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RENEWABLE ENERGY OUTLOOK EGYPT

Based on Renewables Readiness Assessment and REmap analysis

IRENA
International Renewable Energy Agency

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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Renewable Energy Outlook
EGYPT

International Renewable Energy Agency

FOREWORD
from the Minister of Electricity and Renewable Energy

Egypt's Vision 2030 aims to achieve a diversified, competitive and balanced economy within the framework of sustainable development. Renewable energy has a central role to play, a role detailed in the Integrated Sustainable Energy Strategy to 2035, released by the Ministry of Electricity and Renewable Energy in 2015.

The "ISES 2035" ensures continuous, diversified energy security and establishes the necessary conditions to enable the increased development of renewables through the engagement of all sectors. Moreover, the strategy confirms Egypt's ambition to become an energy hub between Europe, Asia and Africa by expanding grid interconnections across the Arab region and beyond. Egypt is home to a wide array of untapped solar and wind resources, and according to the ISES 2035, renewable energy capacity should contribute 42% of power capacity by 2035.

The Renewables Readiness Assessment and REmap country analysis – which together form this Renewable Energy Outlook study – will help Egypt to achieve such targets. These analyses suggest how to build on the initiatives that Egypt has already undertaken to enhance the deployment of renewable energy technologies. The Egyptian electricity sector, for example, has adopted a localisation programme and succeeded in meeting a 30% local content target for overall wind farm requirements, with the aim of increasing that to 70% by 2020. Concentrated solar power (CSP) plants should have 50% local content by the same year.

This analysis was conducted through close collaboration between the Ministry of Electricity and Renewable Energy and the International Renewable Energy Agency (IRENA), with support from the New and Renewable Energy Authority (NREA). It provides vital information to stakeholders in the field of renewable energy, including both governmental and private-sector entities.

This report demonstrates the ability of Egypt to maintain economic growth, sustainability and energy security. It shows how to ensure private-sector engagement, defines the main policy, institutional, market and skills challenges, and offers recommended actions to overcome those challenges.

On behalf of the Ministry of Electricity and Renewable Energy, I would like to express my sincerest appreciation for IRENA's efforts and support in advancing renewable energy deployment in Egypt. I would also like to thank all the personnel involved in this project for their excellent co-operation and contributions. I am certain that this report will play a vital role in Egypt's current strategy to achieve its goals in promoting renewable energy.

H.E. Dr Mohamed Shaker
Minister of Electricity and Renewable Energy
Arab Republic of Egypt

FOREWORD
from the IRENA Director-General

As the most populous country in the Middle East, Egypt faces rising energy demand driven by rapid population growth and an expanding economy. This creates significant challenges in maintaining a steady and continuous supply of energy. Renewable energy can help Egypt not only meet its energy needs, but also power sustainable economic growth and create jobs while achieving global climate and sustainable development objectives.

The government has recognised this opportunity in its Integrated Sustainable Energy Strategy, or ISES 2035, which seeks to ensure energy security, stability and sustainability through the widespread adoption of renewable energy technologies. Major renewable energy projects are now under development, reflecting the government's resolve to turn this vision into reality. Several recent tenders have attracted strong international interest and promising proposals, which could further help ramp up renewable power generation in the coming years. The government's latest targets call for 20% of Egypt's power generation to be based on renewables by 2022, and 42% by 2035.

Renewable Energy Outlook: Egypt highlights the policy, regulatory, financial and capacity-building-related actions needed to meet and even surpass these targets. Prepared by the International Renewable Energy Agency (IRENA) in collaboration with Egypt's New and Renewable Energy Authority (NREA), this report identifies key challenges and opportunities for the country to expand the use of renewable energy.

The report combines two IRENA methodologies: the Renewables Readiness Assessment based on country-led stakeholder consultations; and REmap, IRENA's ongoing series of renewable energy roadmaps that analyse the different technology pathways to maximise a country's renewables potential in the long term.

By adopting the right policies now, Egypt could realistically draw 53% of its electricity from renewables by 2030. This higher uptake of renewable power, when combined with renewables used for heat and transport, would end up reducing total costs, including energy, environmental and health-related costs by USD 9 billion per year on average compared to current energy plans. Moreover, Egypt has a significant comparative advantage through its manufacturing potential in different segments of the renewables value chain. Enhancing local manufacturing capabilities could unlock significant socio-economic benefits, particularly in terms of job creation.

I would like to thank H.E. Dr Mohamed Shaker El-Markabi, Minister of Electricity and Renewable Energy, for his strong support, as well as NREA for its invaluable input. We are also grateful for the important contributions made by various other stakeholders and international partners.

The energy choices that Egypt makes today are likely to resonate far beyond its borders. We sincerely hope that this report will help to accelerate Egypt's transition to a sustainable energy future, and we look forward to working with the Egyptian government in taking forward its recommendations.

Adnan Z. Amin
Director-General
International Renewable Energy Agency

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ABBREVIATIONS

AFD	Agence Française de Développement
BEV	battery electric vehicle
BF	blast furnace
bln	billion
BOO	build-own-operate
BOOT	build-own-operate-transfer
BSP	Bioenergy Service Provider
BSRD	Bioenergy for Sustainable Rural Development
CCGT	combined-cycle gas turbine
CO	coke oven
CO_2	carbon dioxide
CoM	Cabinet of Ministers
CPI	consumer price index
CREMP	Combined Renewable Energy Master Plan
CSP	concentrated solar power
EEA	Egyptian Electricity Authority
EEAA	Egyptian Environmental Affairs Agency
EEHC	Egyptian Electricity Holding Company
EETC	Egyptian Electricity Transmission Company
EGAS	Egyptian Natural Gas Holding Company
EGPC	Egyptian General Petroleum Corporation
EgyptERA	Egyptian Electric Utility and Consumer Protection Regulatory Agency
EIB	European Investment Bank
EPC	engineering, procurement and construction
EV	electric vehicle
FAO	Food and Agriculture Organization of the United Nations
FEI	Federation of Egyptian Industries
FIT	feed-in tariff
GANOPE	Ganoub El Wadi Holding Company
GDP	gross domestic product
HV	high voltage
IFC	International Finance Corporation
IOC	international oil company
IPP	independent power producer
IRENA	International Renewable Energy Agency
ISES	Integrated Sustainable Energy Strategy
JICA	Japan International Cooperation Agency
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LV	low voltage
MOERE	Ministry of Electricity and Renewable Energy
MOF	Ministry of Finance
MV	medium voltage
N/A	not applicable
NDC	Nationally Determined Contribution
NREA	New and Renewable Energy Authority
NUCA	New Urban Communities Authority

ABBREVIATIONS

OCGT	open-cycle gas turbine
O&M	operation and maintenance
PPA	power purchase agreement
PV	photovoltaic
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RDF	refuse-derived fuel
RE	renewable energy
REmap	Renewable Energy Roadmap
RRA	Renewables Readiness Assessment
R&D	research and development
SEC	Supreme Energy Council
SIPHS	solar industrial process heat systems
SMEs	small and medium-sized enterprises
SPV	special purpose vehicle
SWHs	solar water heater
TARES	Technical Assistance to Support the Reform of the Energy Sector for Egypt
TFEC	total final energy consumption
TPES	total primary energy supply
TSO	transmission system operator
T&D	transmission and distribution
UHV	ultra-high voltage
VAT	value-added tax
VRE	variable renewable energy
yr	year

UNITS OF MEASUREMENT

bbl	barrel
EJ	exajoule
GJ	gigajoule
GW	gigawatt
GWh	gigawatt hour
GWth	gigawatt thermal
km	kilometre
km²	square kilometre
ktoe	thousand tonnes of oil equivalent
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
kWh/m²	kilowatt hours per square metre
m²	square metre
m/s	metres per second
Mt	million tonnes
Mtoe	million tonnes of oil equivalent
MVA	megavolt ampere
MW	megawatt
MWh	megawatt hour
PJ	petajoule
toe	tonne of oil equivalent
TWh	terawatt hour
°C	degree Celsius

EXECUTIVE SUMMARY

Solar street lights recharge by day
Photograph: Shutterstock

The Arab Republic of Egypt is the most populous country in North Africa and the Arab region and home to one of the fastest-growing populations globally. The rapidly swelling number of inhabitants has led to a rapid increase in energy demand, putting a strain on the country's domestic energy resources even amid substantial recent offshore natural gas finds. As fuel shortages heightened in 2014, the country's electricity generating capacity struggled to keep pace with rising energy demand.

Egypt's economic development hinges on the energy sector, which represents 13.1% of overall gross domestic product (GDP). To meet burgeoning energy demand, the Egyptian government has pursued an energy diversification strategy, known as the Integrated Sustainable Energy Strategy (ISES) to 2035, to ensure the continuous security and stability of the country's energy supply. This strategy involves stepping up the development of renewable energy and energy efficiency, in part through vigorous rehabilitation and maintenance programmes in the power sector.

Egypt is, therefore, committed to the widespread deployment of renewable energy technologies. To date, the country's total installed capacity of renewables amounts to 3.7 gigawatts (GW), including 2.8 GW of hydropower and around 0.9 GW of solar and wind power. As specified in the ISES to 2035, the Egyptian government has set renewable energy targets of 20% of the electricity mix by 2022 and 42% by 2035.

Egypt has ample potential to achieve these ambitious targets, as it enjoys an abundance of renewable energy resources with high deployment potential, including hydropower, wind, solar and biomass. The establishment of the New and Renewable Energy Authority (NREA) in 1986 was an important milestone in Egypt's efforts to enhance renewable energy deployment. While the NREA focuses particularly on wind and solar technologies, other institutions have devoted efforts to biomass development. Among those institutions are the state-owned electricity generation, transmission and distribution entities operated under the supervision of the Egyptian Electricity Holding Company (EEHC).

This study by the International Renewable Energy Agency (IRENA) provides an in-depth assessment of the policy, regulatory, financial and capacity readiness challenges that need to be overcome to achieve the targets set out in the ISES to 2035. In this respect, it follows the Renewables Readiness Assessment (RRA) methodology, whereby IRENA facilitates country-led consultations with multiple stakeholders, aiming to identify key challenges and highlight solutions to boost renewable energy deployment. It also provides an in-depth analysis based on IRENA's REmap analysis approach, identifying additional renewable energy potential and quantifying other factors, such as costs, investment needs and the effect on externalities related to air pollution and the environment.

Based on this REmap analysis, Egypt has the potential to supply 53% of its electricity mix from renewables by 2030. This amounts to doubling the renewable energy share that could be expected from pursuing existing plans and policies (known in this study as the Reference Case) as well as a significant rise compared to the 9% recorded in 2014 (the base year of the analysis). This assessment is in line with the results obtained for Scenario 3 of the ISES to 2035. With renewable power, heat and fuels all factored in, the REmap analysis shows that renewable energy could provide 22% of Egypt's total final energy supply in 2030, up from just 5% overall in 2014.

Renewable energy could provide 22% of Egypt's energy supply in 2030

The REmap analysis also finds that due to declining costs for renewable power technologies, their increased deployment results in a reduction in total energy costs of USD 900 million annually in 2030, equivalent to a cost reduction of USD 7 per megawatt hour (MWh). This is the case even before taking into account the reductions in external costs from air pollution, which would bring broad social and health benefits worth as much as USD 4.7 billion annually in 2030. Investment in renewable energy capacity over the period would have to be raised, from USD 2.5 billion per year based on existing policies (the Reference Case) to USD 6.5 billion per year with accelerated deployment of renewables (the REmap Case).

Strategies and plans must be updated regularly to reflect new developments

However, the successful realisation of such deployment would require significant adjustments to Egypt's sustainable energy strategy. The present strategy, developed in 2014, does not reflect the rapid economic and technological changes taking place at the national and regional levels. Moreover, plans need to factor in the latest data to account for the cost of externalities, particularly with Egypt's highly subsidised energy prices. Eliminating such subsidies would relieve the government of a heavy financial burden, which has been a strain amid diminishing state revenues. For Egypt to capture the complete benefits of renewables, the government must consider both financial and technical challenges.

This study attempts to identify those challenges and highlight key actions to overcome existing limitations. Based on these recommended actions, Egypt can meet, and in due course exceed, the targets identified in its sustainable energy strategy.

Challenges and recommended actions

- **Update energy and power sector strategies to reflect the growing cost advantages and other benefits of renewables:** Egypt's sustainable energy strategy, ISES to 2035, is based on the least-cost approach, whereby energy subsidies are eliminated by 2022 and different energy sources would be able to compete within a free and fair market structure. The strategy developed in 2014 envisages a total share of 16% for coal, 3.3% for nuclear energy and 42% for renewable energy in the installed capacity mix by 2035.

  The main driver for the introduction of coal in Egypt's energy mix was a result of the 2014 electricity shortages, with imported coal providing a rapid solution to reduce the dependency on imported gas. Today, the approach is subject to drastic change following falling costs for renewables, coupled with the recent natural gas discoveries and rising environmental concerns over coal generation.

  Towards this objective, energy and power sector strategies and plans must be updated regularly to reflect new developments, which permit a share of renewables in power generation as high as 53% to be achieved by 2030. This would also reduce and even eliminate the need for coal and nuclear-related imports, thus strengthening the country's energy security. The overall cost-competitiveness and ease of access to finance for renewables, particularly in comparison to the strenuous planning processes required for nuclear technology, could be reflected in future strategy updates.

- **Reflect the potential of biomass in future updates of the energy strategy:** While the regulatory framework addresses electricity production systems using wind and solar, the strategy has not given sufficient focus to the exploitation of biomass potential. This is evident in the limited progress achieved on biomass mainly due to the shortage of local capacity, along with the considerable upfront costs associated with biomass-based electricity generation.

> Investment in renewable energy capacity, currently set at around USD 2.5 billion per year until 2030, needs to increase further

  Feasibility studies are necessary to assess the potential for developing a strong regulatory framework to enable appropriate policy support schemes. Furthermore, the application of biomass is limited by low awareness of the range of renewable energy technologies available to the end-use sectors. Therefore, the NREA is advised to develop an awareness-raising programme that includes publicity campaigns, along with education and training programmes, to ensure that all the benefits of renewable energy are realised.

- **Streamline regulations and clarify institutional roles and responsibilities for wind and solar development:** Wind and solar deployment is supported through laws, regulations and implementation schemes. Despite the enabling environment to encourage private-sector participation, project developers are discouraged by complex administrative procedures, including the unavailability of contractual documents for projects and multiple focal points for renewable energy deployment. To overcome these challenges, institutional roles ought to be further defined.

