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Addressing energy sustainability issues in the buildings sector in the Arab region

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Addressing Energy Sustainability Issues In The Buildings Sector In The Arab Region

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PREFACE

The present report was prepared by the Energy Section of the Sustainable Development Policies Division (SDPD) of the United Nations Economic and Social Commission for Western Asia (ESCWA), within the framework of a series of reports on energy focusing on the 2030 Agenda for Sustainable Development. The report focuses on energy efficiency in the buildings sector as a major opportunity for substantial progress towards Sustainable Development Goal 7 (SDG7), and highlights the associated policy options contributing to the development of a sustainable energy future in the Arab region. The report intends to inform member States on mainstreaming SDGs into their national development plans related to the buildings sector (paragraphs 80 and 81 of General Assembly resolution 70/1), and to help them develop, implement and monitor related fact-based sustainable energy action plans.

The report reviews the current energy trends in the buildings sector and assesses its share of national energy consumption. It reviews the buildings sector's predominant energy-use patterns, and current efforts in the region to improve its energy performance and sustainability. Furthermore, the report presents a 2030 vision for improving significantly the sector's energy sustainability, based on a holistic but pragmatic approach. Potential targets for 2030 and 2050 are presented based on scenarios of implemented policies and programmes. The analysis is carried out at the national, subregional and regional levels.

The present report was prepared by Mr. Moncef Krarti (PhD, PE, LEED), professor of Building Energy Systems Engineering at the University of Colorado, Boulder-USA. He is a specialist in building energy efficiency technologies, with a vast experience in designing testing, and assessing innovative energy efficiency and renewable energy technologies and policies applied to buildings, including in many Arab countries. The report received substantive inputs from Mr. Mongi Bida, First Economic Affairs Officer at ESCWA, who also reviewed and supervised this work in collaboration with Ms. Radia Sedaoui, Chief of the ESCWA Energy Section.

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EXECUTIVE SUMMARY

The present report evaluates the potential benefits of improving the energy performance of the buildings stock in the Arab region. It reviews the current energy demand trends in the buildings sector in Arab countries, and outlines the main drivers for energy consumption and energy efficiency indicators in the buildings sector in the Arab region and its subregions (Gulf Cooperation Council (GCC) countries, the Mashreq, the Maghreb and Arab least developed countries (LDCs)). A country specific description of current energy policies and their status is provided to assess the region's efforts to enhance energy efficiency and sustainability of the buildings stock. A detailed evaluation of potential energy improvements for both new and existing buildings is carried out based on a systematic analysis approach to assess the benefits of several energy efficiency programmes for the Arab region. The following four categories of energy policies are evaluated:

(i) Adopting stricter minimum energy performance standards (MEPS) for energy intensive products commonly used in buildings;

(ii) Developing and enforcing integrated building energy efficiency codes (BEECs) for new buildings;

(iii) Upgrading and retrofitting of existing buildings to reduce their energy consumption;

(iv) Integrating renewable energy systems to potentially achieve net-zero energy buildings.

The present report sets out the benefits of large-scale implementation of energy efficiency programmes in the Arab region, and estimates future achievable reductions in energy consumption, electricity demands and carbon emissions. It shows that, in 2015, 28 per cent of the total primary energy supply (TPES) was used to cover buildings' energy needs, amounting to 21 per cent of the total final energy consumption (TFEC) of the Arab region, with wide variations between subregions. When only energy use of TFEC and TPES is considered, the share of the buildings sector is respectively 31 per cent and 25 per cent. In 2015, the overall final energy consumption of the buildings sector was 15 per cent for GCC countries, 29 per cent for the Mashreq, 28 per cent for the Maghreb, and 53 per cent for Arab LDCs (corresponding to 26 per cent, 32 per cent, 26 per cent et 47 per cent of the primary energy supply of these subregions, respectively). Historical trends show that the energy consumption level of the buildings sector has increased significantly over the last decade, with an annual growth rate of 3.1 per cent over the period 1990-2015, and is expected to continue increasing in the future owing to population and economic growth. According to available historical data for some Arab countries and reported projection analyses, there is a shift towards higher penetration of energy-consuming appliances and air conditioning in both residential and non-residential buildings. For instance, the air conditioning market, while already saturated in the GCC subregion, is expected to reach higher penetration rates in the Maghreb and Mashreq by 2030. Electricity will therefore continue to be the main energy source for the buildings sector in the Arab region.

The report indicates that the adoption and strict enforcement of comprehensive and adapted sets of MEPS and BEECs can reduce the total final energy consumption of the Arab region's buildings sector by 5 per cent by 2030. The requirement for net-zero energy buildings for all new housing units starting from 2030 would provide 10 per cent additional savings by 2040 and 16 per cent by 2050 of the overall energy used by buildings in the Arab region. Moreover, large-scale deep energy retrofits of existing buildings stocks can reduce the buildings sector's final energy consumption by over 30 per cent by 2050, and by almost 50 per cent when combined with comprehensive MEPs and BEECs if energy efficiency programmes targeting the entire buildings stocks are implemented over a 10-years period, starting in 2030. The main challenges to implementing the proposed energy efficiency programmes in most Arab countries are low energy prices, the lack of readily available financing mechanisms, lax enforcement procedures for existing standards and regulations, and a shortage of skilled labour to design, construct, operate and retrofit sustainable buildings.

In addition to the indicated energy savings, and the associated reductions in carbon emissions, the proposed energy efficiency programmes would create a significant number of jobs (over 200,000 for Saudi Arabia alone) and considerably reduce the need for future power generation capacity.

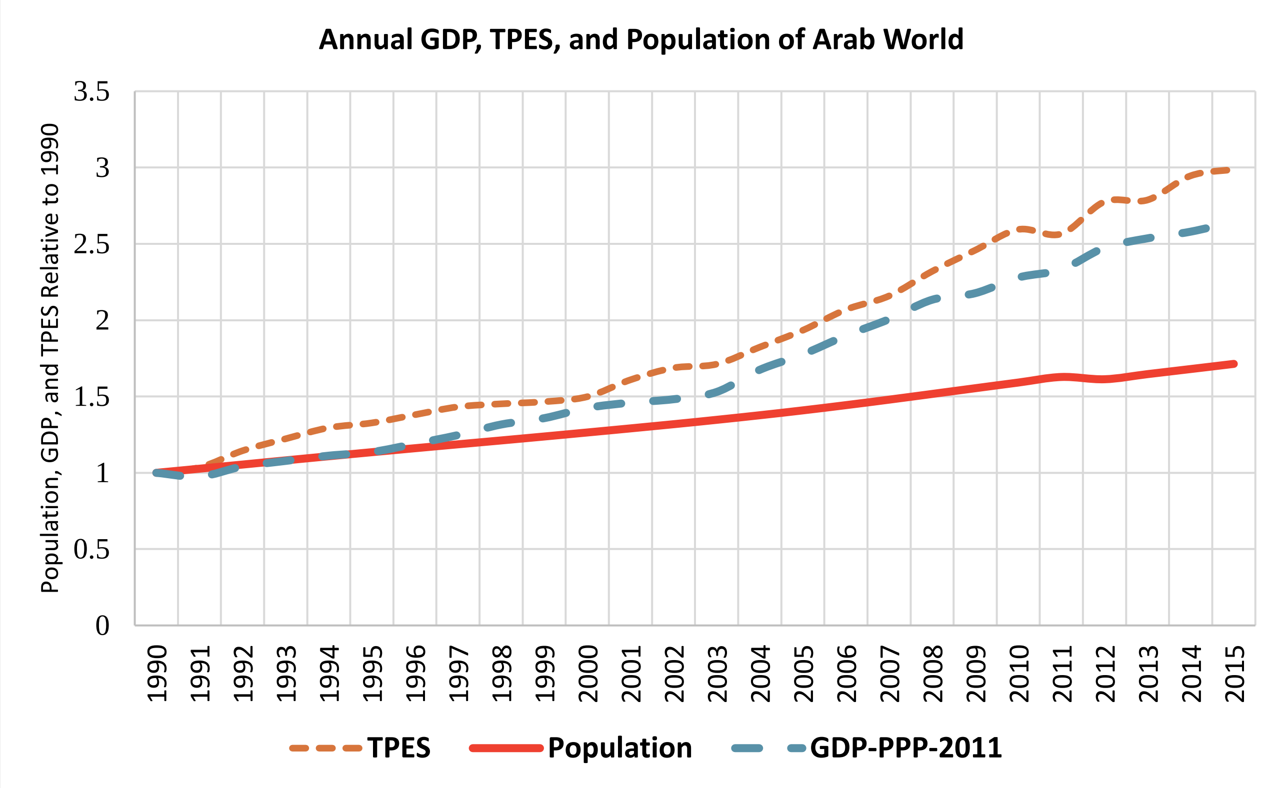
LIST OF ACRONYMS

BEEC	Building energy efficiency code
CDD	Cooling degree days
CFL	Compact fluorescent lamp
COP	Coefficient of performance
EEM	Energy efficiency measure
EER	Electrical efficiency ratio
GCC	Gulf Cooperation Council
GDP	Gross domestic product
HDD	Heating degree days
HVAC	Heating, ventilating, and air conditioning
KgOE	Kilograms of oil equivalent
LCC	Life cycle cost
LDCs	Least developed countries
LED	Lighting emitting diode
MEPS	Minimum energy performance standard
MSLs	Minimum service levels
NZEB	Net-zero energy building
PV	Photovoltaic
TFEC	Total final energy consumption
TPES	Total primary energy supply
TOE	Tons of oil equivalent

INTRODUCTION

Over the period 1990-2015, the total primary energy supply (TPES) in the Arab region[1] increased three-fold owing to population growth (figure 1). However, gross domestic product (GDP) increased by only 60 per cent over the same period, indicating an increase in energy intensity and, ultimately, a decrease in the energy productivity[2] of the Arab region's economy.

Figure 1. GDP, TPES and population growth in the Arab region, 1990-2015



Source: IEA, 2017.

Over the period 1990-2015, per capita GDP in the Arab region was only slightly above the global average but remained significantly lower than similar indicators reported for the European Union and the United States (figure 2). However, per capita GDP varied significantly within the Arab region, especially between GCC countries and other Arab countries. Over the period 1990-2015, the Arab region's primary energy use per capita increased steadily, reaching the global average of 2.0 tons of oil equivalent per person in 2015. The European Union and the United States have significantly higher energy use per capita, which has been declining since 2008 to settle at 3.0 TOE/person and 7.0 TOE/person, respectively, in 2015.

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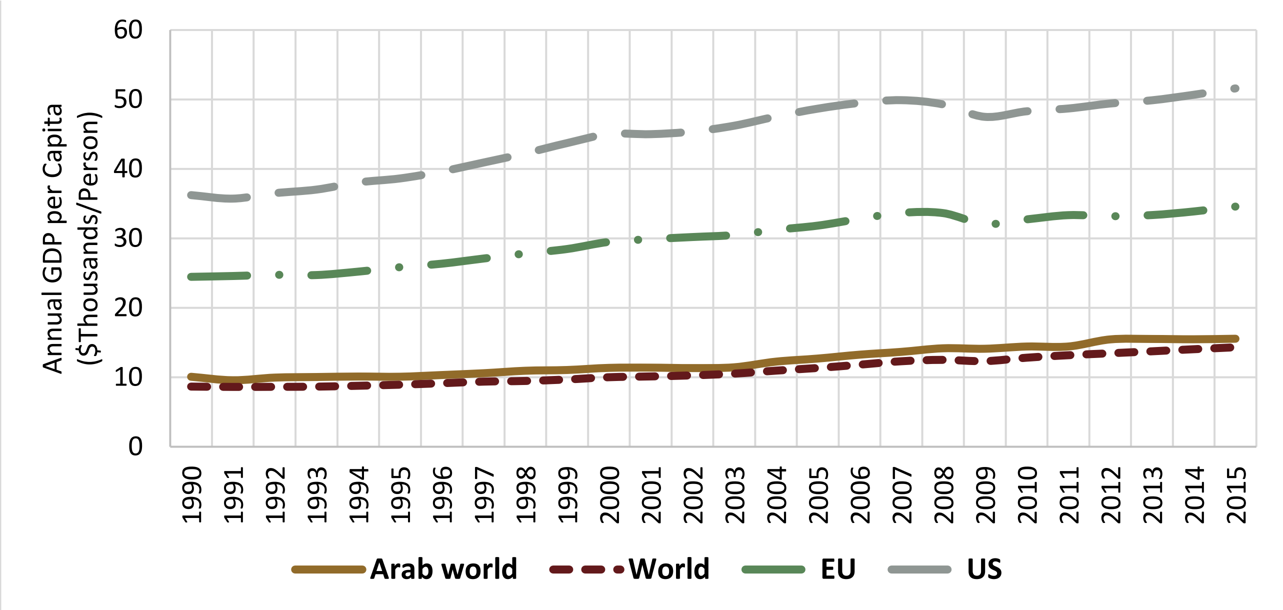
[1] In the context of the present report, the Arab region refers to the following countries: Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, the State of Palestine, Qatar, Saudi Arabia, the Sudan, the Syrian Arab Republic, Tunisia, the United Arab Emirates and Yemen.

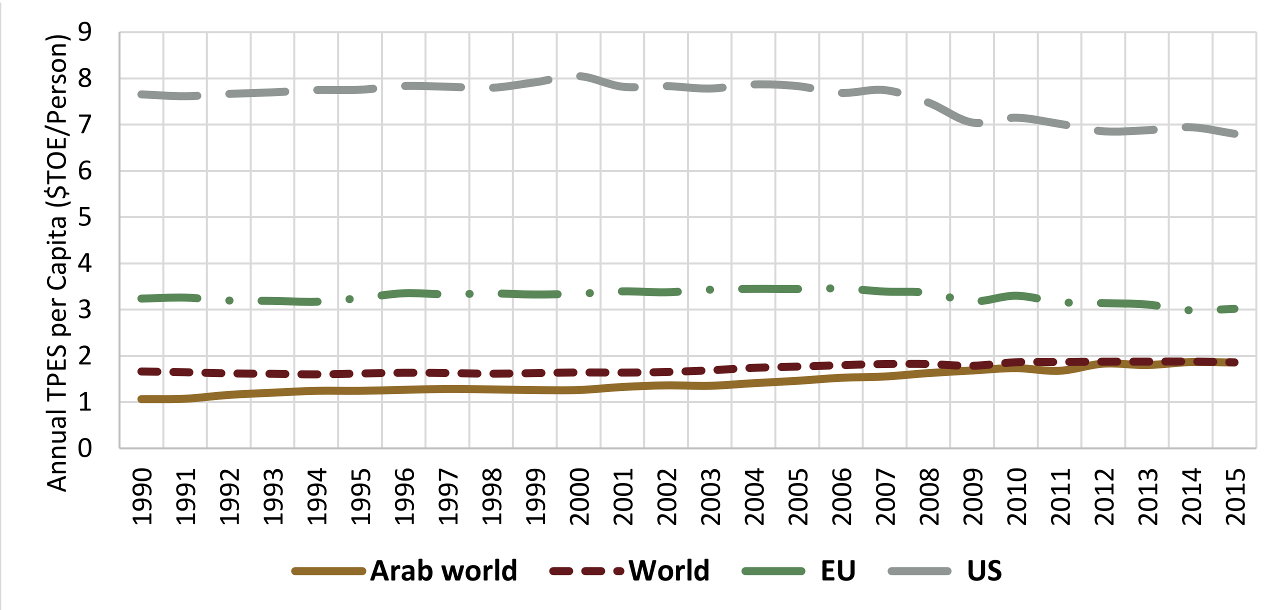
[2] Energy productivity, defined as the inverse of energy intensity, is the ratio of GDP per total primary energy supply.

Figure 2. Variations in GDP per capita for selected regions and countries, 1990-2015



Source: IEA, 2017.

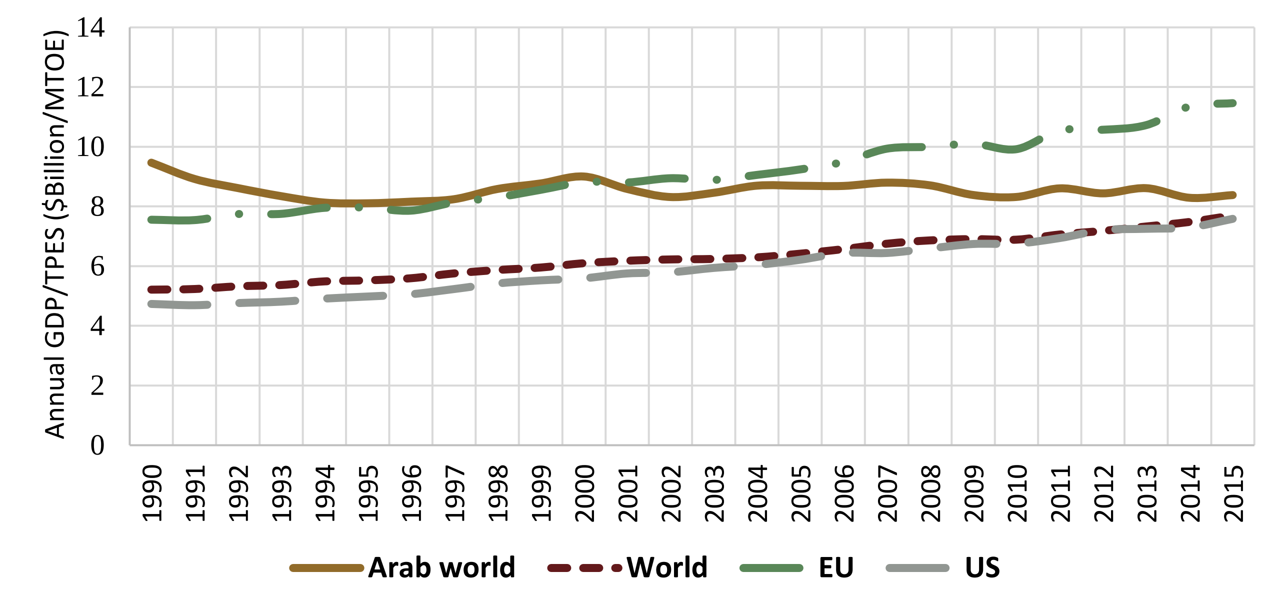
Figure 3. Variations in TPES per capita at the for selected regions and countries, 1990-2015



Source: IEA, 2017.

Because of those GDP and TPES trends, overall energy productivity, defined as the ratio of GDP and TPES, has decreased in the Arab region while it has increased in the rest of the world, including in the European Union and the United States (figure 4). It has been argued that energy productivity provides an indicator of a country's economic, energy and environmental performance, and helps allocate energy resources to optimize economic growth (Kapsarc, 2015). The European Union improved its energy productivity by over 50 per cent between 1990 and 2015, mainly by diversifying its economy so it relies less on energy intensive industries and more on the service sector. Improvements in energy productivity can also result from enhancing energy efficiency in the buildings and various economic sectors. Similar arguments have been used to demonstrate increases in energy productivity in several countries, including the United States, albeit to a lesser extent than those seen in the European Union.

Figure 4. Variations in energy productivity for selected regions and countries, 1990-2015



Source: IEA, 2017.

The relative decrease in energy productivity for the Arab region shown in figure 4 can be attributed to a wide range of factors. Over the last two decades, the region has exhibited a growing rate of urbanization and rising living standards. These two factors have resulted in a sharp increase in energy consumption, especially for services not directly associated to the productive sectors. In addition, the significant reliance in some Arab countries on energy intensive activities, such as industry, with low value added, has resulted in a significant increase in energy consumption outpacing increases in GDP. Another significant factor for low energy productivity is the weak penetration of energy efficiency practices and best available technologies in all economic sectors. To improve energy productivity and decouple energy consumption from GDP, the Arab region must diversify its economy and improve energy efficiency levels in all sectors (industry, transport and buildings). The present report evaluates the potential benefits of large-scale implementation of energy efficiency programmes for the buildings sector in the Arab region. Firstly, general energy consumption trends are assessed for the Arab region and compared with other regions. Secondly, buildings sector contributions to total primary and final energy consumption are estimated based on available data. Thirdly, current energy efficiency indicators and energy policies related to the buildings sector are presented for the Arab region, subregions and selected countries. Lastly, the potential benefits of selected energy efficiency programmes for new and existing residential and commercial buildings are analysed for the Arab region; and the impact of the large-scale implementation of those energy policies on future energy demands in the buildings sector is estimated for selected Arab countries.

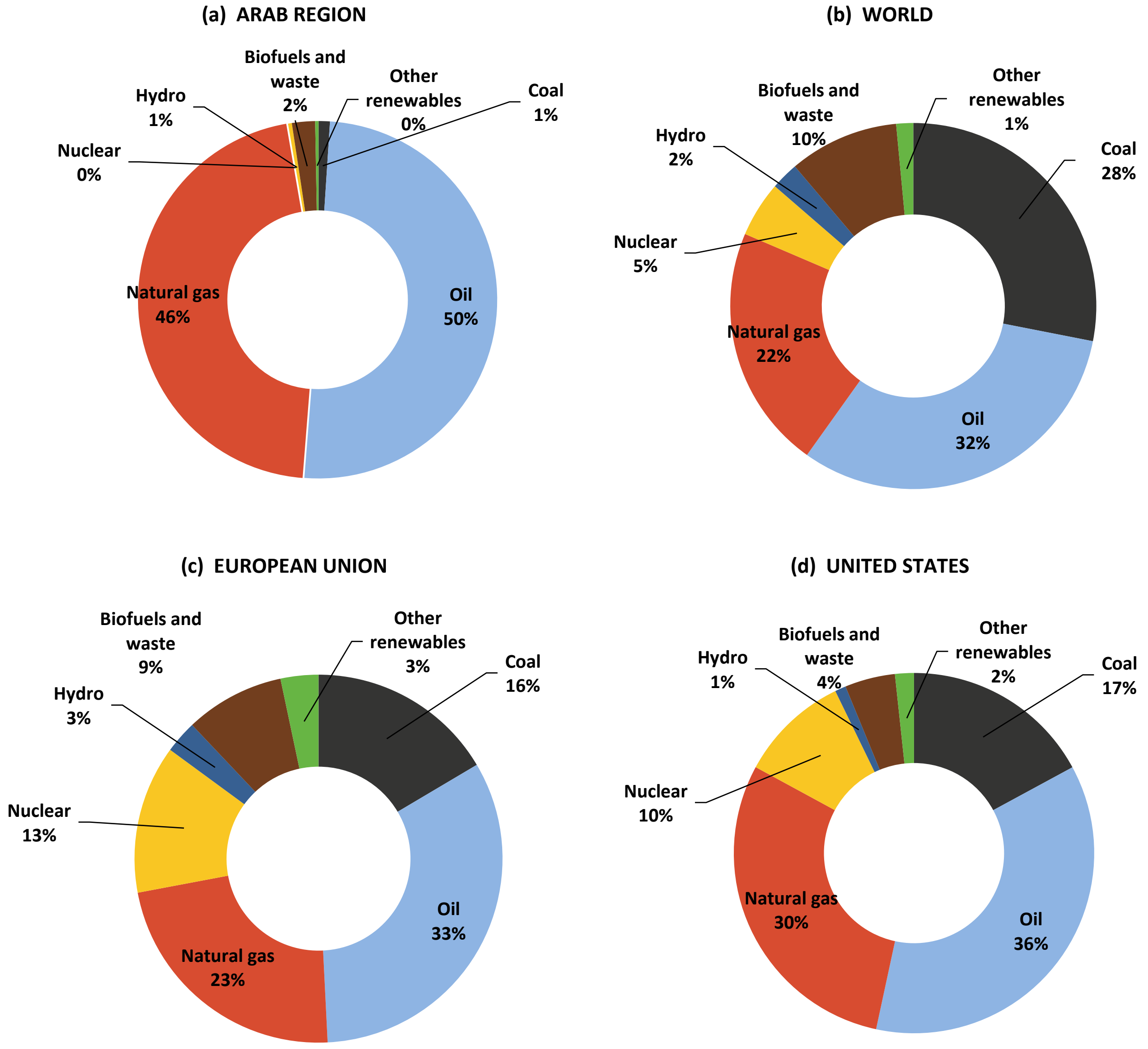
I. OVERALL ENERGY CONSUMPTION TRENDS

A. ARAB REGION

1. Primary Energy Supply

Over the last two decades, the Arab region has consumed mostly oil products and natural gas to power its economy. In 2015, the Arab region relied mainly on oil products (50 per cent) and natural gas (46 per cent) to meet its primary energy needs. In addition to biofuels and waste (2 per cent) and hydro (1 per cent), insignificant other renewable energy sources were utilized in the Arab region (figure 5). In contrast, nuclear, hydro and renewables (energy sources with no carbon emissions) were prominent in other regions, constituting 18 per cent of TPES worldwide, 28 per cent in the European Union, and 17 per cent in the United States.

Figure 5. Primary energy resources, 2015

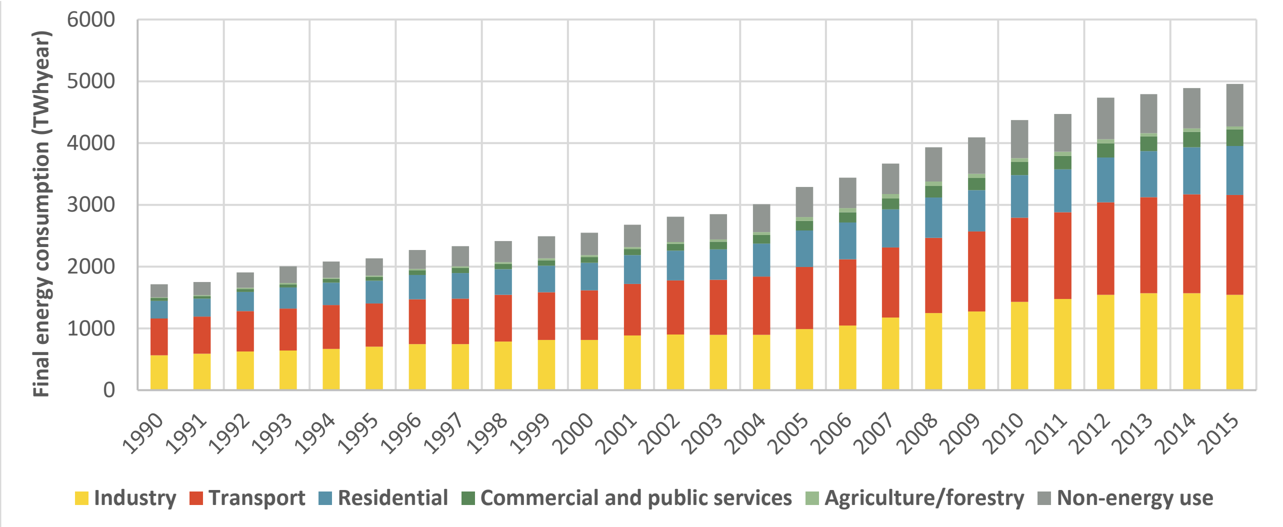


Source: IEA, 2017.

2. Final energy consumption

Figure 6 presents the annual variation and distribution of total final energy consumption (TFEC) in the Arab region over the period 1990-2015. The Arab region has seen a significant increase in energy consumption, with an average annual growth rate of 10 per cent in TFEC since 1990. In 2015, the Arab region consumed almost 5,000 terawatt hours of energy to meet its economies' needs, most of which were attributed to the industry and transport sectors, with 31 per cent and 32 per cent, respectively (figure 7b). However, the contribution of the buildings sector, estimated at 21 per cent relative to TFEC (figure 7a) and 28 per cent relative to TPES (figure 7b) has been steadily increasing, especially in the last decade. Figure 8 illustrates the annual growth in TFEC and the energy consumed by the residential and non-residential buildings sectors. The increase in energy used by non-residential buildings has more than doubled compared with the annual growth of overall TFEC for the Arab region. The annual growth rate in energy consumption specific to commercial and public services buildings averaged almost 25 per cent over the period 1990-2015. For the same period, the annual growth rate trend of energy consumption specific to the residential sector follows that of the overall TFEC (IEA, 2017).

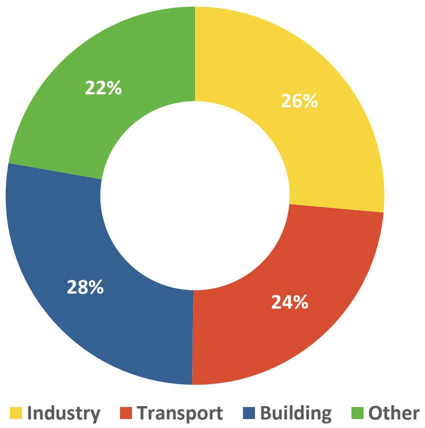
Figure 6. Total final energy consumption in the Arab region, 1990-2015



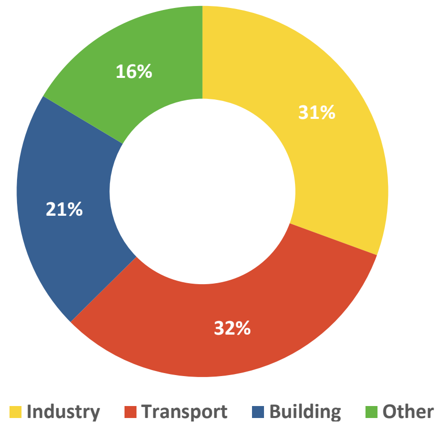
Source: IEA, 2017.

Figure 7. Sectoral distribution of total primary energy supply and total final energy consumption in the Arab region, 2015

(a) Total primary energy supply

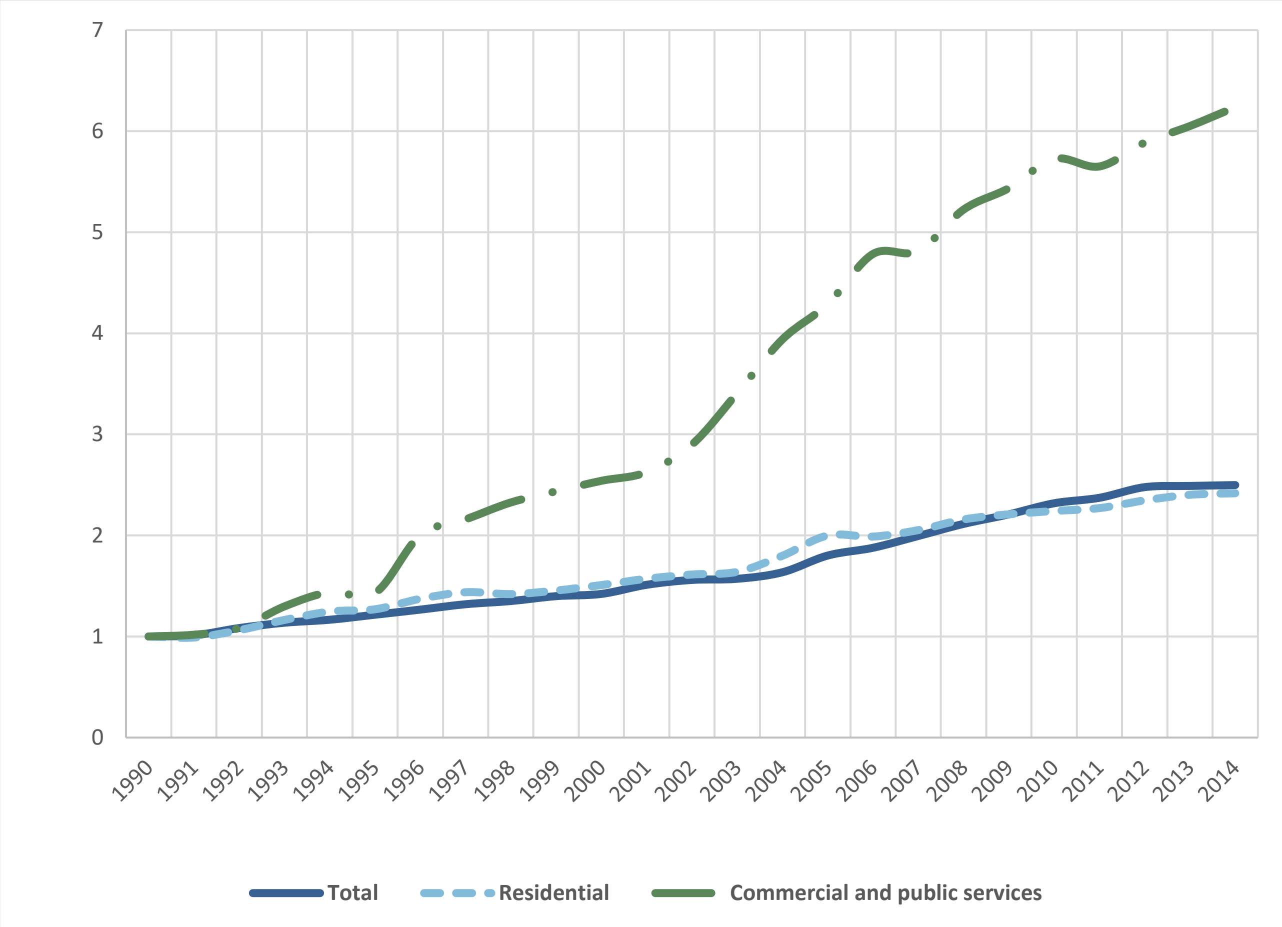


(b) Total final energy consumption



Source: IEA, 2017.

Figure 8. TFEC increases in the buildings sector in the Arab region, 1990-2015

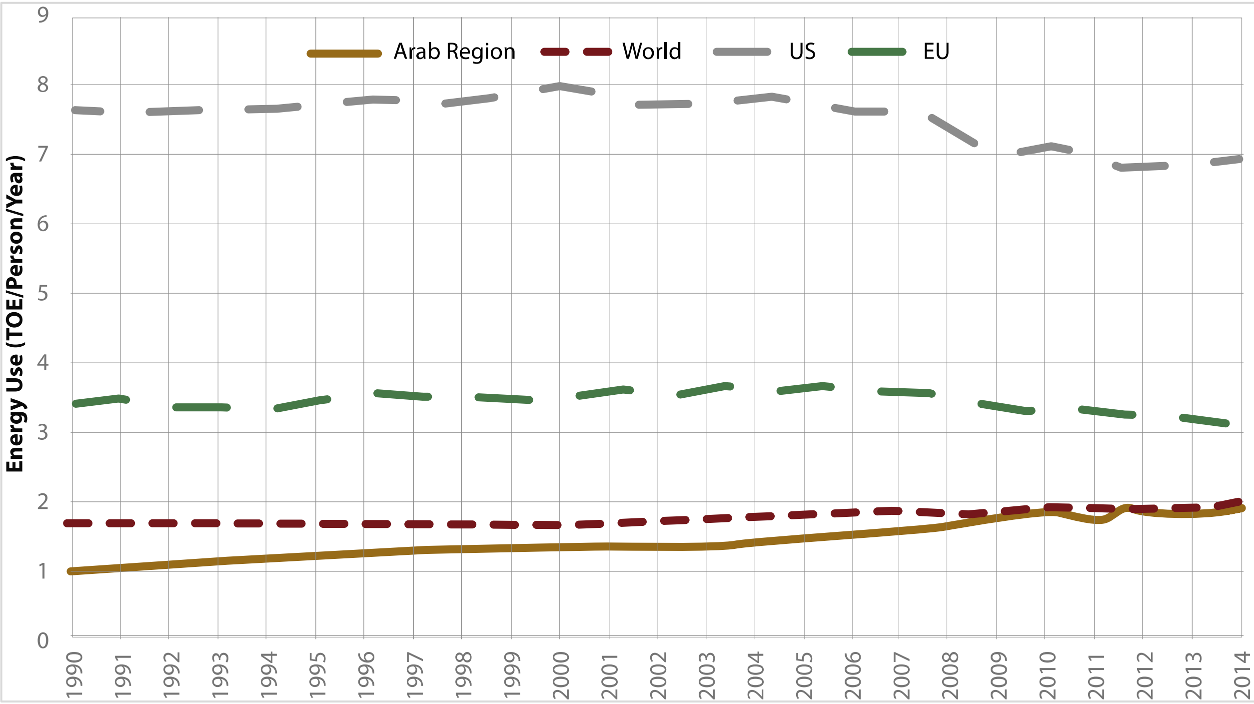


Source: IEA, 2017.

