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Electricity Sector Infrastructure and Energy Exchange in Arab Countries

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UNITED NATIONS
Beirut

Introduction

The electricity sector plays a key role in providing modern energy services to individuals and national economic activities. This sector's infrastructure, including power stations and transmission and distribution networks, is considered a measure to assess efficiency and capacity for meeting economic and social development needs, and a fundamental element in promoting the business environment and creating employment opportunities. Firstly, it is necessary to consider the general concept of infrastructure.

There are several general definitions of infrastructure, including the following:

- The basic structures and systems needed for a country or an organization to function properly, for example buildings, transport systems and power supplies.[1]
- A network of independent, mostly privately-owned, man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services.[2]
- A set of interconnected structural elements providing a support framework for full development infrastructure, considered a key factor for evaluating development in a country or region.[3]

Infrastructure development reduces power generation costs, increases a country's GDP growth rate, and positively impacts living standards. Investment in electricity-sector infrastructure in the majority of Arab countries does not keep pace with increasing demand for electricity at a rate of 5-6 per cent annually during the current decade.[4] Various factors are responsible, including sharp changes in global energy markets and their effects on growth rates in both Arab electricity producing and importing countries; political instability and conflict in some Arab countries, and the heightened investment risk in this field because of insufficient risk-sharing tools and measures and private sector guarantees.

The present report considers the status of electricity sector infrastructure in the Arab region, in terms of sources, technologies, and the efficiency of transmission and distribution networks, including producing/importing fossil fuels; refining, producing, and transporting petroleum products to a thermal power plants; generating hydropower; developing renewable energy technologies such as wind farms, solar thermal plants and photovoltaic systems; and considering projects for nuclear power plants adopted by a few Arab countries. The report also highlights the current status of energy interconnection and exchanges at the regional level, and plans to improve the sector's efficiency under a regional system to enhance common gains.

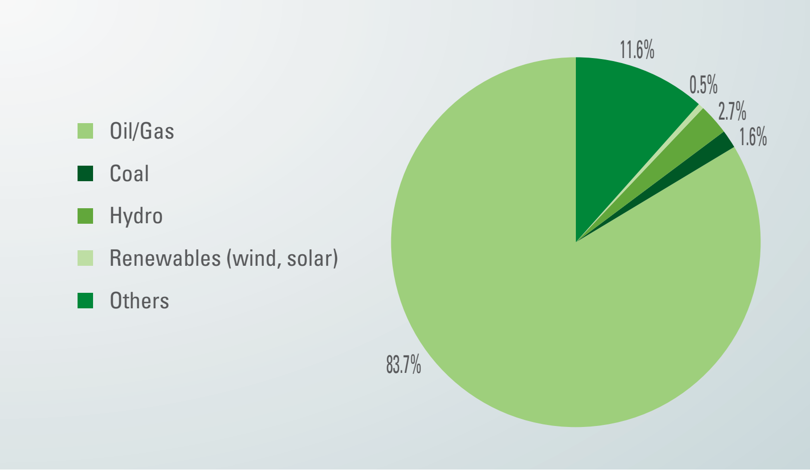
Electricity sources and technologies in the Arab region

Primary energy sources (domestic or imported) and national electricity infrastructure form the basis of a country's power supply for implementing development plans.

1. Electricity sources

Arab countries, except the Sudan that depends on the Nile River as

Figure 1. Contribution rate of sources in electricity production*



Source: Based on data from www.auptde.org/Article_Files/inside%202016.pdf, p.6.
Note: 'Others' cover heat and power co-generation, and landfills.

a source of energy, rely on oil and natural gas as their main source of electricity (around 84 per cent), followed by hydro sources and renewable energy, mainly wind and solar energies. Only Morocco currently uses coal to power thermal plants, but Egypt, Lebanon and Oman are moving to import coal for use in some energy-intensive industries; Egypt is also undertaking electricity planning (figure 1).

(a) Fossil fuels

Fossil fuels (oil, natural gas) are available in many Arab countries to varying extents. Morocco is rich in coal, which to some extent contributes to the national energy mix along with other sources. Table 1 sets out oil and gas production levels and proven reserves, and contributions to the electricity sector in Arab countries (natural gas, light fuel, heavy fuel, coal) as at the end of 2015.

Table 1. Production and proven reserves of oil[5] and gas,[6] and contribution to the electricity sector[7] as at end 2015

Country	Proven oil reserves (million tons)	Production from crude oil and liquid gas (million tons/year)	Proven natural gas reserves (trillion cubic metres)	Production from natural gas (million tons of oil equivalent)	Fuel used in electricity sector (million tons of oil equivalent)
Jordan	Fair	Fair	Unavailable	Unavailable	3.9
United Arab Emirates	13,300	186	6.1	50.2	30.11
Bahrain	13.6	10.5	0.2	14	6.27
Tunisia	54.4	2.6			4.04
Algeria	1,659	83	4.5	74.7	15.68
Saudi Arabia	36,244	565	8.3	95.8	54.21
Sudan	204	6	85		1.23