  This can be achieved by establishing the NREA as the national renewable energy co ordinator throughout the project lifetime, thus empowering the NREA as a "one-stop shop" to expedite processes under any renewable energy development scheme, enhancing both the private-sector contribution to renewable energy deployment and reinforcing its role as a facilitator rather than a project developer. In turn, this would allow for the clear definition of institutional responsibilities and prevent the overlap of roles under different procurement and market schemes.

The NREA has so far been given precedence as a developer, based on its current entitlement to land ownership for renewable energy projects, while also being the recipient of most of the soft loans attributed to these projects.

- **Reform the current market framework to improve project bankability:** Under the New Electricity Law of July 2015, direct contractual relations between suppliers and end users can exist, confirming the transition of the Egyptian Electricity Transmission Company (EETC), state-owned off-taker, to a conductor of system operations and dispatching procedures. With respect to the implementation of power purchase agreements (PPAs), EETC has faced difficulties addressing its financial obligations and securing bankable PPAs. This highlights the need to review the current terms and conditions of renewable energy PPAs to address concerns raised by investors, including putting in place standardised project document templates for renewable energy projects.

- **Bundle renewable energy projects to strengthen risk mitigation and ensure their financial viability:** Currently, local financial institutions do not perceive renewables as low-risk investments, despite their cost-competitiveness. The determining factor for renewables is the scale of the projects, such that smaller renewable energy projects are subject to high interest rates from local financial institutions, while larger renewable energy projects are able to obtain lower interest rates from institutions based outside Egypt, with a trade-off in currency exchange rate fluctuations.

  Smaller-sized renewable energy projects, however, can be bundled to achieve the required scale, reduce transaction costs and bolster local financial institutions' confidence in projects. In turn, enhanced confidence would allow the domestic financial community to develop lending schemes tailored towards renewable energy projects using concessional resources, allowing renewable energy projects to flourish.

Smaller renewable energy projects can be bundled to achieve scale, reduce transaction costs and bolster the confidence of banks

- **Carry out comprehensive measurement campaigns for solar and wind potential:** Several wind and solar resource assessments have been conducted; however, they have not been supplemented with sufficient detail to ensure bankability of projects. The ISES to 2035 includes 52 GW of both large-scale and distributed on-grid renewable energy by 2035. The REmap analysis shows that already by 2030 similar on-grid renewable capacity could exceed 62 GW.

  This necessitates zoning of cost-effective areas with a high potential for renewable energy, while aligning all grid operation and dispatch practices to accommodate the variability in supply that could be expected to follow large-scale solar and wind investments. The measurement campaigns, entailing site appraisal, could be conducted by the developer, thus reducing the burden on the NREA, which currently has the responsibility for resource assessment. In this context, a greater role for variable renewable energy sources will require from NREA to identify viable options for improved power system flexibility, including strengthening cross-border interconnections.

- **Develop a master plan for enhancing local manufacturing capabilities and create a vibrant domestic renewable energy industry:** The ISES to 2035 does not tackle the potential for renewable energy equipment manufacturing and related service sector development. Integrating local content requirements into renewable energy procurement processes is challenging. Most international finance institutions, who are the main funders of large-scale renewable energy projects, are reluctant to accept them on competition grounds.

Nevertheless, studies completed by IRENA highlight Egypt's comparative advantage in different segments of the renewables value chain, particularly in the downstream segments of project development, operation and maintenance. Leveraging this potential to increase the share of local content in manufacturing would facilitate an array of socio-economic benefits.

The current phase of renewable energy deployment has provided 6 000 direct and indirect jobs in total, with solar photovoltaic alone providing half of the jobs created. The government, therefore, is advised to elaborate a national master plan for the development of local manufacturing capabilities, specifically in order to promote knowledge and technology transfer, thus creating local jobs.

Recommended actions

Renewable Energy Outlook: Egypt recommends seven key actions to accelerate the country's uptake of renewables:

- Update energy and power sector strategies to reflect the growing cost advantages and other benefits of renewables
- Reflect the potential of biomass in future updates of the energy strategy
- Streamline regulations and clarify institutional roles and responsibilities for wind and solar development
- Reform the current market framework to improve project bankability
- Bundle renewable energy projects to strengthen risk mitigation and ensure their financial viability
- Conduct comprehensive measurement campaigns for solar and wind potential
- Develop a master plan for enhancing local manufacturing capabilities and create a vibrant domestic renewable energy industry

INTRODUCTION

Solar panels near the Pyramids of Giza
Photograph: Shutterstock

01

1.1 Country background

Located in the north-eastern part of Africa, the Arab Republic of Egypt is bordered by the Mediterranean Sea to the north and the Red Sea to the east, and is therefore at the crossroads between Europe, the Middle East, Asia and Africa. With an area of over 1 million square kilometres (km^2), Egypt is the world's 30th-largest country, the majority of the landscape being desert with a few scattered oases. Of the total population, 95% is concentrated along the narrow Nile Valley and Delta, corresponding to only about 5% of the total land area (World Bank, 2017). In 2016, the population exceeded 95 million inhabitants, with those aged between 15 and 29 years representing 27% of the population (CAPMAS, 2017). Egypt is the most populous country in North Africa and the Arab region and the 15th most populous in the world, with half of its residents living in urban areas.

Egypt is a lower-middle income country and economic activity is concentrated in the services, industrial and agricultural sectors, with their respective contributions of 55%, 33% and 12% to gross domestic product (GDP) (Trading Economics, 2017). The country's fast-growing population is putting a strain on existing infrastructure and services. In 2015, 28% of the total population lived below the national poverty line, with an even higher rate of 60% recorded in Upper Egypt. Furthermore, the unemployment rate reached 12% in mid-2016 (comprised mainly of 26% of the youth group aged between 15 and 29 years), up from a 9% unemployment rate prior to 2011 (Trading Economics, 2017).

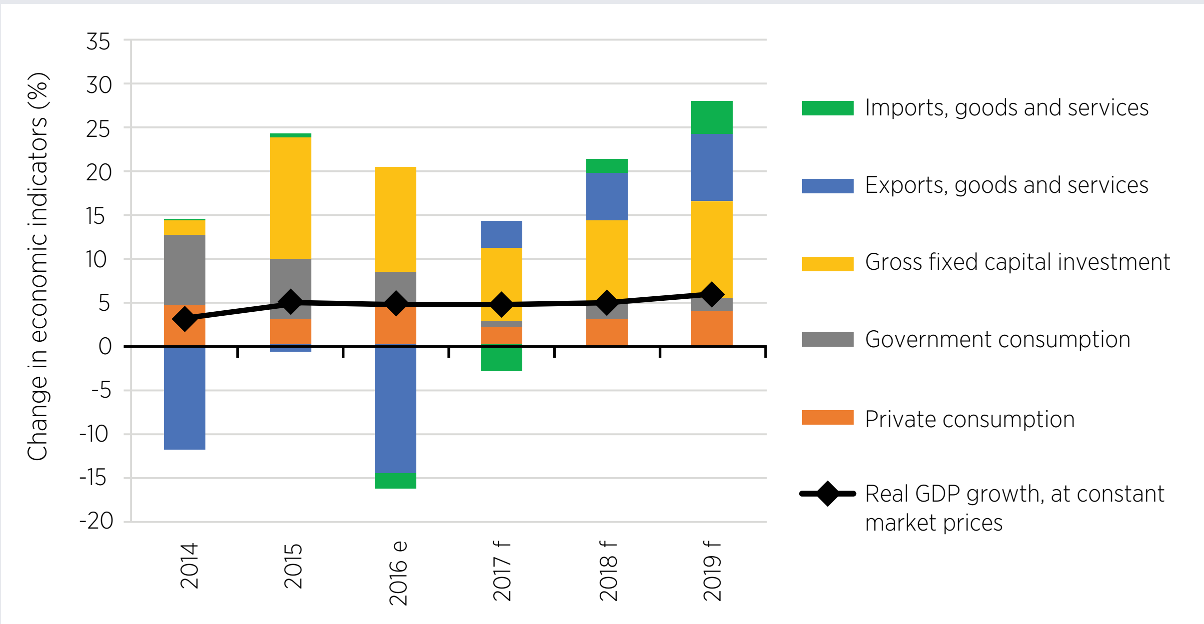
From the 1990s, Egypt's state-driven economy shifted to a market-based, liberalised one, capitalising on trade, privatisation and investment. This in turn led to exchange rate stabilisation, accompanied by a significant increase in foreign investment thanks to the adoption of several legislative reforms and structural arrangements targeted at corporate, income and sales taxes, alongside other financial reforms that were preceded by the International Monetary Fund's debt relief. Then, from the early 2010s, economic indicators showed a rapid decline in the value of imports and exports, with the trade balance as a percentage of GDP falling from 45.2% in 2011 to 30% in 2016 (Trading Economics, 2017). In 2014, driven by fiscal imbalances and energy shortages, the government introduced a comprehensive consolidation programme, which included among other measures a tariff and subsidy phase-out scheme.

The Egyptian economy started to pick up by the end of 2015, with GDP achieving higher, more stable annual growth rates (4.3% in fiscal year 2015/16 and 4.0% in 2016/17), with GDP per capita reaching USD 3 514 in 2016/17 (World Bank, 2017), accompanied by a slight decline in public debt and external debt's contribution to GDP.

Despite macroeconomic conditions showing signs of stabilisation, several factors challenge the national economic situation today. Inflation continues to be a major concern, spiking at a record 32% in August 2017. Furthermore, exchange rate misalignments due to currency depreciation, along with the introduction of value-added tax (VAT) and increased foreign borrowing, led to tighter monetary policy by the Central Bank of Egypt and threatened fiscal consolidation (World Bank, 2017). Furthermore, external economic dynamics, in the context of lower international oil prices and remittances, contribute to an uncertain climate for investment.

According to Egypt's Economic Outlook for 2017, the country's economy should recover by 2019, as presented in Figure 1 (World Bank, 2017). It provides further detail on the changes to the indicators that are used to develop the estimates and forecasts for economic growth, as depicted in the Outlook.

Figure 1. Egypt's economic perspectives



Notes: e = estimate; f = forecast.

Based on: World Bank (2017), Egypt Economic Outlook 2017.

1.2 Energy for development in Egypt

The Sustainable Development Strategy: Egypt Vision 2030 (MOP, 2015) was announced in February 2016 and is indicative of the country's aspirations to achieve a competitive, balanced and diversified economy by 2030 to secure sustainable development in a protected environment for all Egyptians. The strategy identified a set of targeted development indicators to be reached by 2020 and 2030, among which several indicators relate to energy and set significant renewable energy penetration targets, as depicted in Table 1.

Table 1. Development indicators of Egypt's Vision 2030

Targeted development indicators	2016*	2020	2030
GDP real growth (%)	4.2	10.0	12.0
GDP per capita (USD)	3 436	4 000	10 000
Inflation rate (CPI, annual %)	11.8	8.0	5.3
Industrial development rate (%)	5.0	8.0	10.0
Industry share of GDP (%)	12.5	15.0	18.0
Energy sector share of GDP (%)	13.1	20.0	25.0
Renewables' share in primary energy (%)	1.0	8.0	12.0
Renewables in electricity production (%)	1.0	21.0	32.5
Women in workforce (%)	22.8	25.0	35.0
Unemployment rate (%)	12.8	10.0	5.0
Poverty rate (%)	26.3	23.0	15.0
Acute poverty (%)	4.4	2.5	0.0

* Data for 2016 are actual data for the year, as stated in the Sustainable Development Strategy report, which references 31 indicators (MOP, 2015).

Note: CPI = consumer price index.

The Egyptian energy sector is a key driver for the socio-economic development of Egypt, representing around 13% of current GDP and thus making economic growth in the country contingent upon the security and stability of energy supply. Since 2007, Egypt has experienced an energy supply deficit due to the rapid increase in energy consumption and the depletion of domestic oil and gas resources, shifting its position as a net hydrocarbon exporter for the last three decades to that of a net importer. This has brought a set of challenges to the energy sector, including electricity shortages, caused in part by the decline of domestic gas production, as natural gas is the main source of electricity, accompanied by highly subsidised energy prices, with negative financial implications for already dwindling government revenues.

In response, the Government of Egypt has taken bold steps to adopt an energy diversification strategy with increased development of renewable energy and implementation of energy efficiency, including assertive rehabilitation and maintenance programmes in the power sector. The deployment of renewable energy technologies is gaining momentum, such that the total installed capacity of renewable energy stands at 3.7 gigawatts (GW) (mainly 2.8 GW of hydro and 0.887 GW of solar and wind) with a commitment from the government to develop an additional 10 GW of wind and solar projects by 2022, whereby renewables would contribute to 20% of the electricity mix (IRENA, 2018a).

1.3 Methodologies

This study was conducted jointly by the International Renewable Energy Agency (IRENA) and the New and Renewable Energy Authority (NREA) of Egypt, applying two methodologies previously developed by IRENA, namely the Renewables Readiness Assessment (RRA) process and REmap – or Renewable Energy Roadmap – analysis.

Renewables Readiness Assessment

The RRA process is a comprehensive assessment tool for the promotion and deployment of renewable energy, which has been developed by IRENA. It consists of a methodology designed to define a detailed list of criteria considered necessary for the ongoing operation of existing renewable energy facilities, along with the further development of renewable energy. Applying this framework to individual countries provides a comprehensive analysis of the presence or absence of enabling conditions for the development of renewables.

The RRA is a country-initiated and -led process which provides a venue for a multi-stakeholder dialogue to identify challenges to renewable energy deployment and to propose actionable recommendations to overcome them. This involves four main phases: initiation and demonstration of intent; country assessment and action plan; RRA country validation and finalisation; and follow-up. The process includes completing a set of templates and a final report. Under the RRA, all processes and documentation are led by the country and derive inputs from discussions with stakeholders facilitated by the country focal point, the NREA, with the assistance of IRENA and other development partners.

The RRA facilitates a co ordinated approach and the setting of priorities that can facilitate discussions with bilateral and multilateral co operation agencies, financial institutions and the private sector regarding the implementation of actionable recommendations emerging from the RRA report.

In Egypt, the RRA was initiated in April 2016 in conjunction with the NREA, and included a series of national stakeholder consultations throughout the RRA's four-phase implementation process. An overall objective of this project is to highlight the key results that can contribute to formulating Egypt's renewable energy development action plan, helping mobilise all resources necessary to carry out the actions identified and flagging the potential issues that need to be further addressed. More specifically, the RRA aims to:

- Identify the critical and emerging issues associated with, and arising from, the development of Egypt's energy sector in general and the development of the widespread use of renewable energy resources in particular.
- Recommend a portfolio of articulated actionable recommendations that can capitalise on the opportunities revealed through the examination of Egypt's energy sector and the extensive discussions that have taken place with multiple stakeholders during the RRA process, identifying how to effectively turn the assessed potential of resources into a real utilisation of renewable energy resources.
- Outline follow-up activities to ensure the recommendations identified are actionable in the near- and mid-term timeframe and in line with the nationally approved strategies.