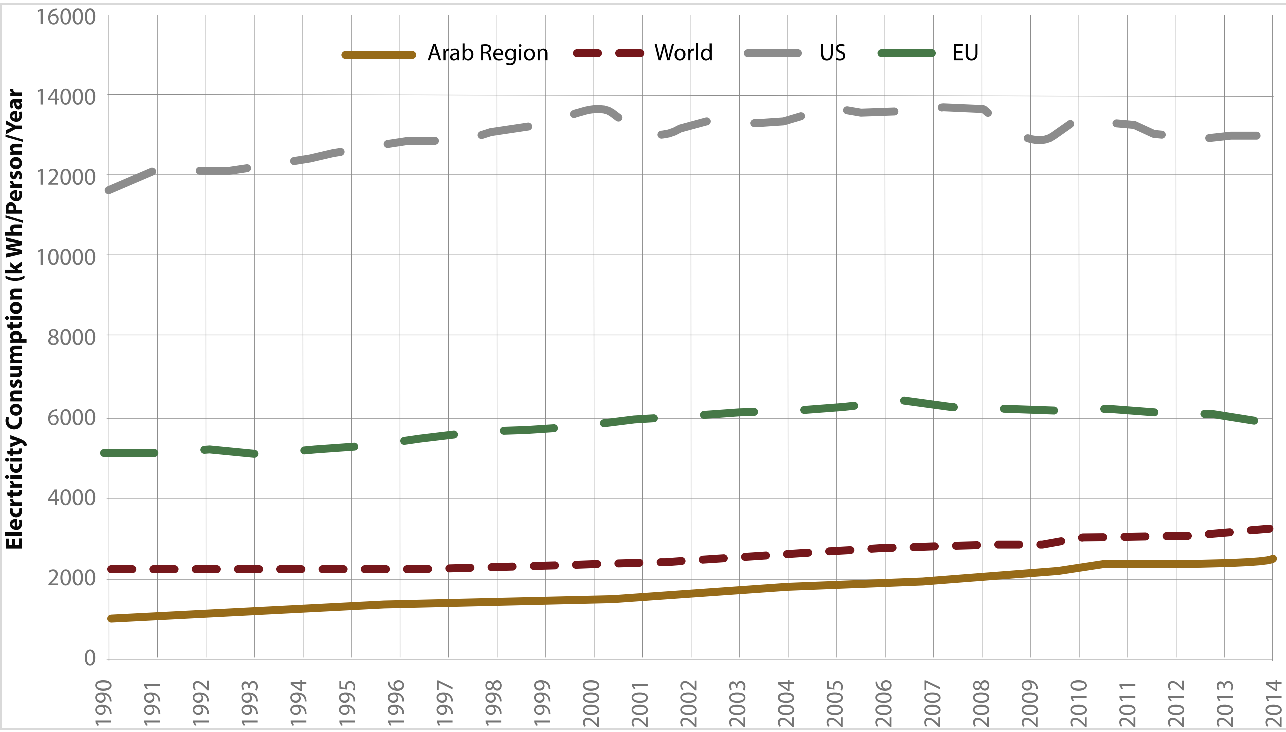
The regional per capita final energy and electricity consumptions are rather low, as noted in figure 9. Overall, the per capita energy use and electricity consumption in the Arab region are close to world averages, but significantly lower than those reported for the European Union and the United States (figure 9 b). Owing to this low per capita energy use, the Arab region generates slightly less carbon emissions per person than the global average and significantly less than European Union and the United States (figure 9 c). However, per capita energy use and carbon emissions have been steadily increasing in the Arab region, while decreasing in the European Union and the United States, especially during the last decade. The trend for higher energy consumption, including electricity demand, in the Arab region is expected to continue over the next decade, especially in the buildings sector because of high population growth, rapid urbanization and rising living standards associated with widespread aspirations for greater comfort. Energy consumption in the Arab region is further boosted by low prices of some household equipment, often with very poor efficiency ratings, making them affordable to growing number of consumers. Annual urban population growth rates in Arab countries range between 2 per cent and 6 per cent, with a regional average of 3.8 per cent (UN-Habitat, 2013). Moreover, a total of $4.3 trillion is forecasted to be spent on construction in the Arab region over the next decade, representing a cumulative growth of 80 per cent of the present construction market size (OEGCP, 2011; Asif, 2015).

Figure 9. Variations of per capita final energy consumption, electricity consumption, and carbon emissions

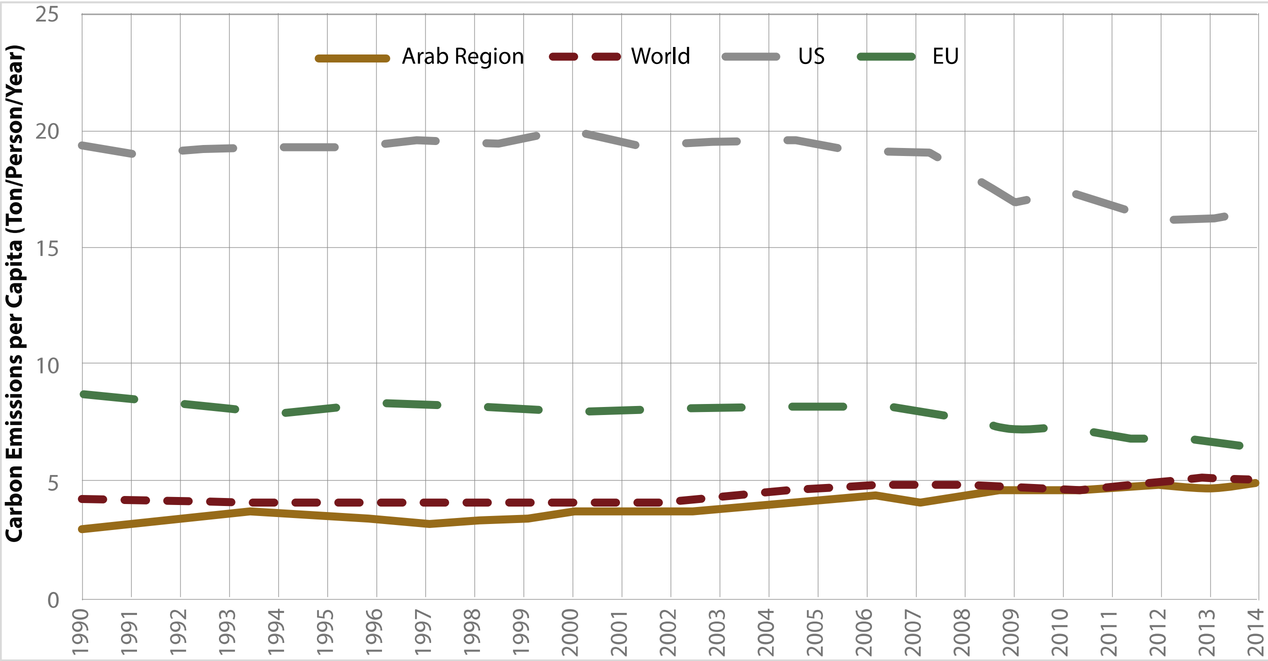
(a) Annual total final energy consumption per capita



(b) Annual electricity per capita



(c) Annual carbon emissions per capita



Source: World Bank, 2017.

B. ARAB SUBREGIONS

The Arab region is divided into four subregions, as summarized in table 1 based on several criteria including geographical locations, cultural tendencies, and living conditions and standards. Table 1 also presents the population, GDP per capita, and TPES per person for each subregion based on 2015 data (IEA, 2017). The GCC subregion has the lowest population, but the highest values for both primary energy use and GDP per person. The Mashreq and the Maghreb have similar economic and energy indicators, even though the Mashreq has almost double the population owing to the inclusion of Egypt. As expected, Arab LDCs have the lowest energy use and GDP per capita among all the Arab subregions.

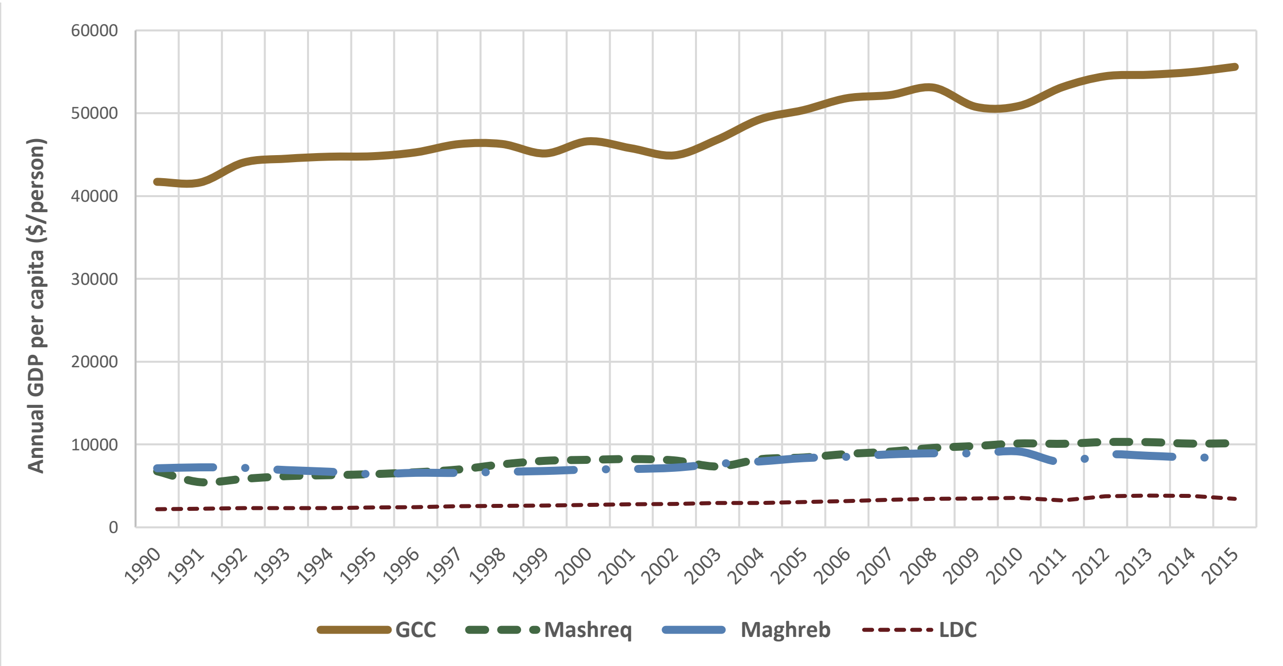
Table 1. Characteristics of Arab subregions

Subregion	Countries	Population (millions)	GDP/capita (USD/person)	TPES/capita (TOE/person)
Maghreb	Algeria; Libya; Morocco; Tunisia	91.580	10,805	1.109
Mashreq	Egypt; Iraq; Jordan; Lebanon; State of Palestine; Syrian Arab Republic	164.670	9,915	0.942
Gulf Cooperation Council	Bahrain; Kuwait; Oman; Qatar; Saudi Arabia; United Arab Emirates	52.700	55,601	7.870
Arab Least Developed Countries	Mauritania; Sudan; Yemen	71.237	3,296	0.287

Source: IAEA, 2012.

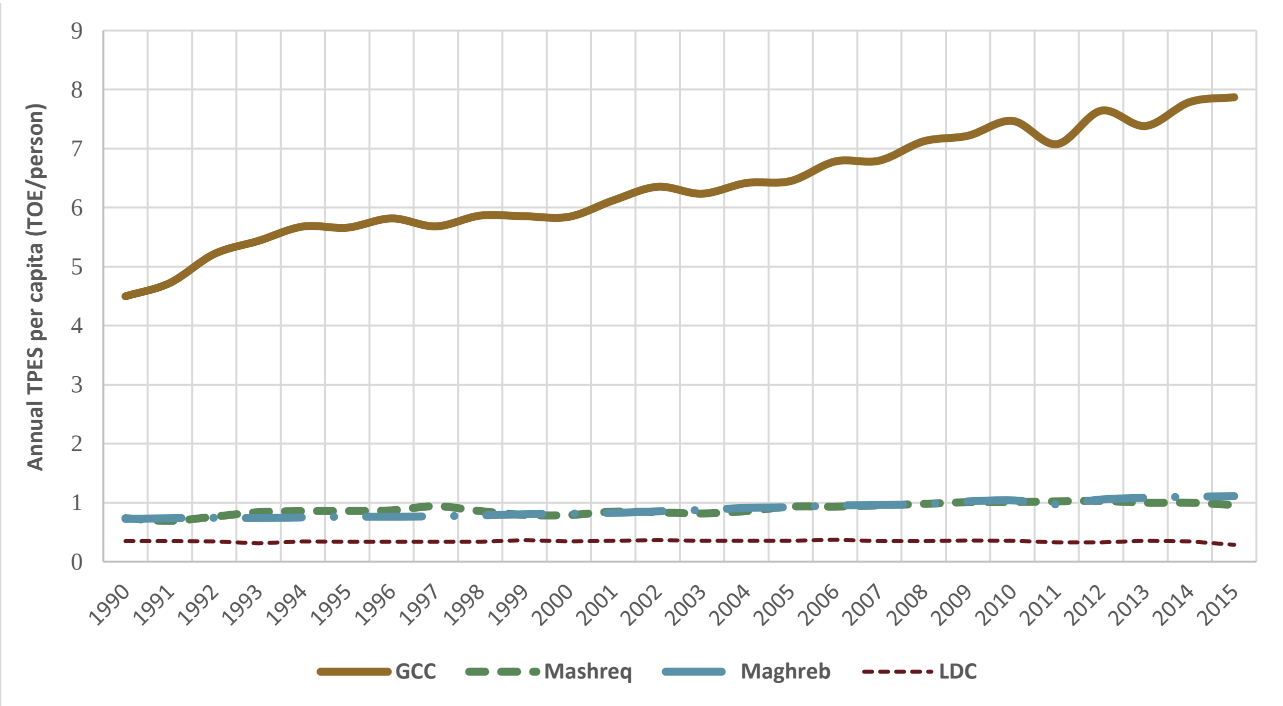
Figures 10 and 11 illustrate variations in GDP per capita and TPES per capita, respectively, over the period1990-2015 in the Arab subregions, using the sum of the values corresponding to the countries included in each subregion. As expected, the GCC region has significantly higher levels for both economic output and energy consumption per capita. while the Arab LDCs have the lowest economic and energy use indicators in the Arab region and globally. GDP and TPES per capita follow the same trend over the entire period 1990-2015 period in the Mashreq and Maghreb.

Figure 10. Variations of GDP per capita by Arab subregion



Source: IAEA, 2012.

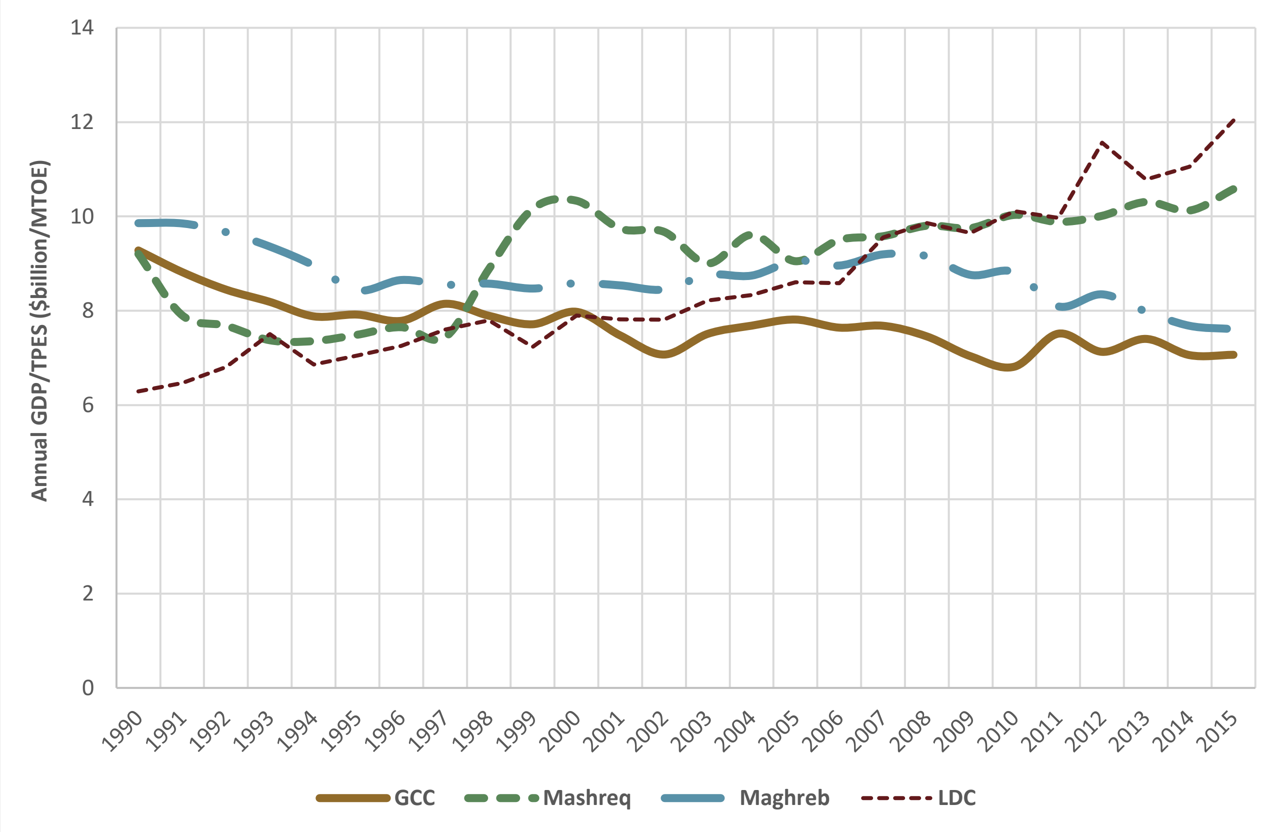
Figure 11. Variation of TPES per capita by Arab subregion



Source: IEA, 2017.

When considering the energy intensity or the economic output per unit of primary energy supply (the energy productivity), Arab LDCs had the highest and increasing energy productivity levels over the last decade among all Arab subregions. In contrast, the GCC region has had the lowest and decreasing energy productivity values since 2000 (figure 12). The Mashreq and Maghreb regions' energy productivity levels are between those of the GCC region and Arab LDCs, with the Mashreq's energy productivity exhibiting an increasing trend while that of the Maghreb has been decreasing since 2007.

Figure 12. Variations in energy productivity by Arab subregion



Source: IEA, 2017.

C. COUNTRY-SPECIFIC ANALYSIS

Basic macroeconomic indicators for Arab countries are listed in table 2, based on 2015 data except for the State of Palestine where 2013 data are used for 2015 (IEA, 2017; World Bank, 2017; United Nations, 2017). Moreover, annual variations in those macroeconomic indicators for representative countries of the Arab subregions are presented in figures 13-15, which show annual variations in per capita TPES, per capita GDP, and the GDP/TPES ratio over the period 1990-2015 in Egypt, Saudi Arabia, Tunisia and Yemen. As expected, Saudi Arabia, representing the GCC subregion, has significantly higher values for both economic output and energy consumption per person. Meanwhile, Yemen, representing the Arab LDCs, has the lowest economic and energy use indicators. GDP and TPES per capita follow the same trend over the entire period 1990-2015 for both Egypt and Tunisia, representing the Mashreq and Maghreb regions, respectively. Figure 15 indicates that Saudi Arabia has lower and decreasing energy productivity (inverse of energy intensity), while Egypt and Tunisia have had stagnant energy productivity over the last decade. In contrast, Yemen is exhibiting higher, albeit irregular, energy productivity levels.

Table 2. Basic macroeconomic indicators for Arab countries, 2015

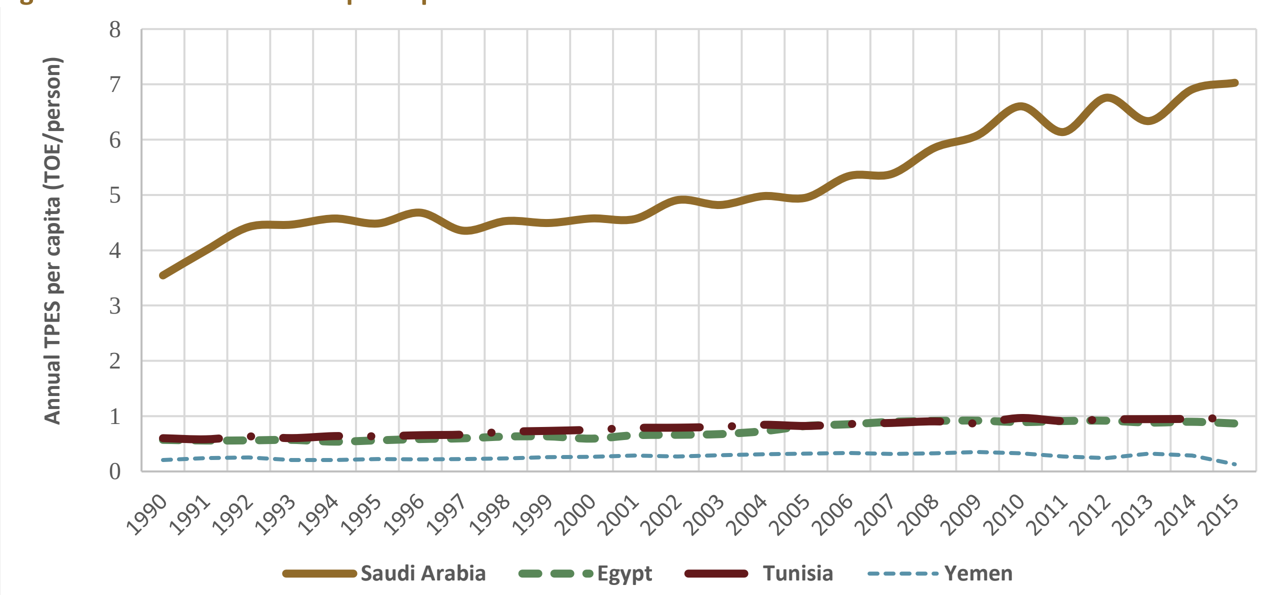
Country	Population[a] (millions)	GDP/capita[b] (PPP 2011 USD/person)	TPES/capita[c] (TOE/person)	TPES/GDP (TOE/1000 PPP 2011 USD)
Algeria	39.872	13,725	1.355	0.099
Libya	6.235	14,847	2.767	0.186
Morocco	34.803	7,407	0.557	0.075
Tunisia	11.274	10,766	0.970	0.090
Egypt	93.778	10,096	0.847	0.084
Iraq	36.116	15,073	1.325	0.088
Jordan	9.159	8,491	0.941	0.111
Lebanon	5.851	13,353	1.306	0.098
Syrian Arab Republic	18.735	2,002	0.533	0.266
State of Palestine	4.422	4,713	0.404	0.086
Bahrain	1.372	43,926	10.402	0.237
Kuwait	3.936	68,476	8.804	0.129
Oman	4.200	39,873	6.043	0.152
Qatar	2.482	119,749	18.315	0.153
Saudi Arabia	31.557	50,724	7.025	0.138
United Arab Emirates	9.154	66,569	8.006	0.120
Mauritania	4.182	3,602	0.308	0.086
Sudan	38.648	4,290	0.405	0.095
Yemen	26.916	2,309	0.129	0.056

[a] Data on population are from World Bank (2017).

[b] Data on GDP PPP 2011 USD are from (World Bank,2017) except for the Syrian Arab Republic where the data is for PPP 2010 USD for IEA (2017).

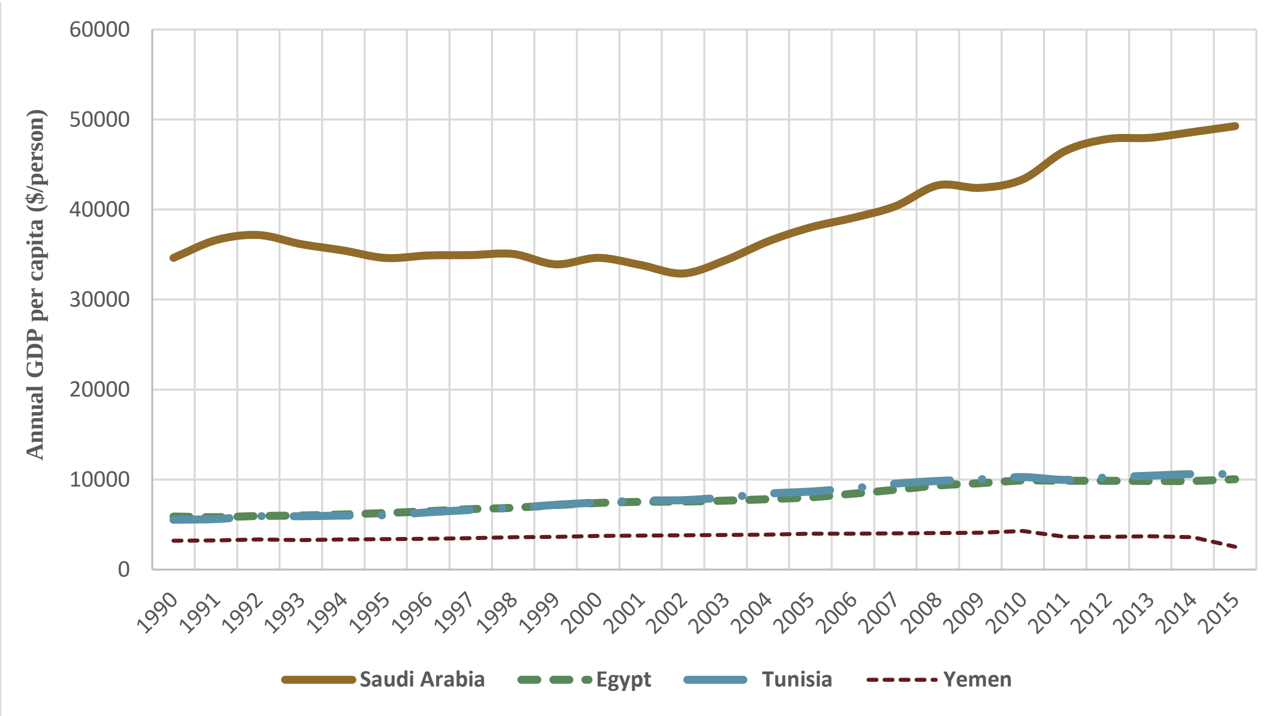
[c] Data on TPES are from IEA (2017), except for Mauritania and the State of Palestine. Data for Mauritania are from UNStat (https://unstats.un.org/unsd/energy/balance/default.htm. Data for the State of Palestine are from the Palestinian Central Bureau of Statistics (http://www.pcbs.gov.ps/site/lang__en/886/Default.aspx).

Figure 13. Variation in TPES per capita for selected Arab countries



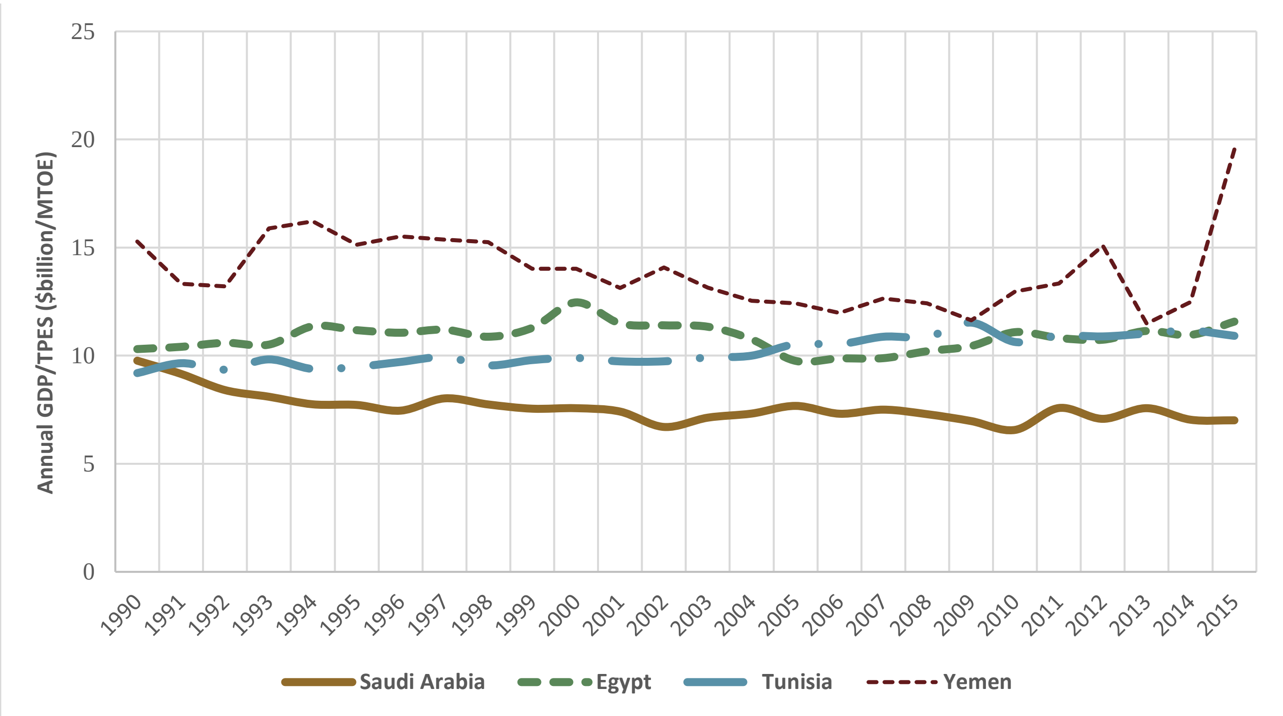
Source: IEA, 2017; World Bank, 2017.

Figure 14. Variations in GDP per capita for selected Arab countries



Source: IEA, 2017; World Bank, 2017.

Figure 15. Variations in energy productivity for selected Arab countries



Source: IEA, 2017; World Bank, 2017.

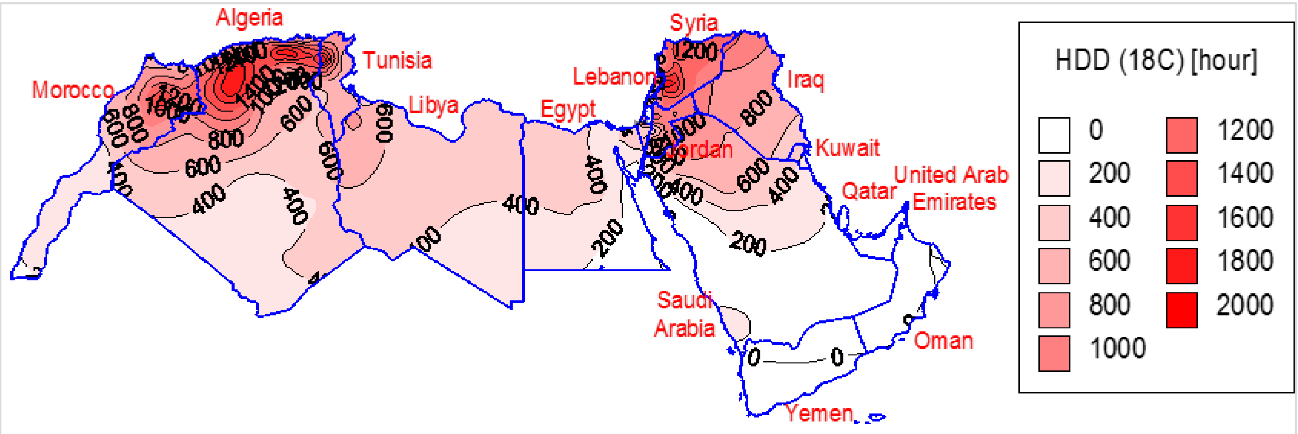
II. BUILDINGS SECTOR ENERGY CONSUMPTION

The present section describes the main drivers for energy use in the buildings sector for the Arab region, including climatic conditions, buildings stock size, penetration rates of air conditioning systems, energy subsidies, and current regulations and standards. Moreover, energy consumption trends for the building sector are presented at various levels, including the overall Arab region, the four subregions, and individual countries. Lastly, energy efficiency metrics of both residential and non-residential buildings are estimated for the Arab region and its subregions, with a discussion of typical end-uses for both residential and commercial buildings in the region and selected countries.

A. CLIMATE CHARACTERISTICS

Degree-days for both heating and cooling were estimated throughout the Arab region, using hourly weather data for 162 cities (Krarti and Ihm, 2016). Figure 16 shows a contour map of annual heating degree-days (HDD)[3] with a base temperature of 18 degrees Celsius for the Arab region where hourly climatic data are available. Figure 17 presents a similar map obtained for annual cooling degree-days (CDD)[4] with a base temperature of 18 degrees Celsius. As indicated in figure 16, HDD values of cities close to coastal areas in the Mediterranean region are higher than in the Arabian Desert. Mediterranean cities therefore have higher space heating energy requirements to maintain acceptable indoor thermal comfort in conditioned buildings during the heating season. In contrast, figure 17 shows that sites located in the Arabian Desert are extremely hot and thus require significant energy to cool buildings compared with sites located in the Mediterranean region.

Figure 16. Contour map of the Arab region for annual HDDs



Source: Krarti and Ihm, 2016.

In hot climates, such as in the GCC region, energy consumption for the buildings sector is aligned with climatic conditions, since most buildings are air-conditioned (Krarti, 2015). For example, figure 18 indicates that the monthly total electricity consumption in Saudi Arabia closely follows the average ambient temperatures, based on data recorded in 2014. The strong correlation between electricity consumption and ambient temperature clearly reflects the importance of air conditioning during the summer months, when electrical demands double compared with levels reported during the winter period.

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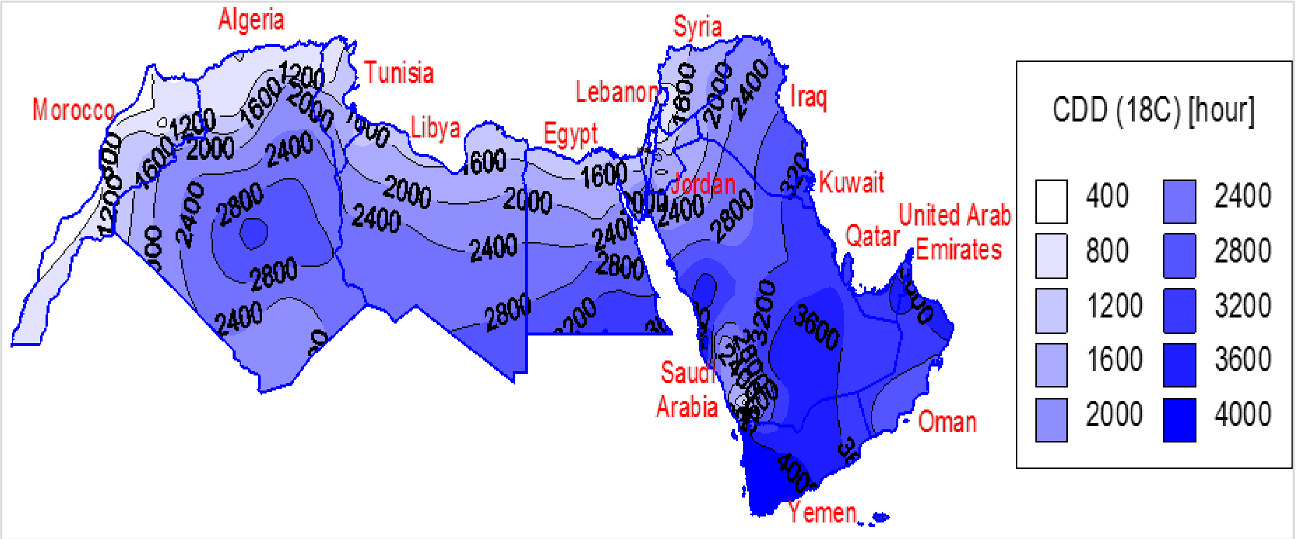
3 Heating degree-days represent the number of degrees associated with all days that have average temperatures below 18 degrees Celsius during one year. They are strongly correlated to buildings' energy requirements for space heating.