Country	Proven oil reserves (million tons)	Production from crude oil and liquid gas (million tons/year)	Proven natural gas reserves (trillion cubic metres)	Production from natural gas (million tons of oil equivalent)	Fuel used in electricity sector (million tons of oil equivalent)
Syrian Arab Republic	340	0.5	0.3	3.9	4.76
Iraq	19,461	175	3.7	0.9	17.15
Oman	721.6	48.8	0.7	31.4	7.48
Palestine					0.08
Qatar	7,140	85.5	24.5	163.3	10.50
Kuwait	13,804	150	1.8	13.5	17.38
Lebanon					2.05
Libya	6,732	22.6	1.5	11.5	9.75
Egypt	476	37.8	1.8	41	34.115
Morocco	Fair	Fair	Unavailable	Unavailable	4.975 (including coal)
Mauritania	Fair	Fair	Unavailable	Unavailable	Unavailable
Yemen	408	1.4	0.3	2.4	Unavailable

2. Thermal plant technologies in Arab countries

Electricity production from thermal plants in most Arab countries relies on steam, gas or combined cycle, diesel engines or coal as fuel. Table 2 sets out the most common plants in the region, representing 84.4 per cent of installed capacity.

(a) Efficiency of thermal plants in the region

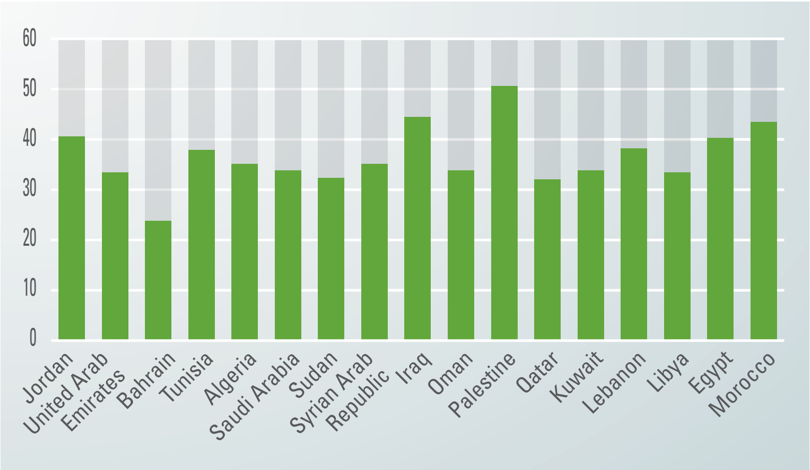
In general, the efficiency of thermal plants in the region is low, with an average of around 36 per cent in 2015 (figure 2).

Table 2. Types of thermal plants in the Arab region

Steam	Gas	Combined cycle
Uses heavy fuel, natural gas or coal (in the case of Morocco) to produce superheated steam (dry steam) under high pressure, needed to drive the motor connected to the electricity generator; diesel fuel can be used as an ignitor.	Relies on the combustion of natural gas, fuel oil or heavy fuel, requiring the presence of atmospheric air in the combustion chamber and the use of an exhaust in driving the motor connected to the electricity generator. Suitable for emergencies and peak times.	Uses gas turbines to produce electricity, benefiting from the exhaust to heat water into superheated steam to drive the gas turbines connected to the generator. Natural gas, fuel oil or heavy fuel is used as the basic fuel.
Constitutes 26.7 per cent of total installed capacity.	Constitutes 32.2 per cent of total installed capacity.	Constitutes 25.5 per cent of total installed capacity.
Efficiency is around 42 per cent in a new plant.	Efficiency is around 37 per cent in a new plant.	Efficiency is around 60 per cent in a new plant.

Source: Based on data from Arab Union of Electricity, 2015 Statistical Bulletin, No. 24.

Figure 2. Average efficiency of thermal plants (%) in Arab countries



Source: Efficiency levels were calculated based on the amounts of fuel used and energy produced in thermal plants, contained in Arab Union of Electricity's 2015 Statistical Bulletin, No. 24, pp. 6 and 14. Mauritania and Yemen are not covered owing to insufficient data.

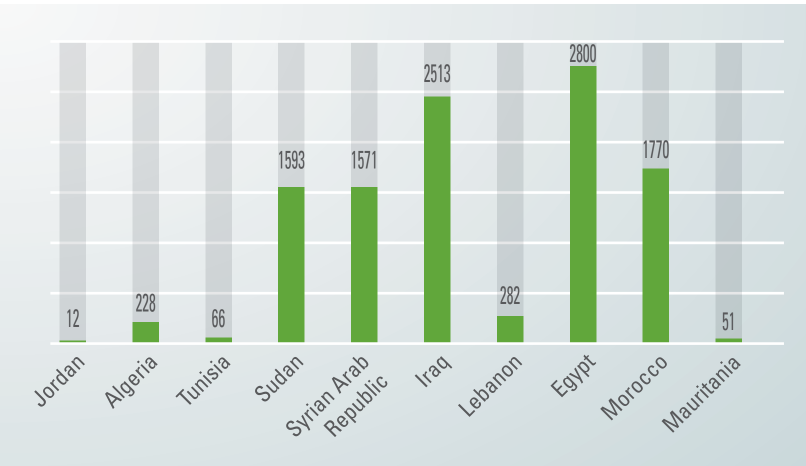
Efficiency rates increase to 40 per cent or more in some countries for various reasons, including programmes to improve energy efficiency and expand the use of combined-cycle technology, as in Egypt and Jordan (representing 33 per cent and 48 per cent, respectively, of total installed capacity); or the introduction of new plants, as in Iraq. In Palestine, there is only one combined cycle thermal plant, with an efficiency rate of over 55 per cent.