Finally, this report serves to facilitate synergy and co ordination among the stakeholders involved to help implement the objectives of Egypt's Integrated Sustainable Energy Strategy to 2035.

REmap – Renewable Energy Roadmap analysis

Egypt's engagement with IRENA on REmap began in early 2015. The results of an initial REmap analysis for the country were published as part of the 2016 REmap global report entitled "Roadmap for a Renewable Energy Future". In early 2016, the REmap team started to revisit the REmap analysis and expand it to provide a more detailed assessment. This effort was aided by an expert officer seconded by the Egyptian NREA. This seconded officer worked at the IRENA Innovation and Technology Centre in Bonn, Germany, for three months supporting the expanded and detailed assessment presented in this report. The results of this analysis were presented in Cairo in May of 2017 during the RRA and REmap workshop. Participants provided in-depth views and critique, and the analysis was subsequently revised. In September 2017, the revised analysis was again shared with the NREA and IRENA for further review.

The REmap analysis for Egypt utilises IRENA's internally developed REmap tool, incorporating data and analysis done by IRENA and Egyptian experts on energy system development and renewables potential in the country. It provides assumptions and a standardised REmap approach for assessment of technologies in terms of their cost, investment and benefits.

The REmap analysis looks out to the year 2030 (consistent with the Egyptian calendar year 2029/30). The year is chosen as the standard assessment timeframe for REmap due to it being in the medium term, a common year for global efforts such as the Sustainable Development Goals, and a common year in Egypt for national-level targets (for 2029/30).

The REmap analysis starts by building the energy balance of a country using 2014 as the base year of the analysis (2013/14), based on national data and statistics, other literature and sources. The country then provides its latest national energy plans and scenarios for renewables and fossil fuels, collated to produce a business-as-usual perspective of the energy system, referred to as the Reference Case, also known as the baseline. This includes total final energy consumption (TFEC) for each end-use sector (buildings, industry and transport) and distinguishes between power, district heating and direct uses of energy, with a breakdown by energy carrier, for the period to 2030.

Once the Reference Case is complete, the additional renewable energy potential by technology is examined for each sector. The potential of these technologies is described as REmap Options.[1] Each REmap Option replaces a non-renewable energy technology[2] to deliver the same energy service. The resulting case, when all of these options are aggregated, is called the REmap Case.

Throughout this study, the renewable energy share is estimated in relation to TFEC[3] in general, but also occasionally in relation to total primary energy supply (TPES) to allow for comparison with targets or indicators that instead focus on primary energy. Modern renewable energy excludes traditional uses of bioenergy.[4] The share of modern renewable energy in TFEC is equal to total modern renewable energy consumption in end-use sectors (including consumption of renewable electricity and district heat, and direct uses of renewables), divided by TFEC. The share of renewables in power generation is also calculated. The renewable energy share can also be expressed in terms of the direct uses of renewables only. Renewable energy use in the buildings sector covers the residential, commercial and public sectors.

The industrial sector includes the manufacturing and mining sectors, in which renewable energy is consumed in direct-use applications (e.g. process heat or refrigeration) and as electricity from renewable sources. It also includes agriculture.

The transport sector can make direct use of renewables through the consumption of liquid and gaseous biofuels or through electricity generated using renewable energy technologies.

1 An approach based on options rather than scenarios is deliberate. REmap is an exploratory study and not a target-setting exercise.

2 Non-renewable technologies encompass fossil fuels, non-sustainable uses of bioenergy (referred to here as traditional bioenergy) and nuclear power. As a supplement to this report's annexes, a detailed list of these technologies and related background data are provided on the REmap website.

3 TFEC is the energy delivered to consumers as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually subdivided into transport, industry, residential, commercial and public buildings, and agriculture. It excludes non-energy uses of fuels.

4 The Food and Agriculture Organization of the United Nations (FAO) defines traditional biomass use as woodfuels, agricultural by-products and dung burned for cooking and heating purposes (FAO, 2000). In developing countries, traditional biomass is still widely harvested and used in an unsustainable, inefficient and unsafe way. It is mostly traded informally and non-commercially. Modern biomass, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry and relies on more efficient methods (IEA and World Bank, 2015).

ENERGY CONTEXT

Solar panels on electric pole, Egypt
Photograph: Shutterstock

02

Egypt is fifth amongst the oil-producing countries of Africa, with a daily production of 588 000 barrels, and is the continent's largest oil and gas consumer. The volatility in the global oil market and increases in its own energy consumption limit the contribution of Egypt's hydrocarbon exports to international markets. In this context, according to Bloomberg New Energy Finance forecasts, electricity generating capacity will continue to struggle to keep pace with rising demand, which will be one of the highest in Africa by the mid-2020s, and in response the country aims to increase capacity by scaling up renewables.

The country aims to double its installed electricity capacity by 2020 from its current level in 2018 of around 50 GW, through the introduction of renewables, coal and nuclear power. The government has taken several initiatives in the power sector to cope with the energy imbalance, including increased reliance on gas imports, diversification through renewables and energy efficiency measures, and operation and maintenance (O&M) programmes.

Egypt is close to reaching universal access to electricity, with the electrification rate estimated at over 99.8% (World Bank, 2017). Most of the population, including rural areas, receive adequate electricity services. However, the country's energy crisis reached a peak in 2014. In turn, this emphasised the need for the Egyptian government to prioritise the implementation of an electricity diversification strategy to ensure a sustained, reliable provision of electricity. The electricity market in 2014 was marked by multiple disruptions and blackouts due to, among other factors, fuel shortages, infrastructure limitations, distortion of the exported fuel price, and population growth, all of which contributed to a widening of the gap between supply and demand. The electricity deficit was reported as reaching its highest point in August 2014, with a peak demand of 28 GW. Despite the availability of installed capacity, these plants were unable to keep up with peak demand due to limitations caused by fuel shortages, which led to electricity outages.

2.1 Energy sector governance

The overall governance of the Egyptian energy sector is guided at the strategy and policy level by regulations and directions issued by the Supreme Energy Council (SEC) and is managed at the execution level by the Ministry of Petroleum and Mineral Resources and the Ministry of Electricity and Renewable Energy (MOERE). Both ministries work in co operation with other relevant ministries and public entities, and in consultation with the private sector and non-governmental organisations. The corresponding sections below provide an overview of the responsibilities of these three government entities. Tables 10 and 11 provide a summary of the role of the institutions involved in Egypt's renewable energy schemes and the principal functions of the main national energy stakeholders in Egypt that are active in the deployment of renewables in the country.

1. **The Supreme Energy Council (SEC)** was established in 1979 under the Prime Minister's decree No. 1093 and was reformed in 2014. Headed and formed by the Prime Minister and including all relevant ministries, it is mandated to review and endorse national energy strategies and policies, monitor the sector's performance and energy pricing policies and approve policies and regulations on energy pricing and incentives for energy sector investments (including promotion of energy efficiency and renewable energy investment).

2. **The Ministry of Petroleum and Mineral Resources** is entrusted with the overall management of all petroleum activities in the country, including exploration, production and distribution of oil, oil products and gas, as well as all related services. The ministry implements its mandate through three affiliated entities: the Egyptian General Petroleum Corporation (EGPC), the Egyptian Natural Gas Holding Company (EGAS), and Ganoub El Wadi Petroleum Holding Company (GANOPE).

3. **The Ministry of Electricity and Renewable Energy (MOERE)** is entrusted with the overall management of the Egyptian electricity sector through its subsidiary company the Egyptian Electricity Holding Company (EEHC), and in co-ordination with the Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA), NREA, Hydro Power Plants Executive Authority, Nuclear Power Plant Authority and Atomic Power Plants Authority.

2.2 Energy resources

Egypt's fossil fuel energy resource endowments (including oil, natural gas and negligible amounts of low-quality coal) are limited. As of end-2014, total proven reserves of petroleum energy (crude oil and natural gases) stood at about 14.8 billion barrels (bbl) of oil equivalent, of which 3.4 billion bbl were in the form of crude oil and about 11.4 billion as natural gas (equivalent to 64 trillion cubic feet of natural gas) (BP, 2017a).

Despite dwindling fossil fuel resources, Egypt enjoys an abundance of renewable energy resources – solar, wind, biomass and hydro. Average daily sunshine totals about 9 to 11 hours per day, with solar direct radiation intensity of about 2 000–3 200 kilowatt hours per square metre (kWh/m^2) per year that can be utilised for both power generation and thermal applications. In addition, Egypt is endowed with vast wind resources, with average annual speeds reaching 8–10 metres per second (m/s) by the coast of the Red Sea and 6–8 m/s along the south-west Nile banks and in the south of the Western Desert, which can be utilised for electricity generation. More than 30 million tonnes of solid biomass waste are also produced annually from both agriculture and municipal resources. Despite an abundance of biomass, hydro, wind and solar renewable sources, the significant potential to harness energy from these sources remains untapped.

2.3 Energy supply and demand

Egypt's TPES mainly comprises (in order of utilisation) natural gas, oil, oil products and hydro, along with wind and solar (Figure 2). In 2014/15, natural gas accounted for 45% of TPES, with production of 36.23 million tonnes of oil equivalent (Mtoe); oil (including crude, liquefied natural gas [LNG] and feedstocks) accounted for 34% of TPES with a production of 27.09 Mtoe; and oil products, composed of liquefied petroleum gas (LPG) and kerosene for heating and cooking, diesel oil and gasoline for transport, accounted for 17% of TPES (IEA, 2017). To compensate for increased local demand, imports of oil and oil products, combined with decreased natural gas resources, saw a spike in their contribution to TPES. As regards electricity production, natural gas and dual-fuel plants accounted for 92% of the power produced in 2015. Natural gas is also consumed by the industrial, petroleum (enhanced oil recovery), residential, commercial and transport sectors. Hydroelectric power and renewables (including wind and solar photovoltaics), accounted for 7.5% and 1% of the electricity mix respectively, as represented in Figure 8.

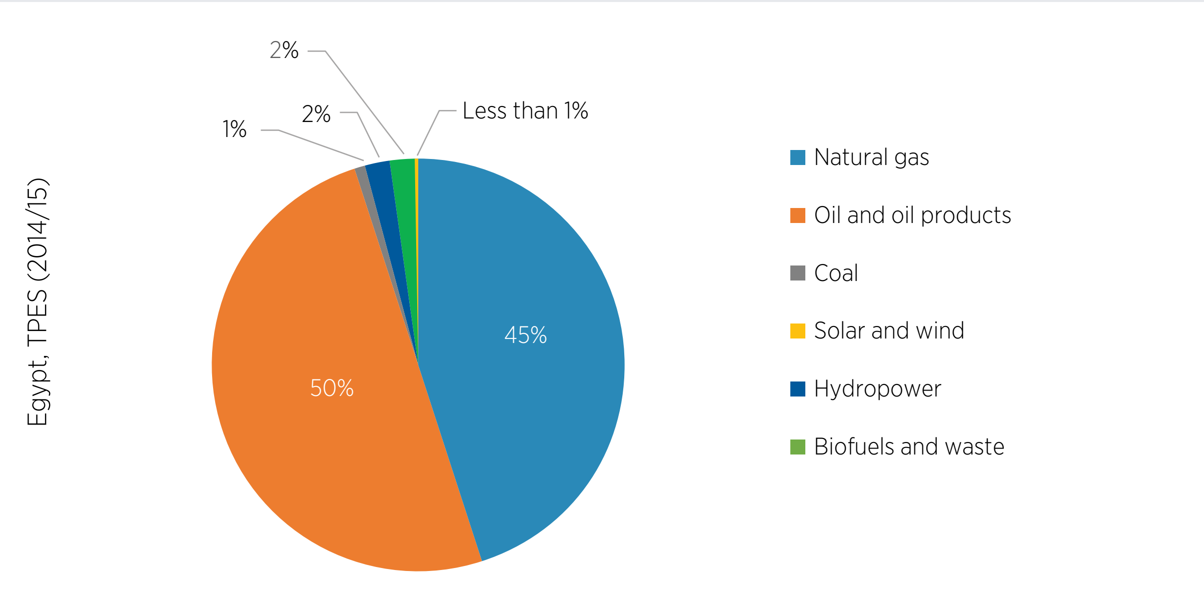
Due to insufficient production of crude oil and oil products, total petroleum imports have been rising, reaching 90.44 million bbl with a value of USD 11 billion in 2012/13, and USD 13.2 billion in 2014. Furthermore, the decline in natural gas production has triggered the country to import LNG since 2014 (BP, 2017b). The share of renewable energy in TFEC stands at 8.7%, including, hydro, solar and wind.

In the short term, the government has addressed the issue of depleting gas reserves and ensured a continuous gas supply through the lease of two floating storage regasification units to allow for LNG imports. This ensured the ability to secure sufficient power generation capacity fed by natural gas through a) the completion of a fast-track investment programme, which targets steam turbine and open-cycle gas turbine (OCGT) capacity, and b) the construction of 14.4 GW of combined-cycle gas turbine (CCGT) capacity, comprising three power plants of 4.8 GW capacity, expected completion by May 2018 (EEHC, 2016a).

The development of renewable energy in Egypt represents a major element in addressing the challenges it faces to secure adequate power production due to inconsistent levels of gas production, and in tackling significant increases in carbon dioxide (CO_2) emissions.

TFEC amounted to 51.86 Mtoe in 2014/15, with transport being the major consumer at 35%, followed by the industrial sector at 27%, residential and commercial at 24% and 7% respectively, non-energy use (mainly for fertiliser production) at 6%, agriculture at 3% and other sectors at 2% (UNStats, 2015).

Figure 2. Total primary energy supply in 2014/15



Based on: EU (2015a), "Integrated Sustainable Energy Strategy"; EU (2015b), "TIMES-EG Model Input and Analysis"; IEA (2017), IEA Energy Balances for 2015, Egypt.