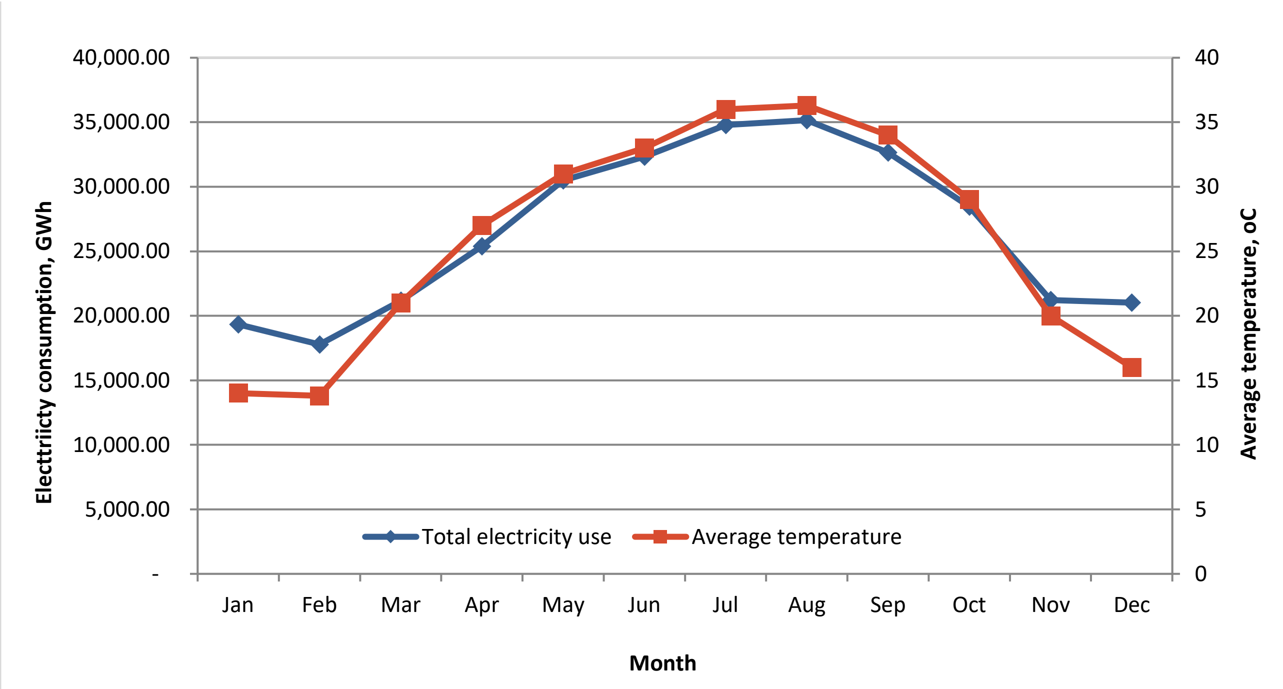
4 Cooling degree-days represent the number of degrees associated with all days that have average temperatures above 18 degrees Celsius during one year. They are strongly correlated to buildings' energy requirements for space cooling.

Figure 17. Contour map of Arab region for CDD



Source: Krarti and Ihm, 2016.

Figure 18. Monthly total electricity consumption and average ambient temperature in Saudi Arabia, 2014



Source: Krarti et al., 2017.

B. BUILDINGS STOCK FLOOR AREAS

Detailed census data for buildings stock, especially building floor areas, in the Arab region is almost non-existent. However, some studies have utilized limited census data to estimate building floor areas for residential and non-residential buildings in some Arab countries. Table 3 summarizes those studies, the estimated building floor areas, and per capita floor areas based on population data reported by the United Nations for the census year.

Table 3. Reported total floor area for buildings in Arab countries based on census data

Country, type of buildings	Census year	Total building floor area (million m^2)	Per capita floor area (m^2/person)	References
Egypt, residential	2006	1476.463	18.9	USAID, 2008; CAPMAS, 2017
Tunisia, residential	2006	274.254	26.9	ANME, 2010
Tunisia, non-residential	2006	28.493	2.8	ANME, 2010
Saudi Arabia, residential	2010	651.616	23.8	Khan and others, 2017

Models for estimating building floor areas have been developed and utilized to assess the energy performance of various building types for countries and regions. In particular, Navigant (2015) indicated that the MENA region, which includes most Arab countries, had a total building floor area of 4.5 billion square metres in 2014 or 11.5 square metres/person. Moreover, GABC (2016) reports that the MENA region has 8 billion square metres of building floor area or 18.65 square metres/person, which is close to the estimate of 20.5 square metres/person provided by Harvey and others (2014). The International Energy Agency (IEA) developed a model that provides per capita floor area for residential buildings as a function of GDP per capita for a country or region (IEA-ETP, 2016). Using the IEA building sector model, table 4 summarizes the average, minimum and maximum values per capita household floor area.

Table 4. Residential floor area per capita as a function of GDP per capita

GDP per capita ($ 2012 PPP/person)	Average	Minimum	Maximum
0	12 m^2/person	7 m^2/person	30 m^2/person
10,000	23 m^2/person	9 m^2/person	50 m^2/person
20,000	34 m^2/person	17 m^2/person	62 m^2/person
30,000	44 m^2/person	25 m^2/person	68 m^2/person
40,000	49 m^2/person	30 m^2/person	71 m^2/person
50,000	51 m^2/person	31 m^2/person	72 m^2/person
60,000	52 m^2/person	32 m^2/person	73 m^2/person

Source: IEA-ETP, 2016.

Using the GDP data for the Arab region, per capita residential building floor area is estimated to range between 11.6 square metres/person and 48.1 square metres/person, with an average of 24.2 square metres/person, a metric that is close to the values listed in table 3 for Tunisia, Saudi Arabia and, to a lesser extent, Egypt. The reported per capita residential floor area of 18.9 square metres/person for Egypt is lower than the average of 24.2 square metres/person, as expected for a country with densely populated urban areas, but is still higher than the minimum value of 11.6 square metres/person.

Estimating floor area is even more challenging for non-residential buildings in the Arab region. Only few models have been reported, with a large variation in per capita floor area estimations for the MENA region. They include (i) 5.5 square metres/person (McNeil and others, 2013); (ii) 4.5 square metres/person (IEA-ETP, 2016); (iii) 4.0 square metres/person (Harvey and others, 2014); and (iv) 2.5 square metres/person (Ürge-Vorsatz and others, 2013). The per capita floor area of 2.8 square metres/person found for non-residential buildings in Tunisia is in the lower range of the reported model estimates. Using the range of 2.5-5.5 square metres/person, the non-residential floor area for the Arab region can be estimated as a function of the population size. In particular, the total floor area for non-residential buildings for 2015 is estimated between 950 million square metres and 2,091 million square metres, with a mean value of 1,521 million square metres.

C. PENETRATION RATES OF AIR CONDITIONING SYSTEMS

As noted in figures 16 and 17, the vast majority of the Arab region is characterized by a cooling dominated climate. Air conditioning (AC) systems are therefore required to maintain desired thermal comfort in both residential and non-residential buildings. Moreover, refrigerators are required to preserve food longer. The penetration of AC, however, varies by Arab subregion. While AC is available in almost all buildings in the GCC region (100 per cent penetration rate), the use of active systems (mechanical equipment) to cool buildings depends on a country and its standard of living. Reported penetration rates of AC systems and refrigerators are listed in table 5 for residential buildings in selected Arab countries representative of the Mashreq, Maghreb and Arab LDCs. The AC penetration rate forecast for the Maghreb are also provided. As noted in several studies, the penetration of AC systems and appliances depends significantly on income level per capital in each country. The penetration rate of AC systems for residences in the Maghreb and Mashreq currently ranges between 40 per cent and 50 per cent, and is expected to exceed 80 per cent by 2030. In the Arab LDCs, the AC and refrigerator penetration rates are low, and do not exceed 30 per cent. It should be noted that significant variations in climatic conditions between Arab countries, as highlighted in figure 18, results in disparities in potential AC operating hours. AC operation, especially for residential buildings, is higher in the GCC subregion compared to other subregions, and is thus expected to affect electrical peak demand and energy consumption more significantly in GCC countries. Moreover, lower operation hours in the Maghreb, Mashreq and Arab LDCs has less of an impact on energy consumption than on electrical peak demand.

Table 5. Penetration rates of AC systems and refrigerators in residential buildings for selected Arab countries

Country	AC penetration rate (year)	Forecasted AC penetration rate (2030)	Refrigerator penetration rate (year)	References
Algeria	37.2% (2015)	84.5%	90% (2009)	(WBG, 2016)
Morocco	9.3% (2015)	49.0%	85% (2009)	(WBG, 2016)
Syrian Arab Republic	9% (2009)	NA	40% (2009)	(RCREEE, 2012)
Tunisia	40.3% (2015)	84.5%	80% (2009)	(WBG, 2016)
Yemen	12% (2009)	NA	30% (2009)	(RCREEE,2012)
Lebanon	50% (2010)	NA	100%(2010)	MEDENER (2013)

Within the Arab region, the GCC subregion remains a significant market for the AC industry. Table 6 lists the number of AC units sold over the period 2011-2016 in the Arab region, itemized by country (JRAIA, 2017). As indicated in table 6, the GCC subregion represents over 80 per cent of total AC demand in the Arab region. However, AC demand in most GCC countries has stabilized, and slightly decreased in some cases, in the last two years most likely because of slower economic activities associated with low oil prices.

Table 6. Total number of AC units (thousands) sold in the Arab region, 2011-2016

Country	2011	2012	2013	2014	2015	2016
Saudi Arabia	1581	1666	2226	2238	2164	1926
Egypt	747	803	765	781	782	758
United Arab Emirates	497	493	713	737	763	731
Oman	248	217	297	321	320	296
Qatar	189	179	275	284	286	278
Algeria	172	176	206	205	194	229
Kuwait	144	147	214	217	225	211
Iraq	274	296	315	320	193	187
Libya	180	174	189	159	159	155
Morocco	122	131	132	135	135	130
Bahrain	77	82	82	78	77	80
Lebanon	69	68	69	77	76	80
All others	231	221	215	227	228	222
Arab region	4531	4653	5698	5779	5602	5283

Source: JRAIA, 2017.

D. ENERGY SUBSIDIES

Energy prices are highly subsidized in the Arab region (table 7). Table 8 lists electricity rates for typical households, in addition to available electricity generating capacity, electricity consumption per capita, and carbon emissions per capita for selected Arab countries. As indicated in table 7, energy subsidies, especially for GCC and oil exporting countries, are among the highest in the world and might explain the high electricity consumption and carbon emissions per person in several Arab countries (table 8). According to IEA, Arab countries are among the largest subsidizers of energy in the world: six of the world's 10 largest subsidizers are from the Arab region, led by Kuwait, Saudi Arabia and Qatar (Ameer and Krarti, 2016). Moreover, GCC countries have the highest electricity consumption per capita globally owing to significant air conditioning loads for buildings, especially during the summer months. However, there is a wide difference in energy consumption levels between Arab countries. The Arab region also has some of the lowest users of energy globally, including electricity. For instance, an average person in Yemen consumes only 147 kilowatt hour/year, as noted in table 8, most likely because of low energy access in rural areas.

Table 7. Energy subsidies in the Arab region

Country	Total energy subsidies (billions of $)	Percent GDP (%)	Subsidies of total energy per capita ($/person)	Subsidies of electricity per capita ($/person)
Algeria	23.870	10.0	604.70	59.83
Bahrain	3.940	11.2	3224.74	1179.72
Egypt	32.349	10.0	365.79	33.20
Iraq	0.495	0.2	13.37	0.00
Jordan	1.424	3.6	208.67	89.90
Kuwait	14.097	7.8	3429.95	409.78
Lebanon	5.246	10.3	1151.99	465.14
Libya	6.442	10.2	1021.64	0.00
Mauritania	0.058	1.3	15.53	15.53
Morocco	1.957	1.6	58.41	NA
Oman	7.267	8.9	1718.97	102.13
Qatar	14.471	6.4	5995.25	1041.12
Saudi Arabia	106.556	13.2	3395.03	352.54
Sudan	1.375	2.1	35.77	NA
Tunisia	2.004	4.0	180.37	115.28
United Arab Emirates	28.961	6.6	3022.85	337.03
Yemen	0.359	0.7	12.69	6.08
Arab region	250.868	8.3	715.65	85.31

Source: IMF, 2015.

Note: The price-gap approach is used to estimate subsidies. It compares average end-user prices paid by consumers with reference prices that correspond to the full cost of supply.

Table 8 indicates that the Arab region has 232,675 megawatts of available electric power generating capacity, with 6 per cent sourced from renewable resources, mostly hydroelectric plants (around 11,000 megawatts). As part of their national renewable energy plans, most Arab countries have set ambitious targets to meet 10-100 per cent of their electricity needs using renewable energy sources by 2030 (IRENA, 2016).

Table 8. Electricity prices, energy use and carbon emissions indicators for selected Arab countries

Country	Cost of electricity ($/kWh)[a]	Electricity generation capacity (MW)[b]	Electricity consumption per capita (kWh/person)[c]	Total final energy consumption per capita (TOE/person)[d]	Carbon dioxide emissions per capita (tons/person)[e]
Algeria	0.051	13 000	1 451	0.944	3.717
Libya	0.016	10 000	1 656	1.322	9.187
Morocco	0.123	8 202	892	0.435	1.744
Tunisia	0.127	4 491	1 458	0.7	2.587
Egypt	0.033	32 483	1 754	0.604	2.199
Iraq	0.009	25 600	1 218	0.496	4.812
Jordan	0.092	4 882	2 288	0.73	3.003
Lebanon	0.046	2 710	2 861	0.835	4.296
Syrian Arab Republic	0.004	3 154	811	0.357	1.599
Bahrain	0.008	3 889	20 190	4.568	23.450
Kuwait	0.007	18 000	14 951	4.523	25.224
Oman	0.026	8 750	6 588	4.548	15.443
Qatar	0.022	8 900	17 460	8.769	45.423
Saudi Arabia	0.013	46 400	9 926	4.6	19.529
United Arab Emirates	0.080	29 348	12 916	5.805	23.202
Sudan	0.049	3 253	264	0.265	0.309
Yemen	0.041	1 500	147	0.095	0.865

[a] Average prices in 2014 for residential buildings estimated based on 500 kWh of consumption (RECREE, 2015).

[b] Data for 2015 obtained from IRENA (2016).

[c] Data for 2015 obtained from IEA (2017).

[d] Data for 2014 (except the Sudan for 2013) obtained from World Bank (2017).

E. BUILDINGS SECTOR ENERGY CONSUMPTION TRENDS

The present section evaluates energy consumption in the buildings sector for the Arab region, subregions and individual countries, based on reported data over the last two decades (IEA, 2017). The general trends of energy consumption and mix for both residential and non-residential buildings are evaluated and discussed.

1. Overall Trends For The Arab Region

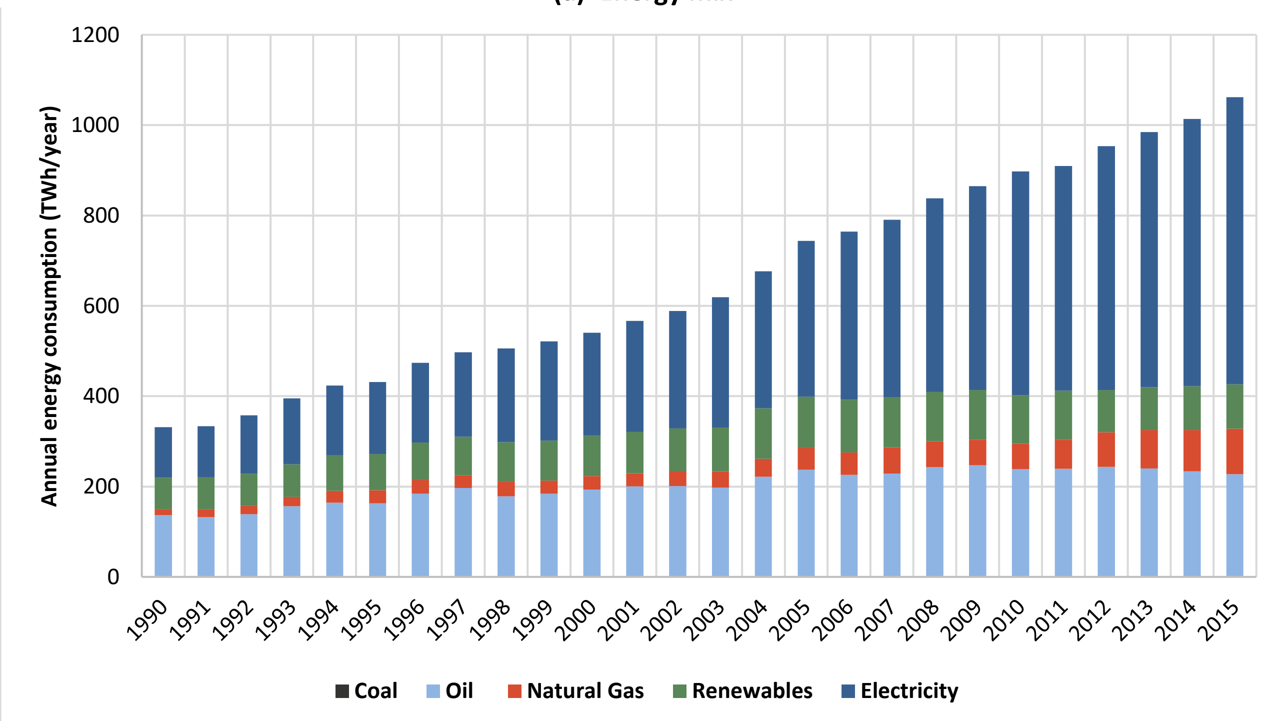
As shown in figure 19, the total final energy consumption (TFEC) attributed to the buildings sector has been increasing steadily in the Arab region since 1990, with a clear transition from oil products to electricity use. As indicated in figure 19(a), the energy mix for the buildings sector has transitioned from a preference for oil products in 1990 representing 41 per cent of the overall buildings TFEC, to a dominance of electricity used to meet over 60 per cent of total Arab buildings sector needs in 2015. Moreover, the annual total final energy consumption of buildings has increased consistently since 1990, as shown in figure 19(b), indicating a linear trend between years and total building energy use. If this trend continues, buildings in the Arab countries will consume 1,450 terawatt hours by 2030, doubling the 2006 energy consumption level; and 2,000 terawatt hours by 2050, almost doubling the 2015 energy use level. Figure 20 indicates that the TFEC share of the buildings sector remained in the range 18-23 per cent over the period 1990-2015, mostly dominated by household energy use. Using the reported efficiencies for converting primary energy supply to final energy consumption, the share of the buildings sector of the total primary energy supply (TPES) is estimated for the Arab region for three years, as illustrated in figure 21: 1990, 2000 and 2015. The overall share of the building sector of the TPES has increased from 23 per cent in 1990 to 28 per cent in 2015. In 2015, buildings in Arab countries consumed 1,076 terawatt hours, mostly in electricity (60 per cent), to meet increasing demand attributed mainly to lighting, appliances and cooling systems (Krarti and Ihm, 2016). For commercial and public buildings in the Arab region, electricity represents 88 per cent of their total energy consumption. For residential buildings, electricity covers 50 per cent of their energy needs in most Arab countries. Oil products, natural gas and renewables provide 21 per cent, 10 per cent and 9 per cent, respectively, of TFEC associated with the buildings sector to meet mostly non-electrical energy demands specific to domestic hot water, cooking and space heating needs (Krarti and Ihm, 2016).

Moreover, TFEC, and its corresponding TPES, includes non-energy usages (energy products used as feedstock in industrial processes, such as those in petrochemical industries). For the Arab region, over 15 per cent of the 2015 TFEC went to non-energy use, as indicated in figure 6. This share is even higher for GCC countries and other oil and natural gas producing countries in the Arab region. For instance, non-energy use accounted for around 27 per cent of Saudi TFEC in 2015. Therefore, the actual share of the region's buildings sector energy needs is higher than previously discussed values (in 2015, the share was around 25 per cent of the energy-only TFEC and about 31 per cent of the corresponding energy-only TPES).

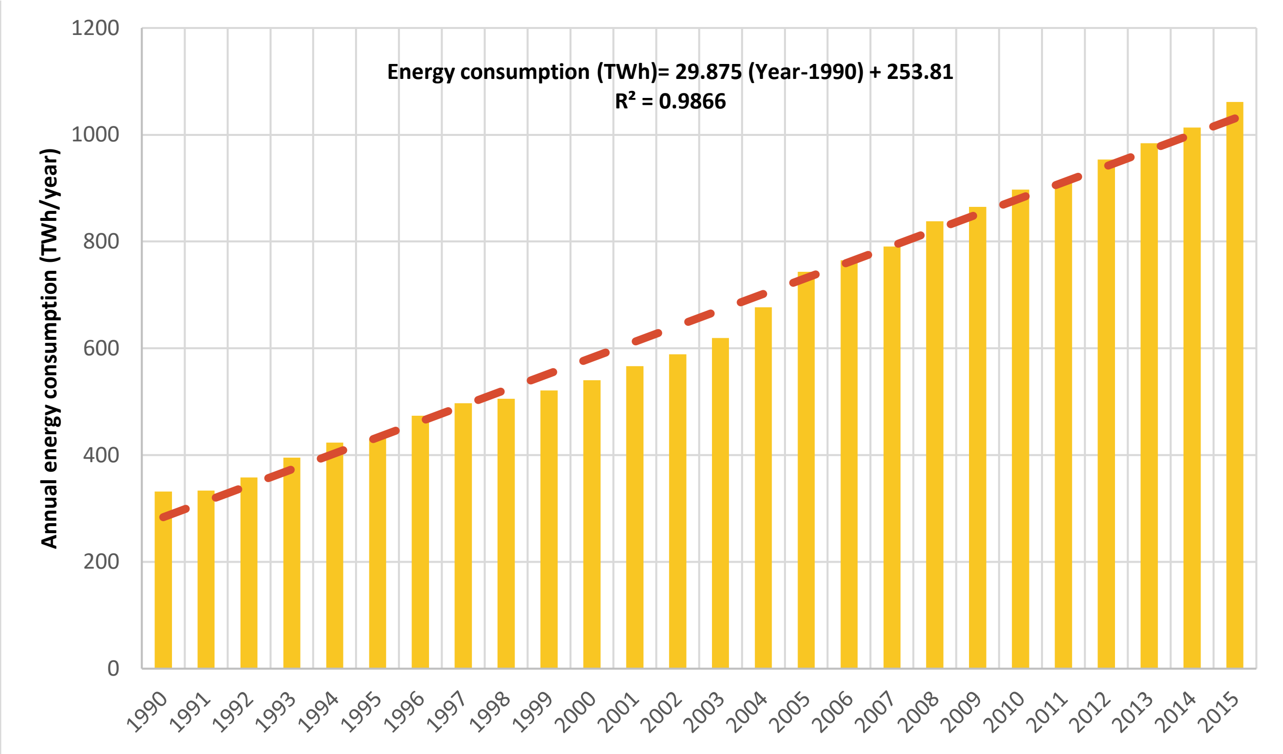
It is also important to note that while electricity represented 60 per cent of the energy used by buildings, it accounted for only 19 per cent of the overall TFEC for the Arab region in 2015 (22 per cent when only energy use of TFEC is considered). Electricity is generated primarily from natural gas (65 per cent) and oil products (30 per cent), with renewables (3 per cent) and coal (2 per cent) providing minor contributions (figure 22).

Figure 19. Total energy use of the buildings sector in the Arab region, 1990-2015

(a) Energy mix

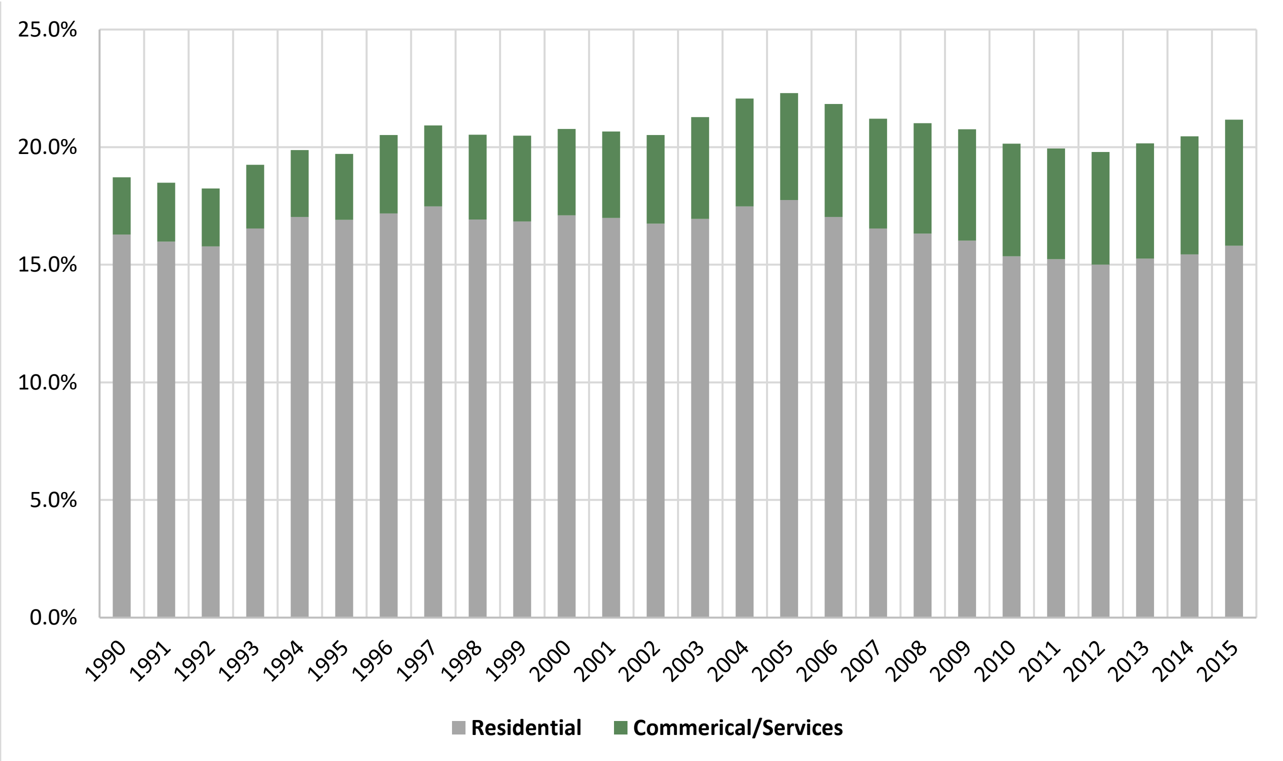


(b) Annual energy consumption trends



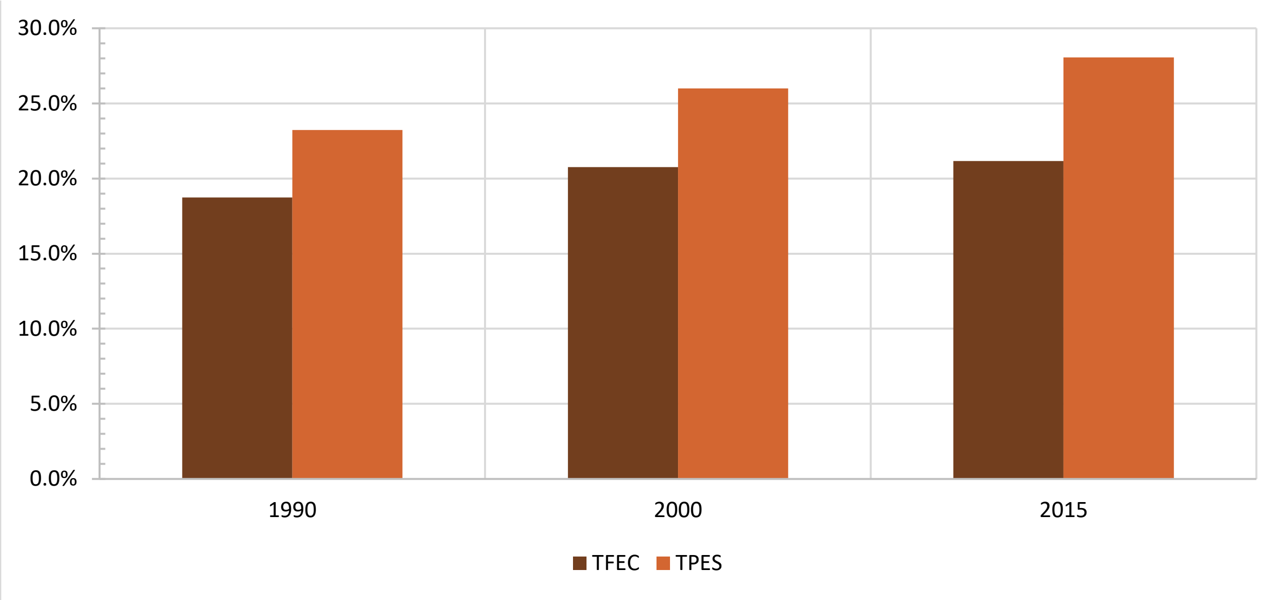
Source: IEA, 2017.

Figure 20. TFEC share of the buildings sector in the Arab region, 1990-2015



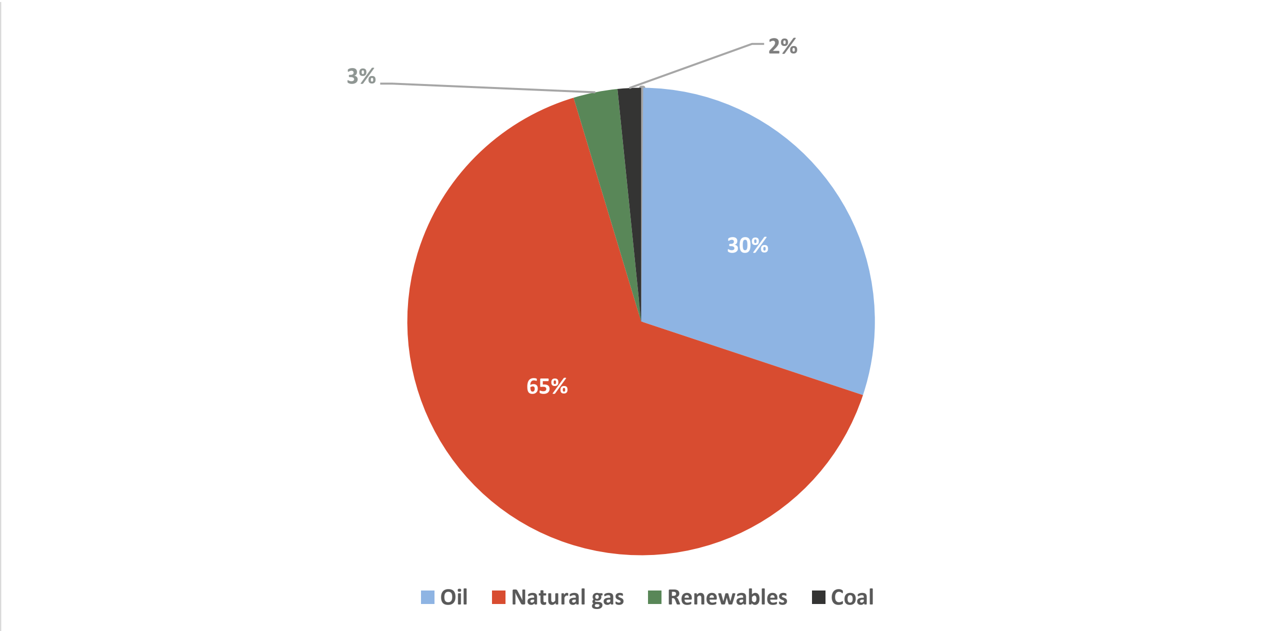
Source: IEA, 2017.

Figure 21. TFEC and TPES share of the building sector in the Arab region for 1990, 2000 and 2015



Source: IEA, 2017.

Figure 22. Energy mix for electricity generation in the Arab region, 2015

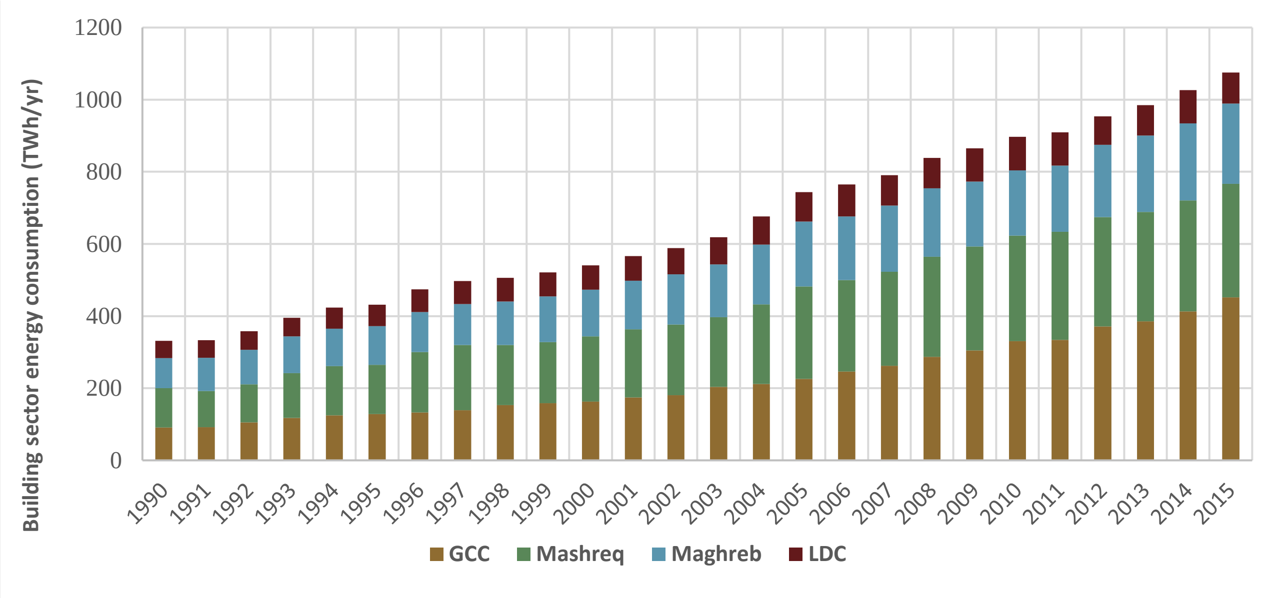


Source: IEA, 2017.

