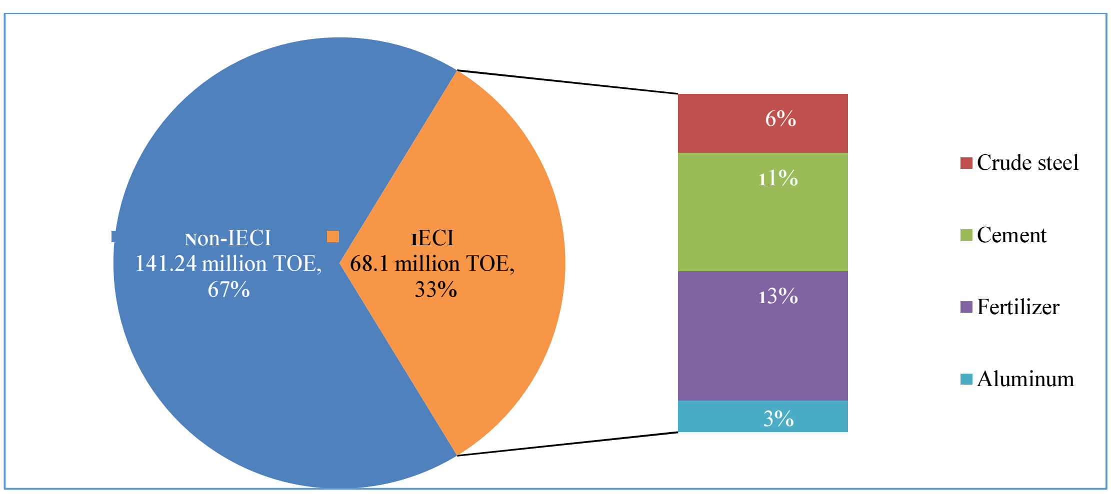
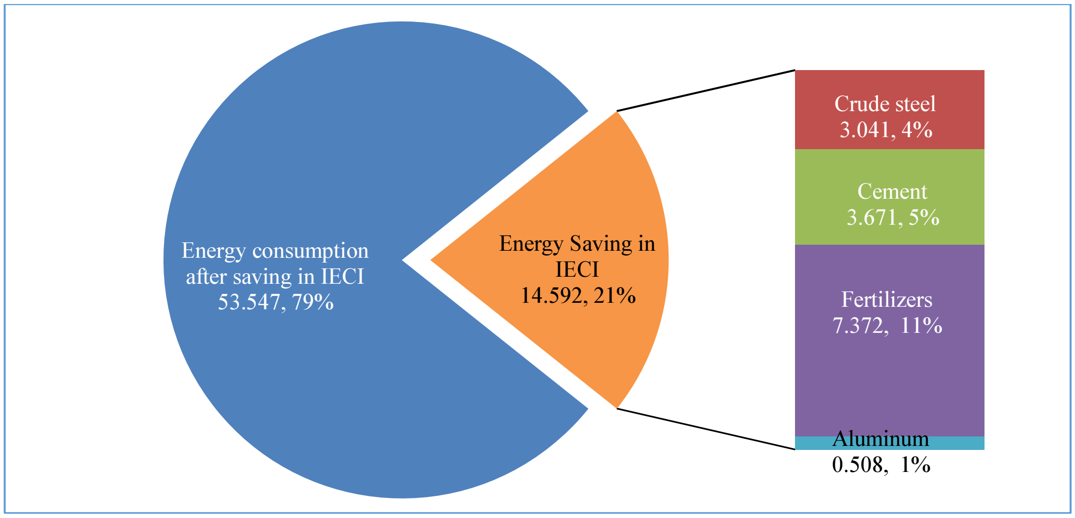


Figure 7. Distribution of energy savings in selected IECI in Arab countries (Mtoe and percentage), 2013



C. Energy saving and EE measures

1. *Energy saving potential*

Energy saving potential is estimated by multiplying energy consumption (table 10) by the percentage of energy saving potential (table 8). The potential for saving energy calculated for crude steel, cement, fertilizer (ammonia, urea and phosphate) and aluminum in 2013 is 3.041, 3.671, 7.372, 0.508 Mtoe respectively, making a total of 14.592 Mtoe, or 21.42 per cent of total energy consumption in the selected IECI (table 11).