2.4 Energy subsidies

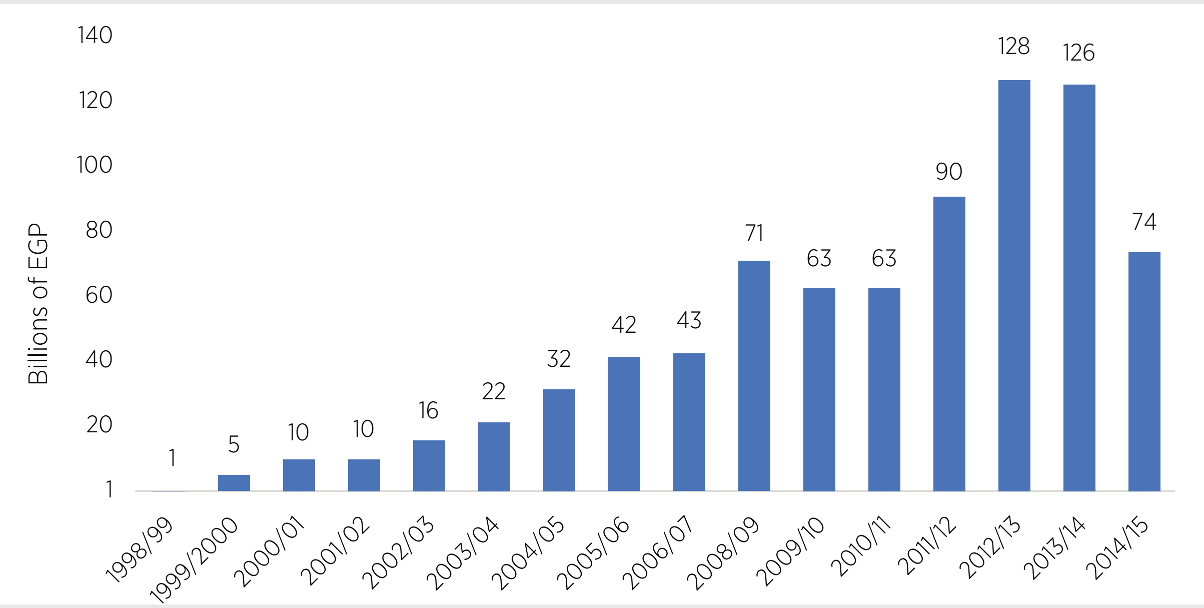
For decades, Egypt has relied on subsidised energy prices as an instrument for social protection and wealth sharing. This has led to a rapid increase in demand, with the subsidy bill increasing at a compound annual rate of 26% between 2002 and 2013. Energy subsidies for oil products and natural gas reached EGP 128 billion (about USD 20 billion) in 2012/13, as shown in Figure 3, with an additional EGP 27 billion (about USD 4.2 billion) for the electricity sector.

In 2013/14, energy subsidies (indirect, direct and cross-subsidies) accounted for 22% of the government budget and nearly 7% of GDP (MOERE, 2017), with electricity subsidies constituting 20% of the energy subsidy bill.

Energy subsidies fell to EGP 73.9 billion in 2014/15, as shown in Figure 3. The decline in oil prices (to USD 36 at the end of 2015 for Brent) reduced the fuel subsidy bill by some USD 10 billion in 2015 from a total recorded of USD 25 billion in 2013. However, declining resources and refining capacity posed a substantial budgetary burden on the government, contributing to the fiscal deficit in the energy sector, which rose from 1.3% in 2010/11 to 16.8% in 2013/14.

To tackle declining resource capacity, in 2014 the Egyptian government decided to launch exploration campaigns through partnerships between the national oil company and international oil companies (IOCs) to advance Egyptian natural gas production, thus reducing reliance on imports. The produced fuel was sold to the state-owned electricity distributor or private distributors without taking into account fluctuations in international prices, along with the devaluation of the currency. Egypt's objective is to manage its energy deficit through increased domestic production, as a substitute for expensive imports. Considering the heavy burden of fuel subsidies on the government, in 2014 the country announced gradual energy subsidy reform for gasoline, diesel and natural gas with a subsidy phase-out for electricity by 2019. A target of reducing subsidies to EGP 4 billion was set for 2017, from EGP 30 billion in 2016 (Ahram Online, 2016), and a phase-out of all energy subsidies five years later, which is elaborated on in further detail in Chapter 2.

Figure 3. Energy subsidies 1998/99–2014/15



Based on: EgyptERA (2016a), Issuance of Electricity Law No. 87 of 2015; EU (2015a), "Integrated Sustainable Energy Strategy"; EU (2015b), "TIMES-EG Model Input and Analysis".

2.5 Electricity sector governance

The Egyptian electricity sector is managed by the MOERE and overseen by the SEC. The sector is regulated by EgyptERA, which is responsible for implementing policy decisions, administering licences and, as of 2015, for setting tariffs with the adoption of the New Electricity Law No. 87 of 2015. The MOERE provided EgyptERA with the authority to set electricity tariffs, thus providing a solution to the heavy burden placed on the government (EgyptERA, 2015).

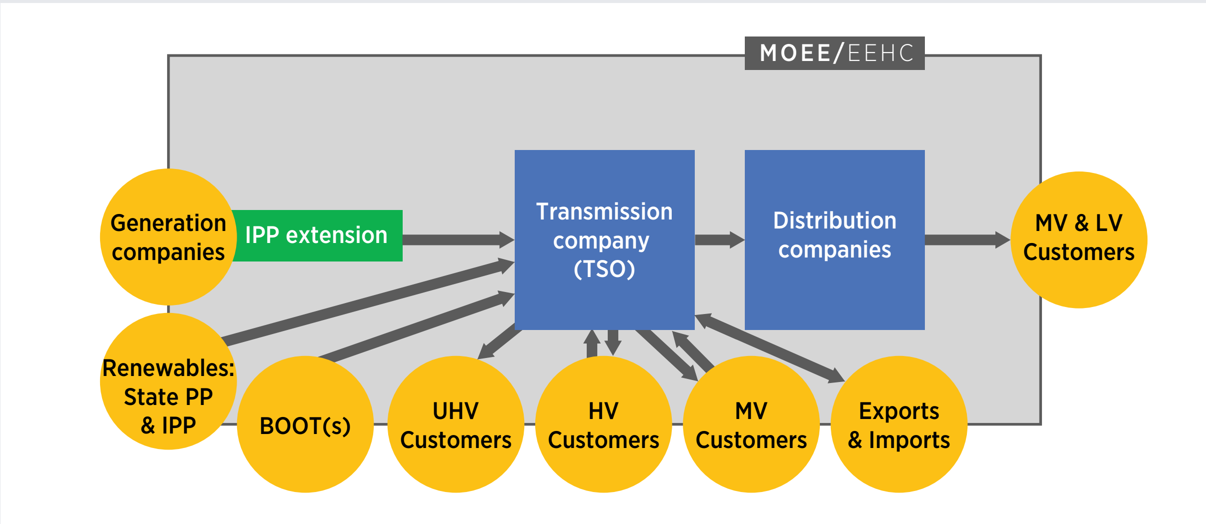
Historically, generation, transmission and distribution assets were fully state-owned and operated under the supervision of the Egyptian Electricity Authority (EEA), now known as the EEHC. The power generation sector began moving towards private-sector participation in the late 1990s,[5] although it did not become prevalent until 2001. As such, the unbundling of generation and transmission and distribution (T&D) was initiated by the EEHC. The EEHC owns 90% of Egypt's generation capacity (under six generating companies) and the entire state-owned T&D network (comprising one transmission and nine distribution companies), although EEHC's monopoly has begun to make way for limited competition from private distribution companies. Each public generation and distribution subsidiary under the EEHC umbrella is established as a separate corporate entity with its own board (EU, 2015b).

The introduction of the New Electricity Law No. 87 of 2015 (EgyptERA, 2016a) ended the monopoly on T&D to create a new competitive power market based on bilateral contracts. However, private participation is so far on a limited scale, accounting for only 10% of total power generation, with power input generated from non-renewable sources.

The NREA is the state agency responsible for developing renewable energy. While the NREA functions independently from the EEHC and other state-owned electricity companies, it nonetheless reports to both the MOERE and EgyptERA.

Figure 4 provides further elaboration on the electricity sector governance described above.

Figure 4. Electricity sector governance in Egypt



Notes: BOOT = build-own-operate-transfer; HV = high-voltage; IPP = independent power producer; LV = low-voltage; MV = medium-voltage; PP = power producers; TSO = transmission system operator; UHV = ultra-high-voltage.

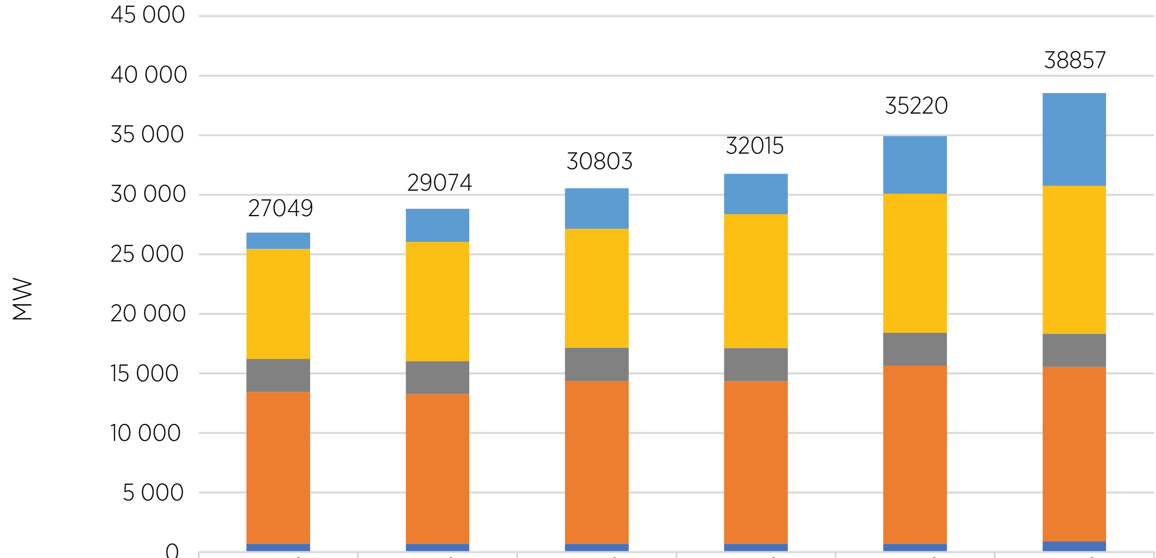
Sources: Mohamed Salah El Sobki (Jr) (2017), "Integration of Renewable Energy into the Egyptian Electricity Grid"; EEHC (2016a), Egyptian Electricity Holding Company Annual Report.

5 For further information see: www.medreg-regulators.org/Portals/45/capacitybuilding/2nd/2nd_Capacity_Building_Session1_EGYPTERA.pdf.

2.6 Power generation capacity

Total installed electricity generation capacity in the year 2015/16 amounted to 38 857 megawatts (MW) (EEHC, 2016a), comprising OCGT plants (7 845 MW), CCGT plants (12 527 MW), hydro (2 800 MW), steam power plants (14 798 MW) and non-hydro renewables (887 MW) as highlighted in Figure 5. The private sector contributed 2 048 MW through the BOOT scheme for thermal electricity generation capacity. Peak load was recorded at 29.2 GW in 2015/16 (Figure 6) (EEHC, 2016a).

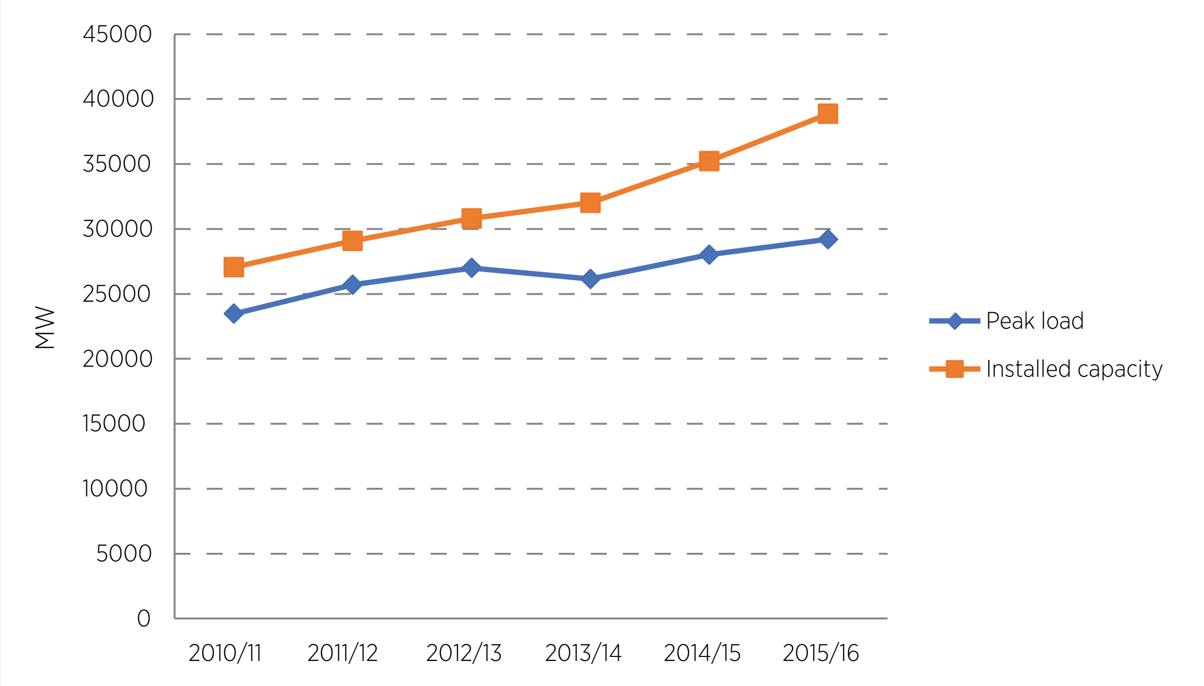
Figure 5. Installed capacity of power plants by plant type



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
OCGT	1376	2826	3428	3415	4874	7845
CCGT	9327	10077	10080	11330	11777	12527
Hydroelectric	2800	2800	2800	2800	2800	2800
Thermal steam	12859	12684	13808	13783	15082	14798
Non-hydro renewables	687	687	687	687	687	887
Total	**27049**	**29074**	**30803**	**32015**	**35220**	**38857**

Source: EU (2015a), "Integrated Sustainable Energy Strategy".

Figure 6. Development of installed capacity and peak load



Note: Electricity shortages were not due to the lack of installed capacity, but due to insufficient supply of fuel to maintain continuous power generation.