2. Trends For Arab Subregions

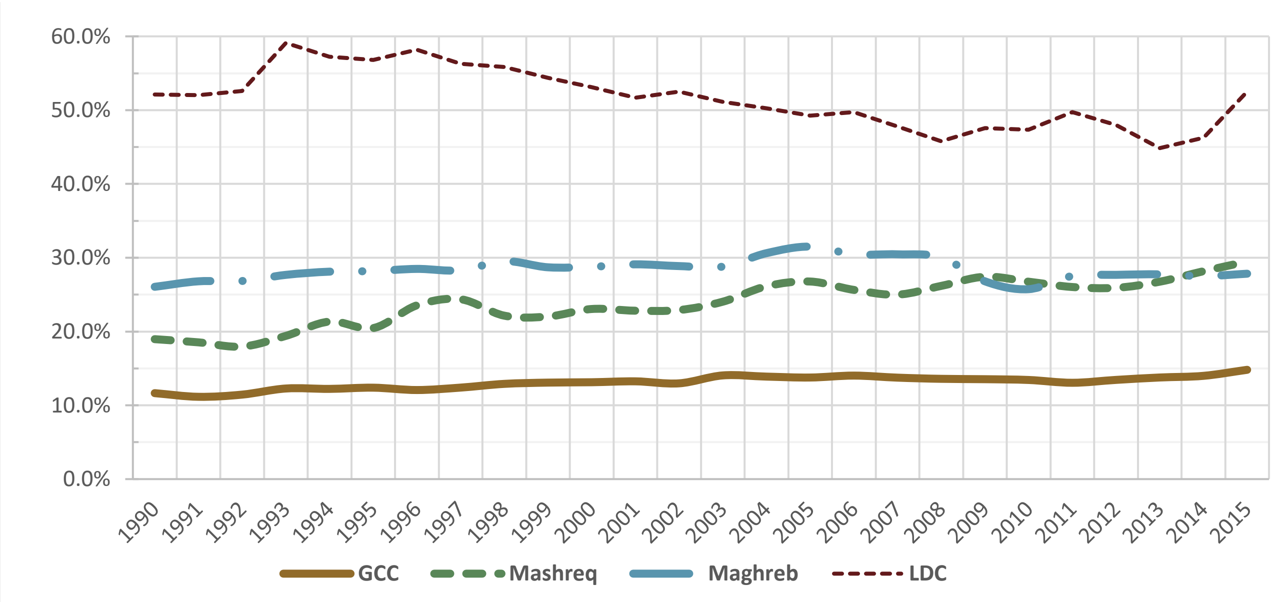
The annual energy consumption associated with the building sector varies between Arab subregions for the period 1990-2015 (figure 23). Since 2010, the GCC subregion has consumed the most energy attributed to buildings among all four subregions, owing to the drivers outlined in the above sections. However, the buildings sector represented only 15 per cent of the overall TFEC of the GCC subregion in 2015, one of the lower shares in the Arab region (figure 24). In 2015, buildings were responsible for 29 per cent, 28 per cent and 53 per cent of TFEC in the Mashreq, Maghreb and Arab LDCs, respectively (when considering the energy-only TFEC, these figures are 18 per cent for GCC subregion, 32 per cent for the Mashreq, 30 per cent for the Maghreb, and 54 per cent for the Arab LDCs).

Figure 23. Final energy consumption for the buildings sector by Arab subregions



Source: IEA, 2017.

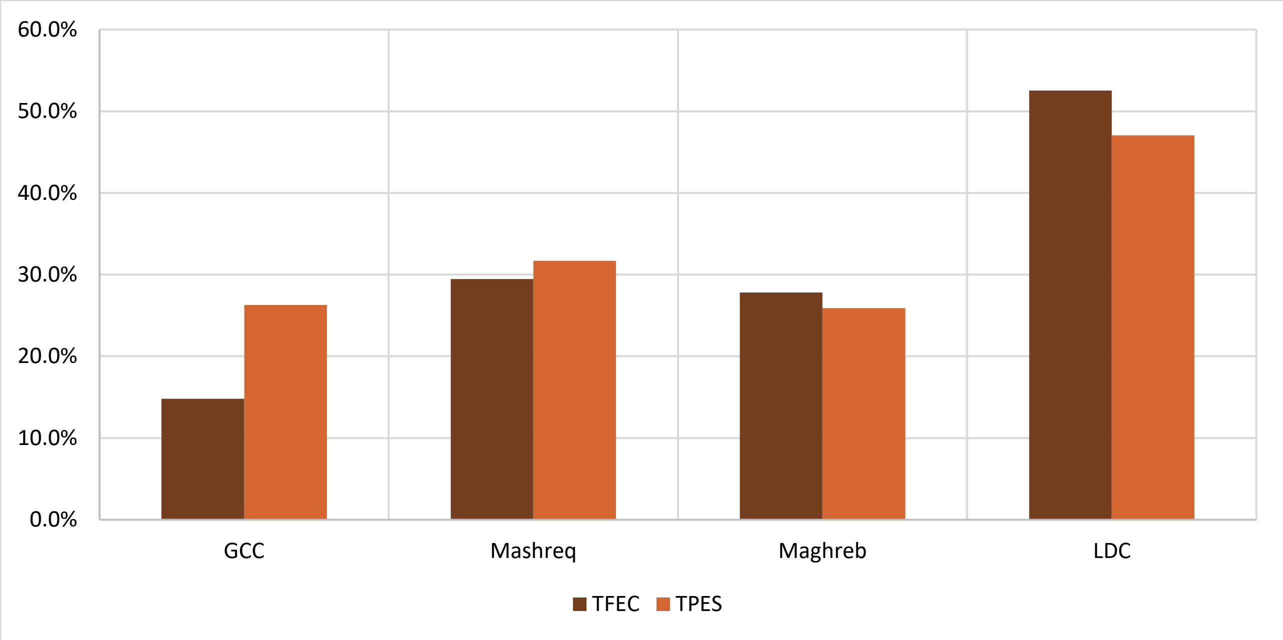
Figure 24. Overall TFEC share of the buildings sector by Arab subregions



Source: IEA, 2017.

When considering the primary energy requirements for generating electricity commonly used in buildings in the Arab region, the buildings sector's share of TPES is higher than its share of TFEC in the subregions where electricity is the main form of energy used in the buildings sector: the GCC and Mashreq subregions (figure 25). In particular, the buildings sector's share for the GCC subregion increases from 15 per cent relative to TFEC to over 26 per cent relative to TPES because of heavy reliance on electricity to meeting buildings' energy needs (when considering the corresponding energy-only TPES, this share increases to 30 per cent for the GCC region).

Figure 25. TPES and TFEC share of the buildings sector by Arab subregions, 2015

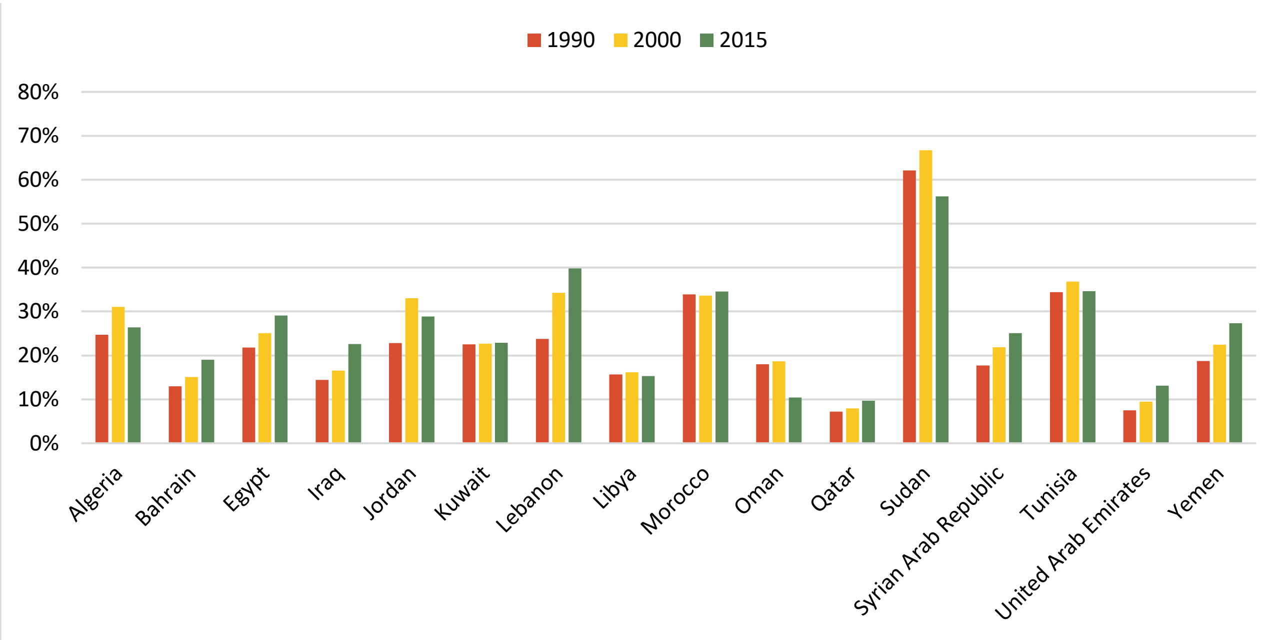


Source: IEA, 2017.

3. Trends For Individual Arab Countries

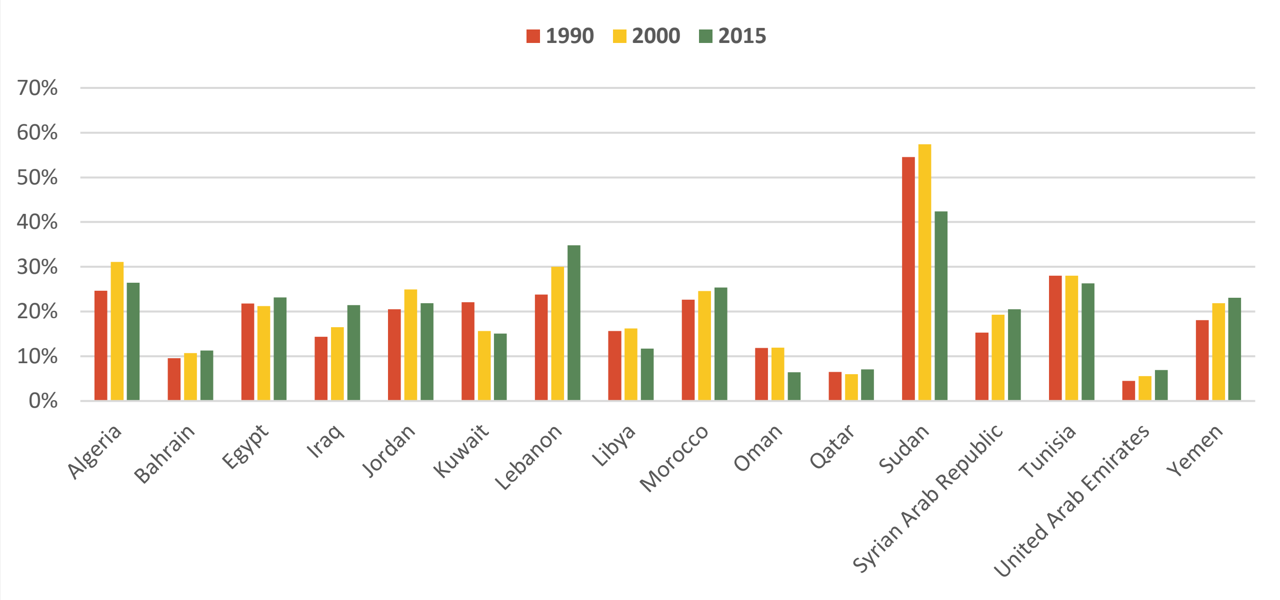
The contribution of the buildings sector to national TFEC varies significantly between Arab countries. Figure 26 shows the annual contribution of the buildings sector to national TFEC in 1990, 2000 and 2015 for Arab countries with reported data (IEA, 2017). Among those Arab countries, the TFEC share of the buildings sector is highest for the Sudan (57 per cent in 2015) and lowest for Qatar (10 per cent in 2015). For all Arab countries, residential buildings consume more energy than commercial/public buildings, as shown in figure 27.

Figure 26. TFEC share of the buildings sector in selected Arab countries, 1990, 2000 and 2015



Source: IEA, 2017.

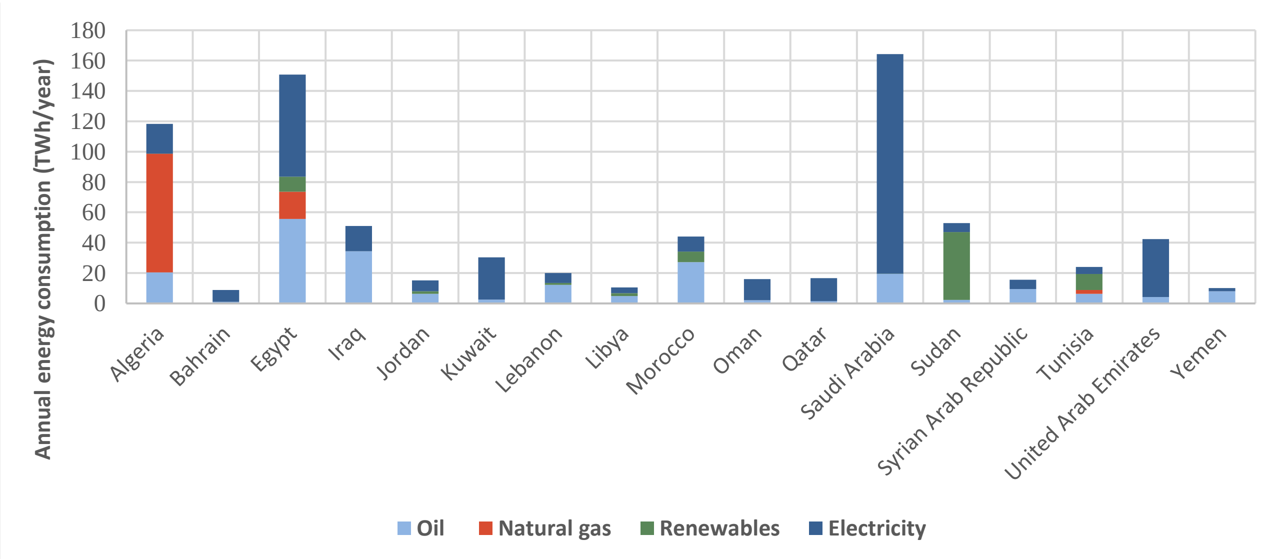
Figure 27. TFEC share of the residential buildings sector in selected Arab countries, 1990, 2000 and 2015



Source: IEA, 2017.

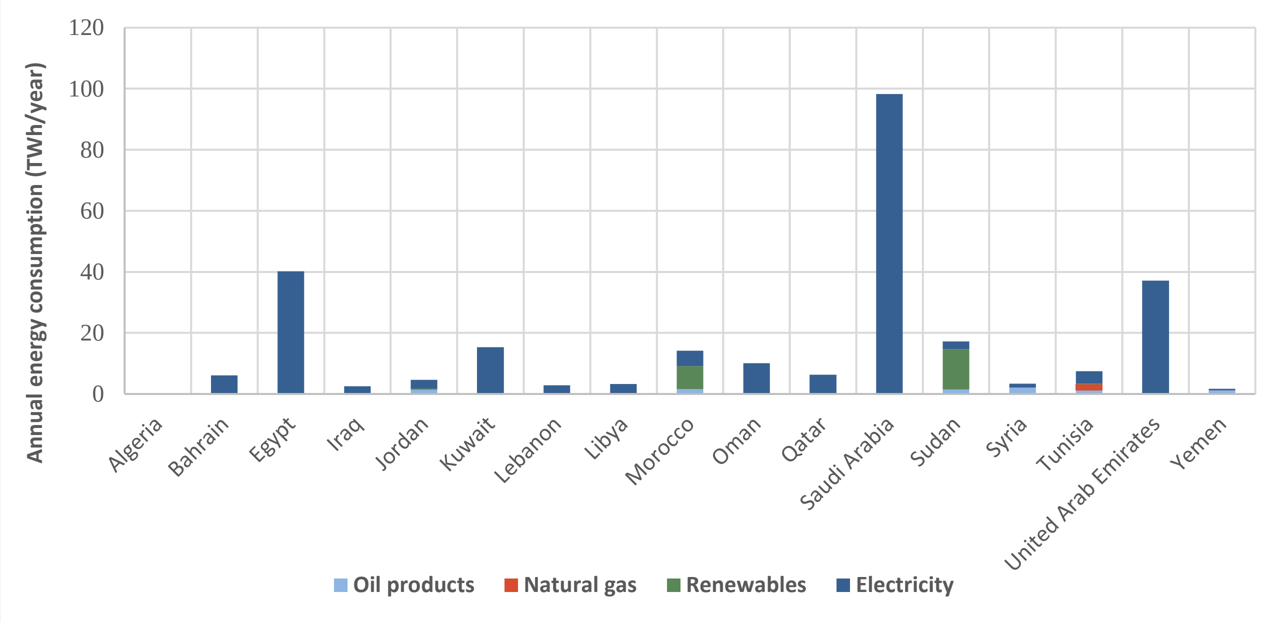
In 2015, residential buildings in Arab countries consumed 791 terawatt hours of total final energy, representing 75 per cent of all energy used by the buildings sector. Figure 28 illustrates the energy mix used by households in each Arab country in 2015 (IEA, 2017). Figure 29 shows the energy mix for commercial and public buildings for Arab countries with available data in 2015. In general, GCC countries utilize mostly electricity, while other countries combine electricity with fossil fuels to meet their energy needs for residential and commercial buildings stocks. As indicated in figures 28 and 29, the Sudan relies heavily on hydroelectric power to cover its buildings' electricity needs, including 84 per cent of the total energy consumed by households. Among all Arab countries, Saudi Arabia consumes the highest energy for both residential and commercial buildings: buildings in Saudi Arabia consumed 260 terawatt hours in 2015, representing a third of the total final energy used by the buildings sector in the Arab region.

Figure 28. Final consumption by energy source for residential buildings in Arab countries, 2015



Source: IEA, 2017.

Figure 29. Final consumption by energy source for non-residential buildings in Arab countries, 2015



Source: IEA, 2017.

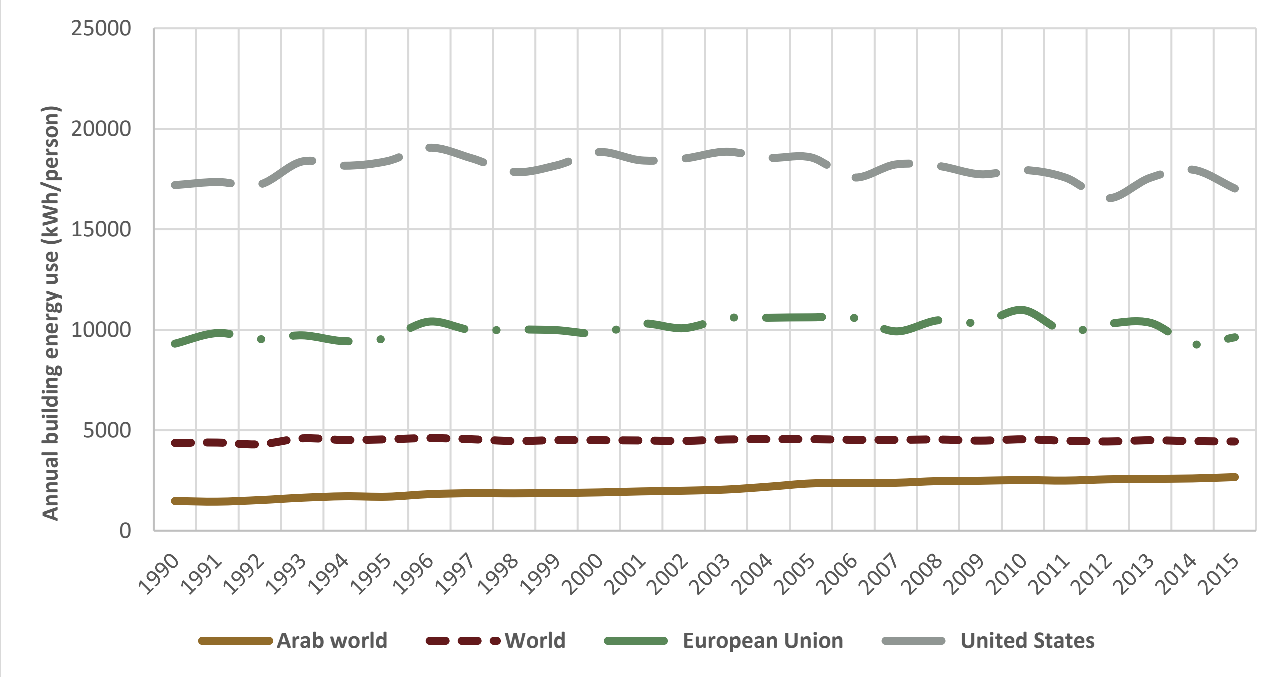
F. ENERGY EFFICIENCY INDICATORS

Two indicators are considered to assess and compare the energy efficiency of the buildings sector: buildings energy use per capita, and buildings energy use per floor area. In the present section, estimations of those energy efficiency indicators are provided for the Arab region and its subregions. The indicators are based on available data and do not account for suppressed energy demand. Low energy consumption in some countries, especially Arab LDCs, can be attributed to suppressed demand owing to limited access to minimum service levels (MSLs) to meet basic human needs. Basic demands for MSLs of large shares of the population in Arab LDCs are not being met (UNFCCC, 2013). The suppressed demand for energy in the Sudan and Yemen is due to low income, high cost of technology, and lack of energy access either because of weak infrastructure (electrical grid networks) or high energy prices. However, for more developed countries, suppressed demand can occur due to frequent power supply cuts (such as in Iraq), or low levels of equipment penetration rates (such as air conditioning equipment in non-GCC countries). Suppressed demand estimates have been outlined for specific Clean Development Mechanism (CDM) projects, using baseline values for MSLs associated with some countries (Hayashi and Michaelowa, 2012; Howells and others, 2005; Horst and Hovorka, 2008). For example, and in the context of rural electrification projects, it is estimated that a household might need at least 55 kilowatt hours/year for lighting and 250 kilowatt hours/year for other appliances (Poyry, 2011). Consequently, with better access to energy and improvements in income levels, the energy indicators provided in this section are expected to increase, especially for Arab LDCs.

1. Buildings Sector’s Energy Use Per Capita

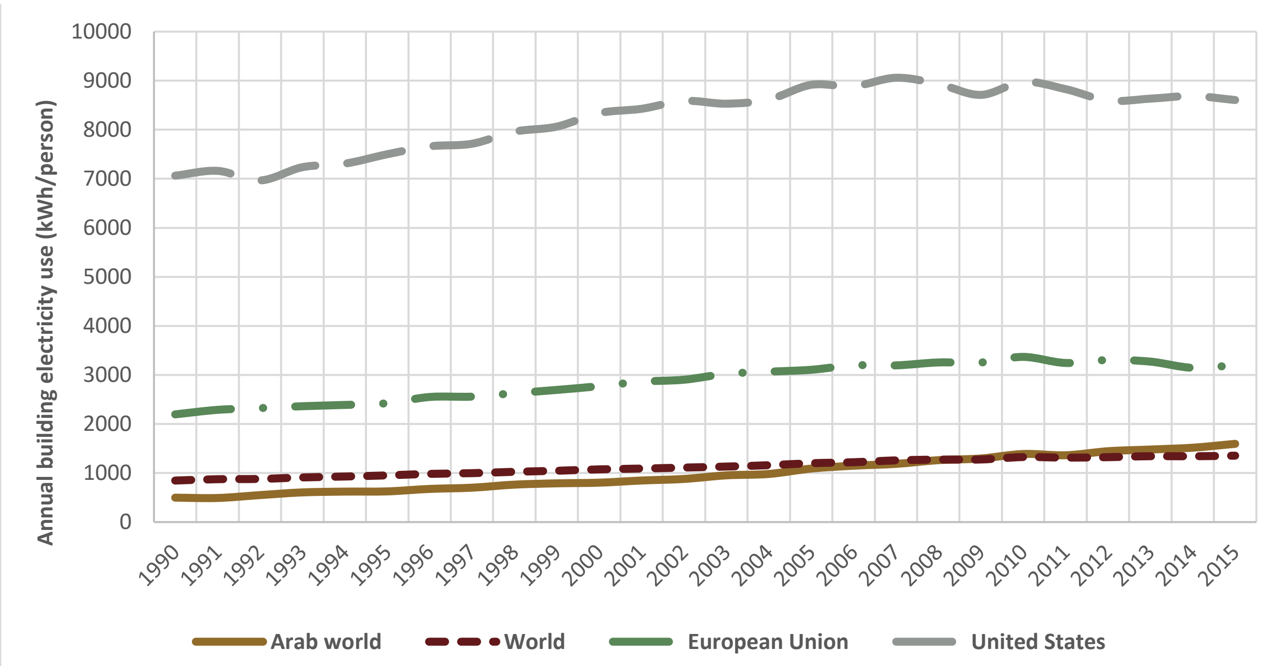
Average buildings energy consumption per capita for the Arab region almost doubled between 1990 (1,475 kilowatts/person) and 2015 (2,665 kilowatts/person) (IEA, 2017), but the Arab region’s per capita buildings energy use remains low compared with the values reported globally and for developed countries, including the European Union and the United States, as shown in figure 30 (IEA, 2017). In contrast, buildings’ energy consumption per capita for the European Union and the United States has declined since 2009, even though they remain significantly higher than the global average. Similar observations can be made for buildings’ electricity consumption per capita, as outlined in figure 31. Since 2010, buildings in the Arab region have consumed slightly more electricity per capita than the global average. Moreover, electricity is playing an ever increasing role in meeting the energy needs of the buildings sector, rising from 34 per cent of total buildings' energy consumption in 1990 to 60 per cent in 2015.

Figure 30. Buildings sector's final energy consumption per capita for selected regions and countries, 1990-2015



Source: IEA, 2017; World Bank, 2017.

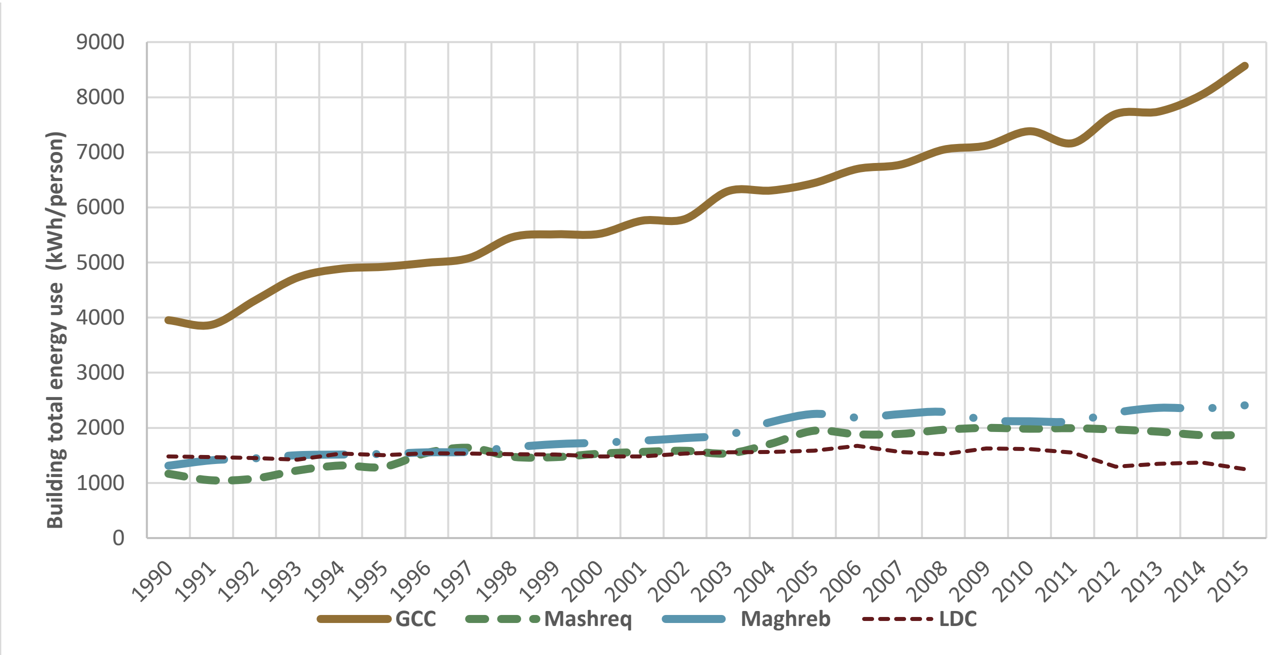
Figure 31. Buildings sector's total electricity consumption per capita for selected regions and countries, 1990-2015



Source: IEA, 2017; World Bank, 2017.

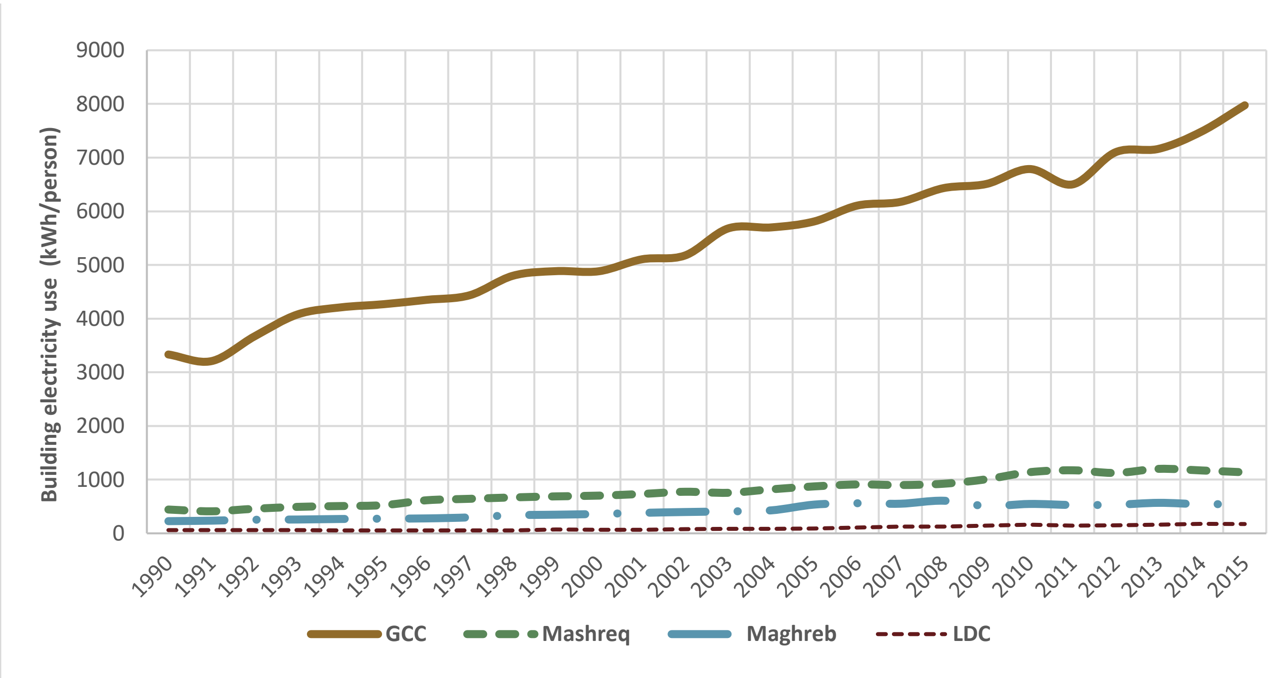
The buildings sector's total per capita energy and electricity consumption vary widely in the Arab region, as shown in figures 32 and 33. Buildings in GCC countries consume per capita significantly more total energy and electricity than those in the other subregions. As noted earlier, electricity constitutes the majority of the energy used in the buildings sector in the GCC subregion, and to a lesser extent in the other subregions.

Figure 32. Buildings sector's total energy consumption per capita by Arab subregion, 1990-2015



Source: IEA, 2017; World Bank, 2017.

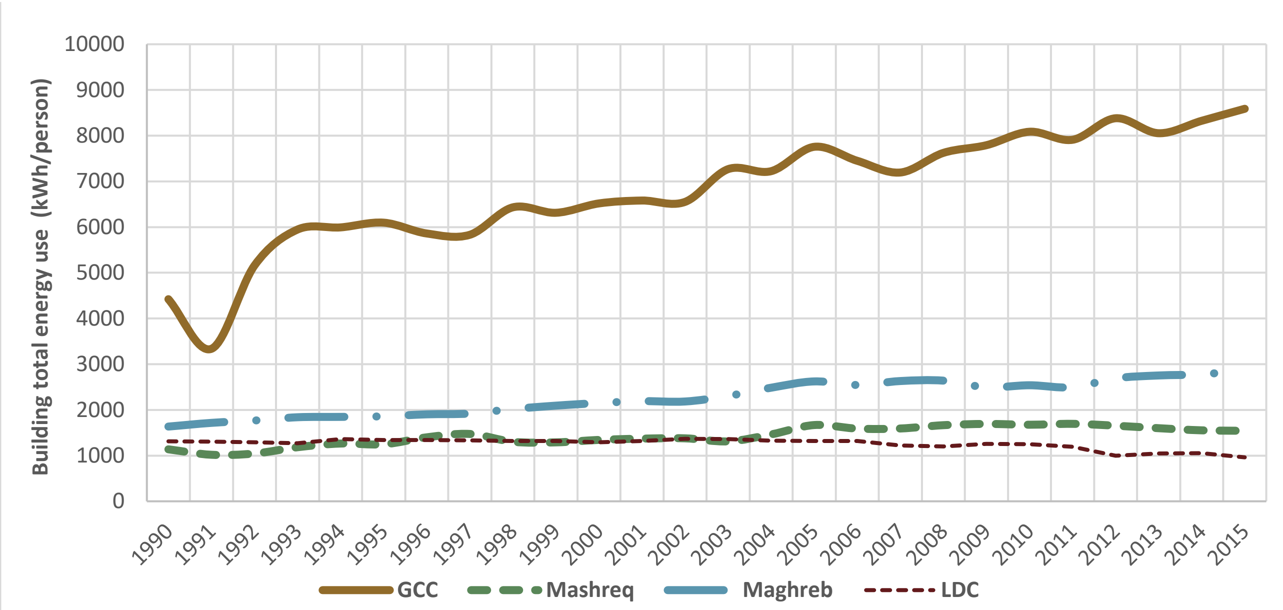
Figure 33. Buildings sector's electricity consumption per capita by Arab subregion, 1990-2015



Source: IEA, 2017; World Bank, 2017.

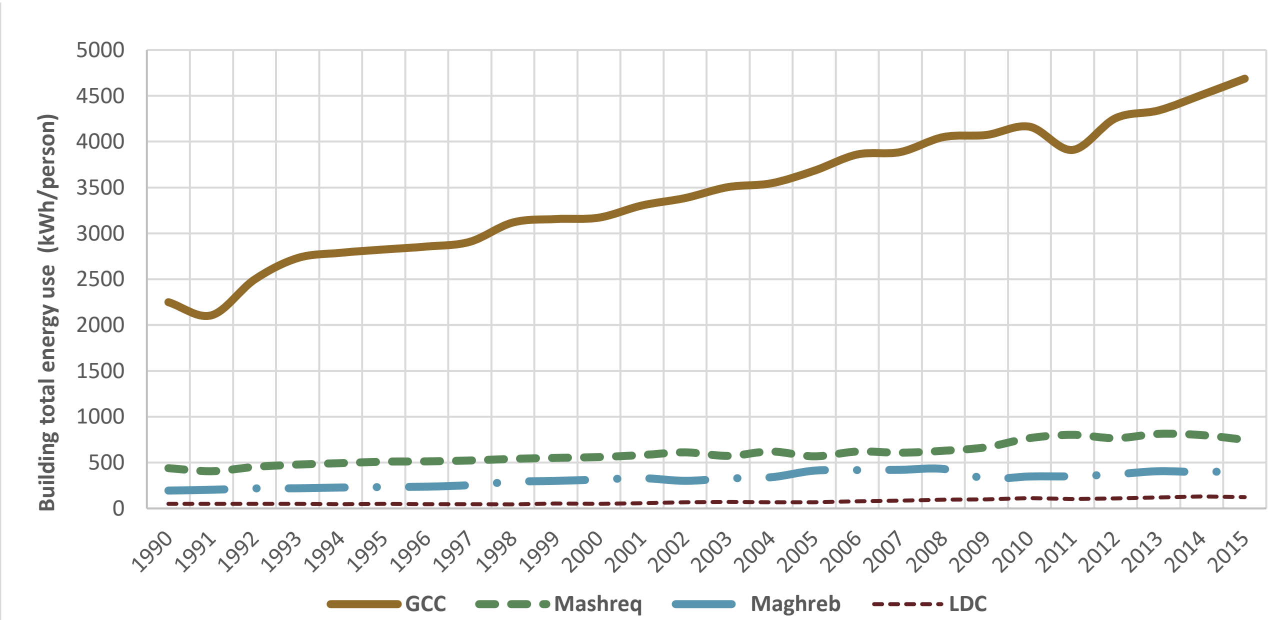
The general trends of total energy use per capita and of electricity use per capita for residential and non-residential buildings in the four Arab subregions are illustrated in figures 34-37. While some data, especially for Arab LDCs, are questionable (showing that prior to 1995 this subregion had similar per capita energy consumption than the Mashreq, possibly owing to heavy use of biofuels for cooking), the results provide general trends between subregions. Figure 35 confirms the observations made earlier: the GCC subregion's energy use per capita is significantly higher for both types of buildings compared with other subregions. In contrast, the Arab LDCs have the lowest energy use per capita in the Arab region and globally.