(b) Renewable energy

Surface water sources

- They contribute no more than 3 per cent to the electricity energy mix in the Arab region. They are concentrated in the Sudan (main source in the energy mix), Egypt, Iraq, the Syrian Arab Republic, Lebanon, Morocco, Algeria and Tunisia.
- The total installed capacity for hydroelectric power plants reached around 11,000 megawatts as at the end of 2015, equivalent to approximately 4 per cent of total Arab installed capacity (figure 3).[8]

Figure 3. Installed capacity (megawatts) of hydroelectric power stations



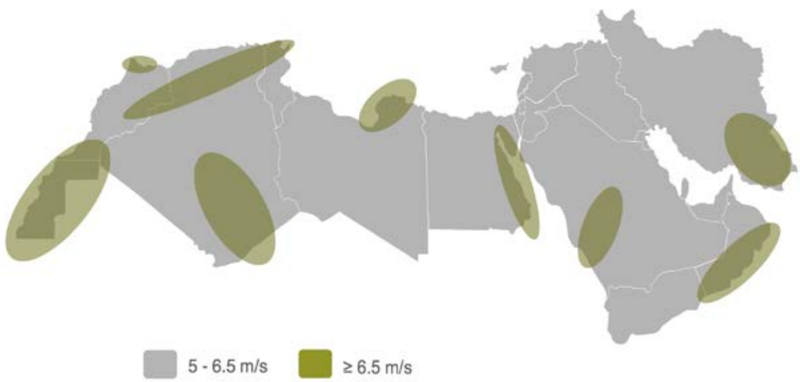
Wind energy

Wind energy can be harnessed at wind speeds of 3-5 metres/second, taking into account that power (latent energy from wind) is proportional to the cube of wind speed (instantaneously) X the rotation swept area of the blade on the metal tower (3.14 X the square of the radius of the blade rotation) X air density X power coeeficient (0.5).

The economic feasibility of establishing wind farms depends on:

The topographic features of the project's location, wind speed structure in terms of distribution and direction, and year-round average. There is great potential for wind power in many Arab countries (figure 4).

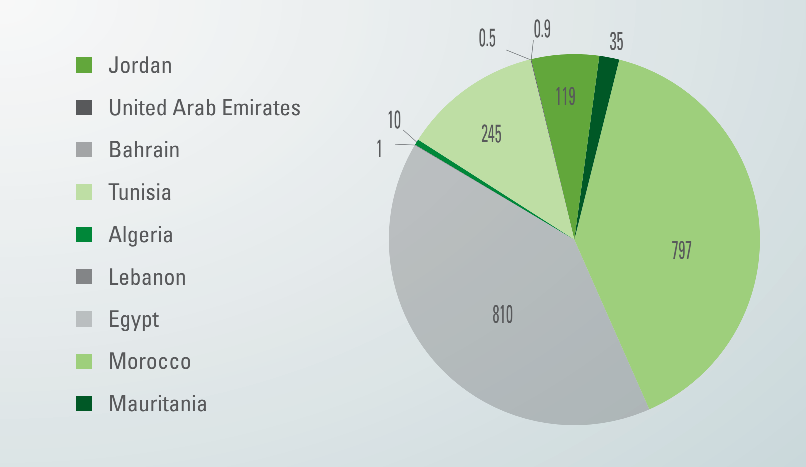
Figure 4. Key locations in the Arab region with wind speeds over 6.5 metres/second, measured at an altitude of 80 metres[9]



The most common turbine in the Arab region has three blades, rotates on a steel tower set above a concrete ground base, with a capacity of 1-3 megawatts/unit.

The total capacity of wind farms in the Arab region reached around 2,000 megawatts at the end of 2015 (figure 5).[10]

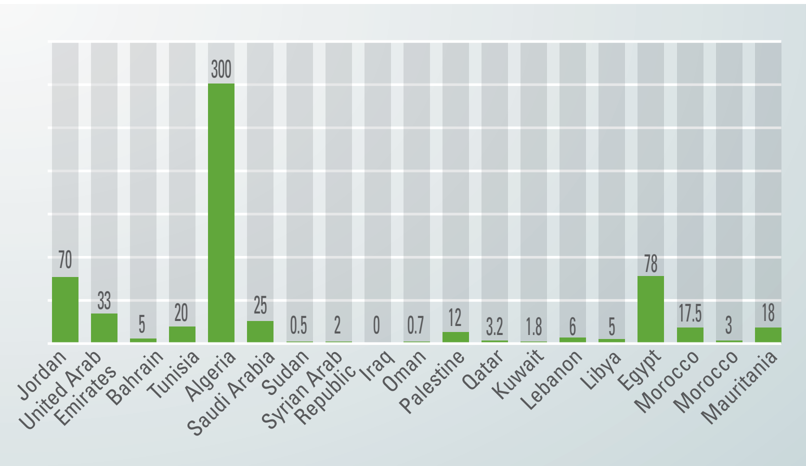
Figure 5. Installed capacity (megawatts) of wind farms in Arab countries