Table 11. Estimated potential annual energy saving in selected IECI in Arab countries, 2013

Country	Crude steel	Cement	Fertilizers	Aluminum	Total energy saving	
					Mtoe	Saving (percentage of total IECI consumption)
Algeria	0.064	0.315	0.1468	NA	0.525	18.20%
Bahrain	NA	0.02	0.2757	0.092	0.388	17.36%
Egypt	0.979	0.85	1.1911	0.034	3.054	21.79%
Iraq	NA	0.062	0.7295	NA	0.792	27.10%
Jordan	0.022	0.085	0.1034	NA	0.21	20.69%
Kuwait	0.218	0.038	0.3884	NA	0.644	26.24%
Lebanon	NA	0.099	0.0041	NA	0.103	15.38%
Libya	0.104	0.034	0.0446	NA	0.182	23.57%
Morocco	0.081	0.253	0.0239	NA	0.358	16.81%
Oman	0.023	0.076	0.202	0.035	0.336	20.03%
Qatar	0.324	0.091	1.7211	0.06	2.196	25.70%
Saudi Arabia	0.793	0.969	2.0483	0.05	3.86	22.34%
Sudan	NA	0.06	NA	NA	0.06	15.45%
Syrian Arab Republic	NA	0.184	0.1299	NA	0.313	19.04%
Tunisia	0.016	0.128	0.0589	NA	0.202	16.92%
United Arab Emirates	0.417	0.357	0.3045	0.238	1.316	16.52%
Yemen	NA	0.051	NA	NA	0.051	15.45%
Total	3.041	3.671	7.3719	0.508	14.592	21.42%

2. *EE measures and priorities areas*

Eleven key measures and technologies for saving energy in IECI (and non-IECI) are set forth in table 12, which also displays indicative energy savings, payback periods for each measure and priority levels of implementation in each industry. Priority given to a certain measure/technology depends on cost, the amount of potential energy saving and other technical, environmental and social considerations. High priority measures include: industrial process control; WHR; improved combustion efficiency; improved thermal insulation; power factor improvements; high-efficiency motors; and cogeneration.

Implementation of EE measures requires appropriate policies and institutional and regulatory frameworks. Incentives could include soft loans for EE, cash back on energy loans, tax reduction for EE equipment, and subsidized energy audits, which should be carried out periodically at various levels in IECI. Also helpful is a total energy management approach (thermal and electrical). Energy tariff restructuring could include: time of use (TOU) tariffs; demand charge tariffs (peak demand contract in kW or kVA); seasonal (summer and winter) rate tariffs; power factor tariffs (PFT). Other measures include: applying energy efficiency standards and codes for energy equipment (such as boilers, furnaces, kilns and electric motors), restricting the import of inefficient equipment; improving operation and maintenance routine and housekeeping in IECI facilities; and enhancing capacity-building and training in EE.

Table 12. Proposed EE measures, indicative energy saving, payback period and priority of implementation in IECI and non- IECI in Arab countries

Industries		*Industrial process control*	*WHR*	*Improvement of combustion efficiency*	*Energy management systems*	*Combined heat and power (CHP)/Cogeneration*	*Power factor improvement*	*High-efficiency motors*	*Advanced insulation and refractories*	*Improving steam systems*	*Using alternative (solid) fuels*	*High-efficiency lighting*
Expected energy saving		5-15	5-45	5-25	7-20	5-40	5-15	5-10	5-20	5-50	2-15	15-50
Expected payback period (number of years)		<2	0.5-1.5	1-3	<2	1-5	1-2	3-5	2-3	1-3	<5	0-0.5
Industry		**Priority of implementation (1 = high priority, 2 = medium priority, 3 = low priority)**										
IECI	Chemicals (fertilizers)	1	1	1	1	1	1	1	1	1	2	1
	Aluminum	1	1	2	1	2	1	1	2	3	2	2
	Iron and steel	1	1	1	1	1	1	1	2	3	1	2
	Cement	1	2	1	2	3	1	1	2	3	1	2
	Glass	2	1	1	2	2	1	1	1	3	2	2
	Petroleum refining	1	2	1	2	1	1	1	1	1	3	1
Non-IECI	Food and beverage	1	1	1	2	1	1	1	1	1	1	1
	Mining	3	3	3	3	3	1	1	3	3	3	2
	Textile	2	1	1	2	1	1	1	1	1	1	1
	Plastics and rubber	2	2	2	1	2	1	1	2	3	3	2
	Fabricated metal	1	2	2	1	3	1	1	3	3	3	2
	Transported equipment	3	3	3	3	2	1	1	3	3	3	2
	Foundries	2	2	1	2	3	1	1	1	3	2	2

Sources: Energetics, Incorporated and E3M, *Energy Use* (see table 4); E/ESCWA/ENR/2001/14; surveys and energy audits undertaken in Arab countries.