Figure 34. Residential buildings' total energy consumption per capita by Arab subregion, 1990-2015



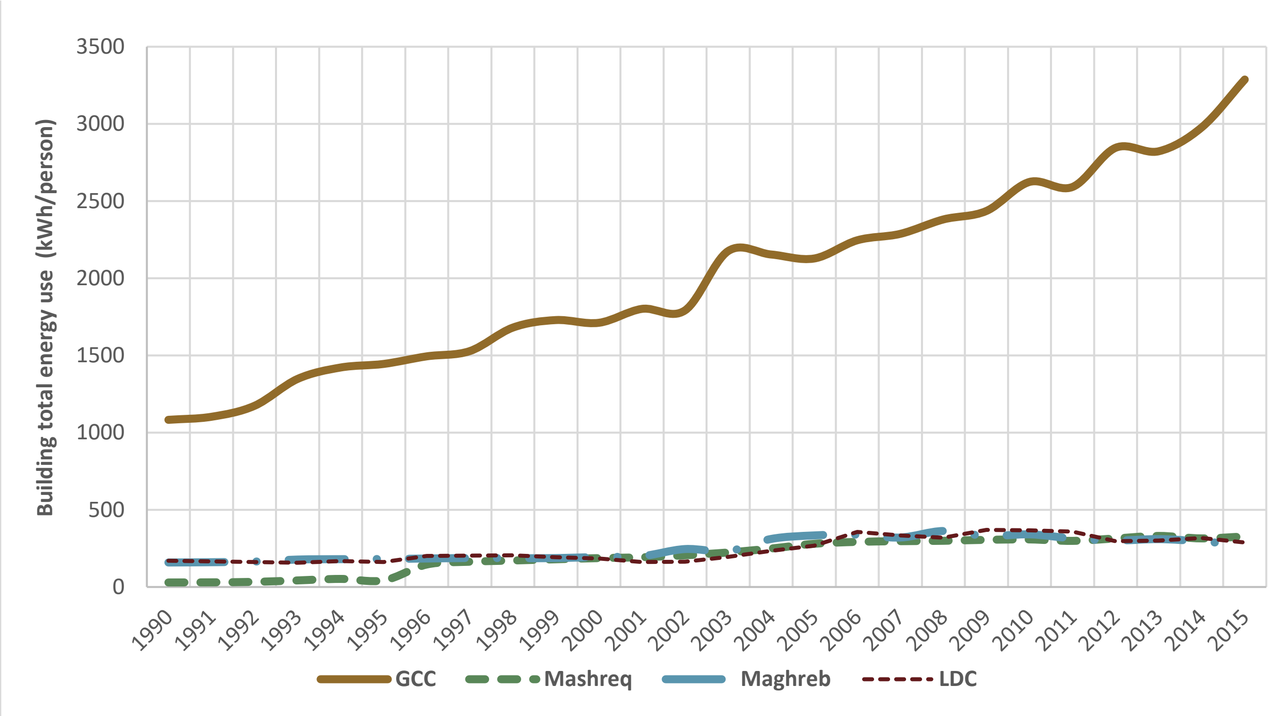
Source: IEA, 2017; World Bank, 2017.

Figure 35. Residential buildings' electricity consumption per capita by Arab subregion, 1990-2015



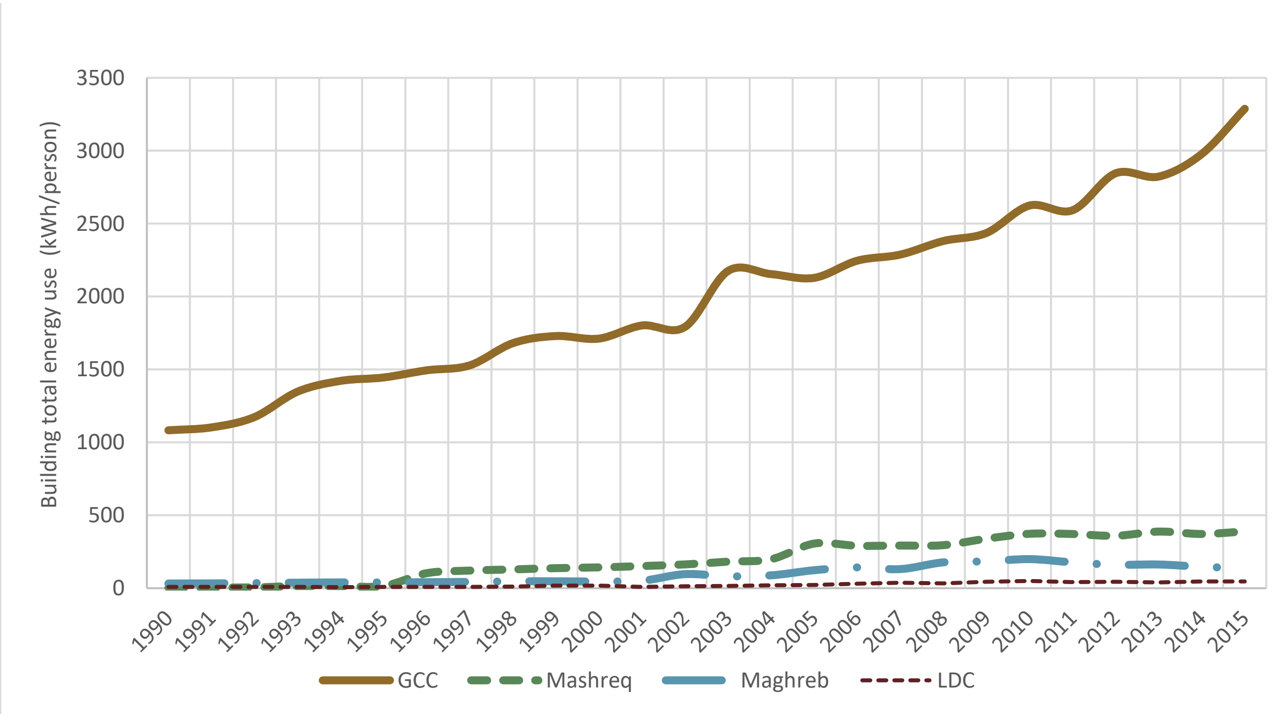
Source: IEA, 2017; World Bank, 2017.

Figure 36. Non-residential buildings' total energy consumption per capita by Arab subregion, 1990-2015



Source: IEA, 2017; World Bank, 2017.

Figure 37. Non-residential buildings' electricity consumption per capita by Arab subregion, 1990-2015



Source: IEA, 2017; World Bank, 2017.

2. Buildings' Energy Use Per Floor Area

Buildings' energy use per floor area provides another measure of buildings' energy performance using the total occupied space. However, the use of this metric must be considered with other factors, such as the number of occupants and the type of equipment present within the building, as well as suppressed demand considerations related to unsatisfied requirements owing to energy prices, cost of systems, and lack of access to energy. For instance, improvements to the envelope, lighting and HVAC systems typically reduce buildings' overall energy use and thus buildings' energy use per floor area. However, the addition of spaces may increase buildings' energy use while decreasing buildings' energy use per floor area.

Table 9 lists reported energy use per buildings floor area, commonly known as energy use intensity (EUI), for the world, the European Union, the United States, China and India. EUI values for the Arab region, based on IEA energy consumption data and average floor area estimates outlined above, are also listed in table 9.

Table 9. Energy use intensity (kWh/m^2) in the building sector for selected regions and countries, 2000, 2006 and 2012

Country/region	2000	2006	2012
World[a]	200	175	165
European Union[a]	223	215	187
Unites States[a]	212	207	197
China[a]	131	108	102
India[a]	195	180	165
Arab region[b]	72	89	96

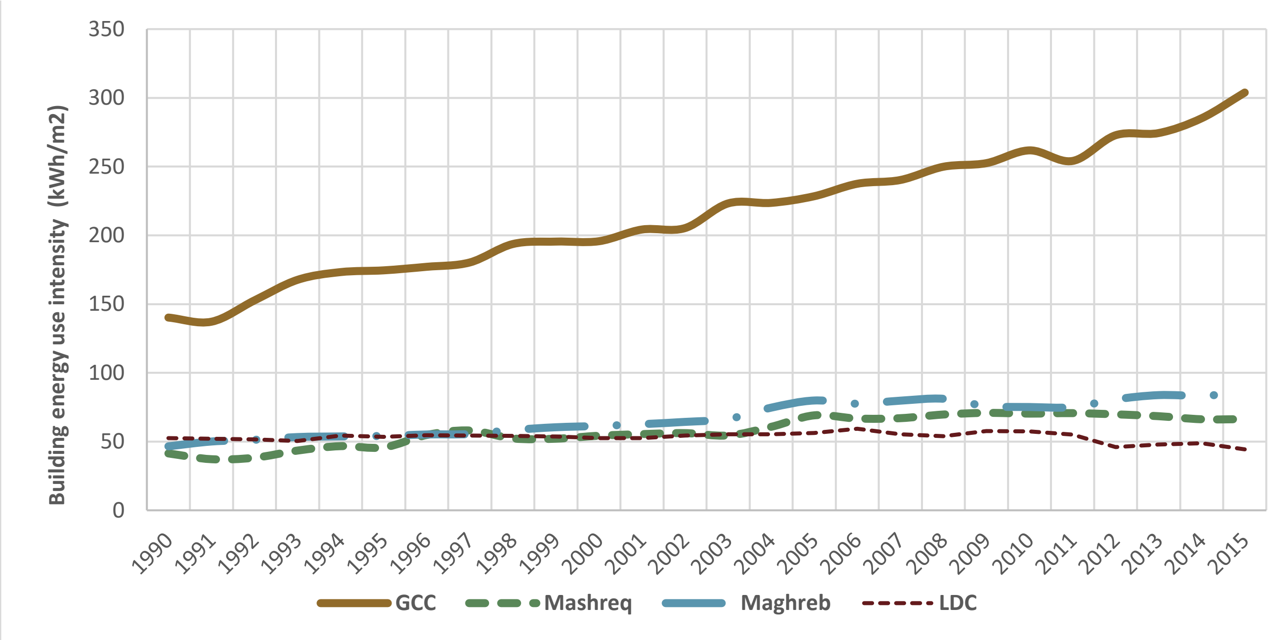
[a] As reported by IEA (2015).

[b] Estimated using IEA (2017) energy data and the average building floor area estimations discussed above.

Two observations can be made from the EUI values summarized in table 9. Firstly, the Arab region's EUI for the buildings sector increased over the period 2000-2012, most likely because of improvements in living standards and the use of energy consuming devices such as air conditioning equipment, lighting and appliances. The EUI values for the buildings sector in other regions are significantly higher than those of the Arab region, but are decreasing. In 2012, EUI for the buildings sector worldwide decreased by 17.5 per cent relative to 2000 levels, most likely driven by the implementation of significant energy efficiency programmes in large economies, including in the United States, the European Union, China and India.

However, as noted earlier for buildings' per capita energy consumption, EUI values vary widely in the Arab region. Figure 38 shows EUI variations for the period 1990-2015 for the Arab subregions. The GCC subregion has seen its buildings' EUI double from 150 kilowatt hour/square metre in 1990 to 300 kilowatt hour/square metre in 2015. Meanwhile, the buildings sector's EUI for the Mashreq and Maghreb regions has slightly increased from 45 kilowatt hour/square metre in 1990 to 66 kilowatt hour/square metre and 85 kilowatt hour/square metre, respectively, in 2015. EUI for the Arab LDCs remained constant at about 50 kilowatt hour/square metre over the same period, most likely because of limited improvements in living standards and a lack of energy-intensive equipment in the buildings sector, such as AC systems.

Figure 38. Buildings sector's energy use per floor area by Arab subregion, 1990-2015

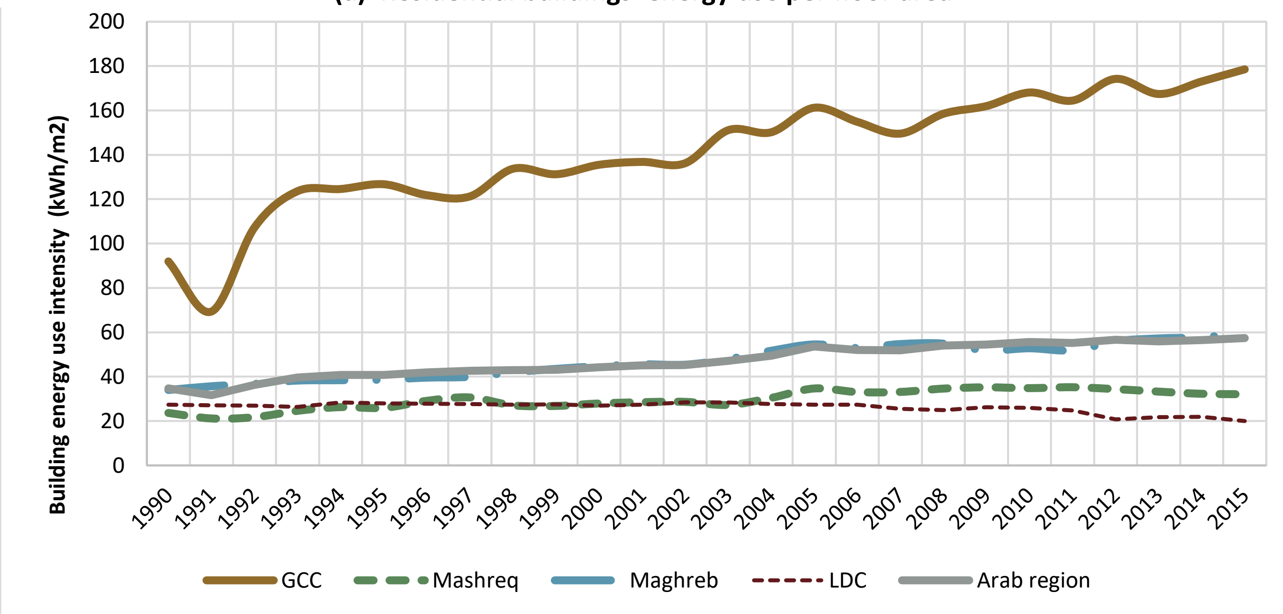


Source: IEA, 2017.

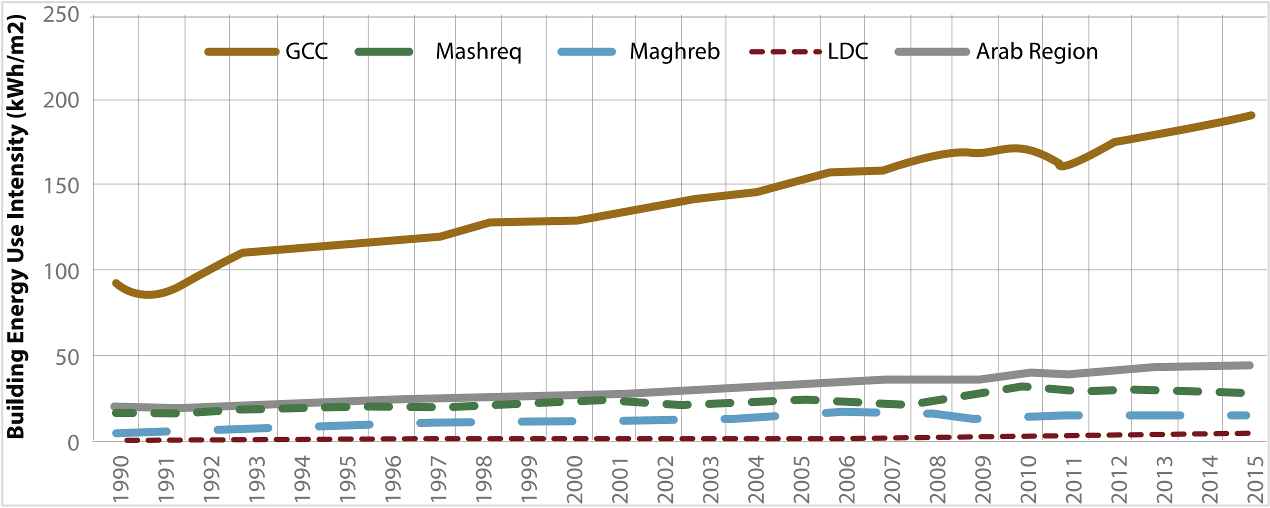
Figure 39 shows EUI variations for the total final energy and electricity consumed by residential buildings over the period 1990-2015 for the four Arab subregions. Those values are consistent with reported energy use data for existing residential buildings in some Arab countries that represent the three subregions, GCC, Mashreq and Maghreb, as summarized in tables 10 and 11. Table 10 utilizes the compiled total residential buildings floor areas for Egypt, Saudi Arabia and Tunisia, summarized in table 3, and IEA data compiled for residential buildings for the relevant year (IEA, 2017). Table 11 lists data obtained from a wide range of sources for selected countries using surveys or audits of existing residential buildings.

Figure 39. Residential buildings' energy use intensity for total energy use and electricity consumption in the Arab region and subregions, 1990-2015

(a) Residential buildings' energy use per floor area



(b) Residential buildings' electricity use per floor area



Source: IEA, 2017.

Table 10. EUI estimates for residential buildings for selected Arab countries

Country	Census year	Total building floor area (million m²)	Energy consumption (ThW/year)		Energy use intensity (kWh/m²)	
			Total	Electricity	Total	Electricity
Egypt	2006	1476.463	99.967	36.603	67.7	24.8
Tunisia	2006	274.254	21.708	2.969	79.2	10.8
Saudi Arabia	2010	651.616	127.582	108.647	195.8	166.7

Source: Estimated using IEA (2017) energy data and the average building floor area estimations discussed above.

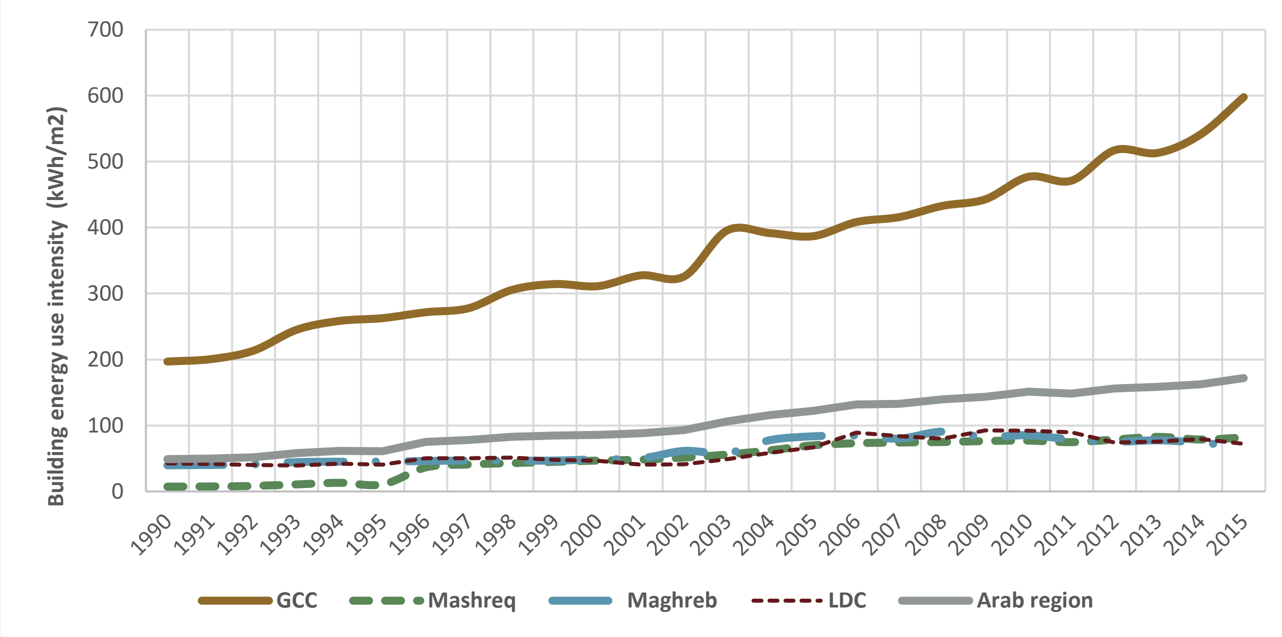
Table 11. Reported EUI values for residential buildings in selected Arab countries

Country (City)	Year of reported data	Type of analysis	Energy use intensity (kWh/m²/yr)	References
Lebanon (entire country)	2013	Survey	135 (Total) 47 (Electricity only)	MEDENER, 2013
Tunisia (entire country)	2023	Survey	79 (Total) 12 (Electricity only)	MEDENER, 2013
Saudi Arabia (Jeddah)	2011	Audit, apartment	350	Taleb and Sharples, 2011
Saudi Arabia (Riyadh)	2015	Calibrated modelling, villa	228	Alaidroos and Krarti, 2015
United Arab Emirates (Al-Ain)	2008	Audit, villa	306	Radhi, 2009
United Arab Emirates (Al-Ain)	2008	Audit, villa	269	Radhi, 2009

Note: The average size of a housing unit in Lebanon is estimated at 120 square metres (Ecofys, 2013).

Figure 40 shows EUI variations for the total final energy consumed by non-residential buildings over the period 1990-2015 for the four Arab sub-regions. Those values are consistent with the reported energy use data of existing non-residential buildings in some Arab countries that represent three sub-regions, GCC, Mashreq, and Maghreb, as summarized in table 12.

Figure 40. Non-residential buildings' energy use intensity of the Arab region and subregions, 1990-2015



Source: IEA, 2017.

Table 12. Reported EUI values for non-residential buildings in selected Arab countries

Country (city)	Year of reported data	Type of analysis	Energy use intensity ($kWh/m^2/yr$)	References
Egypt (entire country)	2009	Survey		UNEP, 2011
Office buildings			84	
Shopping malls			770	
Hotels			730	
Tunisia (entire country)	2006	Survey/audit reports		ANME, 2010
Office buildings			21	
Retail stores			231	
Hotels			266	
Banks			284	
Universities			26	
All non-residential buildings			87	
Saudi Arabia (Dammam)	2011	Audit, shopping malls	268	Fasiuddin and Budaiwi, 2011
Saudi Arabia (Dammam)	2010	Audit, six shopping malls	250-276	Fasiudddin and others, 2010
Kuwait (Kuwait-City)	2011	Audit, educational buildings	300-600	Alajmi, 2012
Bahrain (Manama)	2007	Audit, office buildings	100-805	Radhi and Sharples, 2007

G. ENERGY END USES

Limited analyses have been conducted on the energy end uses of the buildings sector in the Arab region. However, a detailed disaggregated end-use analysis for both residential and non-residential buildings for Tunisia has been carried out (ANME, 2010). The present section discusses the main outlines of buildings energy end-use analysis for Tunisia, and provides an analysis for the Arab region based on the adaption of published analysis results performed using 2010 data (Harvey and others, 2014).

1. Buildings Energy End-Use Analysis For The Arab Region

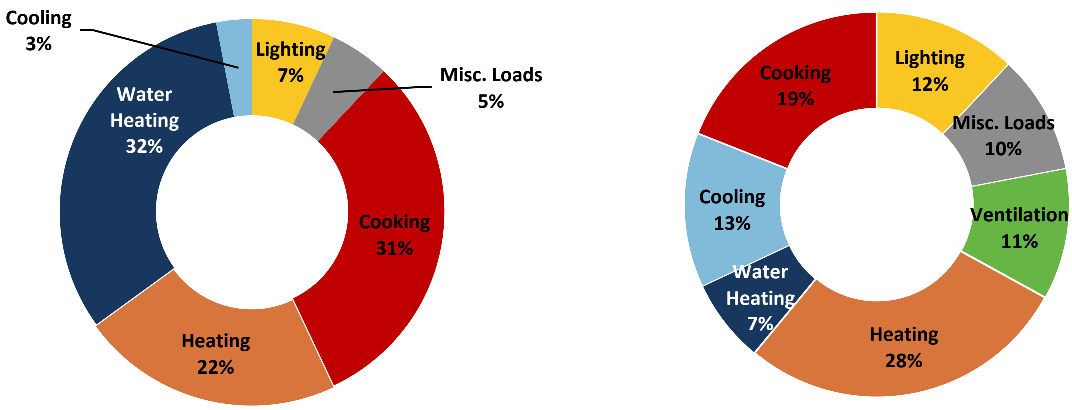
Using the modelling analysis described by Harvey and others (2014), disaggregated end uses for both residential and non-residential buildings can be estimated for the Arab region, as indicated in figure 41(a). This disaggregation is compared with the results reported by IEA at the global level per building types, as shown in figure 41(b). Most of the energy consumed in residential buildings in the Arab region is used for water heating (32 per cent), cooking (31 per cent) and space heating (22 per cent). Similar household end uses are reported globally, with cooking (33 per cent), space heating (30 per cent) and water heating (20 per cent) responsible for over 80 per cent of all energy consumption. For non-residential buildings, space heating has the highest energy consumption both in the Arab region (28 per cent) and in the world (44 per cent). Lighting, space cooling and water heating are responsible for an additional 32 per cent in the Arab region and 34 per cent globally.

It should be noted that this particular modelling tool seems to overlook some other important end uses in the residential sector in the Arab region, such as domestic refrigeration that accounts for about 16 per cent of the total electrical consumption of households (Barthel and Götz, 2012),[5] corresponding to about 10 per cent[6] of their total final energy consumption. These figures are corroborated by the country analyses of Egypt and Tunisia (figures 42 (a) and (c), respectively). It is therefore important to develop more adapted tools to assess the importance of the different energy end uses in the buildings sector in the Arab region to enhance the targeting of energy efficiency programmes in the buildings sector.

Figure 41. Energy end uses for residential and non-residential buildings

(a) Energy end-uses for residential buildings - Arab region, 2010

(b) Energy end-uses for non-residential buildings - Arab region, 2010



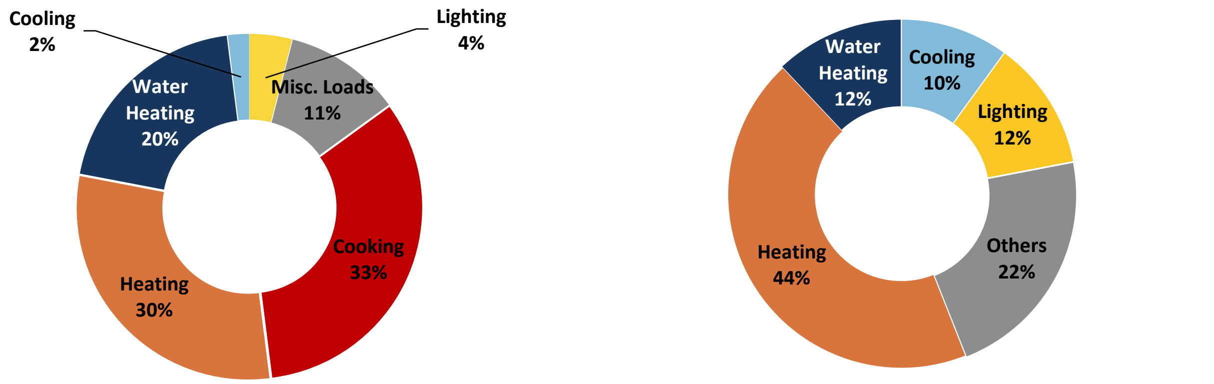
Source: Adapted from Harvey and others (2014).

5 The 16 percent figure is reported for MENA countries, which includeIran and Israel in addition to the countries forming the Arab region as defined in the present report.

6 The 10 per cent figure is estimated based on the 60 percent share of electricity in the total residential final energy consumption in the Arab region.

(c) Energy end-uses for residential buildings - World, 2013

(d) Energy end-uses for non-residential buildings - World, 2013

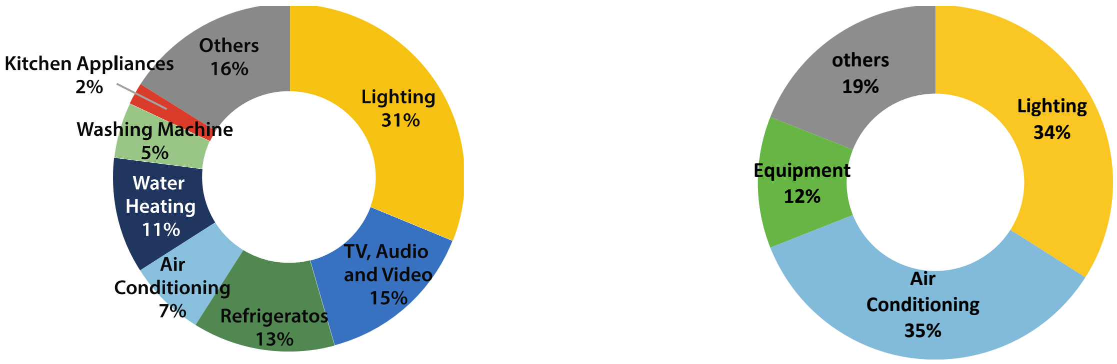


Source: IEA-ETP, 2016.

Figure 42. Energy end uses for residential and commercial buildings in selected Arab countries

(a) Energy end-uses for residential buildings – Egypt

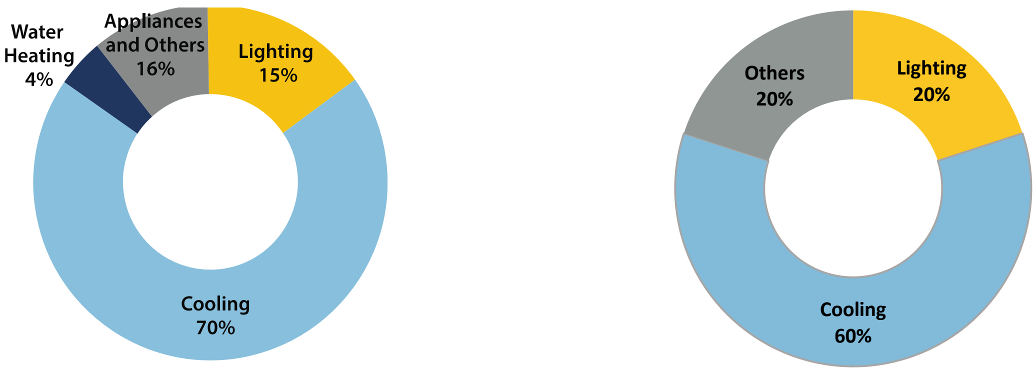
(b) Energy end-uses for commercial buildings - Egypt



Source: Liu and others, 2010.

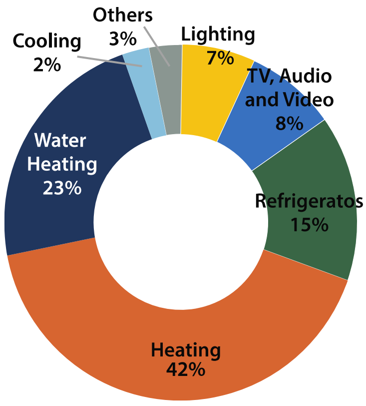
(c) Energy end-uses for a typical household – Saudi Arabia

(d) Energy end-uses for a typical office building – Saudi Arabia

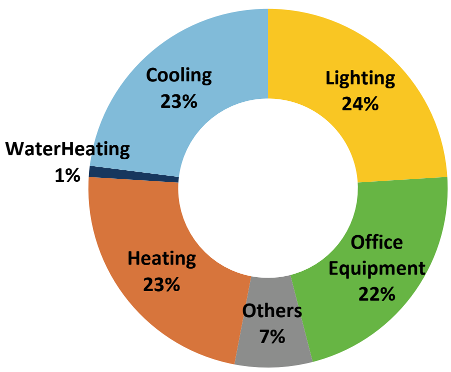


Source: Krarti and and others, 2017.

(e) Energy end-uses for residential buildings – Tunisia



(f) Energy end-uses for office buildings – Tunisia



Source: ANME, 2010.

Figure 42 shows reported results for three Arab countries to assess the energy end uses for both residential and commercial buildings. Space cooling uses 70 per cent of the total energy consumption in residential building and 60 per cent in commercial buildings in Saudi Arabia owing to the extreme climatic conditions characterized by high ambient temperature throughout the year. This pattern is typical for all GCC countries. Buildings in Tunisia require both heating and cooling due to the large climatic variations between winter and summer seasons. Space heating accounted for 42 per cent and 23 per cent of the total final energy consumption in residential and office buildings, respectively, throughout Tunisia. In contrast, air conditioning for heating and cooling is not as significant in Egypt, consuming 7 per cent and 35 per cent of the total final consumption of residential and commercial buildings, respectively. In Egypt, lighting is the main end user of energy in both residential and commercial buildings at 31 per cent and 34 per cent, respectively.

2. Case Study: Building Energy End-Use Analysis For Tunisia

(A) Residential Buildings Energy End Use

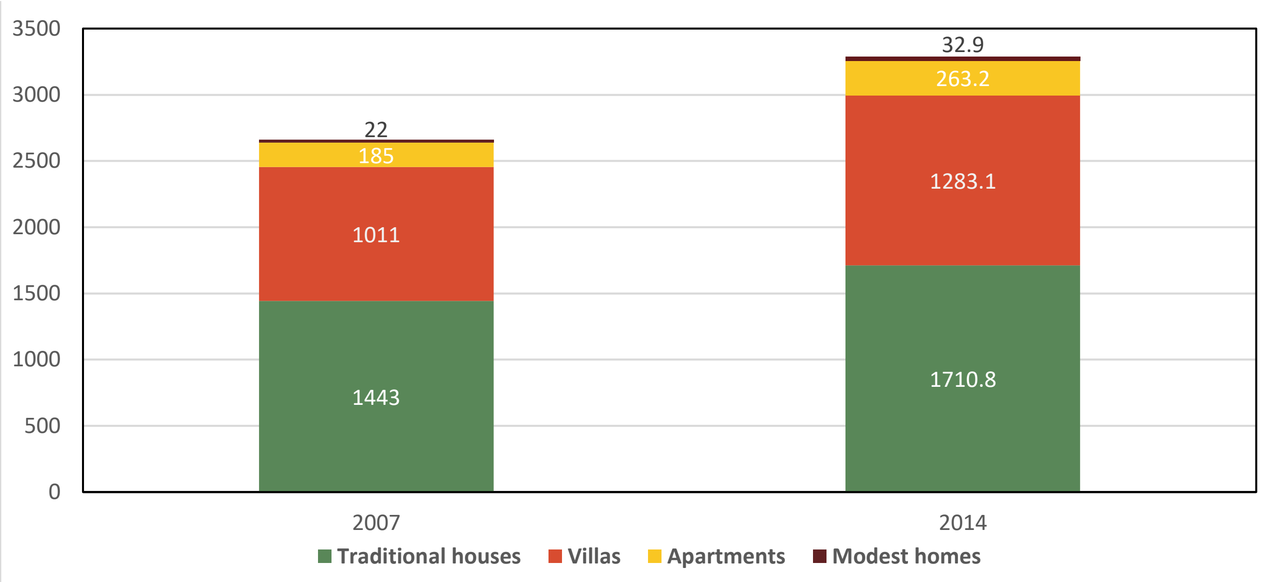
The residential buildings stock in Tunisia has increased steadily in the last 30 years (table 13), with an average annual growth rate of 3.0 per cent. The make-up of the residential buildings stock is dominated by traditional houses (over 52 per cent) followed by villas (39 per cent), apartments (8 per cent) and modest dwellings (1 per cent), as illustrated in figure 43. The majority of the housing stock in Tunisia is located in coastal areas, in climatic zone ZT1 (ANME, 2010).