Solar power

The Arab region falls within the Sunbelt. Solar photovoltaics systems are the most common (both distributed systems and grid-connected). The total installed capacity from these systems in the Arab region for electricity production, water desalination/pumping, and wireless connection, among others, is around 600 megawatts.

Figure 6. Installed capacity of photovoltaics systems (megawatts) as at the end of 2015

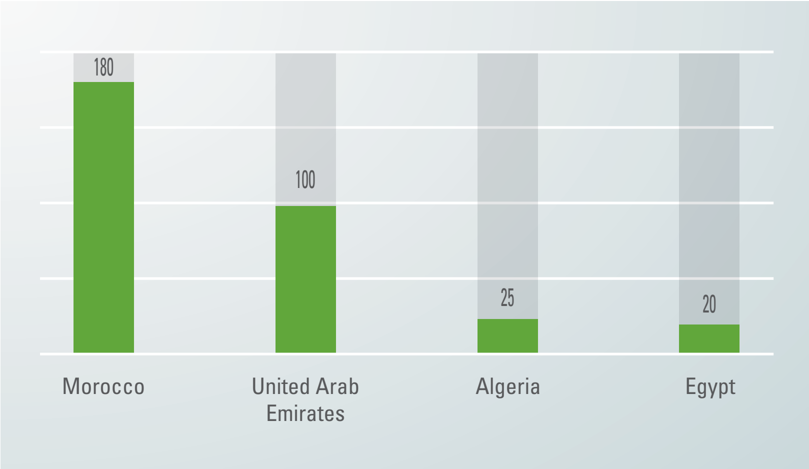


Algeria[11] occupies the top position in this field, with a total capacity of around 300 megawatt. Figure 6 shows the installed capacity of photovoltaics systems in Arab countries as at the end of 2015.[12]

Solar thermal power plants, reliant on parabolic trough technology and connected to national grids, are concentrated in Morocco, the United Arab Emirates, Algeria and Egypt, with a total capacity of 325 megawatts as at the end of 2015 (figure 7).[13]

Jordan and Qatar are working on implementing similar projects.

Figure 7. Installed capacity of solar thermal power plants as at the end of 2015



3. Nuclear power[14]

Reserves of uranium ore, as a source of nuclear power, exist in Jordan (around 65,000 tons), Algeria (around 29,000 tons), and Egypt in small amounts. Large amounts of phosphate rock, containing uranium, are present in Egypt, Jordan, Morocco and Saudi Arabia. Table 3 highlights the shift of some Arab countries towards the nuclear option for electricity production, taking into account the energy mix.

Table 3. Status of large nuclear projects for electricity production and water desalination in selected Arab countries

Country	Plan	Current status
Jordan	Establishing a nuclear power plant with a 2,000 megawatt capacity, in two phases	The project's location has been identified, and a memorandum of understanding was signed with a Russian company on 28 January 2013 to build the first reactor. The project is build-own-operate, as is expected to begin between 2023 and 2025.
Algeria	Establishing a plant with a 1,000 megawatt capacity between 2030 and 2040	There are two research reactors. Preparing technical reports on establishing the first nuclear reactor using government funds. Signing an agreement with Russia on 3 September 2014 on the peaceful uses of nuclear power and building a nuclear power plant. The location has not yet been identified.
United Arab Emirates	Installed capacity of 5,600 over four stages.	Establishing a nuclear power body and issuing related legislation in 2009. Singing a contract with South Korean power companies to establish the first reactor (around 1,400 megawatts) in Barakah, for operation in 2017.
Saudi Arabia	A nuclear power plant with a combined capacity of 18 gigawatt until 2032.	Establishing a nuclear holding company in 2013. Signing memorandums of understanding to cooperate with China, France, Russia and South Korea. Comparing between three potential locations.
Egypt	4,800 megawatts, in several stages, over the period 2022-2026.	There are two research reactors. Selecting El Dabaa in northern Egypt as a location, developing technical specifications, preparing bidding documentation, and signing a memorandum of understanding with Russia in February 2015. Signing building contracts with Russia in 2017. The first reactor (1,200 megawatts) is expected to become operational in 2022.