D. IECI CO_2 EMISSION INDICATORS

About 40 per cent of total global CO_2 emissions come from industry through fuel combustion and chemical reaction in industrial processes. If they remain unchecked, total CO_2 emissions could increase by 90 per cent by 2050 compared with 2007.[56] IECI are major CO_2 emitters: the cement, iron and steel, and chemical and petrochemical industries accounted for 73 per cent of total industrial CO_2 emission worldwide in 2007.[57] In order to meet that challenge, there is a need to improve EE along the energy path and, where possible, switch to low carbon energy sources.

CO_2 emissions due to energy use in the selected IECI in Arab countries were estimated by multiplying the emission factor (kg CO_2/koe) by energy consumption (table 10). The estimated combined emissions for the selected IECI in the 17 countries studied are 191.71 million tons (table 13), or 32.4 per cent of total industrial sector emissions. Potential emission reduction is estimated by multiplying the emission factor by the energy saving potential calculated in table 11. The results appear in table 13 and figure 8.

Table 13. Annual CO2 emissions and reduction due to energy saving in selected IECI in Arab countries, 2013

			CO_2 emissions (million tons/year)					Reduction in CO_2 emissions due to energy saving (million tons/year)				
Country	CO_2 emission factor (kg CO_2/kgoe)	Total CO_2 emission from industrial sector (million ton/year)	Crude steel	Cement	Fertilizers	Aluminum	Total IECI	Crude steel	Cement	Fertilizers	Aluminum	Total reduction
Algeria	2.9	24.3	0.73	5.9	1.74	0	8.36	0.19	0.91	0.43	0	1.52
Bahrain	1.9	7.77	0	0.25	1.82	2.17	4.25	0	0.04	0.52	0.17	0.74
Egypt	2.9	64.87	11.16	15.95	12.32	1.21	40.65	2.84	2.47	3.45	0.1	8.86
Iraq	3.3	31.61	0	1.33	8.31	0	9.64	0	0.21	2.41	0	2.61
Jordan	2.6	3.9	0.22	1.43	0.99	0	2.64	0.06	0.22	0.27	0	0.55
Kuwait	2.8	14.92	2.39	0.69	3.79	0	6.87	0.61	0.11	1.09	0	1.8
Lebanon	3.2	4.51	0	2.05	0.09	0	2.15	0	0.32	0.01	0	0.33
Libya	2.9	13.75	1.18	0.64	0.42	0	2.24	0.3	0.1	0.13	0	0.53
Morocco	3.1	7.1	0.99	5.08	0.54	0	6.61	0.25	0.79	0.07	0	1.11
Oman	2.5	30	0.23	1.23	1.65	1.09	4.2	0.06	0.19	0.51	0.09	0.84
Qatar	2.6	40.9	3.31	1.53	15.43	1.95	22.22	0.84	0.24	4.47	0.16	5.71
Saudi Arabia	2.9	182.41	9.04	18.18	21.11	1.78	50.12	2.3	2.81	5.94	0.14	11.19
Sudan	1	0.96	0	0.39	0	0	0.39	0	0.06	0	0	0.06
Syrian Arab Republic	2.9	18.71	0	3.45	1.33	0	4.77	0	0.53	0.38	0	0.91
Tunisia	2.7	5.45	0.17	2.23	0.83	0	3.23	0.04	0.34	0.16	0	0.55
United Arab Emirates	2.8	129.72	4.59	6.47	2.99	8.27	22.32	1.17	1	0.85	0.67	3.69
Yemen	3.2	10.56	0	1.06	0	0	1.06	0	0.16	0	0	0.16
Total		591.45	34.02	67.85	73.37	16.47	191.71	8.65	10.49	20.69	1.33	41.16

Notes: 0 = data unavailable.

The CO_2 emission factor (kg CO_2/koe) represents average values at the national level.