Table 13. Size of residential buildings stock in Tunisia and its average annual growth rate

Year	Number of housing units	Growth Rate
1975	1,021,000	--
1984	1,313,000	2.8%
1994	1,868,000	3.6%
2004	2,550,000	3.2%
2014	3,290,000	2.6%

Source: INS, 2014.

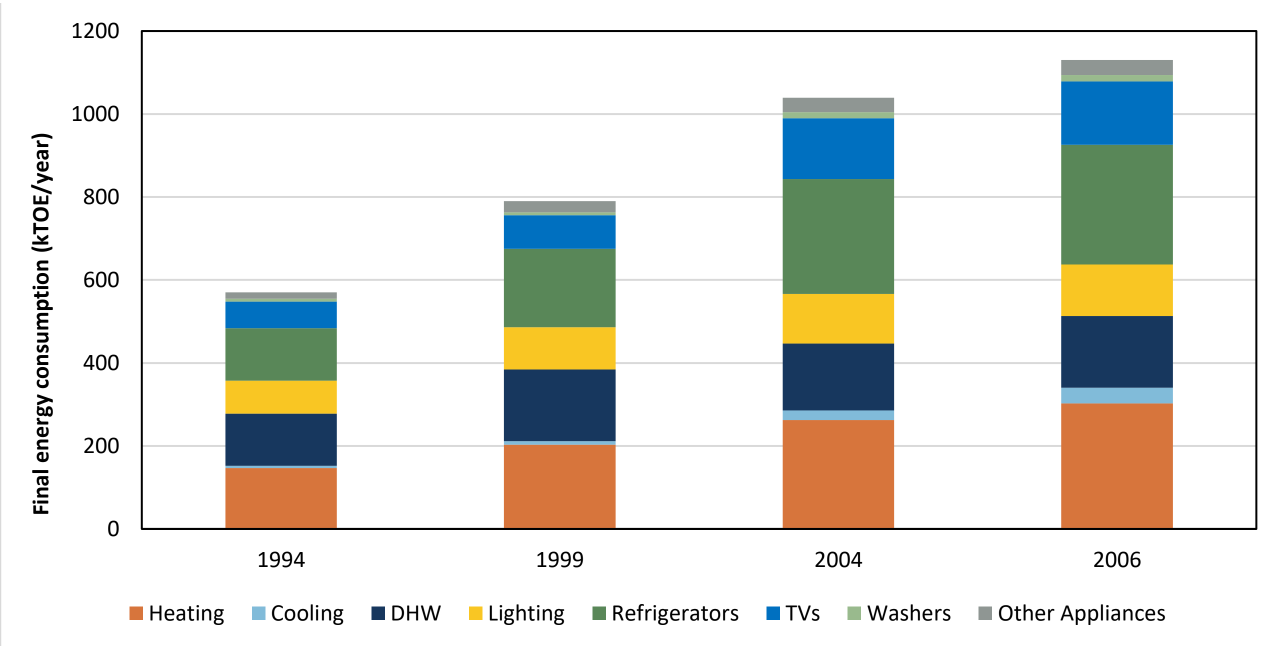
Figure 43. Breakdown of residential buildings stock in Tunisia (thousands)



Source: INS, 2014.

Figure 44 shows variations in energy end uses for Tunisian residential buildings over the period 1994-2006 (ANME, 2010). The overall final energy consumption almost doubled between 1994 and 2006 in Tunisia because of growing numbers of households and the penetration of energy-consuming systems such as televisions, refrigerators and air conditioners. While the buildings stock grew by 45 per cent from 1994 to 2006, energy consumption increased seven-fold for space cooling and by 150 per cent for refrigerators, televisions and washers. The increase in energy use attributed to space heating and domestic hot water has been rather modest at 106 per cent and 38 per cent, respctively. In the case of Tunisia, there has been a clear shift by households over the last 20 years towards using more electrical energy for space cooling, refrigerators and other appliances.

Figure 44. Final energy end uses for residential buildings stock in Tunisia



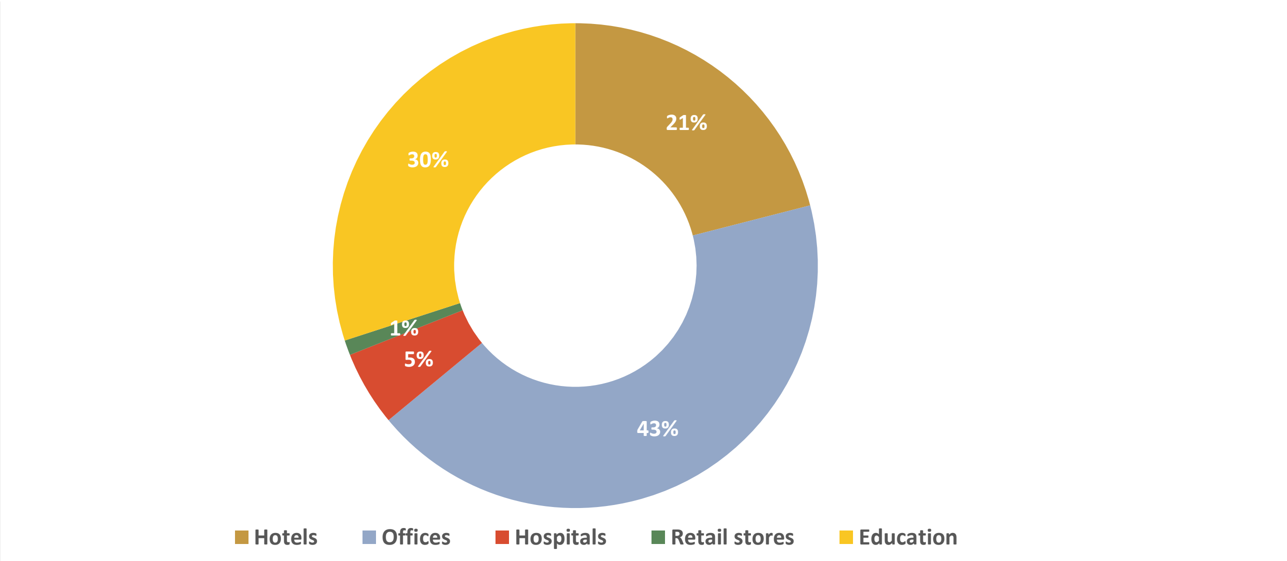
Source: ANME, 2010.

(B) Non-Residential Buildings Energy End Use

The non-residential buildings stock in Tunisia is mostly made up of office spaces, education facilities and hotels. Figure 45 illustrates the distribution by floor area of Tunisian non-residential buildings, based on statistics for 2006. As shown in figure 45, office buildings constitute 43 per cent of the total existing floor area for non-residential buildings stock, while education facilities (primary and secondary schools and universities) and hotels make up 30 per cent and 21 per cent, respectively. Hotels and retail spaces represent 5 per cent and 1 per cent, respectively, of the overall floor area.

Table 14 details the final energy end uses for various Tunisian non-residential building categories. The energy end-use distribution varies significantly with building type. Energy consumption by office spaces is attributed to lighting (24 per cent), space cooling (23 per cent) and space heating (25 per cent). However, energy consumed by hotels is dominated by space heating (23 per cent) and domestic hot water (24 per cent), followed by other equipment (18 per cent) and space cooling (14 per cent). Space heating consumes most of the final energy specific to hospitals (52 per cent), while lighting is the dominant energy end use for education facilities (37 per cent).

Figure 45. Total floor area distribution for Tunisian non-residential buildings stock, 2006



Source: ANME, 2010.

Table 14. Final energy end uses for the non-residential buildings stocks in Tunisia, 2006

Building type	Hotels		Hospitals		Offices		Retail stores		Education	
End-use	TFEC (kTOE)	Share	TFEC (kTOE)	Share	TFEC (kTOE)	Share	TFEC (kTOE)	Share	TFEC (kTOE)	Share
Lighting	7.997	6%	1.715	9%	13.414	24%	1.505	28%	4.979	37%
Space cooling	19.422	14%	2.301	12%	12.75	23%	1.774	33%	0.835	6%
Space heating	33.158	23%	9.869	52%	13.996	25%	0.269	5%	2.707	20%
Refrigeration	2.856	2%	0	0%	0	0%	1.075	20%	0.269	2%
Domestic hot water	34.153	24%	0.753	4%	0.177	0%	0	0%	1.863	14%
Office equipment	0	0%	0	0%	12.404	22%	0	0%	0	0%
Medical equipment	0	0%	1.269	7%	0	0%	0	0%	0	0%
Cooking	18.86	13%	0.484	3%	0	0%	0	0%	0.874	6%
Other	24.735	18%	2.511	13%	3.198	6%	0.753	14%	2.032	15%
Total	141.181	100%	18.902	100%	55.939	100%	5.376	100%	13.559	100%

Source: ANME, 2010.

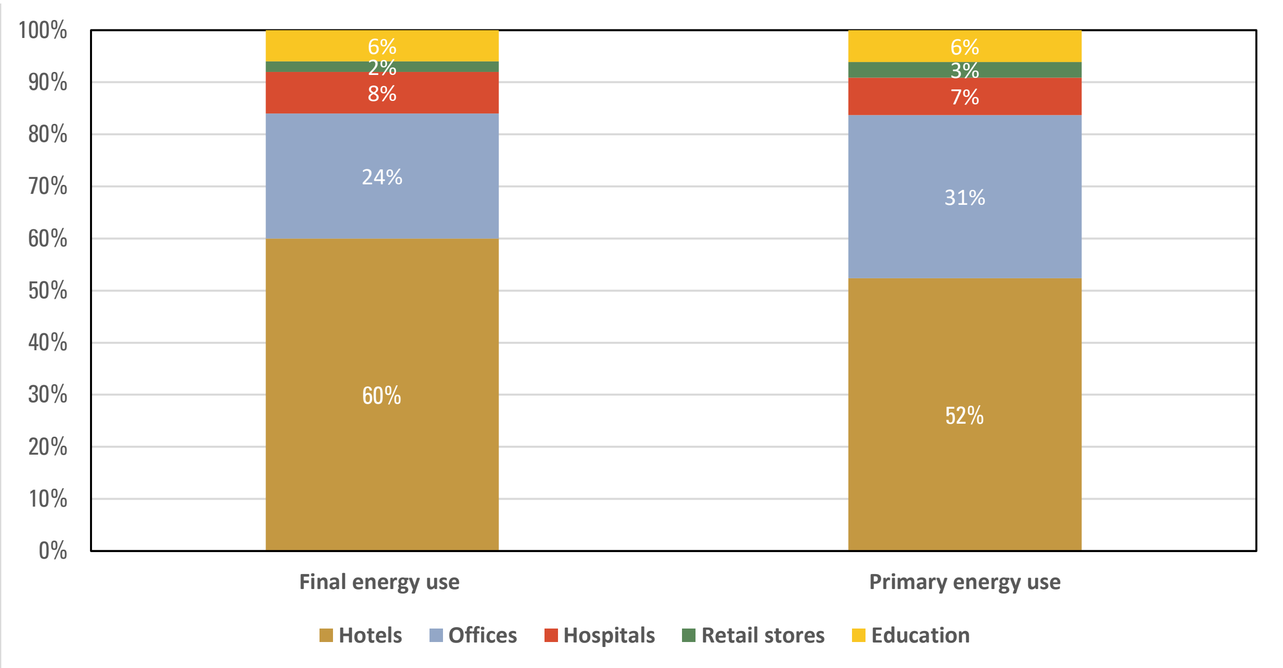
Table 15 summarizes the total floor area and the overall and per unit floor area of final and primary energy uses for various non-residential building types in Tunisia in 2006. Figure 46 compares the final and primary energy-use distribution for Tunisian non-residential buildings stock categories. Hotels used the most energy among non-residential buildings, with 60 per cent of the total final energy consumption and 52 per cent of the primary energy consumption. Office buildings follow with 24 per cent and 31 per cent, respectively. Hotels also had the highest final energy use intensity (22.96 KgOE/square metre), while retail stores had the highest primary energy use intensity (56.7 KgOE/square metre). Education facilities, especially primary/secondary schools, had the lowest energy use per unit floor area with 1.59 KgOE/square metre for final energy consumption and 3.57 KgOE/square metre for primary energy consumption. Schools in Tunisia are not typically air conditioned because they are not cooled and are often not heated either.

Table 15. Final energy use per unit area for non-residential buildings stocks, 2006

Non-residential Buildings	Floor area	Final energy use		Primary energy use	
	(million m^2)	(kTOE)	(KgOE/m^2)	(kTOE)	(KgOE/m^2)
Hotels	6.150	141.181	22.96	246.700	40.11
Offices	12.340	55.909	4.53	148.360	12.02
Hospitals	1.430	18.903	13.22	34.730	24.29
Retail stores	0.270	5.375	19.91	15.310	56.70
Education	8.545	13.559	1.59	30.490	3.57
Primary/secondary	5.340	3.554	0.67	10.130	1.90
Universities	3.205	10.005	3.12	20.370	6.36
All non-residential	**28.735**	**234.929**	**8.18**	**475.590**	**16.55**

Source: ANME, 2010.

Figure 46. Final and primary energy distributions for Tunisian non-residential buildings stock, 2006



Source: ANME, 2010.

(C) Penetration Of Air Conditioners In Tunisia

As noted earlier, energy consumption attributed to space cooling has increased significantly over the last two decades in Tunisia owing to higher living standards, as shown by higher annual sales and penetration rate of ACs since year 2000 (table 16).

Table 16. Air conditioners stock size, sales and penetration rate in Tunisia

Year	Stock of AC units (1000)	Sales of AC units (1000)	AC penetration rate
2000	50	NA	3%
2005	200	50	8%
2010	1200	220	20%
2013	2050	344	36%

Source: Khlafallah and others, 2016.

AC penetration rate and stock projections are estimated using a diffusion model, correlating household income and climate conditions to purchasing ACs for cooling (Khlafallah and others, 2016). The diffusion model based on household income and climate indicators (cooling degree-days) is utilized to predict future stocks for a wide range of energy-consuming systems in different countries (McNeil and others, 2013). The annual projections for future AC market and penetration rates for Tunisia between 2015 and 2030 are summarized in table 17. Based on projections, the Tunisian AC market will reach saturation conditions by 2030. In these conditions, the AC market will be driven by replacements rather than increases of AC units per households. The same study (Khlafallah and others, 2016) finds that the AC market for Algeria would be almost saturated by 2030. However, AC penetration rates in Morocco will reach only 50 per cent by 2030, and therefore will continue to expand driven by increases in sales of ACs to households.

Table 17. Projected annual AC stock size and penetration rate in Tunisia

Year	Number of households (1000)	Number of AC per household	Number of AC units (1000)	AC penetration rate
2015	2,776	1.48	4108	40%
2020	3,118	1.63	5082	61%
2030	3,854	1.93	7438	92%

Source: Khlafallah and others, 2016.

III. CURRENT ENERGY EFFICIENCY POLICIES IN THE ARAB REGION AND THE WAY FORWARD

The development, implementation and enforcement of energy efficiency requirements for new buildings are the most effective approach to reducing energy consumption in the buildings sector for countries with high construction activities, as is the case in the Arab region. Buildings' lifespan can reach 40-50 years and even higher in some Arab countries. Therefore, the impact of energy savings associated with energy efficient buildings can last for decades, resulting in a significant reduction in national energy consumption and greenhouse emissions. Some Arab countries have developed energy efficiency codes, standards and label ratings for buildings and/or energy consuming equipment, such as appliances (refrigerators in particular), cooling systems (air conditioners and chillers) and lighting fixtures (use of CFLs or LEDs instead of incandescent lamps). However, the level of implementation and enforcement of those codes and standards varies between countries (EES, 2014; RCREEE, 2015; RCREEE, 2017, MEDENEC, 2015; WBG, 2016, World Bank, 2016; Krarti and Ihm, 2016).

The present section reviews current regulations and standards for buildings and related systems for all Arab countries.

A. ENERGY EFFICIENCY POLICIES FOR BUILDINGS

Building energy efficiency codes (BEECs) are also known as energy standards for buildings, thermal building regulations, energy conservation building codes, or simply energy building codes. Energy policymakers and Governments utilize BEECs as regulatory mechanisms to reduce energy consumption and the environmental impact of buildings, while maintaining acceptable indoor environmental quality. Typically, BEECs consist of mandatory design requirements to improve buildings' energy performance. Since the 1970s, BEECs have been developed and implemented in several countries. For some countries, it has been shown that BEECs are effective in reducing buildings' energy consumption. For example, the implementation of mandatory BEECs has resulted in energy use reduction in households for most European Union countries: the reduction in energy consumption for residential buildings has ranged from 22 per cent in Germany and the Netherlands to 6 per cent in southern European countries (IEA, 2016).

Two approaches are commonly considered when developing BEECs for new buildings:

- **Prescriptive-based approach:** BEECs include sets of minimum energy performance requirements for each component of the building: windows, walls, and heating and cooling equipment. Two compliance paths can be considered: (a) each building component has to meet strict minimum energy performance requirements, such as minimum thermal performance levels for walls and windows (U-values and SHGC-values), or (b) trade-offs between the energy performance requirements of different components. While prescriptive-based approaches are simple to implement and enforce, they lack flexibility and do not encourage integrated design of buildings. They also often fail to achieve adequate energy performance accomplishments for complex buildings;
- **Performance-based approach:** BEECs based on performance set requirements for the overall building energy consumption. Performance-based BEECs therefore encourage an integrated design approach to account for interactions between building components to optimize energy performance for the entire building. Several options for performance-based BEECs can be developed and implemented, including the following:
  - ❑ *Partial performance of subsystems: such as addressing the energy performance of the* building envelope, using the overall thermal transfer value (OTTV) analysis approach;
  - ❑ *Performance of multiple subsystems: addressing the energy performance of more than one building subsystem, but not the entire building energy performance, such as setting* maximum values for the energy use and/or demand for lighting and air conditioning systems;

- *Total building performance:* energy consumption or energy cost, using the following three options:
  - Fixed budget approach using a fixed energy consumption level such as kilowatt hour/square metre (key assumptions are required including operation settings and internal loads);
  - Custom budget approach using a comparative analysis with a reference building (typically, the reference building is the same as the proposed building but that complies with a set of prescriptive requirements);
  - Points system using a score system for different energy efficiency measures.

Energy efficiency policies and regulations are still in their infancy in the Arab region (Liu and others, 2010; Asif 2015; RISE, 2016). Many Arab countries have limited or no mandatory buildings energy efficiency requirements. Even in countries with some regulations, the enforcement mechanisms have not yet been fully implemented (Asif, 2015). Based on detailed reviews of existing energy efficiency regulations related to the buildings sector, table 18 summarizes the status of building energy efficiency regulations in various Arab countries. The enforcement of mandatory codes remains the main challenge for implementing energy efficiency regulations in most Arab countries. Several countries have established enforcement procedures, typically divided into the following three phases: (i) review of design plans, (ii) inspection of construction site, and (iii) issuance of occupancy permits, but their actual application and implementation are not reliable. The enforcement mechanisms for countries with mandatory building energy efficiency codes are noted in table 18. Moreover, table 18 lists the RISE score provided for each country for their efforts to implement energy efficiency policies (RISE, 2016). Tunisia has the highest score, mostly owing to its development and implementation of building energy efficiency codes for both residential and commercial buildings. Moreover, Tunisia has developed labelling and MEPS for household equipment and lighting fixtures, as discussed above, and set mandatory energy audits for various commercial buildings and industrial facilities with some innovative incentives and financing mechanisms. The Tunisian energy efficiency code for new buildings is one of the most developed in the Arab region, and includes both prescriptive and performance paths for compliance. The requirements depend on the building type and the climatic zone. Details of the energy efficiency code for Tunisia are described in annex I. Compliance and energy analysis software specific to the Tunisian buildings energy efficiency code has been developed, including an online tool. Tunisia has also established a compliance mechanism that is firmly tied to the buildings construction permit process, to ensure the implementation of the Tunisian BEEC.

Table 18. Status of building energy efficiency regulations in Arab countries

Country	Building energy efficiency regulations	Type of compliance	Mandatory/ voluntary	RISE energy efficiency score (0-100)
Algeria	Thermal insulation for building envelope (2005)	Prescriptive	Mandatory (D)	56
Libya	None	NA	NA	NA
Morocco	Energy efficiency code (2015)	Prescriptive and performance	Mandatory (D)	42
Tunisia	Energy efficiency code for residential (2009) and selected commercial and institutional buildings (2008)	Prescriptive and performance	Mandatory (D, C, P)	68
Egypt	Energy efficiency code for residential (2005), commercial (2009), and public buildings	Prescriptive and performance	Mand0atory (D)	48

Country	Building energy efficiency regulations	Type of compliance	Mandatory/ voluntary	RISE energy efficiency score (0-100)
Iraq	Energy efficiency specifications for buildings (2012)	Prescriptive	Voluntary	NA
Jordan	Energy conservation building code (2010)	Prescriptive	Mandatory (D)	57
Lebanon	Thermal insulation requirements ARZ building rating system for existing buildings (LBGC, 2017)	Prescriptive Evidence-based building rating systems for existing commercial buildings	Voluntary Voluntary	35
Syrian Arab Republic	Thermal insulation code (2009)	Prescriptive	Mandatory (D)	NA
State of Palestine	Energy efficiency code for buildings (2004)	Prescriptive	Voluntary	NA
Bahrain	Thermal insulation requirements for commercial buildings (1999) and other building types (2013)	Prescriptive	Mandatory (D, P)	25
Kuwait	Energy conservation code of practice No. R-6 (1983 updated in 2014)	Prescriptive	Mandatory (D)	30
Oman	None	NA	NA	
Qatar	Global Sustainability Assessment System (GSAS): All new public buildings (2012) All new commercial buildings (2016) All new residential buildings (2020)	Sustainable building label system	Mandatory (D)	50
Saudi Arabia	Thermal performance code (2014)	Prescriptive	Mandatory (D, P)	49
United Arab Emirates (Dubai)	Thermal insulation requirements (2003) Green building regulations and specifications (2011)	Prescriptive Performance	Mandatory (D) Voluntary	63
Mauritania	None	NA	NA	9
Sudan	None	NA	NA	19
Yemen	None	NA	NA	12

Source: ANME, 2010; Liu and others, 2010; RCREEE, 2015; RCREEE, 2017, Krarti, 2015, Krarti and Dubey, 2017; Krarti and others, 2017.

Note: Enforcement mechanisms are noted as D for reviewing design plans, as C for inspecting construction sites and P for issuing occupancy permits.

B. BUILDING RATING SYSTEMS

Instead or in addition to some energy efficiency codes, some Arab countries have adopted and others have developed building rating systems to foster sustainable buildings design. Specifically, the Leadership in Energy and Environmental Design (LEED) certifications have been accredited to several new buildings in the Arab region, as summarized in table 19 based on the latest reported data (USGBC, 2017). GCC countries, led by the United Arab Emirates, have the most LEED certified buildings (about 90 per cent). In addition, the following buildings rating systems have been developed in Arab countries:

- The Global Sustainability Assessment System (GSAS), developed in Qatar by the Gulf Organization for Research and Development in collaboration with University of Pennsylvania (GORD, 2010). Similar to LEED, GSAS is a performance-based rating system to assist designers in reducing the ecological impact of buildings, while considering local environmental needs. Specifically, GSAS considers the following eight assessment categories with different weights: urban connectivity, site, energy, water, materials, indoor environment, cultural and economic value, and management and operation. Residential, commercial and institutional buildings are rated relative to reference levels for both energy performance (expressed in kilowatt hours/square metre/year) and carbon emissions (expressed in kilogrammes of carbon dioxide/square metre/year). GSAS allows for some flexibility in meeting energy performance and carbon footprint requirements in the design and operating phases by taking into account improvements in building envelope, lighting, and air conditioning systems as well as human comfort (Sharifi and Murayama, 2013). Since 2016, GSAS has been adopted as a mandatory rating system for all new government buildings in Qatar;
- The Pearl rating system (PRS) is a green building rating certification system developed by the Abu Dhabi Urban Planning Council as part of its sustainable development initiative *Estidama*. PRS was developed using similar LEED standards, with several rating levels that depend on a scoring system with mandatory and optional credit points ranging from one pearl to five pearls. PRS was developed specifically for designing buildings in hot and arid climates, with several categories including natural systems, resourceful energy, precious water, stewarding materials, and innovating practice. PRS requires a minimum energy performance of buildings using either prescriptive or performance approaches. Any additional improvements from the minimum can be awarded credit points. Since 2010, a minimum certification of one pearl is required for all new construction in Abu Dhabi. For new government buildings, a level of two pearls is required;
- The ARZ building rating systems was developed by the Lebanon Green Building Council in 2011, and used an evidence-based approach to measure and rate existing commercial buildings. The rating system is based on scores provided for the following nine modules: energy performance, thermal energy, electrical energy, building envelope, materials, indoor air quality, operation and management, water management, and sustainable technologies (LBGC, 2017).

Table 19. Number of LEED certified buildings in Arab countries as at 26 December 2017

Country	Certified	Silver	Gold	Platinum	In progress	Total
Algeria	0	1	0	0	1	2
Libya	0	0	1	0	1	2
Morocco	0	2	1	0	3	6
Tunisia	1	0	0	0	2	3
Egypt	1	8	7	2	26	44
Iraq	0	0	0	0	2	2
Jordan	0	2	4	1	19	26
Lebanon	2	0	7	1	32	42
Syrian Arab Republic	0	0	0	0	1	1
State of Palestine	0	0	0	0	1	1
Bahrain	0	1	0	0	20	21
Kuwait	1	0	2	0	39	42
Oman	1	3	2	0	24	30
Qatar	0	1	3	12	0	97
Saudi Arabia	4	11	82	5	120	222
United Arab Emirates	131	39	79	13	559	821
Mauritania	0	0	0	0	0	0
Sudan	0	0	0	0	0	0
Yemen	0	0	0	0	1	1
Total	141	68	188	34	851	1363

Source: USGBC, 2017.

C. ENERGY PERFORMANCE LABELLING SYSTEMS AND MINIMUM ENERGY PERFORMANCE STANDARDS

Energy performance labelling systems and minimum energy performance standards (MEPS) are effective instruments in transforming the markets for energy-consuming devices, including appliances, lighting and air conditioning systems. These instruments support the adoption of new and more energy efficient technologies and products. They cover products for all end uses and fuel types, with a focus on appliances, information and communication devices, lighting, heating and cooling systems, and other energy-consuming equipment. The most common approach for energy performance labelling systems and MEPS is the categorical labelling scheme, using a number of stars, alphabetical (A, B, C, etc.) or numeral (1,2,3, etc.) rating classes. Categorical labels are easy to understand by consumers when purchasing products and by building inspectors when checking for code compliance. Categorical labelling also offers a framework to easily revise specific MEPS requirements, as products that are more energy efficient become available on the market. Mandatory energy performance labelling systems are enforced to allow consumers to make informed choices about the products they buy and MEPS are usually implemented by prohibiting certain labelling categories from being sold on the market.

Tables 20 and 21 set out the status of energy performance labelling systems and MEPS requirements for household appliances and lighting systems in the Arab region. Several Arab countries have recently developed and adopted labelling systems and MEPS for selected products; however, the enforcement of those regulations remains a challenge for many Arab countries mainly owing to a lack of qualified testing facilities to ensure that appliances and lighting systems sold in the region are properly labelled and meet MEPS requirements (Asif, 2015). Saudi labelling systems and MEPS were among the first standards introduced in the Arab region and have been regularly revised (SASO, 2012; SASO, 2013; SASO, 2014). Annex II provides a brief description of Saudi labelling systems and MEPS for air conditioners, freezers, refrigerators and washing machines. It also outlines the recently adopted buildings energy code for building envelope components.

Table 20. Status of energy performance labelling systems and MEPS for air conditioning and appliances in Arab countries

Country	Regulation type	Status of policy
Algeria	Mandatory energy labelling standard for air conditioners, freezers and refrigerators	Adopted since 2009
Libya	Not available	NA
Morocco	Legal framework for mandatory energy labelling standard and MEPS (Energy Law N°47/09)	Energy labelling standards and MEPS under development
Tunisia	Freezers, and refrigerators: 1. Established mandatory energy performance labelling standards using an EE scale from classes 1 (most EE) to 10 (least EE). 2. Mandatory MEPS: Baned from the market classes 7 & 8 (July 2006) and classes 5 & 6 (July 2007) and class 4 (April 2009). Air conditioners: 1. Established mandatory energy performance labelling for individual ACs with capacity less than 12 kW using an EE scale from classes 1 (most EE) to 8 (Least EE). 2. Mandatory MEPS: Baned from the market classes 6, 7 and 8 (January 2010), class 5 (January 2011) and Class 4 (January 2012).	Adopted in 2004 (JORT n°75/17 Sep. 2004) Adopted in 2005 (JORT n°88/04 Nov. 2005) and 2008 (JORT n°88/31 Oct. 2008) Adopted in 2009 (JORT n°32/21 Avr. 2009) Adopted in 2009 (JORT n°53/3 Jul. 2009), 2010 (JORT n°79 du 01 Oct. 2010) and 2011 (JORT n°61/16 Aug. 2011)
Egypt	Air conditioners, refrigerators, freezers and washing machines	Adopted since 2003 and revised in 2006
Iraq	Not available	NA
Jordan	Air conditioners, freezers, refrigerators and washing machines	Adopted since 2014

Country	Regulation type	Status of policy
Lebanon	Policy framework for mandatory energy labelling standard and MEPS	Energy labelling standards and MEPS under development
Syrian Arab Republic	Refrigerators	Adopted since 2008
State of Palestine	Not available	NA
Bahrain	Mandatory energy labelling standard for air conditioners	Adopted in 2015 (Official Journal N°3223/2015)
Kuwait	MEPS for air conditioners	Adopted since 1983 as part of the Energy Conservation Code of Practice for Buildings. The Code was updated in 2010 and 2014
Oman	Not available	NA
Qatar	Mandatory energy labelling standard and MEPS for air conditioning systems (Standard QS 2663/2013), refrigerators/freezers (Standard QS SASO 2664/2016) and Washing machines (Standard QS SASO 2692/2016)	Energy labelling standard and MEPS for Air Conditioning implemented in 2016 Energy labelling standard and MEPS for refrigerators/freezers in consultation phase
Saudi Arabia	Mandatory energy labelling standard and MEPS for air conditioning systems (SASO 2663/2014 replaced by SASO 2663/2018), refrigerators and freezers (2664/2013 replaced by SASO 2892/2018), washing machines (SASO 2692/2013 replaced by SASO 2885/2018), clothes dryers (SASO 2883/2017) and water heaters (SASO 2884/2017).	MEPS for air conditioners adopted since 2007 then energy labelling standard and MEPS implemented in 2012 & 2013 with major revisions in 2018. Energy labelling standard and MEPS for refrigerators/freezers and washing machine implemented in 2013 with major revisions in 2018. Energy labelling standard and MEPS for clothes dryers and water heaters implemented in 2018.
United Arab Emirates (Dubai)	Mandatory energy labelling standard and MEPS for air conditioning systems, refrigerators, washing machines, domestic water heaters and dishwashers	Adopted since 2013/updated in 2016 for air conditioners
Mauritania	Not available	NA
Sudan	Not available	NA
Yemen	Not available	NA

Sources: EES, 2014; RCREEE, 2017; UN Environment, 2018. Checked/updated by ESCWA using available countries' official information as at September 2018.

Table 21. Status of energy efficiency regulations for lighting systems in Arab countries

Country	Buildings energy efficiency regulations	Status of policy
Algeria	Requirement for energy labelling of lighting fixtures	Adopted since 2009
Libya	Not available	NA
Morocco	Legal framework for mandatory energy labelling standard and MEPS (Energy Law N°47/09)	Energy labelling standards and MEPS under development
Tunisia	Eliminated from the market incandescent lamps rated 100 W or above (January 2011)	Adopted in 2010 (JORT n°69/27 Aug. 2010)
Egypt	Mandatory energy performance labelling for CFL/Voluntary energy performance labelling for lighting systems	Adopted since 2009
Iraq	Not available	NA
Jordan	Regulation for lighting minimum energy efficiency requirements	Adopted since 2014
Lebanon	Policy framework for mandatory energy labelling standard and MEPS	Energy labelling standards and MEPS under development
Syrian Arab Republic	Energy performance labelling for CFL and linear fluorescent lamps	Implemented

Country	Buildings energy efficiency regulations	Status of policy
State of Palestine	Not available	NA
Bahrain	MEPS for household light bulbs based on European Commission regulation No. 244/2009	Adopted in 2015 (Official Journal N°3199/2015)
Kuwait	Mandatory use of smart LED lighting systems in public buildings (Ministry of Electricity and Water R-6/2014)	Adopted since 2014
Oman	Not available	NA
Qatar	Ban on imports of incandescent light bulbs (Tungsten). First phase of the ban included 100W and 75W incandescent bulbs. Implementation began in 2014.	Implemented since 2016
Saudi Arabia	Mandatory energy performance labelling and MEPS (Standards SASO 2870/2015)	Implemented since 2016
United Arab Emirates	Government adoption of the Emirates Authority for Standardization and Meteorology (ESMA) ban on import and sales of incandescent and low quality energy saving lamps (Cabinet Decision N°34/2013)	Import ban since 2014/Sales ban since 2015
Mauritania	Not available	NA
Sudan	Not available	NA
Yemen	None	NA

Sources: EES, 2014; RCREEE, 2017; UN Environment, 2018. Checked/updated by ESCWA using available countries' official information as at September 2018.

D. POLICY OPTIONS FOR IMPROVING THE BUILDINGS SECTOR ENERGY SUSTAINABILITY

Based on current energy efficiency practices and the energy consumption trends outlined in the present study, Arab Governments can consider a wide range of policy options to improve energy sustainability of new and existing buildings in the Arab region. The main energy policies recommended for the region include the following:

- Improve energy efficiency in the existing buildings stock by implementing large-scale retrofit programmes that include relevant and easily achievable energy efficiency measures targeting all types of buildings, and through tailor made energy efficiency measures specifically targeting energy intensive buildings;
- Improve energy efficiency in new buildings by implementing and reinforcing energy performance buildings codes for all types of new buildings, and specific energy performance requirements for energy intensive buildings such as airports and large commercial and office buildings;
- Develop, implement and reinforce the energy performance requirements of buildings energy systems and equipment through energy performance labelling and MEPS specific to commercial buildings (lighting, heating, cooling and appliances);
- Develop, implement and reinforce the energy performance requirements of common household appliances through energy performance labelling and MEPS (refrigerators, room air conditioners, televisions and washing machines);
- Establish and improve knowledge in Arab countries of energy consumption patterns in the buildings sector by implementing and reinforcing systematic and sustainable statistical data collection of end-use energy consumption patterns per energy source for each of the main building branches, and by defining and monitoring relevant key energy performance indicators;
- Provide the human and financial resources required, and the time requirements for mobilizing resources to implement energy efficiency policies, and build the capacity of the relevant stakeholders.