It should be noted that:

- The Arab region is poor in uranium, with deposits in Jordan, Algeria and Egypt representing around 0.5 per cent, 0.3 per cent and 0.1 per cent, respectively, of global uranium stocks.[15] Arab countries developing shifting towards nuclear power will be obliged to secure uranium supplies from outside the region.
- The first phase of the nuclear project in the United Arab Emirates will be the first in the Arab region in terms of commercial operation (2017).
- The Egyptian project will be the second to become operational in the region in the next decade, in line with current steps to secure funding, prepare infrastructure at the selected location, launch the bidding globally, examine offers and selecting the most appropriate, and conducting negotiations before signing construction contracts.
- Four countries in table three have signed memorandums of understanding/agreements in this field with Russia in particular; the related operational procedures remain unclear.

Electricity transmission lines

The electricity transmission system is the backbone of the electricity grid linking production and distribution, using overhead lines and underground cables to transmit electricity from power plants via transformer substations to consumption destinations so as to provide the power supply necessary macroeconomic growth. Electricity is transmitted using lines: very high voltage (over 230 kilovolts), high voltage (35-230 kilovolts), medium voltage (1-35 kilovolts) and low voltage (1 kilovolt), in accordance with global classifications.[16] The cables can be underground (residential), overhead (non-residential) or submarine for regional connections).

Overhead lines are hung on metal towers (or wooden towers in rural areas), insulators, conductors and their components. The overhead lines are low cost, easy to locate and fix faults quickly and low maintenance costs, but with significant power loss during transmission. Underground cables are expensive to install and maintain, and faults are hard to locate and fix, but they result in less power losses.

In Arab countries, government-owned companies have established alternative current transmission cables, with voltages between 500 kilovolts in Egypt, Saudi Arabia and the Sudan and 400 kilovolts in other countries, with widespread use of 220 kilovolts and below. Saudi Arabia has the longest transmission grid at 69,500 circuit kilometres, followed by Egypt at 23,100 circuit kilometres; Lebanon is at the bottom of the list with 1,100 circuit kilometres.[17] In the Arab region, the infrastructure in this field generally lacks inefficient, with 19 per cent power loss in transmission and distribution compared with a global average of 8 per cent.[18]

Power loss on the transmission grid; difficulty in locating the leak or quickly fixing faults; the absence of forecasting and precaution programmes and of modern devices, especially those connected to low voltage grids; the inability to monitor power quality; and the absence of a transmission system operator are among the reasons for the low efficiency of transmission systems in many Arab countries.

Distribution networks[19]

Electricity is transmitted via grids to all consumers. In 2015, at the sectoral level, households in the Arab region consumed the most electricity at an average rate of 43 per cent, followed by industry at 20 per cent, trade at 17 per cent, and all other sectors combined (agriculture, tourism, transport, services, public buildings, etc.) at 20 per cent.

Over 98 per cent of the population in most Arab countries are connected to the grid, except Mauritania and the Sudan at 34 per cent and Yemen at 52 per cent, taking into account the impact of current conflicts in some Arab countries on the electricity supply. Significant disparities exist in per capita electricity shares in Arab countries for various reasons. For example, Gulf countries provide quality basic services to their populations and high levels of human development compared with other Arab countries, despite a desert environment with harsh weather conditions that increase consumption costs. Per capita electricity share reaches a maximum of 16,056 kilowatt-hours in Kuwait and a minimum of 6,935 in Oman. In countries with natural resources for producing electricity that are insufficient for meeting national needs, such as Tunisia, Egypt and Morocco, per capita share is 1,633 kilowatt-hours, 2,003 kilowatt-hours and 873 kilowatt-hours, respectively. Jordan and Lebanon rely mainly on imports to meet their power needs, with per capita shares of 2,728 kilowatt-hours and 2,395 kilowatt-hours, respectively. Individuals in the Sudan and Yemen receive the lowest share of electricity in the Arab region (339 kilowatt-hours and 273 kilowatt-hours, respectively). Palestine is a special case, with per capita shares of 1,142 kilowatt-hours provided by Israeli networks mainly, a thermal plant in Gaza with a 140-megawatt capacity, imports of around 30 megawatts from Egypt, and limited photovoltaic systems.

The average efficiency of distribution grids, especially low voltage ones, is low in many Arab countries for many reasons, some of which are technical such as old networks; low power factor in systems; transformer inefficiency; multiple faults; losses and inability to accurately locate leaks; neglected maintenance and precaution programmes; and insufficient capacity to forecast faults or overloads, especially at peak times. Other problems are linked to the bad practices of some individuals, such as electricity theft.

Other challenges include: widespread inefficient consumption patterns per capita in many countries; non-use of smart meters that are accurate, record consumption curves, allow for longer periods of remote reading, transfer information from the grid to consumers and vice versa, monitor leaks on distribution grids, and manage demand to avoid over consumption during peak periods.

Electricity transmission and distribution grids must be technically efficient and economical, by reducing losses during transmission; establishing a high-performance control centre; adapting grids to increase the contribution of renewable energy in the national energy mix. Integrating wind farms and solar plants into the grid requires developing a renewable energy grid code due to their intermittent nature, besides using digital technology and monitoring systems, among others, to collect information from electricity generation, transmission and consumption points (energy consumption patterns, technical information on grid performance, etc.), and amending grid performance accordingly. Adopting this approach to managing grids is known as smart grids.