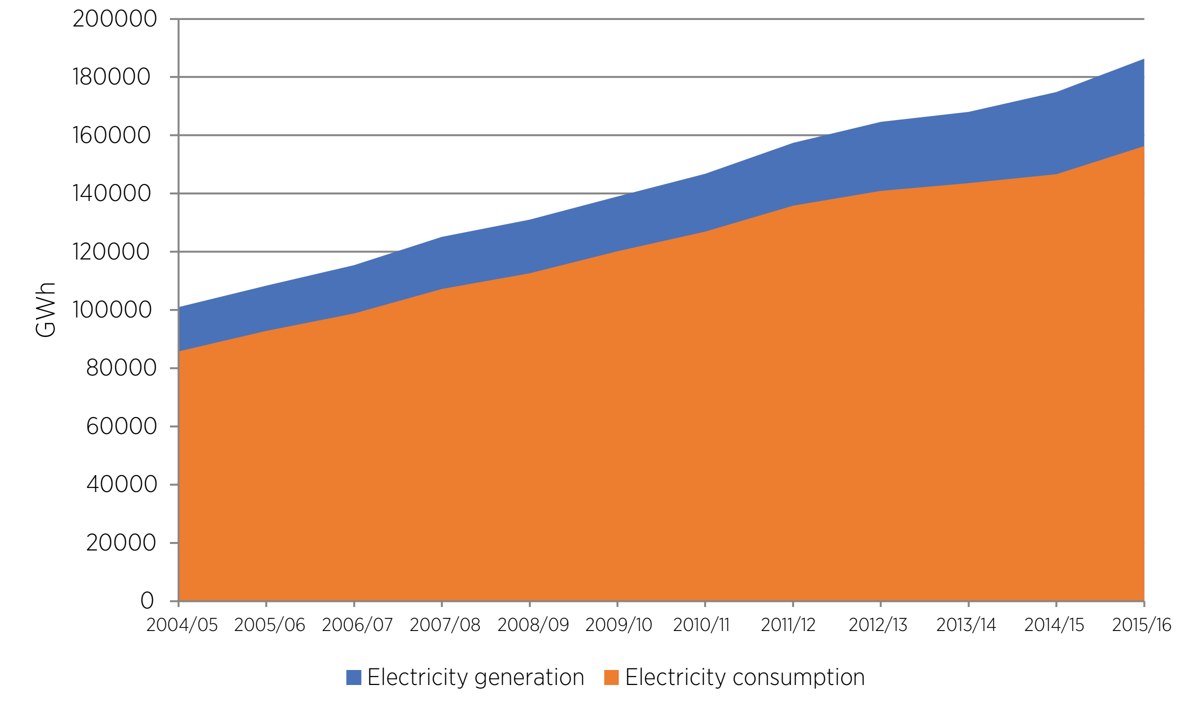
Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EEHC (2015), Egyptian Electricity Holding Company Annual Report 2014/15.

Egypt's power demand has grown consistently over the past decade, recording an annual growth rate of 6%. In 2016, the peak load demand was close to installed capacity (MOERE, 2017).

In 2014, the MOERE initiated plans to add 51.3 GW of conventional and renewable sources to respond to the growing power needs, based on an estimated annual requirement for new capacity of approximately (though not consistently) 2.5 GW per year, as illustrated in Figure 7.

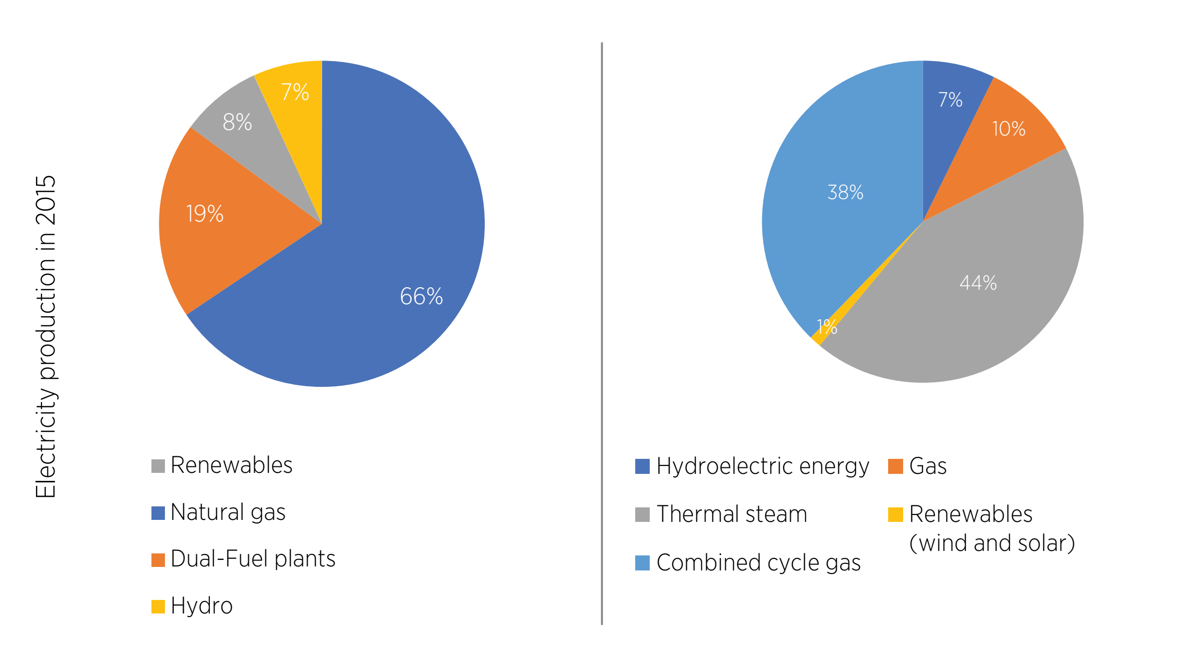
Given the increase in installed capacity, total electricity generation in 2015/16 amounted to 186 320 gigawatt hours (GWh), whereas total electricity consumption was 156 300 GWh in 2015/16, resulting in sufficient reserves of over 16.11% to meet electricity demand surges.

Figure 7. Evolution of electricity generation and consumption from 2004/05 to 2015/16



Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EEHC (2015), Egyptian Electricity Holding Company Annual Report 2014/15.

Figure 8. Electricity generation and sources in 2015

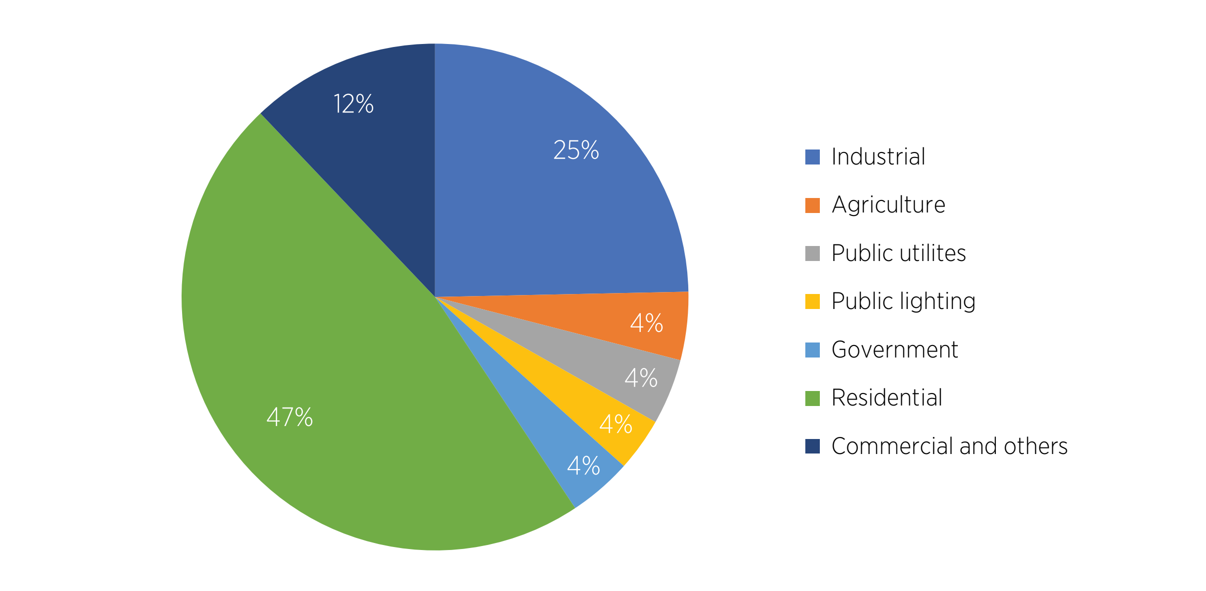


Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EEHC (2015), Egyptian Electricity Holding Company Annual Report 2014/15. IEA Energy Balances for 2015, Egypt.

Electricity is consumed by different end users in the economy, divided between residential (47%), industrial (25%) and commercial (12%), with the remainder used by government, agriculture, public lighting and public utilities (4%), as shown in Figure 9.

Egypt's power demand has grown steadily

Figure 9. Electricity consumption by sector



Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EEHC (2015), Egyptian Electricity Holding Company Annual Report 2014/15.

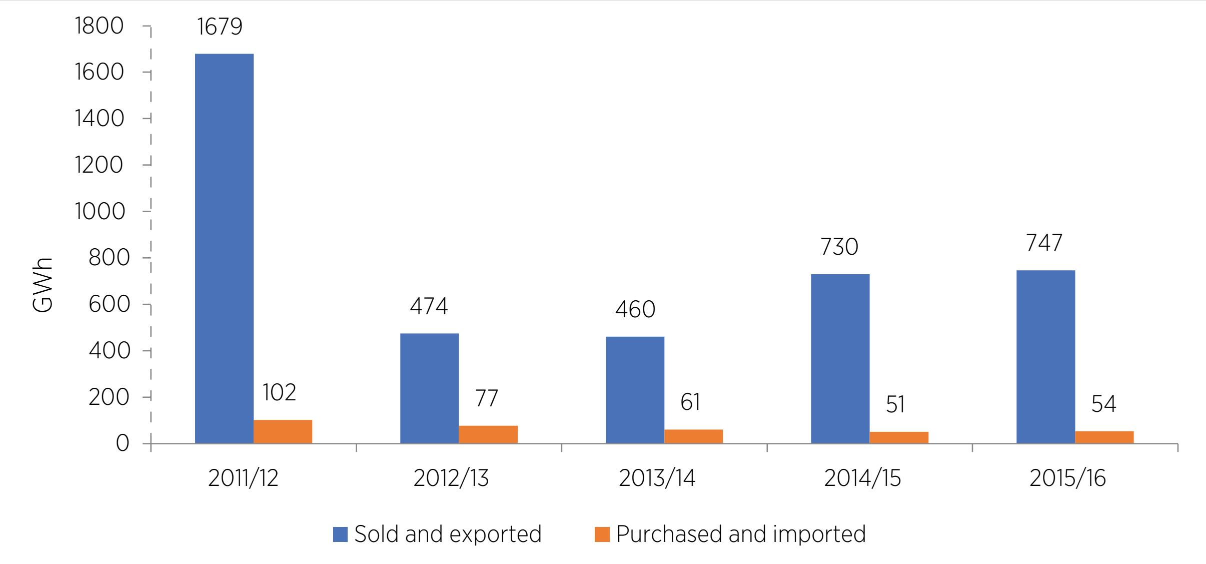
2.7 Transmission and distribution

Egypt's transmission network consists of overhead transmission lines and underground cables, with a total length of 44 200 kilometres (km) and a total transformer capacity of 99 600 megavolt amperes (MVA). Moreover, Egypt has electricity interconnection lines with its neighbours Jordan and Libya, as shown in Figure 10, indicating the electricity exchange from year 2011/12 to 2015/16 (EEHC, 2016a).

Egypt's distribution network constitutes 460 897 km of low-voltage and medium-voltage lines and cables with a total transformer capacity of 71 103 MVA (EEHC, 2016a).

The number of customers served by the affiliated T&D companies on all voltages reached 32.4 million in 2015/16 compared with 31.4 million in 2014/15, a rate of increase of 3.2% (EEHC, 2016a).

Figure 10. Total electric energy exchange from 2011/12 to 2015/16



Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EEHC (2015), Egyptian Electricity Holding Company Annual Report 2014/15.

According to the New Electricity Law No. 87 of 2015, the grid will operate under two market schemes, the regulated and the competitive, such that the transmission company, the Egyptian Electricity Transmission Company (EETC), operates as a TSO in both markets but with distinct roles. Under the regulated market, EETC will purchase electricity from generators and sell to customers that are not eligible under the competitive market scheme, including customers at the LV and MV residential level. However, in the competitive market industrial HV and extra-high-voltage users will purchase electricity from generators directly (making up 16% of current consumption). In this market, generators will simply pay a wheeling fee to the TSO, i.e. EETC, as depicted in Figure 4.

Under the regulated market, distribution companies (comprising nine public and seven private companies) will sell directly to end users, purchasing electricity from EETC to distribute it to end users such as MV and LV customers. However, in the competitive market, the distribution companies will lose their role and be phased out of this network, as shown in Figure 4.

2.8 Costs and tariffs

The New Electricity Law No. 87 of 2015 indicates that electricity tariffs are to be set according to the cost of producing energy (or an energy service) and its associated variables including the cost of transmitting energy, the rate of inflation, a fuel coefficient and more recently the targets set by the subsidy reform. This is based on the calculation methodology set by EgyptERA (EgyptERA, 2016b).

The production cost of electricity in Egypt averaged USD 0.045 (EGP 0.855) per kilowatt hour (kWh) in 2017, up from USD 0.04 (EGP 0.64) per kWh in 2016,[6] and up from USD 0.03 (EGP 0.47) per kWh in 2014.[7]

In comparison to other countries in the region, electricity tariffs are considered to be low, if not one of the lowest. Using a brackets system, electricity tariffs in Egypt vary according to feeding voltage level and type of consumer group, amount of consumption and time of usage (peak/off-peak) periods. Residential tariffs are divided into seven blocks ranging from EGP 0.13[8] for the first block of monthly consumption up to 50 kWh, to EGP 1.35 for over 1 000 kWh of consumption, paid as a flat rate for the total consumption.

A five-year plan to phase out internal subsidies in the electricity sector was officially endorsed as per the Prime Minister's Decree No. 1257 of 2014. Steps were taken in July 2014 to implement a comprehensive five-year subsidy reform initiative, which includes annual tariff increases for most user segments on 1 July each year until 2018. Annual tariff increases have been deemed necessary by the government to eliminate subsidies, the effects of which have been exacerbated by currency devaluation and financial obligations of the Ministry of Finance (MOF) to meet return deficits resulting from the low electricity sale revenues that the national oil company (Egyptian General Petroleum Corp.) is subject to in the grid. This situation, in turn, does not aid EEHC in covering its financial debt to IOCs that have set up exploration sites to support the domestic production of fossil fuels; therefore, the MOF must also compensate for this balance of debt (for example EGP 0.75 billion for grid capacity expansion and maintenance and IOC debts).