To develop and implement the above-mentioned policies and programmes, short, mid and long-term strategies and action plans should be developed, taking into account the urgency of addressing certain buildings energy performance issues, and the time needed to mobilize the required human and financial resources.

Moreover, the success of the Arab region's transition towards more sustainable energy systems in the buildings sector requires capacity-building and training for all operators involved in the process, including the following:

- Architects;
- Engineers involved in the design and execution processes;
- Contractors;
- Equipment suppliers;
- Field operators (workers, works supervisors and controllers).

Building occupants might also require some basic trainings to ensure that they operate buildings in a sustainable and energy efficient manner.

IV. ANALYSIS OF ENERGY EFFICIENCY POTENTIAL IN THE BUILDINGS SECTOR

The potential for improving the energy performance of buildings in the Arab region is significant for both new and existing building stocks, owing to the lack of any stringent energy efficiency codes and practices in most Arab countries. Several opportunities are available to reduce energy consumption and enhance the sustainability of buildings through well designed and targeted energy policies. The present section evaluates some of those opportunities based on detailed analyses and reported studies. The potential benefits of large-scale implementation of selected energy efficiency programmes are also presented for both new and existing building stocks.

A. IMPACT OF ENERGY EFFICIENCY PROGRAMMES FOR BUILDING EQUIPMENT AND APPLIANCES

The following two examples outline the potential benefits of energy efficiency programmes related to buildings equipment and appliances in the Arab region.

1. Potential Benefits Of Improved MEPS

The potential benefits of setting MEPS based on available energy efficiency equipment and appliances commonly used in buildings have been estimated by United for Energy Efficiency (U4E, 2017). The analysis considers energy consuming products commonly used in residential buildings, including air conditioners, refrigerators and lighting. The potential annual savings in both electricity consumption and carbon emissions in 2025 and 2030 for most Arab countries are summarized in table 22 for lighting, table 23 for refrigerators and table 24 for air conditioners based on the implementation of stricter MEPS in 2020. While refrigerators are specific to residential buildings, lighting and air conditioners can affect energy consumption in both residential and commercial buildings.

Table 22. Potential benefits of lighting MEPS in Arab countries

	Electricity use (TWh/year)		Energy cost ($ million/year)		Carbon emissions (million tons/year)*	
Country	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**
Algeria	2.365	2.371	70.9	71.1	1.470	1.474
Libya	1.417	1.418	42.5	42.5	1.023	1.024
Morocco	1.479	1.476	177.5	177.2	1.118	1.115
Tunisia	0.771	0.715	69.4	64.3	0.383	0.355
Egypt	1.711	2.198	78.7	101.1	0.840	1.079
Iraq	1.333	1.387	10.7	11.1	1.351	1.406
Jordan	0.442	0.468	88.4	93.6	0.284	0.300
Lebanon	0.452	0.477	28.9	30.5	0.344	0.363
Syrian Arab Republic	0.251	0.325	2.5	3.3	0.163	0.212
State of Palestine	0.150	0.156	23.7	24.6	0.119	0.124
Bahrain	0.305	0.316	7.0	7.3	0.207	0.215
Kuwait	1.571	1.618	15.7	16.2	1.355	1.396
Oman	0.725	0.746	37.7	38.8	0.593	0.610
Qatar	1.395	1.437	34.9	35.9	0.693	0.714
Saudi Arabia	8.000	8.200	400.1	412.4	6.400	6.600
United Arab Emirates	3.100	3.200	361.1	367.3	2.038	2.072
Sudan	0.180	0.225	8.4	10.4	0.061	0.076
Yemen	0.109	0.114	3.0	3.1	0.075	0.078
Total	25.756	26.847	1461.1	1510.7	18.517	19.213

Source: U4E, 2017.

* Estimate based on IEA carbon emission factors for each country (IEA, 2017).

Table 23. Potential of MEPS for refrigerators in Arab countries

Country	Electricity use (TWh/year)		Energy cost ($ million/Year)		Carbon emissions (million tons/year)*	
	2025	2030	2025	2030	2025	2030
Algeria	0.803	1.545	24.1	46.4	0.499	0.960
Libya	0.136	0.262	4.1	7.9	0.098	0.189
Morocco	0.458	0.897	55.0	107.7	0.346	0.678
Tunisia	0.177	0.336	15.9	30.2	0.088	0.167
Egypt	1.901	3.963	87.40	182.3	0.933	1.945
Iraq	0.511	1.020	4.1	8.2	0.518	1.034
Jordan	0.117	0.243	23.4	48.6	0.075	0.156
Lebanon	0.094	0.189	6.0	12.1	0.072	0.144
Syrian Arab Republic	0.376	0.756	3.8	7.6	0.245	0.493
State of Palestine	0.074	0.153	11.7	24.2	0.059	0.112
Bahrain	0.047	0.090	1.1	2.1	0.032	0.061
Kuwait	0.180	0.325	1.8	3.3	0.156	0.280
Oman	0.069	0.137	3.6	7.1	0.056	0.112
Qatar	0.035	0.072	0.90	1.8	0.017	0.036
Saudi Arabia	0.800	1.500	40.4	77.20	0.600	1.200
United Arab Emirates	0.400	0.700	40.9	85.7	0.231	0.484
Sudan	0.608	1.255	28.3	58.4	0.206	0.425
Yemen	0.186	0.408	5.0	11.0	0.127	0.280
Total	6.972	13.851	357.5	721.8	4.358	8.756

Source: U4E, 2017.

* Estimate based on IEA carbon emission factors for each country (IEA, 2017).

Table 24. Potential benefits of MEPS for air conditioners in Arab countries

Country	Electricity savings (TWh/year)		Carbon emissions reduction* (million tons/year)	
	2025	2030	2025	2030
Algeria	0.392	0.756	0.215	0.415
Libya	0.122	0.201	0.237	0.391
Morocco	0.252	0.484	0.140	0.269
Tunisia	0.133	0.238	0.063	0.113
Egypt	0.687	1.266	0.275	0.507
Iraq	0.683	1.246	0.693	1.264
Jordan	0.105	0.18	0.061	0.105
Lebanon	0.072	0.122	0.056	0.094
Syrian Arab Republic	0.346	0.852	0.081	0.199
State of Palestine	0.003	0.006	0.002	0.005
Bahrain	0.021	0.033	0.008	0.012
Kuwait	0.055	0.091	0.039	0.065
Oman	0.117	0.2	0.057	0.097
Qatar	0.051	0.085	0.015	0.026
Saudi Arabia	2.2	3.6	1.258	2.058
United Arab Emirates	1.1	1.7	0.499	0.770
Sudan	0.346	0.852	0.183	0.451
Yemen	0.04	0.082	0.083	0.170
Total	6.448	11.271	3.965	7.012

Source: U4E, 2017.

* Estimate based on IEA carbon emission factors for each country (IEA, 2017).

As shown in tables 22-24, the overall electrical savings that can be achieved by 2030 from updating, implementing and enforcing MEPS are highest for lighting (26.847 terawatt hours/year) followed by refrigerators (13.851 terawatt hours/year) and then room air conditioners (11.271 terawatt hours/year).

Based on the baseline scenario (BAS) projections for 2030, those savings represent 1.9 per cent (lighting), 0.9 per cent (refrigerators) and 0.8 percent (room air conditioners) of the final energy consumption of the buildings sector in the Arab region. BAS projections are based on an annual growth rate of 3.1 per cent for the Arab region, in line with IEA estimates for the region (IEA, 2017). Moreover, BAS projections account for the benefits associated with utilizing more energy efficient products as technology progresses, even in the absence of any standards and regulations. The savings in tables 22-24 are rather small, especially considering the potential uncertainties in estimating future energy consumption levels.

Table 25 summarizes the cumulative savings in both electricity and carbon emissions owing to improved MEPS for lighting, residential refrigerators and air conditioners in Arab countries. Improvements in lighting standards can have the highest impact among all three options, with potential savings over the period 2020-2030 of 227 terawatt hours in electricity consumption, and of 144 million tons in carbon emissions - three times the benefits of improving MEPS for either residential refrigerators or air conditioners.

Table 25. Cumulative benefits of improved MEPs for lighting, residential refrigerators and air conditioners in Arab countries, 2020-2030

	Lighting		Residential refrigerators		Air conditioners	
Country	Electricity use savings (TWh)	Carbon emissions reduction (million tons)*	Electricity use savings (TWh)	Carbon emissions reduction (million tons)*	Electricity use savings (TWh)	Carbon emissions reduction (million tons)*
Algeria	20.5	11.2	8.7	4.8	4.3	2.4
Libya	12.3	23.9	1.5	2.9	1.3	2.5
Morocco	12.8	7.1	5	2.8	2.7	1.5
Tunisia	6.6	3.1	1.9	0.9	1.4	0.7
Egypt	16.3	6.5	21.3	8.5	7.3	2.9
Iraq	11.8	12.0	5.6	5.7	7.3	7.4
Jordan	3.9	2.3	1.3	0.8	1.1	0.6
Lebanon	4	3.1	1	0.8	0.7	0.5
Syrian Arab Republic	2.4	0.6	4.2	1.0	0.7	0.2
State of Palestine	1.3	0.8	0.8	0.7	0	0.0
Bahrain	2.7	1.0	0.5	0.2	0.2	0.1
Kuwait	13.8	9.8	1.9	1.4	0.6	0.4
Oman	6.4	3.1	0.8	0.4	1.2	0.6
Qatar	12.2	3.7	0.4	0.1	0.5	0.2
Saudi Arabia	70.3	40.2	8.7	5.0	22.5	12.9
United Arab Emirates	27.2	12.3	4	1.8	10.7	4.8
Sudan	1.7	0.9	6.8	3.6	4.2	2.2
Yemen	1	2.1	2.1	4.4	0.5	1.0
Total	227.2	143.7	76.5	45.6	67.2	40.9

Source: U4E, 2017.

* Estimate based on IEA carbon emission factors for each country (IEA, 2017).

2. Impact Of Led Integrated Systems For Commercial Buildings

For commercial and public buildings, the application of integrated LED fixtures with advanced control capabilities is becoming more widespread because of their ease of installation and lower costs. LED fixtures with integrated control systems reduce both lighting power density and lighting energy use, since they can act as sensors in small or open spaces and provide daylight dimming and occupancy triggered controls. A field study demonstrates the performance of integrated control LED fixtures for two commercial buildings in the United States (Shackelford and others, 2015). Each integrated control LED unit includes LED lamp, driver, a set of daylighting controls, and an occupancy sensor. The LED units are designed to replace T-8 and T-12 fluorescent fixtures using existing wiring systems. The analysis shows that integrated control LED units can save more than 50 per cent of lighting energy consumption and 30 per cent of lighting power density in commercial buildings. Consequently, large-scale replacement programmes of fluorescent lighting systems with integrated control LED units should be considered for both commercial and public buildings in the Arab region, with a 10-year implementation plan starting by 2020. Conservative savings of 40 per cent of electricity energy and 20 per cent at peak demand are estimated for Arab countries. Most Arab countries experience highest electricity demand during the hot summer days (all GCC and most Maghreb and Mashreq countries), due to air conditioning loads; these loads will be reduced as a result of the reduction in the lighting loads.

The potential benefits of such programmes are summarized in table 26. The overall reduction in annual electrical energy use is estimated at 21.660 terawatt hours by the end of 2030, representing 1.5 per cent of total final energy consumed by the building sector in the Arab region - a relatively small reduction, especially when considering projection uncertainty for future energy consumption. Such programmes can be implemented and enforced through retrofit initiatives specific to commercial and public buildings.

Table 26. Potential benefits of using integrated control LED lighting units in commercial and public buildings in the Arab region

Country	Electricity use savings (TWh/year)		Peak demand reduction (MW)		Carbon emissions reduction (million tons/year)	
	2025	2030	2025	2030	2025	2030
Algeria	-	-	258.960	517.920	-	-
Libya	0.133	0.266	309.600	619.200	0.258	0.517
Morocco	0.568	1.137	216.808	433.616	0.316	0.632
Tunisia	0.300	0.600	134.280	268.560	0.142	0.285
Egypt	1.607	3.214	929.500	1859.000	0.644	1.288
Iraq	0.101	0.202	762.960	1525.920	0.103	0.205
Jordan	0.184	0.368	132.200	264.400	0.107	0.214
Lebanon	0.113	0.227	76.680	153.360	0.088	0.175
Syrian Arab Republic	0.137	0.273	78.750	157.500	0.072	0.145
Bahrain	0.246	0.491	77.220	154.440	0.090	0.180
Kuwait	0.615	1.229	720.000	1440.000	0.438	0.875
Oman	0.402	0.804	269.500	539.000	0.195	0.391
Qatar	0.251	0.501	228.908	457.816	0.075	0.150
Saudi Arabia	3.930	7.861	1545.660	3091.320	2.247	4.494
United Arab Emirates	1.487	2.973	994.740	1989.480	0.674	1.347
Sudan	0.690	1.380	109.873	219.746	0.161	0.323
Yemen	0.066	0.133	57.600	115.200	0.138	0.276
Total	10.830	21.660	6903.239	13806.478	5.748	11.496

Source: Author's analysis.

B. IMPACT OF ENERGY EFFICIENCY PROGRAMMES FOR NEW BUILDINGS

1. Buildings envelope thermal performance

As noted above, there are no specific mandatory energy conservation requirements for buildings in several Arab countries. Even in countries with mandatory codes, enforcement procedures are lax and the implementation of required thermal insulation is minimal (Asif, 2015). Improving the envelope energy performance can be beneficial even for non-conditioned buildings, since it can immediately improve indoor thermal comfort and reduce energy consumption if the building becomes conditioned. A 10 per cent average reduction in annual energy consumption and electrical peak demand can be achieved for new buildings if more energy performance walls and roofs and better glazing for windows are installed. Savings for countries with hot climates, such as GCC countries, are expected to be higher. Using the floor area estimates discussed above and the bottom-up analysis carried out by Krarti (2015), the economic and environmental benefits of the envelope energy performance requirements on new buildings are summarized in table 27. Only countries with no building energy efficiency codes prior to 2014 are included in the analysis. Carbon emissions from electricity generation are based on countries' emission factors. It is estimated that the annual contribution of energy consumption of new buildings is 4 per cent, based on the trend outlined in figure 21.

Table 27. Economic and environmental benefits of buildings envelope systems for all new buildings in Arab region

Building type	Annual energy use savings (TWh/yr)	Peak demand savings (MW)	Annual CO_2 emissions savings (million tonnes/year)
Residential buildings	1.263	228	0.39
Commercial and public buildings	0.532	96	0.17
Total	1.795	324	0.560

Source: Author's analysis based on the approach of Krarti (2015).

Note: Countries considered in the analysis are Iraq, Lebanon, Libya, Morocco, Oman, Saudi Arabia and Yemen.

2. Integrated Building Energy Performance

Proven energy efficiency strategies can be effective in significantly reducing building energy consumption in the Arab region. When appropriate energy efficiency strategies are applied to new buildings, over 30 per cent of energy can be saved relative to the current construction practices in the Arab region.

Using life-cycle costs (LCC) optimization analysis, the feasibility requirements and implementation costs of high energy performance villas in selected Arab countries are evaluated (Krarti and Ihm, 2016). Table 28 summarizes the annual electrical energy consumption, reductions in LCC for 30 years, and increases in construction costs to achieve optimal energy efficiency designs. The reduction in LCC is estimated relative to the baseline design for the villas. The increase in construction costs include additional costs for installing energy efficiency designs. As shown in table 28, energy savings ranging between 31 per cent and 56 per cent are found in all Arab cities. The optimal design for residential buildings has lower LCC values in all climates, with LCC reductions ranging from 13 per cent to 25 per cent. The additional costs of implementing the optimized energy efficiency options are reasonable, with an increase in construction costs relative to that of the baseline design varying between 2 per cent and 20 per cent, depending on the climate and the energy-efficiency measures required. LCC reduction is mainly attributed to lower operating costs associated with a decrease in annual energy consumption. Over the buildings lifetime, annual energy cost reduction outweighs the increase in building construction costs to implement energy-efficient features (Krarti and Ihm, 2016).

Table 28. Energy savings and LCC values and implementation costs for minimizing LCC

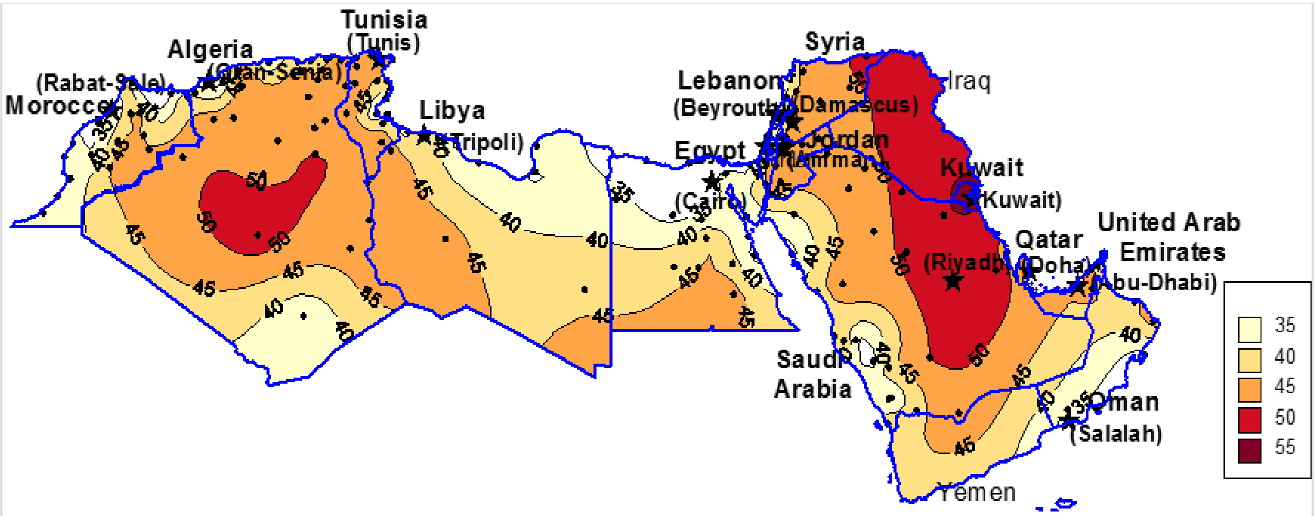
Country	City	Optimal energy saving [%]	Optimal LCC reduction [%]	Construction cost increase for optimal design [%]*
Algeria	Oran-Senia	33	14	5
Libya	Tripoli	47	16	17
Morocco	Rabat	33	15	2
Tunisia	Tunis	47	16	17
Egypt	Cairo	31	13	4
Jordan	Amman	45	15	17
Lebanon	Beirut	32	14	3
Syrian Arab Republic	Damascus	49	18	17
Kuwait	Kuwait	56	25	20
Oman	Salalah	32	14	2
Qatar	Doha	47	17	14
Saudi Arabia	Riyadh	55	22	20
United Arab Emirates	Abu Dhabi	43	16	11

Source: Krarti and Ihm, 2016.

Note: The construction costs considered in the analysis include those of walls, roofs, HVAC and lighting systems.

Figure 47 shows the contour map of potential annual energy savings that can be achieved in residential buildings for the Arab region, based on the optimal analysis of energy efficiency measures (Krarti and Ihm, 2016). Annual primary energy savings ranging between 35 per cent and 55 per cent can be achieved using optimal designs. The highest savings are achieved for hot climates, especially in the GCC region, while the lowest savings are seen in regions with mild climates.

Figure 47. Contour map of potential energy savings in the Arab region (%)



Source: Krarti and Ihm, 2016.

Using integrated design approaches, more effective BEECs can be developed for all new buildings in the Arab region. Throughout the Arab region, 35-55 per cent savings can be achieved using integrated and optimal designs for residential buildings. In this analysis, the impact of integrated design-based BEECs is set at 30 per cent savings in both energy consumption and peak demand associated with new buildings stock. This conservative savings level is used to account for diversity of climate conditions, behavioural changes and energy efficiency rebound effects in the Arab region (Majcen and others, 2013; Jacobsen and Kotchen, 2013). The benefits of integrated design based BEECs applied to new buildings are summarized in table 29.

Table 29. Economical and environmental benefits of implementing integrated BEECs for all new buildings in the Arab region

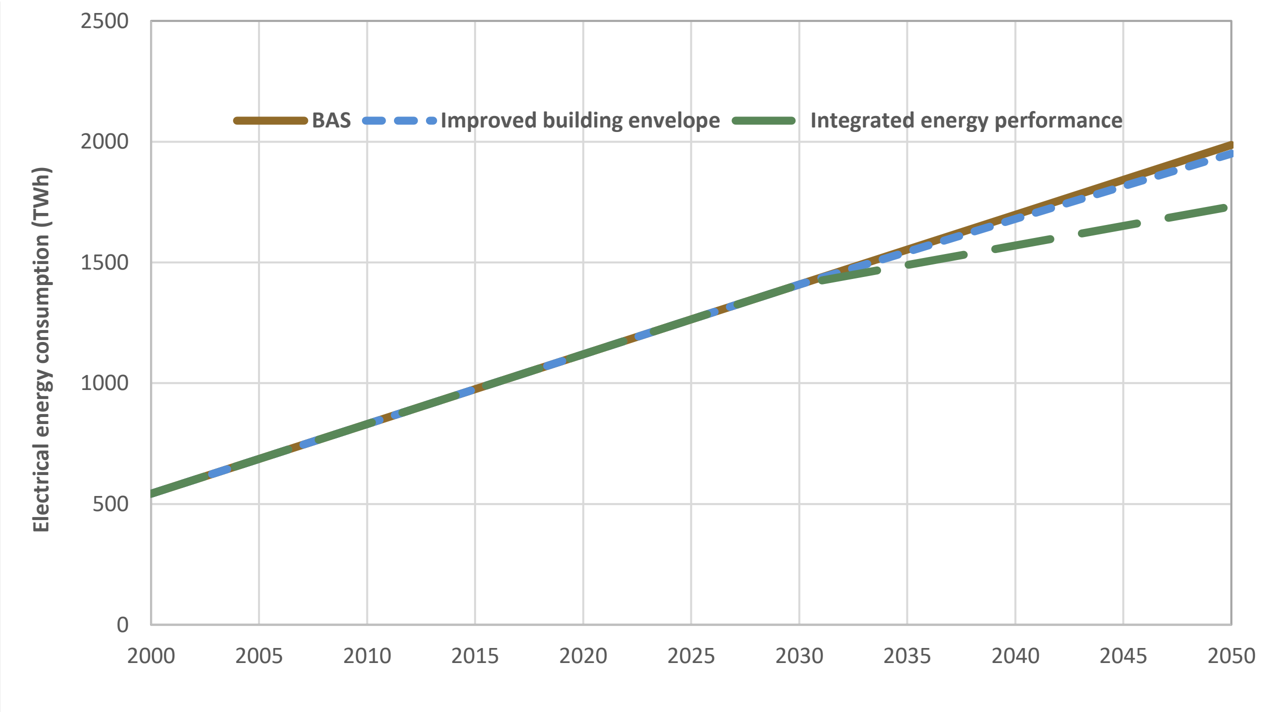
Building type	Annual energy use savings (TWh/yr)	Peak demand savings (MW)	Annual CO_2 emissions Savings (million tonnes/year)
Residential buildings	9.490	1543	2.960
Commercial and public buildings	3.249	528	1.014
Total	12.739	2071	3.974

Source: Author's analysis based on the approach of Krarti and others (2017).

The baseline scenario for future energy consumption for buildings in the Arab region is estimated to have an average annual growth rate from 2015 to 2050 of 3.1 per cent, which is consistent with the rates considered for the MENA region of 3.6 per cent by EIA for the buildings sector energy consumption and of 2.9 per cent for electricity demand (IEA, 2017).

As indicated in figure 48, the implementation in 2030 of the two BEEC types outlined above reduces future energy consumption slowly as the buildings stock is replaced by new construction over time. To account for new construction, including demolition and renovation of existing buildings stock, a 4 per cent annual rate of new buildings relative to the total building stock is considered for the Arab region (Krarti and others, 2017). The implementation in 2030 of an integrated design-based BEEC has the potential to reduce substantially buildings' energy demand. Annual savings in the Arab region could reach 127 terawatt hours and 382 terawatt hours by 2030 and 2050, respectively.

Figure 48. Impact on buildings' total final energy consumption of implementing energy efficiency codes for new buildings in the Arab region starting in 2030



Source: Author's analysis based on the approach of Krarti and other (2017).

C. IMPACT OF ENERGY EFFICIENCY PROGRAMMES FOR EXISTING BUILDINGS

To improve the energy performance of existing buildings stock, the following three levels of building retrofits are considered, with different capital cost requirements and varying energy saving potentials and economic and environmental benefits (ASHRAE, 2011; Krarti, 2015):

- ***Level-1 energy retrofit:*** This basic retrofit involves mostly low-cost energy efficiency measures, such as replacing lighting fixtures with LED units and weatherizing building shells to reduce air infiltration. As detailed in several other studies, the estimated average energy savings from a level-1 retrofit program are about 8 per cent for all building types, based on the simulation analysis carried out for several Arab countries (Krarti, 2015; Krarti and others, 2017; Krarti and Dubey, 2017) and on case studies reported for residential, commercial and governmental buildings (Krarti and Ihm, 2015);
- ***Level-2 energy retrofit:*** In addition to level-1 measures, this retrofit includes use of energy efficient equipment and temperature and lighting controls. Based on reported studies in the Arab region and simulation results outlined in the present study, average energy savings of about 23 per cent can be achieved for level-2 retrofits for all building types (Hong et al., 2015; Ameer and Krarti, 2016);
- ***Level-3 energy retrofit:*** This type of retrofit, known as a deep retrofit, requires the implementation of capital-intensive measures, including adding roof thermal insulation, replacing cooling systems, and installing automated control systems. While deep retrofits are typically costly, they can provide significant energy savings exceeding 50 per cent (Krarti, 2015; Krarti and others, 2017; and Krarti and Dubey, 2017).

The specific measures of each retrofit level have to be tailored to building type and climate. Table 30 illustrates three options of specific energy efficiency measures that can be considered for residential building types based on a study conducted in Oman for all three retrofit levels (Krarti and Dubey, 2017).

Table 30. Options for energy efficiency measures specific to three retrofit levels of Omani residential buildings

Recommended options	Retrofit description[a]	Retrofit level for residential buildings		
		Level 1	Level 2	Level 3
1.	List of EEMs	EEM-1	EEM-1, EEM-2, and EEM-3	EEM-1, EEM-2, EEM-3, and EEM-4
	Energy use savings	12%	28%	54%
	Range of reduction in savings due to behavioural and rebound effects[b]	0-6 %	0-6 %	0-6%
2.	List of EEMs	EEM-2	EEM-4	EEM-2, EEM-3, and EEM-6
	Energy use savings	10.0%	29%	51.0%
	Range of reduction in savings due to behavioural and rebound effects[b]	0-4%	0-4%	0-4%
3.	List of EEMs	EEM-3	EEM-5	EEM-5, and EEM-6
	Energy use savings	10%	28%	52%
	Range of reduction in savings due to behavioural and rebound effects[b]	0-4%	0-6%	0-6%

Source: Krarti and Dubey, 2017.

Notes: [a] Description of EEMs:

EEM-1: Increase the cooling set from 21°C to 23°C, from 22°C to 24°C or from 23°C to 25°C, depending on the existing operating conditions.

EEM-2: Replace existing lighting fixtures by LEDs.

EEM-3: Seal air leakage sources around building envelope (i.e., window and door frames so ACH =0.21).

EEM-4: Replace the existing AC unit by high efficiency system (COP=4.0).

EEM-5: Better lighting controls including dimming daylighting and occupancy sensors for commercial buildings.

EEM-6: Insulate the roof using RSI-3.

[b] The behavioural and rebound effects are estimated based on previous studies. Typically, the effects are higher for measures that relay on temperature and lighting controls (i.e., EEM-1 and EEM-5).

Table 31 summarizes the annual energy use, electricity peak demand, and carbon emissions savings for level 1, 2 and 3 buildings energy retrofit programmes applied to the entire existing buildings stock in the Arab region. Significant energy and environmental benefits can be achieved at all levels of the buildings energy retrofit programmes. The economic and environmental benefits that can be realized for residential buildings are significantly higher than those of commercial and public buildings for all energy retrofit levels. Over 74 per cent of the overall benefits can be achieved by solely retrofitting residential buildings in the Arab region, as indicated in table 31, because dwellings represent the dominant buildings type contributing to energy consumption in the Arab region. However, when considering individual buildings, non-residential structures such as office buildings, hospitals and hotels provide high energy saving opportunities. Thus, in terms of implementation, it would be better to start with retrofitting non-residential buildings and then consider residential buildings.

Table 31. Energy and environmental benefits for the three levels of buildings energy efficiency retrofit programmes

Retrofit programme	Level 1	Level 2	Level 3
Annual energy savings (TWh/year)			
• Residential buildings	63.269	166.523	344.180
• Commercial buildings	21.660	59.346	125.623
Total existing buildings stock	84.929	225.870	469.803
Peak demand savings (MW)			
• Residential buildings	9,720	24,301	49,074
• Commercial buildings	3,328	8,318	16,358
Total existing building stock	13,048	32,619	65,432
Annual CO_2 savings (tons/year)			
• Residential buildings	19.764	52.561	109.326
• Commercial buildings	6.729	17.896	37.224
Total existing buildings stock	26.493	70.458	146.550

Source: Author’s analysis based on the approach of Krarti (2015).

Note: Benefits are estimated when the entire existing buildings stock within the Arab region is retrofitted (over a 10-year span starting from 2030).

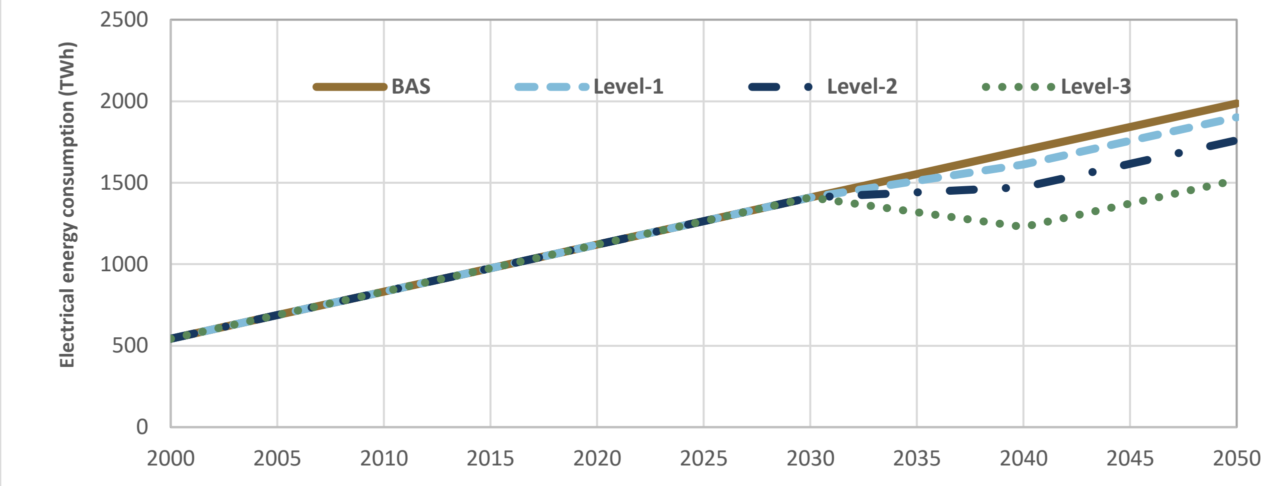
The implementation of large-scale building energy retrofit programmes are expected to be gradual, requiring several years because of significant investments needed for renovating the entire existing buildings stock, and a lack of qualified energy efficiency contractors in most Arab countries that require a few years to train. However, any of the three energy retrofit programmes can result in significant economic and environmental benefits for the Arab region, even when only a small fraction of the existing buildings stock is targeted (table 31). The energy retrofit programmes for the existing buildings stock have a significant impact on both final energy consumption, peak electrical demand, and carbon emissions in the Arab region, even when implemented gradually over a 10-year period starting from 2030 (figure 49). Level 3 retrofits have the highest impact with, an annual energy consumption reduction of 470 terawatt hours and a decrease in electrical demand of 65 gigawatts and 146 million tons per year of carbon emissions when the programme is fully implemented. A basic level 1 retrofit programme would still save 85 terawatt hours in annual final energy consumption, without significant investment requirements (Krarti et al., 2017).

Retrofit programmes can start with non-residential buildings, since they provide higher energy savings per unit floor area than residential buildings. Moreover, it is easier to perform energy audits and retrofits for larger non-residential buildings through energy service companies than it is for smaller residential buildings. In addition, retrofitting residential buildings is associated with specific privacy and cultural sensitivity challenges in several Arab countries (Krarti and others, 2017). As indicated in figure 49, the potential benefits depend on when the programmes are initiated and the retrofit rate. The results in figure

50 assume a 10 per cent retrofit rate (meaning that 10 per cent of the existing buildings stock is retrofitted each year). If lower retrofit rates are considered, the potential benefits will be reduced accordingly.

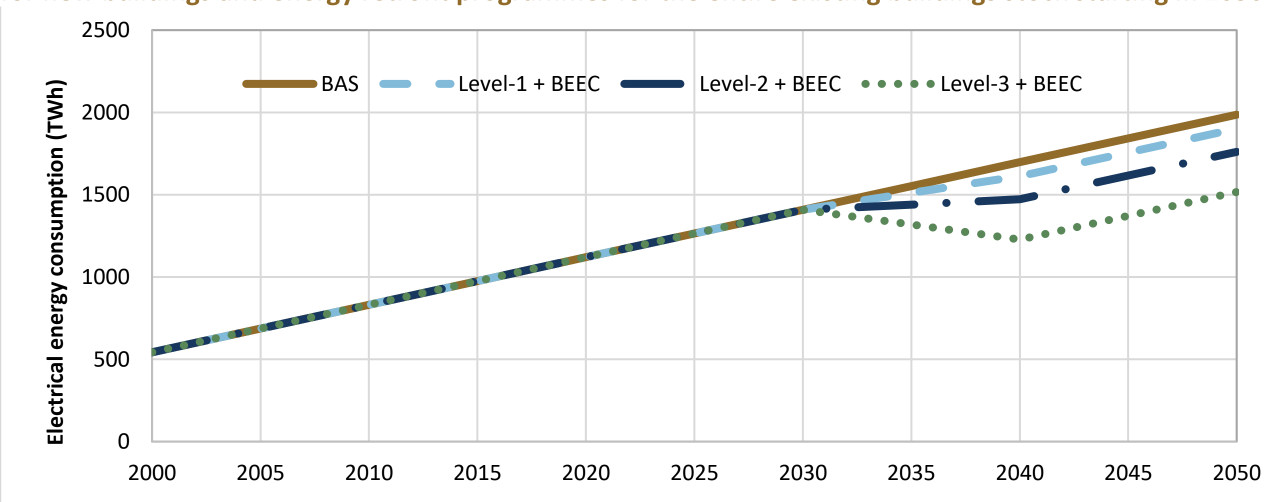
The highest impact scenario for reducing the final energy use and peak demand would be to simultaneously implement integrated BEECs for new buildings, and upgrade over a 10-year span the entire existing buildings stock using level 3 energy retrofit. Figure 50 shows that there is a significant potential saving of buildings energy consumption, especially when level 3 energy retrofit programme is implemented over a 10-year period and new buildings are constructed using an integrated energy efficiency code. In this scenario, and if the code and the retrofit programme is implemented by 2030, the total annual final energy consumption for the Arab region could be reduced by 597 terawatt hours (or 43 per cent) from a projected 1,409 terawatt hours per year. Similar reductions in both electrical peak demands and carbon emissions can be achieved. The required investments to implement such energy efficiency programmes can be significant. However, the economic benefits can be substantial for most countries, as reported for several GCC countries (Krarti, 2015; Krarti and others, 2017; Krarti and Dubey, 2017).