Electrical interconnection and energy exchange between Arab countries

Arab electrical interconnection projects are being implemented since the 1990s in three geographical areas, as follows:

Eight-interconnection: between Egypt, Iraq, Jordan, Lebanon, Libya, Palestine, the Syrian Arab Republic and Turkey.

Maghreb interconnection: between Algeria, Libya, Morocco and Tunisia. The Moroccan and Spanish networks are linked. The link between the Libyan and Tunisian networks is not operational because of technical difficulties.

Gulf interconnection: between Gulf Cooperation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates).

Energy exchange exists between countries, but is limited (table 4).

Table 4 shows weak energy exchange between Arab countries, whereas the net exchange average is around 2 per cent of total energy produced in 2015.

Current interconnection projects include implementing an Egypt-Saudi Arabia line (500 kilovolts) to exchange loads of around 3,000 megawatts, for trial operation in 2018. This will result in the Gulf-Eight interconnection. There are also plans for implementing an Egypt-Sudan interconnection.

The remaining interconnection projects have been discontinued (Iraq, Libya, Yemen), because on the current political unrest and conflict, as well as the slow implementation of plans in some oil-exporting countries in view of the sharp drop in oil prices resulting in decreased national income.

Table 4. Current electricity exchange[20] between Arab countries via regional grid interconnections[21]

Country	Existing interconnection	Exported energy (gigawatt hours)	Imported energy (gigawatt hours)	Net % of total energy exchange
Jordan	Egypt: 400 kilovolts Syrian Arab Republic: 230, 400 kilovolts (eight link)	50	604	2.9
United Arab Emirates	Saudi Arabia: 400 kilovolts Oman: 220 kilovolts (Gulf link)	170	146	0.02
Bahrain	Saudi Arabia: 400 kilovolts (Gulf link)	213	205	0.05
Tunisia	Algeria: 90, 150, 220 kilovolts 400 kilovolts ready to use from Algeria since 2008 (Maghreb link) Libya: 220 kilovolts (not operational for technical reasons)	453	403	0.27
Algeria	Tunisia: 150, 220 kilovolts 400 kilovolts ready to use from Algeria since 2008 Morocco: 225, 400 kilovolts (Maghreb link)	641	610	0.05
Saudi Arabia	Bahrain: 400 kilovolts Kuwait 400 kilovolts Qatar: 400 kilovolts Emirates: 200 kilovolts (Gulf link)	512	461	0.01
Sudan	Ethiopia: 220 kilovolts	5	129	0.9

Country	Existing interconnection	Exported energy (gigawatt hours)	Imported energy (gigawatt hours)	Net % of total energy exchange
Syrian Arab Republic	Lebanon: 400 kilovolts (working, but no energy exchange) Jordan: 230, 400 kilovolts Turkey: 400 kilovolts (working) (Eight link)	262	-	1.3
Iraq	Syrian Arab Republic: 400 kilovolts Turkey: 400 kilovolts Iran: limited local network	-	6,569 (mostly via the link with Turkey and Iran)	7
Oman	Emirates: 220 kilovolts (Gulf link)	Unavailable	Unavailable	-
Palestine	Egypt: provides 30 megawatts to Gaza		4,315 (from Israel)	-
Qatar	Saudi Arabia: 400 kilowatt (Gulf link)	98	79	0.05
Kuwait	Saudi Arabia: 400 kilovolts (Gulf link)	175	133	0.06
Lebanon	Syria: 400 kilovolts (Eight link)	-	262	-
Libya	Egypt: 220 kilovolts Tunisia: 220 kilovolts (not operational for technical reasons)	Unavailable	Unavailable	-
Egypt	Jordan: 400 kilovolts Libya: 220 kilovolts	730	51	0.4
Morocco	Algeria: 225 and 400 kilovolts (Maghreb link) Spain: 400 kilovolts	165	5,138 (mostly from the link with Spain)	16.6
Mauritania	Mali and Senegal: 225 kilovolts	Unavailable	Unavailable	Unavailable
Yemen	No regional link	-	3,200	-

Future vision for electricity infrastructure

Arab electricity infrastructure is expected to suffer from significant pressures over the coming years for various reasons, including increased consumption because of growing populations and efforts to meet the requirements of sustainable development plans. The sector requires considerable investments; the renewal of installed capacity in accordance with life-span cycles over the next decade, estimated at a third of current operational joint capacity (i.e. around 82 gigawatts);[22] updating and increasing the capacity of transformer substations and transmission and distribution lines to ensure the transmission and distribution of additional electricity. Undoubtedly, regional interconnections, upon completion, will result in technical and economic benefits for the Arab electricity sector.