While the annual tariff increase has allowed the government to save EGP 18 billion from the electricity subsidy bill, the government has recently extended the subsidy to 2022. The plan was subject to two revisions in July 2015 and 2016 to ensure the protection of low-income consumers, while compensating for the accelerated increase in the sector 's expenditure on new plants, taking into account the changes in the USD exchange rate (ENFRWC, 2017).

6 According to exchange rate of 16 EGP/USD.

7 According to exchange rate of 15.6 EGP/USD.

8 Exchange rates vary, as follows: 7.6 EGP/USD (2014-2015); 8 EGP/USD (2015-2016); 9 EGP/USD (2016-2017); 18.15 EGP/USD (2017-2018), 17.9 EGP/USD (2018-2019).

Figure 11. Residential electricity tariff (0—100 kWh)

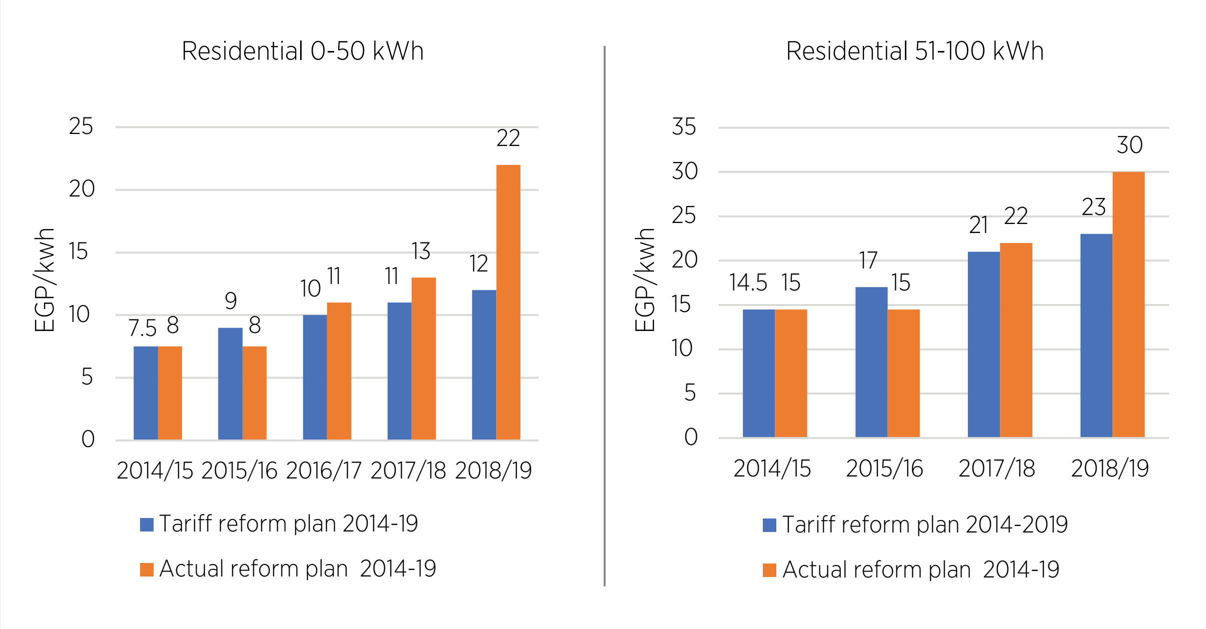


Figure 12. Residential electricity tariff (101—1000 kWh)

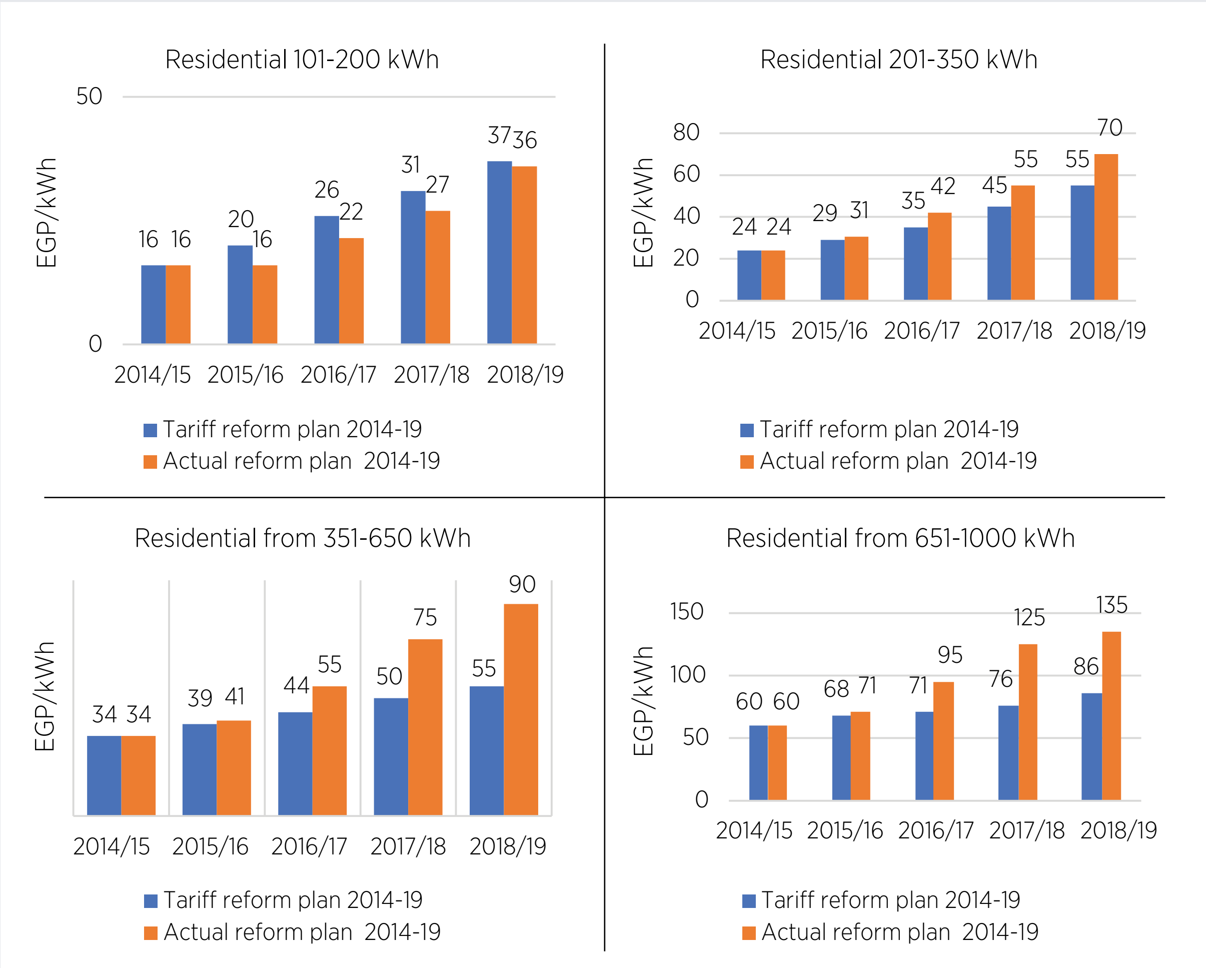


Figure 13. Residential electricity tariff (>1 000 kWh)

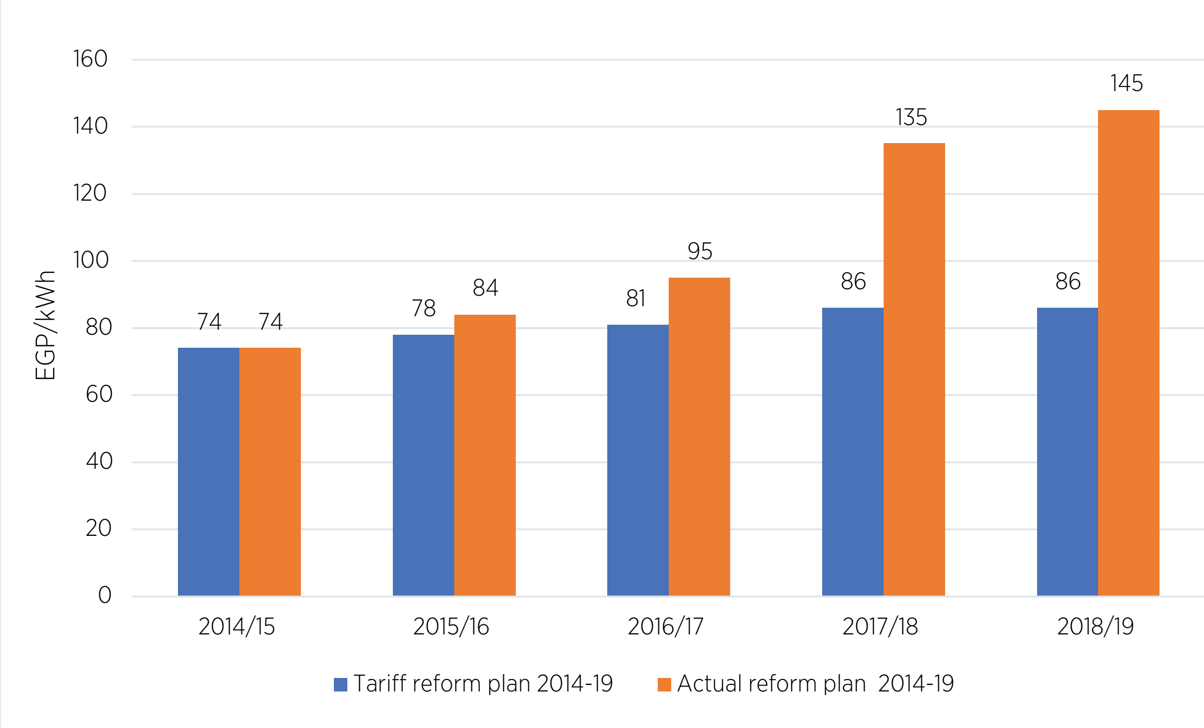
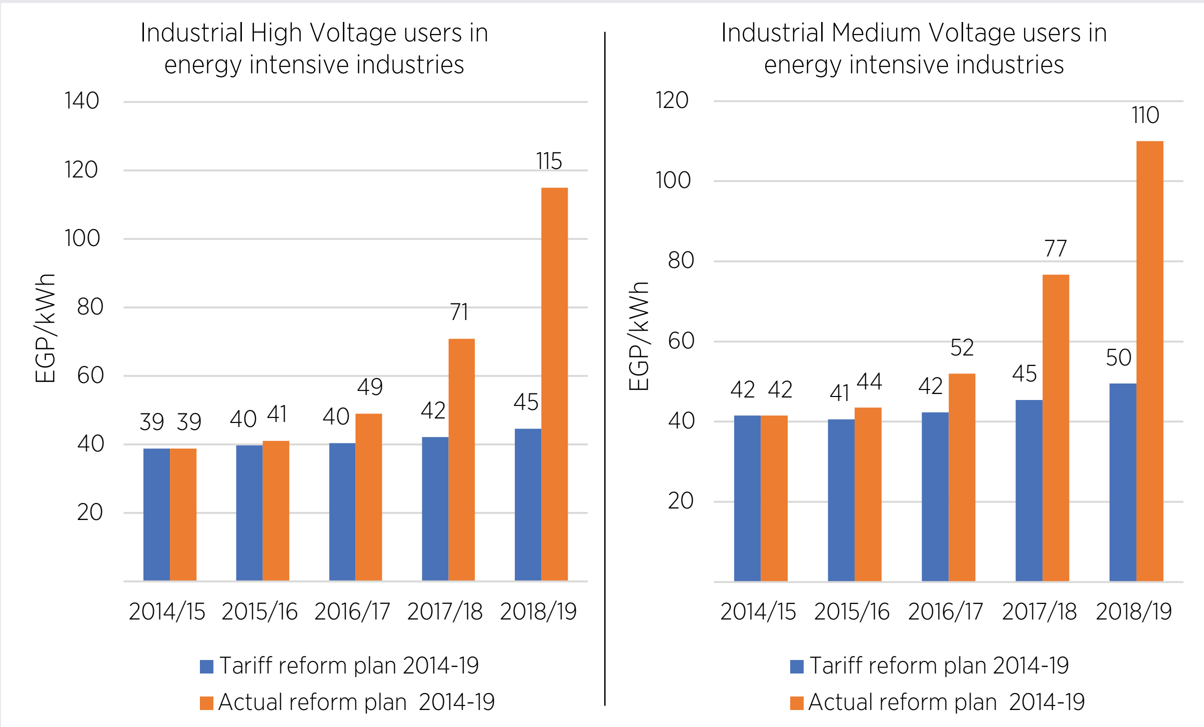


Figure 14. Industrial electricity tariff for energy-intensive HV and MV users



2.9 Electricity interconnection and trade

Since the late 1980s, the Egyptian government has devoted efforts to identifying and implementing several electricity grid interconnection projects in co-operation with other countries of the Arab region to enhance the sector's reliability and allow for the exchange of generated electricity at the sub-regional level. Feasibility studies were performed to evaluate the interconnection potential with sub-Saharan African countries and in co operation with European countries through several EU funded projects.

Interconnection projects in the Arab region have connected Egypt to Iraq, Jordan, Lebanon, the Syrian Arab Republic, and Turkey as shown in Table 2. The first phase of these interconnection projects used 400 kilovolt (kV) lines to link Egypt, Jordan, Lebanon and the Syrian Arab Republic. This was completed and became operational in the mid-1990s. The second phase was delayed due to regional political instability.

The Arab-Maghreb interconnection linked Egypt to Libya as of 1998 through a 220 kV power line that will be integrated further with Morocco and Tunisia through a 400/500 kV line to be completed by the end of 2018.

An Egypt-Saudi Arabia interconnection is expected to be operational by 2021, with an exchange capacity of 3 000 MW (Ahram Online, 2017). The Arab League adopted a resolution in September 2016 to support actions for the establishment of Pan-Arab Electricity Market Integration to create a common electricity market in the region (LAS and RCREEE, 2016).

Several steps have been taken to explore the possibility of building interconnections with countries in sub-Saharan Africa. A study was completed on the feasibility of interconnections between Egypt, Ethiopia and Sudan to exchange 3 200 MW, of which 2 000 MW would be dedicated to Egypt. In parallel, a 200 MW project to connect Egypt and Sudan is ongoing. Other efforts are being explored to evaluate the potential of forming interconnections with the Democratic Republic of the Congo (LAS and RCREEE, 2016).