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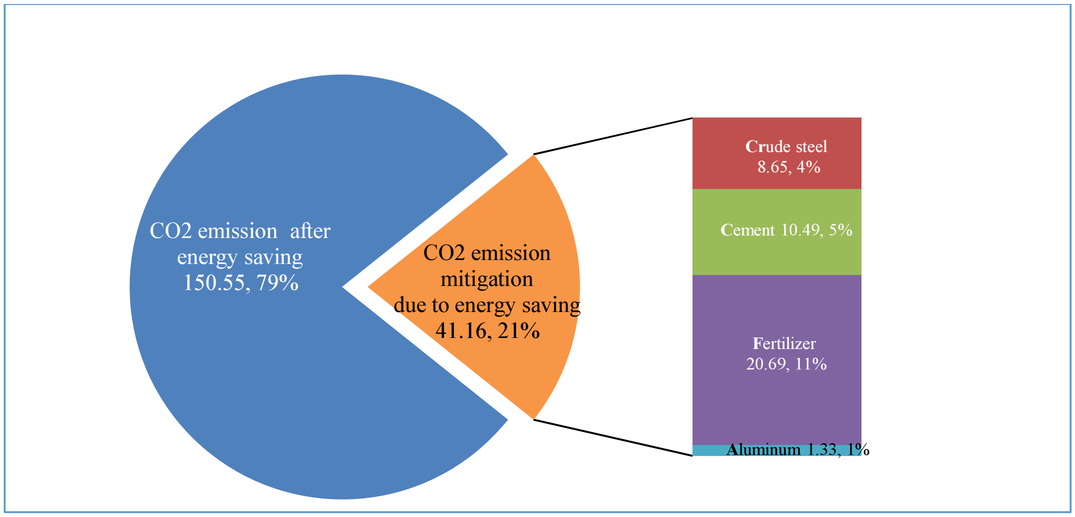
56 Brown and others, Reducing CO_2 emissions.

57 Ibid.

Figure 8. Distribution of CO2 emissions reduction in selected IECI in Arab countries (millions of tons and percentage), 2013



E. NET PROFIT EE AND CO_2 ABATEMENT MEASURES

The marginal abatement cost curve (MACC) for CO_2 mitigation technologies is crucial when it comes to selecting EE and CO_2 abatement measures and technologies. In one study, 41 new and retrofitted CO_2 abatement measures and technologies have been identified for three IECI (iron and steel, cement, and chemicals and petrochemicals). Fifteen of them are negative cost (see table 14), while 25 are positive cost and one measure is zero cost. Negative cost for a specific technology provides net profit (revenue) along the life cycle of the technology, while positive cost requires expenditure.[58]

Table 14. Negative cost EE & CO2 abatement measures and technologies

Iron and steel	Cogeneration (NB) Cogeneration (RF) Coke substitution (NB) Coke substitution (RF)
Chemicals	Efficient motor systems (NB) Fuel shift oil to gas (NB) Efficient motor systems (RF) Fuel shift oil to gas (RF) CHP (NB) CHP (RF)
Cement	Clinker substitution by other mineral components (NB) Clinker substitution by fly ash (NB) Alternative fuels (waste) (NB) Clinker substitution by slag (NB) WHR (NB)

Source: Brown and others, Reducing CO_2 emissions.

Notes: NB: New build; RF: Retrofit.

[58] Ibid.

Annual revenue generated by implementation of the 15 net profit EE and CO2 abatement measures and technologies in the selected IECI (table 14) could reach $574.8 million (table 15).

Table 15. Revenue from due to net profit EE & CO2 abatement measures and technologies in the Arab region, 2013

Industry	The most economic (negative cost) EE & CO_2 abatement measures and technologies	Total CO_2 reduction (million tons/ year)* (1)	Percent of negative cost of CO_2 abatement from total abatement** (2)	Distribution of CO_2 reduction EE & CO_2 abatement measures/ technologies** (3)	Amount of CO_2 reduction by technology (million ton/year) (4)=(1)x(2)x(3)	Negative CO_2 abatement cost/revenue (United States dollar/ton saved CO_2 equivalent/year)** (5)	Annual revenue due to CO_2 abatement (million United States dollars/year) (6)=(4) x (5)
Iron and steel	Cogeneration (NB)	8.65	21%	65%	1.18	75.5	89.1
	Cogeneration (RF)	8.65	21%	25%	0.45	71.0	32.2
	Iron and steel coke substitution (NB)	8.65	21%	7%	0.13	11.3	1.4
	Coke substitution (RF)	8.65	21%	3%	0.05	10.1	0.6
Total iron and steel				**100%**	**1.8**		**109.54**
Chemicals	Efficient motor systems (NB)	20.69	30%	50%	3.10	69.8	246.7
	Fuel shift oil to gas (NB)	20.69	30%	15%	0.93	57.4	53.5
	Efficient motor systems (RF)	20.69	30%	4%	0.25	57.4	14.3
	Fuel shift oil to gas (RF)	20.69	30%	4%	0.25	52.9	13.1
	CHP (NB)	20.69	30%	20%	1.24	6.8	8.4
	CHP (RF)	20.69	30%	7%	0.43	2.3	1.0
Total chemicals				**100%**	**6.2**		**337.0**
Cement	Cement clinker substitution by other MIC (NB	10.49	68%	20%	1.43	36.0	51.4
	Clinker substitution by fly ash (NB)	10.49	68%	25%	1.78	22.5	40.1
	Alternative fuels (waste) (NB)	10.49	68%	25%	1.78	9.0	16.1
	Clinker substitution by slag (NB)	10.49	68%	25%	1.78	3.4	6.0
	Waste heat recovery (NB)	10.49	68%	5%	0.36	2.3	0.8
Total Cement				**100%**	**7.1**		**114.4**
Grand Total					**15.2**		**574.8**

* From table 13.