1. Regional interconnection and establishing an Arab electricity market

Given the strategic importance of developing and updating electricity infrastructure, the Arab Ministerial Council of Electricity of the League of Arab States published a study in 2014 on Arab electricity interconnection, funded by the Arab Fund for Economic and Social Development. The study included several alternatives for full interconnection, concluding that interconnecting electricity grids and natural gas pipelines along some paths was the best solution, as shown in table 5.[23]

Table 5 a. Draft proposal for electricity interconnection in view of the findings of the study of the Arab Ministerial Council of Electricity

Country	Voltage (kilovolt)	Department	Expected year of operation*
Libya-Egypt	500/400	1	2017
Tunisia-Libya	400	1	2020
Saudi Arabia-Jordan	400	2	2020
Saudi Arabia-Yemen	400	2	2025
Iraq-Kuwait	400	2	2020
Egypt-Jordan	400 (second line)	Additional department	2020
Jordan-Syrian Arab Republic	400 (second line)	Additional department	2020

* The expected year of operation, as set out in the study's recommendations, are inconsistent with the reality on the ground in many Arab countries for economic, financial and security reasons.

Table 5 b. Proposal for natural gas linkages in view of the findings of the study of the Arab Ministerial Council of Electricity

Project/country	Capacity (billion cubic metres/year)	Expected year of operation*
Gas pipeline Egypt-Libya	20	2018
Gas pipeline Iraq-Kuwait	20	2017
Terminal for receiving liquefied natural gas in Bahrain	5	2018

* The expected year of operation, as set out in the study's recommendations, are inconsistent with the reality on the ground in many Arab countries for economic, financial and security reasons.

The Arab interconnection projects, when completed, will increase load exchange between countries, especially at peak times, and decrease the reserve capacity in interconnected grids without affecting reliability and security, thus reducing the necessary investments to support the required loads, improving interconnected grid performance and reducing losses, reducing operational and maintenance costs, and using less costly production units in the most economically feasible locations.

The study estimates economic capital gains over 15 years, following the completion of interconnecting projects, at $3.7 billion resulting from eliminating the need for production units of around 6.5 gigawatts. Annual operational benefits are estimated at $120 million.[24]

On 8 September 2016, the Ministerial Council of Electricity of the League of Arab States approved a memorandum of understanding on establishing an Arab electricity market by 2034.[25] Relevant steps include the following:

First stage	Second stage
• Network database (code) • Institutional and legal frameworks for comprehensive interconnection • Legislation on a competitive and transparent electricity market • Regional cooperation between the three interconnected groups.	• Establishing an institutional entity with a legal personality to undertake: • Financial settlements due to energy exchange • Technical supervision of interconnected grids, including operation, planning and development (coordination centre).

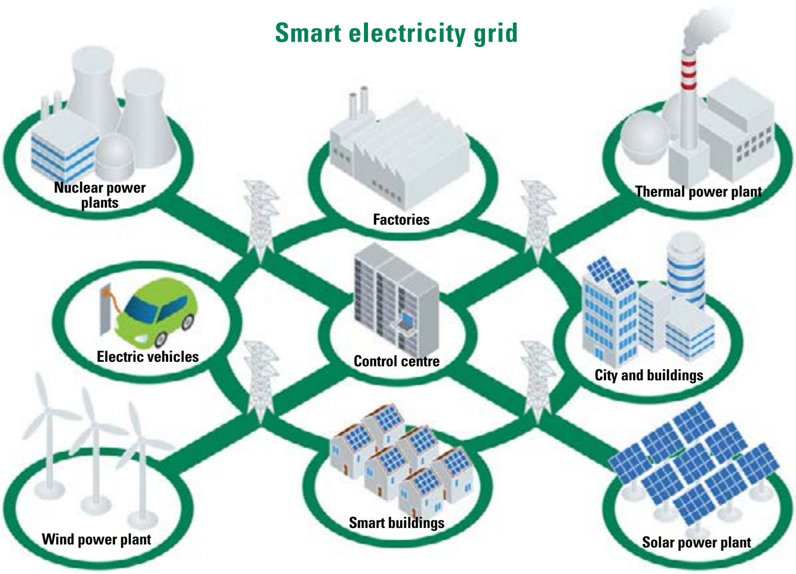
2. Quality of electricity infrastructure

- The quality of electricity infrastructure depends on sustaining electricity supply, through strategic planning to develop the sector towards smart electricity grids.

- Procedures and measures for improving energy efficiency and energy conservation positively affect electricity system at the levels of production, transmission, distribution and consumption. Renewables technologies and energy storage are among the pillars of the smart grid.

- Smart electricity grids are a chain of small decentralized electricity systems, relying on varied sources of electricity production along with a storage system. They are linked by a high voltage grid at the core of the system, managed by a control centre (figure 8).[26]

Figure 8. Example of a smart electricity grid



Smart electricity grids have the following features:

Reliability: maintains plant balance, ability to identify and self-fix faults resulting in uninterrupted electricity supply; ability to withstand natural disasters or sabotage attempts.

Decentralized electricity generation: by distributing production near load centres and allowing reverse flows to the main grid if there is an electricity surplus in the local subgrid after meeting consumption needs. It also enables individuals' participation as electricity suppliers, and allows consumers to choose their electricity source.

Flexibility: diversifying sources of electricity production and the ability to expand renewable energy use and/or dual systems (conventional/ renewable) near load centres increases network capacity and capability to supply electricity.