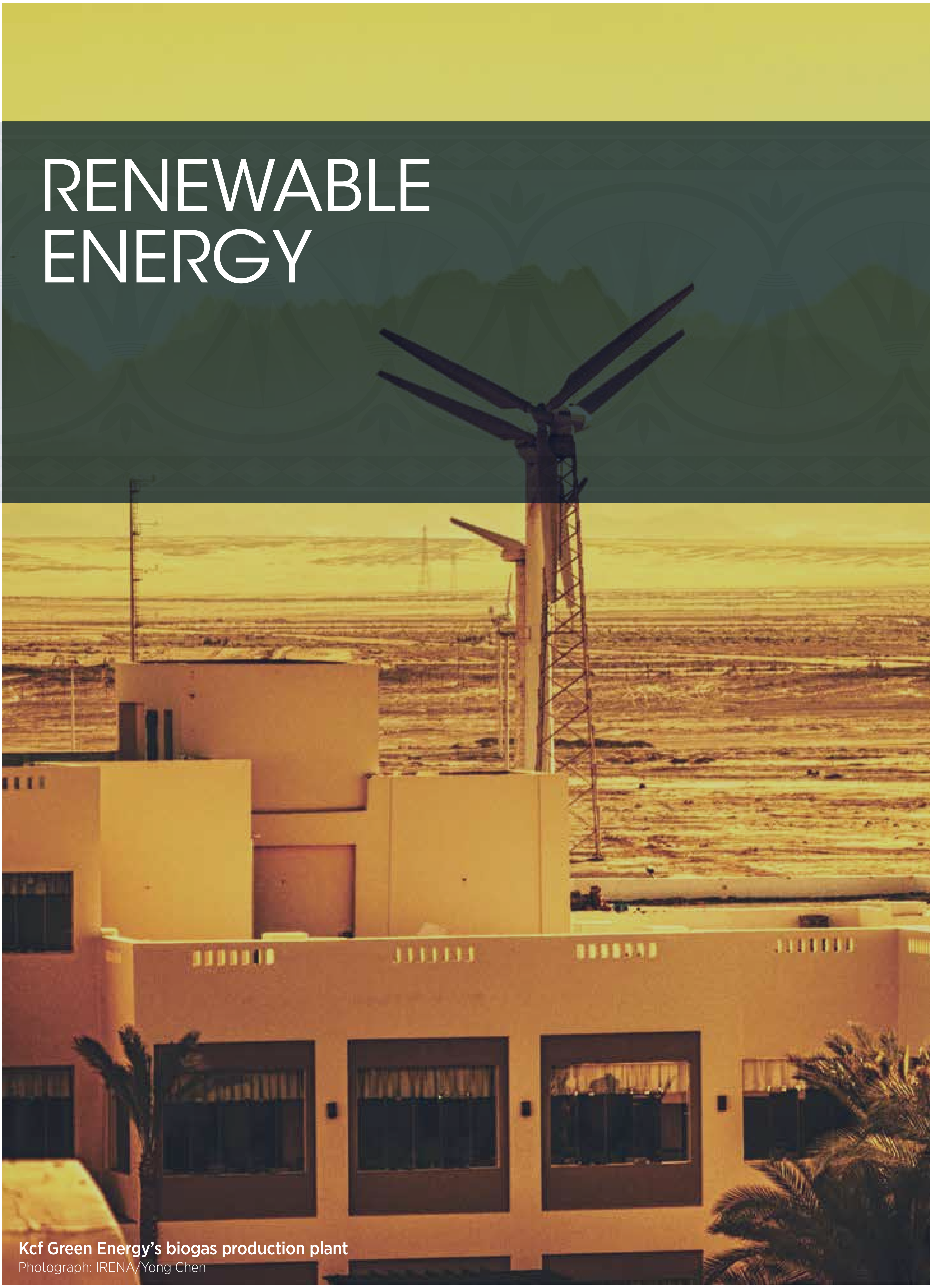
Egypt continues to work with the European Union to evaluate feasible options to facilitate future exchange of electrical power across the Mediterranean, particularly from renewable energy sources, through possible interconnections between Tunisia and Italy, and potentially between Egypt, Cyprus and Greece. The prospective interconnections would serve to transfer electricity generated from renewable energy sources to Europe (EEHC, 2016b).

Table 2. International electrical interconnections

<table>
<tr><th>Description</th><th>Egypt/Libya</th><th colspan="3">Egypt/Jordan</th></tr>
<tr><td>Interconnection date</td><td>May 1998</td><td colspan="3">October 1998</td></tr>
<tr><td>Interconnection voltage (kV)</td><td>220</td><td colspan="3">400</td></tr>
<tr><td>Interconnected countries</td><td>Libya</td><td>Jordan</td><td>Syrian Arab Republic</td><td>Lebanon</td></tr>
<tr><td>Sold and exported energy (GWh)</td><td>292</td><td>454.7</td><td>-</td><td>-</td></tr>
<tr><td>Purchased and imported energy (GWh)</td><td>15.98</td><td>37.8</td><td>-</td><td>-</td></tr>
</table>

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16.

RENEWABLE ENERGY



Kcf Green Energy's biogas production plant
Photograph: IRENA/Yong Chen

03

This chapter covers Egypt's available renewable energy resources, their current status and their future development potential. It also addresses the enabling environment and related regulatory framework for renewable energy.

Renewables can have a myriad of benefits: renewable energy technologies can often provide a secure and reliable energy alternative, while investment in local renewable energy infrastructure and services can create significant local added value through job creation and boosting local economic growth (IRENA, 2017c). Moreover, power provided by renewables would free up depleting hydrocarbon reserves, reducing distortion of the energy markets by alleviating the heavy burden subsidies place on government finance and investment.

Egypt enjoys an abundance of renewable energy resources with high deployment potential. These are mainly hydro, wind, solar and biomass. Since the late 1970s, the Egyptian government has initiated programmes for demonstrating, testing and evaluating different renewable energy applications and technology systems in co-operation with various countries and international entities, including France, Germany, Italy, Spain, Denmark, Japan, the European Union and the United States. The co operation between these entities translated into the installation of solar water heaters (SWHs) in new cities, solar industrial process heat systems (SIPHS), wind farms and photovoltaic (PV) applications in water pumping, cold stores and desalination plants, as well as biogas digesters in rural areas.

The establishment of the NREA in 1986 (through Law No. 102 of the year 1986) was an important milestone in efforts to develop renewable energy sources in Egypt. The NREA focuses particularly on wind and solar technologies and has recently expanded its focus to include biomass development. Other national institutions have also devoted efforts to biomass development, among them the EEHC and the Ministry of Environment.

3.1 Renewable energy contribution to primary energy production

The contribution of renewable energy resources to primary energy production stood at 4% in 2009/10, mainly from hydro (3%) and wind (1%). Their contribution is expected to reach a total of 8% by 2021/22 and 14% in 2034/35, corresponding to 22.8 Mtoe in that year. On the basis of those contributions, renewable energy is expected to make up 20% and 42% of electricity generation in 2021/22 and 2034/35, respectively (EU, 2015a). The average growth rate for renewable energy in primary energy supply reaches 7.3%, as depicted in Figure 19.

3.2 Renewable energy contribution to installed power capacity

The total installed capacity of renewable energy sources is expected to reach 19.2 GW by 2021/22 and increase to 49.5 GW and 62.6 GW in years 2029/30 and 2034/35 respectively. Table 3 shows the development of installed electric capacity for the different renewable technologies from 2009 to 2035 (EU, 2015a). The MOERE and the Ministry of Investment and International Cooperation have recently modified the long-term energy strategy, maximising the contribution of renewable energy in the capacity mix to 42% in 2035, alongside maximising energy efficiency measures. The subsections that follow address the different sources of renewable energy technologies deployed in Egypt.

3.3 Renewable energy potential and use

Hydroelectric energy

The main hydro resource in Egypt is the River Nile, with the highest potential in Aswan where a series of power stations are located totalling 2 800 MW, with corresponding electric generation of 13 545 GWh annually. Hydroelectricity represented almost 50% of the Egypt's total generated electricity in the 1960s and 1970s. However, due to the increase in the share of thermal power stations, electricity from hydro resources represented only 7.2% of the total electricity generated in 2015/16 (EEHC, 2016a).

Hydropower is the most mature of the renewable energy technologies in Egypt, with an average rate of growth in energy generated from hydropower plants of 1.2% per year during the period 2011/12 to 2015/16. In this context, several projects have been realised and the breakdown of hydroelectric stations in 2015 is depicted in Table 4.

Table 3. Evolution of installed renewable energy power capacity in GW

Type of power station	2009/10	2021/22	2029/30	2034/35
Hydro	2.8	2.8	2.9	2.9
Wind	0.5	13.3	20.6	20.6
PV	0.0	3.0	22.9	31.75
CSP	0.0	0.1	4.1	8.1
Total	**3.3**	**19.2**	**50.5**	**62.6**

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; Eversheds and PricewaterhouseCoopers (2016), Developing Renewable Energy Projects: A Guide to Achieving Success in the Middle East, Fourth Edition.

Table 4. Hydroelectric stations and their capacity

Station	Capacity (MW)	Annual generated electricity (GWh)
High dam	2 100	9 484
Aswan 1	280	1 578
Aswan 2	270	1 523
Esna	86	507
Naga Hamady	64	453
Total	**2 800**	**13 545**

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; Eversheds and PricewaterhouseCoopers (2016), Developing Renewable Energy Projects: A Guide to Achieving Success in the Middle East, Fourth Edition.

An additional four hydroelectric plants are being developed at Assiut in Upper Egypt with a capacity of 32 MW, and are due to become operational by late 2018.

In 2015, plans to build a 2 400 MW pumped storage hydroelectric plant in Attaqa were initiated, due for completion in 2022 (Andritz, 2016). This project is due to operate at peak hours, based on water flowing from an upper to a lower reservoir with a 28-metre height difference. In the off-peak period, the flow is reversed and the upper reservoir will refill normally by using the turbines as pumps and the generators as motors.

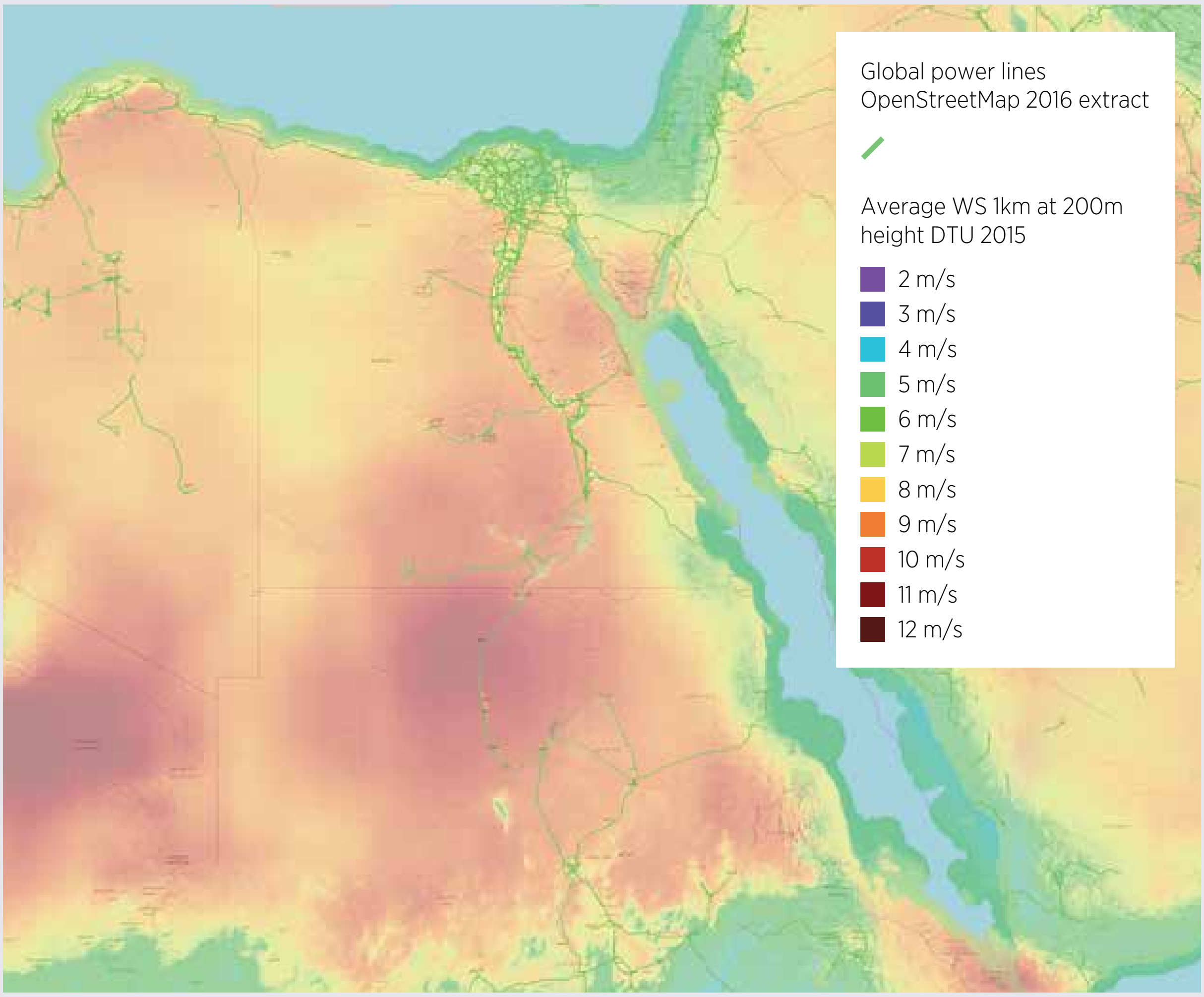
The electricity needed to operate the motor generators is produced by surplus power capacity available during off-peak periods. A conditional contract was signed with Sanyo in China for building the plant subject to the acceptance of the technical and financial offers by the MOERE and EEHC. The project is expected to start operation in late 2022.

Wind energy

According to Egypt's Wind Atlas (Wind Atlas for Egypt Measurement and Modelling 1991-2005), the country is endowed with abundant wind energy resources, particularly in the Gulf of Suez area. This is one of the best locations in the world for harnessing wind energy due to its high stable wind speeds that reach on average between 8 and 10 m/s at a height of 100 metres, along with the availability of large uninhabited desert areas.

Moreover, promising new regions have been discovered east and west of the Nile river in the Beni Suef and Menya Governorates and El Kharga Oasis in the New Valley Governorate. They offer wind speeds that vary between 5 and 8 m/s and are suitable for electricity generation from wind and other applications such as water pumping. Figure 15 presents the new wind atlas published in 2016 on IRENA's *Global Atlas* platform, measured at a resolution of 1 km and a height of 200 metres.