Figure 49. Impact on electrical energy consumption of implementing energy retrofit programmes for the entire existing buildings stock starting in 2030



Source: Author’s analysis based on the approach of Krarti and others (2017).

Figure 50. Impact on final energy consumption of implementing comprehensive energy efficiency codes for new buildings and energy retrofit programmes for the entire existing buildings stock starting in 2030



Source: Author’s analysis based on the approach of Krarti and others (2017).

The costs of the retrofit programmes vary by level and by country. Based on a recently reported bottom-up analysis (Krarti and others, 2017), the implementation costs and the benefits of large-scale energy retrofit programmes have been *estimated* for the buildings stock in *Saudi Arabia*. Table 32 summarizes the required investments and the potential benefits of the three retrofit levels for *all* existing residential and non-residential buildings. *The study concluded the following:*

- Given the low electricity prices in Saudi Arabia, it makes little sense for households and other private organizations to invest in energy efficiency. Subsidies for the energy prices must be reduced for building owners and/or operators to cost-effectively invest in energy efficiency;
- When the economic benefits from avoided fuel consumption and reduced needs for electricity generation capacity are considered, energy efficiency investments by the Saudi government for retrofitting existing buildings are highly cost effective. For instance, a basic retrofit (level 1) of households can pay for itself within a year;
- Other benefits include stimulating employment in energy auditing and management and carbon mitigation. In particular, over 76 million tons of carbon emissions can be eliminated when a level 3 retrofit programme is implemented for the existing building stock in Saudi Arabia. The same programme would avoid the construction of 22,900 megawatts in power plant capacity and the consumption of 100,000 gigawatt hours of electrical energy per year. In addition, a level 3 retrofit programme would create 247,000 new jobs per year over a 10-year implementation period, totalling 2,470,000 jobs;
- Innovative financing mechanisms will need to be developed to incentivize the private sector to undertake large-scale energy efficiency investments. For instance, the creation of energy service companies can be initiated by the Government using the concept of performance contracting as a means of financing energy efficiency based on future savings;
- Successful implementation for any energy efficiency programme for both new and existing buildings will require the development of strong institutional and labour force capacity.

Table 32. Investments and benefits for buildings energy retrofit programmes in Saudi Arabia

Retrofit programme	Level 1	Level 2	Level 3
Investments required (USD billions)	10	104	207
Avoided electricity consumption (GWh/year)	16,000	46,000	100,000
Value of avoided electricity consumption (USD billion/year)	0.5	1.4	3.0
Avoided energy subsidies (USD billion/year)	1.2	3.5	7.5
Avoided electricity generation capacity (MW)	3,700	10,500	22,900
Value of avoided electricity capacity (USD billion)	2.8	7.9	17.2
Jobs created (per year over a 10-year period)	12,000	123,000	247,000
Reduced carbon emissions (million tons/year)	12	35	76

Source: Krarti and others, 2017.

D. IMPACT OF INTEGRATED RENEWABLE ENERGY SYSTEMS ON BUILDINGS ENERGY CONSUMPTION

The present section evaluates the impact of integrating renewable energy systems in buildings in the Arab region by installing rooftop photovoltaics (PV) panels. Recent studies have assessed the implementation costs and benefits of installing PV systems on roofs of existing housing stock in Saudi Arabia (Khan and others, 2017). Table 33 summarizes the main findings of those studies specific to Saudi Arabia, and results from a similar analysis conducted for Tunisia. Table 33 estimates the annual avoided carbon emissions and the electrical energy that can be generated when rooftop PV systems are installed on all available roof areas for the existing residential buildings stock in Saudi Arabia and Tunisia. The new analysis for the PV rooftop systems for Tunisia is based on statistical data for the number and type of housing units obtained from the most recent census (INS, 2014). Potential rooftop PV electricity generation is 51.0 terawatt hours/year in Saudi Arabia, representing about a third of current electricity needs for residential buildings. For Tunisia, rooftop PV panels can provide 15.2 terawatt hours/year of energy, equivalent to the overall current electricity consumption of the entire housing stock.

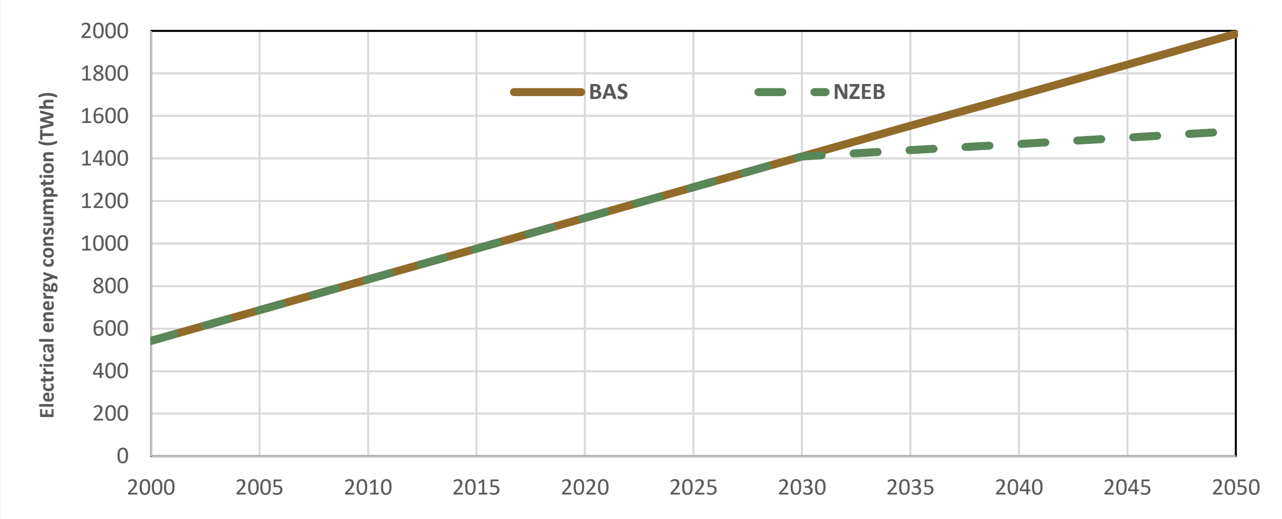
Table 33. Size and benefits of PV systems installed on the roofs of all existing residential buildings in Saudi Arabia and Tunisia

Size/benefits	Saudi Arabia	Tunisia
PV roof area available for housing units (million m^2)	221.8	70.0
Size of roof-pv systems (GW)	38.0	10.5
Annual electricity generated by PV (TWh/year)	51.0	15.2
Carbon emissions avoided (million tons/year)	29.2	7.2

Source: Khan and others (2017) for Saudi Arabia; and author analysis for Tunisia.

One approach to promote integration of PV systems in buildings is to require net-zero energy buildings (NZEBs) for new housing units. NZEB requirements are set to start in several regions of the world, including the European Union, in 2020 for all new buildings, (EU, 2010; EU, 2012; EC, 2012) and in selected states in the United States for new homes by 2030 (CEC, 2015). The analysis for prototypical residential building throughout the Arab region has shown that NZEB designs are possible based on integration of proven energy efficiency measures with rooftop PV systems (Krarti and Ihm, 2016). Figure 51 presents the impact of NZEB requirements for all new residential buildings on the future final energy consumption of buildings in the Arab region starting in 2030. When the programme starting year is set to 2030, annual energy savings are expected to reach 229 terawatt hours by 2040 and 458 terawatt hours by 2050. The main challenge to implementing the NZEB programme is the capital investment needed to install PV roof systems. Based on $2500/kilowatt installation cost, the required capital costs for rooftop PV panels are estimated at $90.6 billion in Saudi Arabia and $25.4 billion in Tunisia (Khan and others, 2017). However, the cost of PV panels is expected to decrease in the coming years, possibly making NZEB designs cost-effective for most Arab countries, especially when energy subsidies are reduced or eliminated.

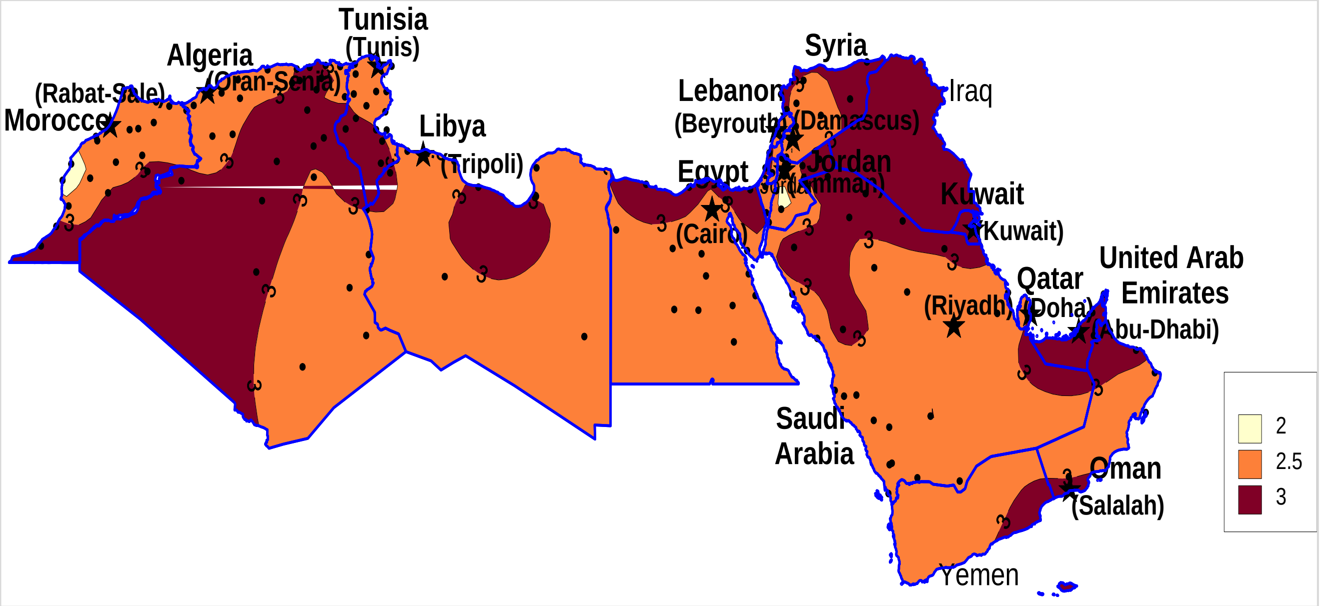
Figure 51. Impact on electrical energy consumption of implementing net-zero residential buildings for the new housing stock in the Arab region starting in 2030



Source: Author's analysis.

Figure 52 indicates the size of the PV system required to achieve NZEB design for homes in the MENA region. A PV system ranging between 2.5 kilowatts and 3.0 kilowatts is required in the vast majority of Arab countries to generate sufficient electricity to meet the annual energy requirements for the prototypical home.

Figure 52. Contour map of PV panel size (kW) to achieve NZEB homes in selected Arab countries



Source: Krarti and Ihm, 2016.

ANNEX I
BUILDINGS ENERGY EFFICIENCY CODE FOR TUNISIA

To improve the energy efficiency of its buildings stock, Tunisia has developed a series of energy efficiency programmes through the Agence Nationale de la Maitrise de l'Energie, including a national BEEC for new constructions of residential buildings, office buildings, hotels and hospitals.

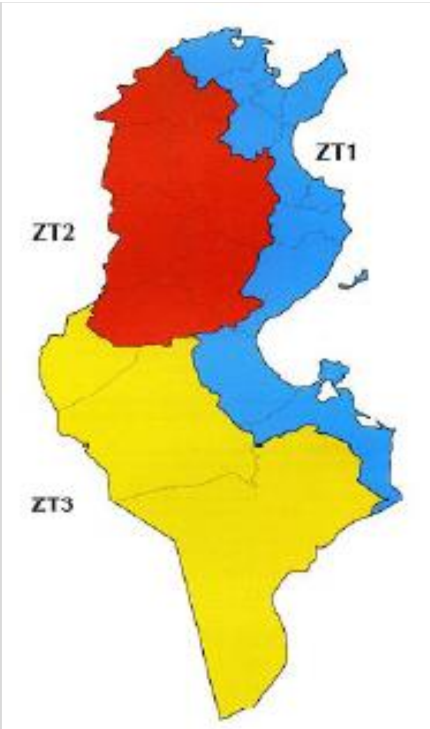
The present annex summarizes the performance and prescriptive paths of the energy efficiency code for new buildings in Tunisia. The code requirements depend on both building type and climate.

CLIMATIC ZONES

In Tunisia, the building energy efficiency code is based on three main climatic zones as depicted in Figure AI.1. These three climatic zones are defined as follows:

- Climatic zone ZT1: covers the coastline areas, including the governorates of Bizerte, Tunis, Ariana, Ben Arous, Manouba, Zaghouan, Nabeul, Sousse, Monastir, Mahdia, Sfax, Gabès and Médenine except delegations of Matmata and Médenine;
- Climatic zone ZT2: consists of the western and central geographical areas of Tunisia and includes the governorates of Jendouba, Béja, Kef, Siliana, Kairouan, Kasserine, Sidi Bouzid, and Gafsa;
- Climatic zone ZT3: comprises the southern part of Tunisia, including the governorates of Tozeur, Kébili and Tataouine and the delegations of Matmata and of Médenine.

Figure AI.1 Geographical locations of climatic zones in Tunisia



Source: ANME and FFEM, 2010.

BEEC COMPLIANCE APPROACHES

The Tunisian BEEC utilizes both prescriptive and performance compliance approaches, as discussed in the following sections.

PRESCRIPTIVE APPROACH

The prescriptive approach sets the threshold values of buildings envelope specifications, including U-value of exterior walls, roofs, and windows as well as shading coefficient for windows glazing. These threshold values depend on the climatic zone and window-to-wall ratio (WWR) of heated and/or cooled spaces as well as the repartition of windows on the different orientations. The application of the prescriptive approach in the Tunisian BEEC is currently limited to residential buildings and office spaces. The details of the prescriptive compliance approach for both of these building types are provided below.

Residential buildings: When at least 80% of its useful floor area is used as living space, a facility is defined as residential building in the current version of the Tunisian BEEC. The prescriptive approach cannot be applied to multi-residential buildings composed of ground floor and four or more levels (i.e, five or more story-buildings). It is also not applicable when the overall window to wall ratio or WWR value is higher than 45% and/or when the WWR value for conditioned areas oriented east (+/-45°) and west (+/- 45°) is higher than ± 35%.

Table A-1 summarizes the prescriptive compliance specifications and provides the maximal requirements for U-values associated with roofs, exterior walls, and windows as well as for SC values associated with windows glazing for residential buildings in various climatic zones. In table AI.1, the following definitions for both U-value and SC values are provided:

U-Value: it is the thermal heat coefficient for any building envelope surface. It corresponds to the heat transferred per unit of time and surface and under a temperature gradient of 1K. This coefficient is expressed in W/(m²K).

Shading Coefficient, SC: it corresponds to the ratio of solar heat gain coefficient of the glazing in question to that of a simple reference glazing as defined by the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE).

For an entire building, an equivalent solar shading coefficient, SC*, is defined using Equation (1):

$$\mathrm{SC}^* = \frac{\sum_{\mathrm{i}}(\mathrm{SC_i.BV_i.Fma_i})}{\sum_{\mathrm{i}}(\mathrm{BV_i})} \tag{1}$$

With:

- SC_i: Solar thermal coefficient (SC) of glazing « i » of heated and/or cooled spaces.
- BV_i: Area of glazing « i » of heated and/or cooled spaces.
- Fma_i: Architectural mask coefficient of glazing « i » of heated and/or cooled spaces defined in table AI.2.
- $\sum_i$: Summation of values associated with all the glazing types of the building except for those oriented north (+/- 30°) with the condition that the solar coefficient (SC) of glazing oriented north (+/- 30°) must be lower or equal to the highest SC_i value.

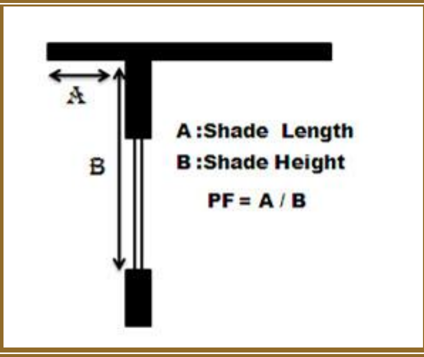
The WWR specifications depending on the WWR values for various windows located in different building facades. Table AI.3 defined the WWR ratings of “Low”, “Medium”, “High”, and “Very High”.

Table AI.1 Maximum requirements of U-values of Shading Coefficient for residential buildings

	WWR Rating	*U for exposed roof (W/m².K)*	*U for exterior walls (W/m².K)*	*U for Window glazing (W/m².K)*	*SC for Window glazing*
Climatic Zone ZT1	Low	≤ 0.75	≤ 1.10	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.10	≤ 6.2	≤ 0.7
		≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.85
	High	≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.75
	Very High	≤ 0.65	≤ 0.8	≤ 3.2	≤ 0.7
Climatic Zone ZT2	Low	≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.95
		≤ 0.75	≤ 0.8	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.7
	High	≤ 0.75	≤ 0.7	≤ 3.2	≤ 0.7
	Very High	≤ 0.65	≤ 0.7	≤ 1.9	≤ 0.6
Climatic Zone ZT3	Low	≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.85
		≤ 0.75	≤ 0.8	≤ 6.2	≤ 0.8
	Medium	≤ 0.75	≤ 1.10	≤ 3.2	≤ 0.6
	High	≤ 0.65	≤ 0.7	≤ 3.2	≤ 0.6
	Very High	Prescriptive approach is not applied in this configuration			

Source: OJRT, 2008.

Table AI.2 Values of architectural mask coefficient, Fma, for windows shades

<table>
<tr><th colspan="2">Type of window shade</th><th>Fma</th></tr>
<tr><td colspan="2">No shading</td><td>1.0</td></tr>
<tr><td rowspan="3">
</td><td>A shading feature with south orientation (+/- 45º) with FP parameter defined in Figure 6 such that 0.15<FP≤0.25</td><td>0.85</td></tr>
<tr><td>A shading feature with south orientation (+/- 45º) with FP parameter defined in Figure 6 such that 0.25<FP≤0.35</td><td>0.75</td></tr>
<tr><td>A shading feature with south orientation (+/- 45º) with FP parameter defined in Figure 6 such that FP>0.35</td><td>0.70</td></tr>
<tr><td colspan="2">A shading feature with any other than south orientation (+/- 45º)</td><td>1.0</td></tr>
</table>

Source: OJRT, 2008.

Table AI.3 Definition of WWR rating for Windows

X-1 = ∑ WWR-all-orientations (Conditioned)	
X-2=WWR-East + WWR-West (Conditioned)	
WWR Rating	**Range for X1 and X2**
Low	X1=<15% AND X2=<10%
Medium	15%<X1=<25% AND 10%<X2=<15%
High	25%<X1=<35% AND 15%<X2=<25%
Very high	35%<X1=<45% AND 25%<X2=<35%

Source: OJRT, 2008.

Office buildings: For the Tunisian BEEC, office buildings are divided into two categories: (i) public buildings owned and operated by the central government, local communities, or public institutions, and (ii) private buildings owned by non-governmental institutions including private companies.

The prescriptive approach is applicable only for buildings whose covered area is higher than 1500 m². Moreover, the prescriptive approach is not applicable in the following conditions:

- For public office buildings: if the overall window to wall ratio or WWR values is higher than 35% and/or WWR for conditioned areas oriented east (+/-45°) and west (+/- 45°) is higher than ± 25%;
- For private office offices: if the overall window to wall ratio or WWR value is higher than 45% and/or WWR for conditioned areas oriented east (+/-45°) and west (+/- 45°) is higher than ± 35%.

Tables AI.4 and AI.5 provide the maximal requirements for U-values associated to roofs, exterior walls, windows glazing as well as and SC values associated with windows glazing for respectively, public and private office buildings in various climatic zones. The definitions for WWR ratings, U-values, and SC values for office buildings are the same as those provided for residential buildings.

Table AI.4 Maximum requirements of U-values of Shading Coefficient for public office buildings

	WWR rating	*U for exposed roof (W/m².K)*	*U for exterior walls (W/m².K)*	*U for window glazing (W/m².K)*	*SC for window glazing*
Climatic Zone ZT1	Low	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.1	≤ 3.2	≤ 0.6
	High	≤ 0.75	≤ 1.1	≤ 1.9	≤ 0.5
Climatic Zone ZT2	Low	≤ 0.55	≤ 0.6	≤ 3.2	≤ 0.8
	Medium	≤ 0.55	≤ 1.10	≤ 1.9	≤ 0.5
	High	Prescriptive approach is not applied in this configuration			
Climatic Zone ZT3	Low	≤ 0.55	≤ 1.10	≤ 3.2	≤ 0.6
	Medium	≤ 0.55	≤ 0.8	≤ 1.9	≤ 0.5
	High	Prescriptive approach is not applied in this configuration			

Source: OJRT, 2008.

Table AI.5 Maximum requirements of U-values of Shading Coefficient for private office buildings

	WWR rating	*U for exposed roof (W/m².K)*	*U for exterior walls (W/m².K)*	*U for window glazing (W/m².K)*	*SC for window glazing*
Climatic Zone ZT1	Low	≤ 0.75	≤ 1.2	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.7
	High	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.6
		≤ 0.75	≤ 0.8	≤ 6.2	≤ 0.7
	Very High	≤ 0.75	≤ 1.1	≤ 3.2	≤ 0.6
Climatic Zone ZT2	Low	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.7
	High	≤ 0.75	≤ 1.1	≤ 1.9	≤ 0.6
		≤ 0.75	≤ 0.8	≤ 3.2	≤ 0.6
	Very High	≤ 0.65	≤ 0.8	≤ 1.9	≤ 0.5
Climatic Zone ZT3	Low	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.95
	Medium	≤ 0.75	≤ 1.1	≤ 6.2	≤ 0.6
	High	≤ 0.75	≤ 1.1	≤ 1.9	≤ 0.5
		≤ 0.55	≤ 0.8	≤ 3.2	≤ 0.6
	Very High	≤ 0.75	≤ 0.6	≤ 1.9	≤ 0.5
		≤ 0.55	≤ 0.8	≤ 1.9	≤ 0.5

Source: OJRT, 2008.

Hotels and hospitals: There is no prescriptive compliance approach for hospitals in the current version of the Tunisian BEEC. Only a performance compliance approach is available for lodging part of hotels (i.e., patient rooms) and for the lodging part of hotels.

PERFORMANCE APPROACH

The performance approach defines the threshold limit values for the overall thermal performance of the building. These threshold limit values are defined using overall annual thermal heating and cooling loads required to maintain desired level of thermal comfort within the conditioned building spaces. These heating and cooling thermal loads are determined using whole-building thermal analysis calculation method or tool based on predefined building occupancy level, internal gains, and operation schedules typical for the Tunisian context and building space type.

The overall annual thermal heating and cooling load (BECTh) for a given building is determined by adding both heating and cooling loads and dividing the sum by the total building conditioned floor area. Thus, BECTh can be estimated using the following equation:

$$\mathrm{BECTh} = \frac{\mathrm{BECh+BERef}}{\mathrm{STC}} \tag{2}$$

Where:

- *BECTh*: overall annual thermal heating and cooling load expressed in kWh/m² year;
- *BECh*: annual thermal heating load expressed in kWh/year and calculated for the winter season with an interior temperature setting of T_{ch} = 20°C;
- *BERef*: annual thermal cooling load for expressed in kWh/year and calculated during summer season with an interior temperature setting of T_{ref} = 26°C;
- *STC*: total building conditioned floor area expressed in m² and represents the total floor area of conditioned spaces within the building.

In the Tunisian BEEC, the heating season is extended from 15 November to 31 March while the cooling season is extended from 1 June to 30 September.

Residential buildings: As noted earlier, the prescriptive approach cannot be applied to multi-residential buildings composed of ground floor and four or more levels (i.e, five or more story-buildings). It is also not applicable when the overall window to wall ratio or WWR value is higher than 45% and/or when the WWR value for conditioned areas oriented east (+/-45°) and west (+/- 45°) is higher than ± 35%. Under these conditions, only the performance compliance approach should be utilized. Moreover, the Tunisian BEEC allows the use of performance compliance under almost any conditions for both detached homes, and apartment buildings.

The thermal performance for a residential building is rated according to eight (8) different classes depending on the building overall annual thermal heating and cooling load (BECTh) value as defined in table AI.6.

Table AI.6 Thermal Performance Classes for Residential Buildings

Building Thermal performance Class	*BECTh vlaue (kWh/m².year)*
Class 1	$BECTh \leq 36$
Class 2	$36 < BECTh \leq 41$
Class 3	$41 < BECTh \leq 46$
Class 4	$46 < BECTh \leq 51$
Class 5	$51 < BECTh \leq 60$
Class 6	$60 < BECTh \leq 72$
Class 7	$72 < BECTh \leq 87$
Class 8	$BECTh > 87$

Source: OJRT, 2008.

A residential building is said to comply only if its thermal performance class is at least class-5, that is, if its BECTh value is equal to or below 60 kWh/m^2 peryear.

Office buildings: For the Tunisian BEEC, the performance compliance approach can be applied to any office building whose floor area is at least 500 m². As noted for the prescriptive approach, two categories of office buildings are defined in the BEEC including public and private buildings.

The thermal performance for an office building is rated according to eight (8) different classes depending on the building overall annual thermal heating and cooling load (BECTh) value as defined in table AI.7.

Table AI.7 Thermal performance classes for office buildings

Building thermal performance class	*BECTh value (kWh/m².year)*
Class 1	$BECTh \leq 75$
Class 2	$75 < BECTh \leq 85$
Class 3	$85 < BECTh \leq 95$
Class 4	$95 < BECTh \leq 105$
Class 5	$105 < BECTh \leq 125$
Class 6	$125 < BECTh \leq 150$
Class 7	$150 < BECTh \leq 180$
Class 8	$BECTh > 180$

Source: OJRT, 2008.

An office building complies with the performance approach defined by the Tunisian BEEC when:

- For a public building: its thermal performance class is at least class-3, that is, if its BECTh value is equal to or below 95 kWh/m^2 per year;
- For a private building: its thermal performance class is at least class-5, that is, if its BECTh value is equal to or below 125 kWh/m^2 per year.

Hotels:[7] The performance compliance approach for hotels depends on the hotel category and its star rating. The current version of the Tunisian BEEC considers only the lodging spaces (i.e., guest rooms) and the office spaces of the hotels. For the other spaces, no BEEC compliance is needed. For the office spaces, the

[7] The Tunisian BEEC requirements for hotels have not been officially implemented yet (as of September 2018) and are included in the present report to provide an idea about the adopted approach in the development of these BEEC requirements.

performance compliance criteria are discussed above and are summarized in table AI.10. For the lodging spaces, the thermal performance for the hotel is rated according to eight (8) different classes depending on the building overall annual thermal heating and cooling load (BECTh) value as defined in table AI.8.

Table AI.8 Thermal performance classes for lodging spaces of hotels

Building thermal performance class	*BECTh value (kWh/m².year)*
Class-1	$BECTh \leq 90$
Class-2	$90 < BECTh \leq 100$
Class-3	$100 < BECTh \leq 110$
Class-4	$110 < BECTh \leq 120$
Class-5	$120 < BECTh \leq 135$
Class-6	$135 < BECTh \leq 160$
Class-7	$160 < BECTh \leq 190$
Class-8	$BECTh > 190$

Source: ANME, 2011.

The lodging space of a hotel complies with the performance approach defined by the Tunisian BEEC when:

- For a 5-Star hotel: its thermal performance class is at least class-3, that is, if its BECTh value is equal to or below 110 kWh/m^2 per year;
- For a 4-Star hotel: its thermal performance class is at least class-4, that is, if its BECTh value is equal to or below 120 kWh/m^2 per year;
- For a 3-Star hotel: its thermal performance class is at least class-5, that is, if its BECTh value is equal to or below 135 kWh/m^2 per year.

Hospitals:[8] Similar to the hotels, the current version of the Tunisian BEEC considers only the lodging spaces (i.e., patient rooms) and the office spaces of the hospitals. For the other spaces, no BEEC compliance is needed. For the office spaces, the performance compliance criteria are discussed above and are summarized in table AI.7. For the lodging spaces, the thermal performance for the hospital is rated according to eight (8) different classes depending on the building overall annual thermal heating and cooling load (BECTh) value as defined in table AI.9. Two types of hospitals are considered by the code in Tunisia: private or public hospitals or clinics.

[8] The Tunisian BEEC requirements for hospitals have not been officially implemented yet (as of September 2018) and are included in the present report to provide an idea about the adopted approach in the development of these BEEC requirements.

Table AI.9 Thermal performance classes for lodging spaces of hospitals

Building thermal performance class	*BECTh value (kWh/m².year)*
Class-1	$BECTh \leq 135$
Class-2	$135< BECTh \leq 145$
Class-3	$145< BECTh \leq 155$
Class-4	$155< BECTh \leq 165$
Class-5	$165< BECTh \leq 180$
Class-6	$180< BECTh \leq 200$
Class-7	$200< BECTh \leq 230$
Class-8	$BECTh >230$

Source: ANME, 2011.

The lodging space of a hospital complies with the performance approach defined by the Tunisian BEEC when:

- For a public hospital: its thermal performance class is at least class-3, that is, if its BECTh value is equal to or below 155 kWh/m^2 per year;
- For a private hospital: its thermal performance class is at least class-5, that is, if its BECTh value is equal to or below 180 kWh/m^2 per year.

ANNEX II
ENERGY PERFORMANCE LABELLING, MEPS AND BUILDING ENERGY CODES FOR SAUDI ARABIA

Saudi Arabia has introduced energy efficiency regulations and mandatory labelling for refrigerators and freezers, washing machines, and air conditioners since 2007 and have been regularly updated. Table AII.1 illustrates the minimum energy performance standards for refrigerators, freezers, and air conditioners set by the Saudi Arabia Standard Organization (SASO, 2012 and 2013). Specifically, Table AII.1 provides energy performance thresholds for various star-rating levels expressed in energy efficiency ratio (EER) for air conditioners, electrical energy consumption per load for washing machines, and percent reduction relative to baseline energy use for refrigerators and freezers. Currently, regulations are being prepared by Saudi Energy Efficiency Program (SEEP) to focus on the phase out of the least efficient light sources in residential and commercial buildings (Krarti and others, 2017). It should be noted that major revisions to the scheme of the energy labelling standards and MEPS took place in 2018,[9] changing the rating system from a “star” scale type of rating scheme to an “alphabetical” scale type of rating scheme similar to the European Union Energy Labelling system (SEEC, 2018). The validity of the old labelling system should end by October 2018, and the implementation of the new system is scheduled to start in July 2017 and be completed by September 2019.

Moreover, and since 2014, the Saudi government has started to require mandatory installation of thermal insulation for walls and roofs for all new buildings as one condition to have electrical service connection with the Saudi Electricity Company (Saudi Royal Decree No. 6927/MB). [10] Table AII.2 summarizes the requirements for thermal performance properties of Saudi building envelope components depending on climate zones.

Table AII.1 Labels for minimum energy performance standards for refrigerators, freezers, air conditioners and washing machines

Star rating	Air conditioners (EER=3.412 COP expressed in Btu/Wh)	Refrigerators/freezers (percentage of energy consumption relative to a baseline)	Washing machines (function of energy use per load capacity)
1	< 7.5	5%	< 2.0
2	7.5-8.5	10%	2.0-2.9
3	8.5-9.0	15%	3.0-3.9
4	9.0-9.5	20%	4.0-4.9
5	9.5-10.0	25%	5.0-5.9
6	10.0-11.5	30%	>6.0
7	11.5-12.4		
7.5	12.4-13.4		
8.0	13.4-14.5		
8.5	14.5-15.6		
9.0	15.6-16.8		
9.5	16.8-18.1		
10	< 18.1		

Source: SASO, 2012, 2013, 2014.

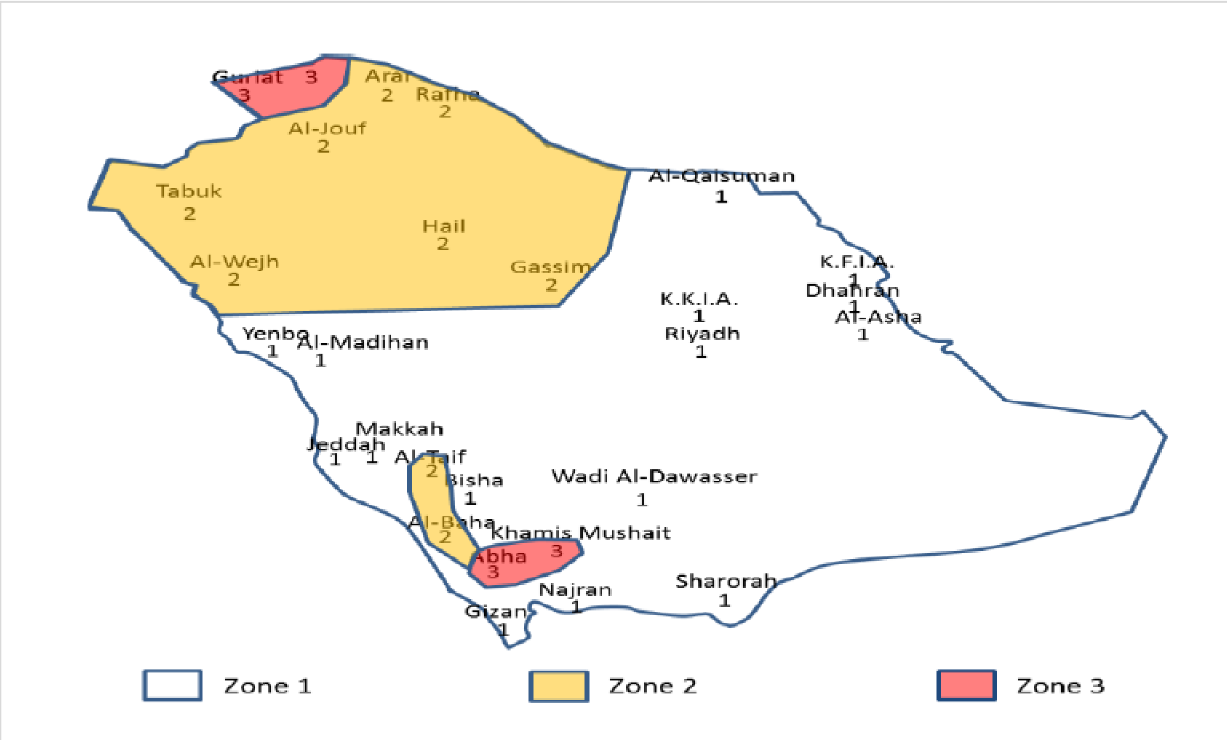
Note: SASO has updated the energy performance standards for washing machines (conforming to star rating 4 and above only), refrigerators (conforming to star rating 1 and above only), and air-conditioners (conforming to star rating 3 and above can only be sold and manufactured).

[9] Air conditioning equipment (SASO 2663:2018), refrigerators and freezers: (SASO 2892:2018), washing machines: (SASO 2885:2018), clothes dryers: (SASO 2883:2017), water heaters: (SASO 2884:2017).

[10] https://www.se.com.sa/en-us/Pages/ThermalInsulationinBuildings.aspx.

Table AII.2 Thermal performance requirements for Saudi building envelopes depending on climatic zones

Properties of Building Envelope	Saudi Arabia Climatic Zone		
	Zone-1	Zone-2	Zone-3
U-value (W/m².K)			
Walls	0.34	0.4	0.45
Roof	0.2	0.24	0.27
Windows	2.67	2.67	2.67
Doors	2.84	2.84	2.84
SHGC (fraction) Glazing	0.25	0.25	0.25



Source: Based on SASO 2856/2014.
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