Economical operation: by modernizing control centres; using performance monitoring programmes; maintaining a normal operation balance in plants, especially following faults or cuts; relying on electricity production from central power plants, thus reducing blackouts; limiting the time needed to restore power following faults, which positively impacts on operational and maintenance costs; and optimally using existing units.

Good load management: reduced demand at peak times eliminates the additional cost of backup generators and extends the lifetime of equipment.

Identifying cost indicators for consumers: to reduce consumption at peak times, by providing a consumer pricing system over time and to display intraday prices for kilowatt-hours, for clients to identify changing price indicators in a short time.

Shifting towards a smart grid system requires the following:

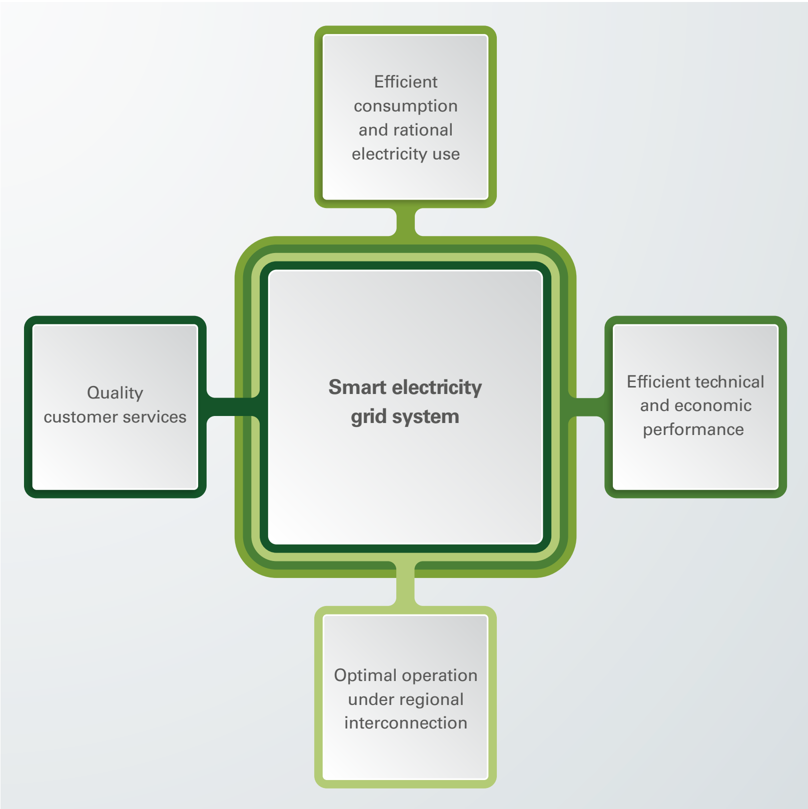
Advanced measuring devices in all parts of the grid (production, transport, precaution, control) and ensuring the speed of continual data transfer.

Fault forecasting systems/programmes to anticipate power cuts because of overloads, and coordination between consumers and producers to avoid such faults.

Necessary consumer devices to determine choice, and pricing projects to incentivize consumers to limit use so as to benefit from price changes according to supply and demand.

Advanced communication systems, by using electricity lines to transfer information signals that allow for the storage of information about the grid and improve grid control.

Power storage systems to ensure the optimal use of energy from renewable sources, lowering load curves, enabling consumers to overcome power cuts, reducing dependence on power plants, and supporting grid independence, among others.



Endnotes

1. See http://dictionary.cambridge.org/dictionary/english-thai/infrastructure.
2. See http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.89.2276&rep=rep1&type=pdf, p.12.
3. See www.marefa.org/index.php (in Arabic).
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5. Based on data from the OPEC Annual Statistical Bulletin, 2016, pp. 8, 14 and 26.
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12. E/ESCWA/SDPD/2015/4, 24 Dec. 2015, p. 34; IRENA, Mauritania Renewable Readiness, 2015.
13. REN21, GSR2016, p. 146.
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15. See carnegie-mec.org/2016/01/28/ar-pub-62623.
16. See elec4eng.blogspot.com/2013/10/blog-post_18.html.
17. Arab Union of Electricity, 2015 Statistical Bulletin, No. 24, p. 12.
18. E/ESCWA/SDPD/2015/4, p. 32.
19. Arab Union of Electricity, 2015 Statistical Bulletin, No. 24, pp. 9, 11 and 19.
20. Arab Union of Electricity, 2015 Statistical Bulletin, No. 24, pp. 4, 6 and 16.
21. E/ESCWA/SDPD/2014/Pamphlet.2, Institutional Frameworks for Managing Selected Energy Subsectors in Arab Countries, p. 12.
22. E/ESCWA/SDPD/2015/4, p. 34.
23. E/ESCWA/SDPD/2015/4, 24 Dec. 2015, p. 59.
24. See www.arabfund.org/default.aspx?pageId=467.
25. Ministerial Council resolution 8088 of 8 September 2016.
26. See www.eng2all.com.

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