** Based on Brown and others, Reducing CO_2 emissions.

IV. CONCLUSIONS

The potential for energy saving in IECI in Arab countries could be as high as 21 per cent of energy consumption. To achieve that, they must carry out long-term EE programmes, comprising four components and including 17 actions (figure 9). Implementation will require a strong commitment by decision-makers. In developing countries, particularly in the short term, savings could be as high as: 50 per cent in aluminum (5 per cent in aluminum smelters); 40 per cent in glass; 30 per cent in the iron and steel industry; 25 per cent in cement; and 14 to 30 per cent in the chemical and petrochemical sector. That alone should motivate governments and decision-makers to act.

Potential EE measures in IECI include: industrial process control; WHR; cogeneration; improved combustion efficiency; better thermal insulation; improved power factor; high-efficiency motors; energy management systems; and improved operation and maintenance practices. Integrating EE systems in IECI through initial design (or substantial redesign) and by introducing advanced technologies is expensive, but more profitable in the long run than retrofitting existing technologies.

A range of barriers could stand in the way of EE programmes in IECI in the Arab countries:

(a) Financing: The lack of financial resources or simply an unwillingness to fund EE measures (particularly those with long payback periods) or replace existing technologies with more efficient ones;

(b) Energy subsidies: Elevated subsidies (among the highest in the world, according to IEA) on energy and fuel in the Arab countries, especially in IECI, which lead to high growth rates in energy consumption, poor service and low efficiency in industrial facilities;

(c) Institutional and regulatory weaknesses: Weak EE institutional frameworks, combined with the absence of appropriate standards, codes, legislation and regulations (including audit and monitoring mechanisms);

(d) Skills, capacity and awareness: A shortage of skilled EE technicians and engineers, a lack of awareness (particularly among decision-makers) of the economic and environmental benefits deriving from improved EE in IECI, a scarcity of data, and the failure to disseminate information on rational energy consumption and EE.

Figure 9. Main components for EE programmes in IECI and related actions

Component I Developing EE institutional frameworks	• Creating an energy efficiency and management body • Identifying EE stakeholders and their respective responsibilities
Component II Developing EE policies and regulations	• Reforming energy tariffs (fuels and electricity) • Issuing certifications, codes, standards and labels for EE in IECI • Launching economic incentives to encourage EE in IECI • Enhancing finance mechanisms for EE projects • Capacity-building
Component III Identifying and assessing EE measures	• Performing energy audits/surveys, field visits and data collection at various levels in IECI • Identifying and assessing EE measures and policies based on economic, technical and environmental criteria • Identifying priority areas for EE (measures and policies)
Component IV Implementing the programme	• Making a commitment to the EE programme • Setting benchmarks/goals/targets • Creating an action plan within a proposed timeframe, including needs, stakeholders and responsibilities • Implementing the action plan • Evaluating the progress achieved • Monitoring and reassessing • Disseminating the results and replicating the implementation

In order to meet those challenges, policymakers in Arab countries need to develop appropriate institutional and regulatory frameworks, engage in energy price and subsidy reform, enhance the business and financial environment for EE, and build skills and technical capacity. Policy and programme planning and setting realistic targets are keys. Equally important is the monitoring of progress using EE analytical tools, such as gap analysis using normalization techniques; SEC norms; ISO 50001; energy audits in IECI; and benchmarking. Key recommendations include:

- Institutional and regulatory frameworks should be developed within the total/integrated energy management concept, focusing on EE codes and standards, incentives and environmental regulations;
- Energy prices should be restructured and subsidies in IECI reformed, including through use of time of use (TOU) rates, demand (capacity) charges and seasonal rates;
- Efforts should be made to foster the use of advanced technologies in IECI with a view to making industry more sustainable, including through technology and knowledge transfer, enhanced cooperation with developed countries, investment in innovation and R&D;
- Financing mechanisms need to be established to encourage the implementation of EE programmes in IECI, with a focus on bankable and financially feasible programmes;
- IECI energy data collection should be improved, including through energy audits and the compilation of energy indicators;
- Capacity needs to be built through skills training, aware-raising and the dissemination of information on EE in IECI.