Figure 15. Egypt's wind atlas



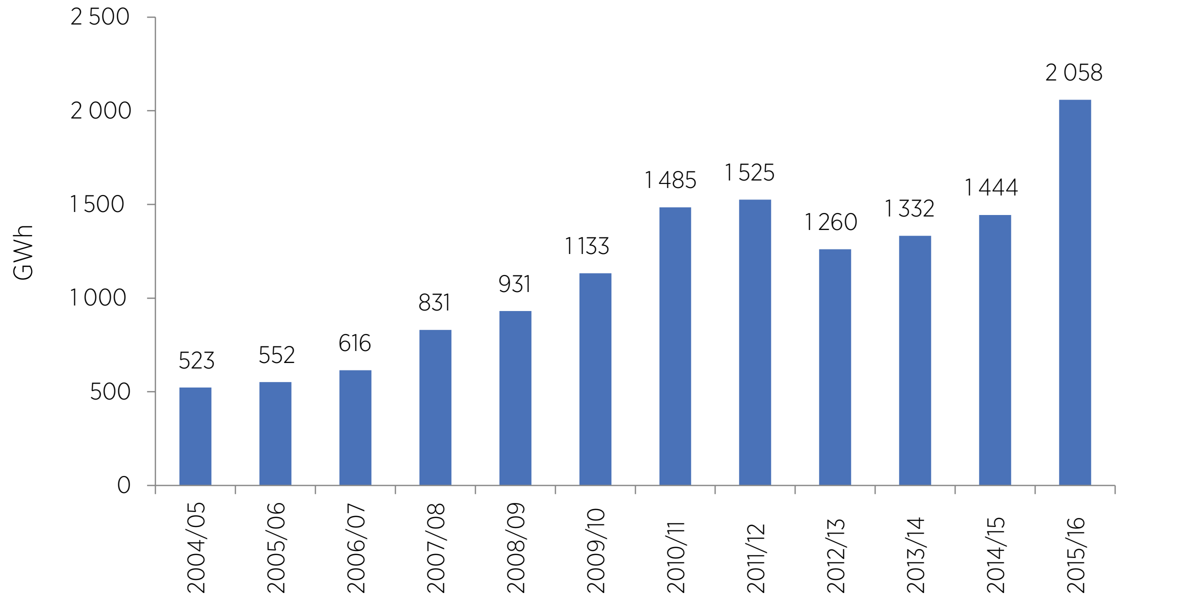
IRENA (n.d.) *Global Atlas for Renewable Energy*, DTU Global Wind Dataset 1 km onshore wind speed at 200 metres height.

Disclaimer: The designations employed and the material presented in this map do not imply any opinion on the part of IRENA concerning the legal status of any region, country, territory or area, or concerning the delimitation of frontiers or boundaries.

The first wind farm in Egypt was established in Hurghada in 1993 with 42 units of differing technologies and a total capacity of 5.2 MW. Since 2001, the NREA, in co-operation with Germany, Spain, Japan and Denmark, has established a series of large-scale wind farms that totalled 545 MW in 2010/11, increased to 750 MW in November 2015, under an engineering, procurement and construction (EPC) scheme in both Zaafarana (545 MW) and Gulf of El Zayt (200 MW).

This installed capacity corresponded to total wind-generated electricity ranging from 260 GWh in 2001/02 to 2 058 GWh in 2015/16. Accordingly, total conventional fuel savings as a result of utilising wind energy for electricity generation increased from 58 Mtoe in 2001/02 to 432 Mtoe in 2015/16. Consequently, the avoided CO_2 emissions are estimated at 143 000 tonnes in 2001/02 and 1.131 million tonnes in 2015/16 (EEHC, 2016a). In this context, Figure 16 provides further detail on the evolution of wind-generated electricity in Egypt in the past 10 years.

Figure 16. Wind-generated electricity from 2004/05 to 2015/16



Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16;
EU (2015a), "Integrated Sustainable Energy Strategy".

Four wind power plants, with a total installed capacity of 2 610 MW, are planned to be installed and operational by year 2023. They are being developed co-operatively between the NREA and EETC, and will be constructed by international and Egyptian private-sector entities through either build-own-operate (BOO) or EPC schemes. In addition, 2 000 MW capacity of wind energy projects are being progressed by Siemens under an EPC and finance scheme; it includes the creation of a manufacturing facility for the necessary blades, according to a memorandum of understanding signed between the NREA and Siemens in April 2015. Further details on the planned wind projects up to 2023 are highlighted in Table 5.

Table 5. Planned wind projects up to 2023

Project	Technology	Status	Size	Contract
Gulf of Suez	Wind	Under development	250 MW	NREA-KfW, EIB, AFD EPC scheme
Gulf of Suez	Wind	Under development	250 MW	GDF Suez, Toyota, Orascom BOO scheme
Gulf of Suez	Wind	Under development	200 MW	NREA-Masdar EPC scheme
Gulf of Suez	Wind	Under development	200 MW	AFD-KfW EPC scheme
Gulf of Suez	Wind	Under development	2 000 MW	Siemens EPC scheme
Gabal El Zayt	Wind	Under construction	220 MW	NREA-Japan-JICA EPC scheme
Gulf El Zayt	Wind	Under construction	320 MW	Italgen BOO scheme
Gabal El Zayt	Wind	Under construction	120 MW	Spain-NREA
West Nile-1	Wind	Under development	250 MW	BOO scheme
West Nile	Wind	Under development	200 MW	Japan EPC scheme
West Nile	Wind	Tender-bidding Phase	600 MW	NREA IPP scheme

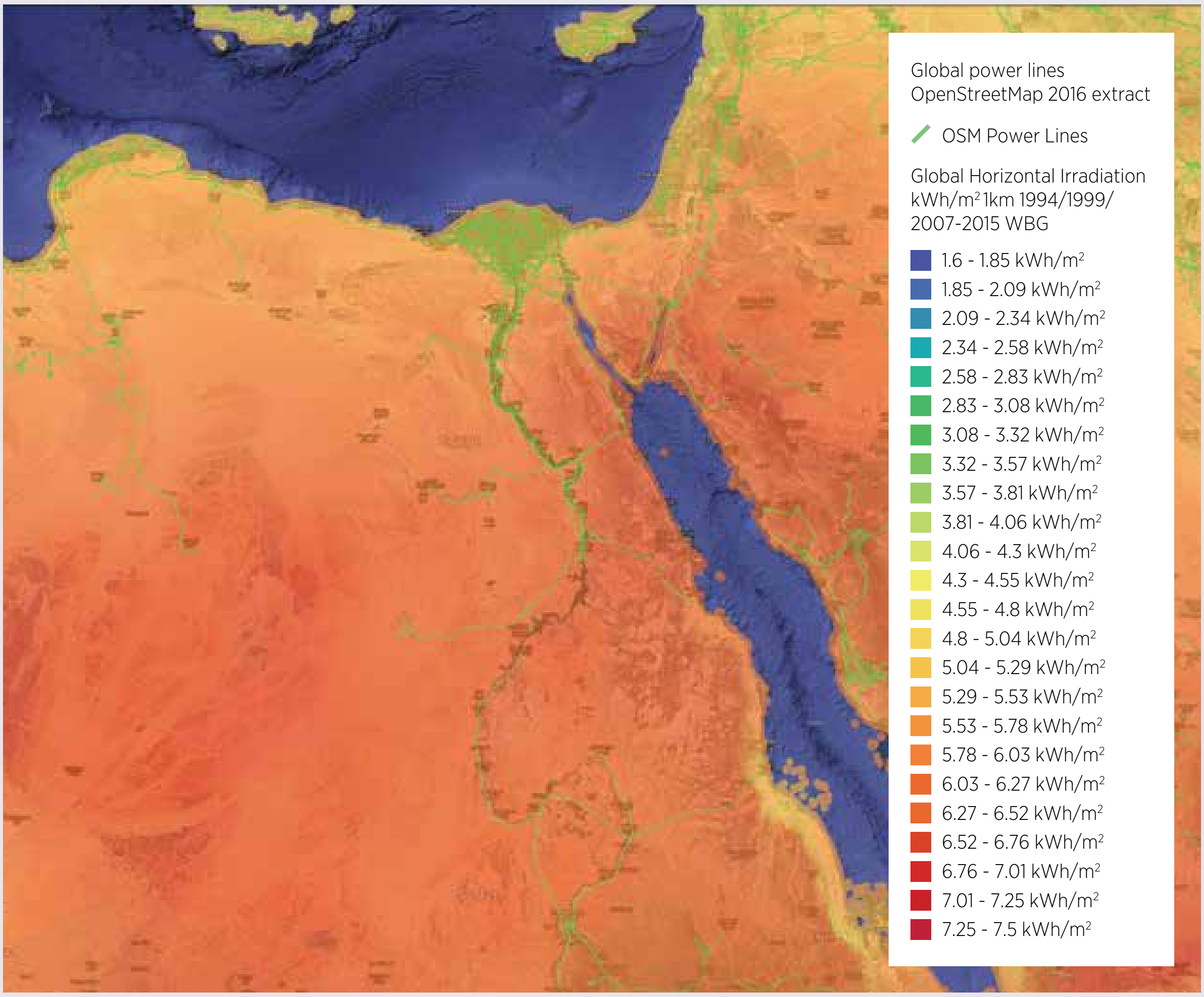
Notes: AFD = Agence Française de Développement; EIB = European Investment Bank; JICA = Japan International Cooperation Agency.
Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; Eversheds and PricewaterhouseCoopers (2016), Developing Renewable Energy Projects: A Guide to Achieving Success in the Middle East, Fourth Edition; MOERE (2017), Full Scale Program for Renewable Energy in Egypt.

Solar energy

Egypt enjoys favourable solar radiation intensity. In 1991, the solar atlas for Egypt was issued indicating that the country enjoys between 2 900 and 3 200 hours of sunshine annually, with annual direct normal intensity of 1 970-3 200 kWh/m^2 and a total radiation intensity varying between 2 000 and 3 200 kWh/m^2/year from the north to the south of Egypt, as presented in Figure 17.

IRENA's *Global Atlas* platform combines recent irradiation potential and includes a new solar atlas released in 2016, thus reiterating Egypt's high solar potential. On a global scale, Egypt is one of the most appropriate regions for exploiting solar energy both for electricity generation and thermal heating applications.

Figure 17. Egypt's Solar Atlas



Source: IRENA (n.d.), *Global Atlas for Renewable Energy* (www.irena.org/GlobalAtlas), World Bank ESMAP Global Solar Dataset 1 km Global Horizontal Irradiation (GHI).

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Since the early 1980s, solar PV systems have been demonstrated in Egypt for different applications, including pumping, lighting, advertising, cold storage and desalination. The technology was used for commercial applications in remote areas, particularly for emergency road and navigation lighting.

The total installed capacity of small-scale PV systems amounted to 6 MW in 2013, while a cumulative 30 MW of off-grid power plants had been installed and operational by the end of 2016. The MOERE started to develop larger-capacity PV systems, particularly after the adoption of the feed-in tariff (FIT) scheme in 2014. With the amplification of the electricity shortage in Egypt in 2014, coupled with the reduction in the cost of PV panels, several other Egyptian authorities have directed efforts towards adopting PV applications, particularly rooftop systems and street lighting. The section that follows summarises current key achievements in Egypt in that regard (IETA, 2017).

Centralised grid-connected solar PV

The NREA has finalised feasibility studies for two large-scale PV plants with an installed capacity of 20 MW and 26 MW, respectively, to be constructed in Hurghada and Kom Ombo, and expected to be realised late in 2019. The first is to be financed by JICA (Japan) and the second by AFD (France). They are each expected to produce about 32 GWh and 42 GWh annually respectively, saving about 40 000 tonnes of CO_2 combined. Further details on planned grid-connected projects are listed in Table 6.

Table 6. Planned PV projects up to 2023

Project	Type	Status	Size	Contract
Kom Ombo	PV	Binding	200 MW	BOO scheme
West Nile	PV	Binding	600 MW	Sky Power and EETC BOO
West Nile	PV	Binding	200 MW	EETC BOO
West Nile	PV	Binding	600 MW	BOO scheme
FIT	PV	Operational	50 MW	EETC PPA
FIT	PV	Under development	1 415 MW	EETC PPA
Hurghada	PV	Tendering	20 MW	NREA-JICA EPC scheme
Zaafarana	PV	Under development	50 MW	NREA-AFD EPC scheme
Kom Ombo	PV	Under development	26 MW	NREA-AFD EPC scheme
Kom Ombo	PV	Under development	50 MW	NREA-AFD EPC scheme

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; Eversheds and PricewaterhouseCoopers (2016), Developing Renewable Energy Projects: A Guide to Achieving Success in the Middle East, Fourth Edition; EU (2015a), "Integrated Sustainable Energy Strategy"; Meza, E. (2015), "Solar opportunities on the rise in Egypt"; MOERE (2017), Full Scale Program for Renewable Energy in Egypt.

Note: BOO = build, own, operate; EETC = Egyptian Electricity Transmission Co.; PPA = power purchase agreement; NREA = New and Renewable Energy Authority (Egypt); JICA = Japan International Cooperation Agency; EPC = engineering, procurement and construction; AFD = French Development Agency (Agence Française de Développement).

Distributed solar PV

Installation of on-grid distributed PV systems only began in mid-2014 through two government initiatives for rooftop PV systems on public buildings, under which about 3 MW of PV systems were installed and connected to the distribution network. This resulted in an increase of about 10 MW after the adoption of the first phase of the FIT.

In 2015/16 the NREA, in co-operation with the United Arab Emirates, implemented several off-grid PV projects for electrification of remote villages with a total capacity of 32 MW, including 6 942 stand-alone systems totalling 2 MW; eight centralised systems totalling about 30 MW; plus street lighting systems and hybrid PV-diesel systems.

Several initiatives for small-scale PV have been introduced to add to the total 6 MW installed up to 2013. Distributed solar PV technologies are developing quite rapidly with many projects in the pipeline. As electricity subsidies are removed and tariffs go up, the industrial and commercial sectors can couple small-scale PV systems to meet heightened energy demand and decrease their utility bills. Various small-scale PV projects are detailed in Table 7.

Table 7. Small-scale PV distributed Initiatives

Small-scale PV distributed initiative	Description
CoM Initiative	• Initiated in December 2013. • Mandates all government entities to implement rooftop PV systems with a total installed capacity of 20-30 MW (for 1 000 government buildings). • Under the framework of this initiative, the EEHC and affiliated subsidiaries have implemented 30 solar PV systems with a total capacity of 840 kW at a capital cost of EGP 8.2 million.
FIT Programme	• 300 MW of small-scale rooftop installations through the FIT were targeted in 2014, initially with the aim of achieving this level within a two-year period. The programme was then extended in 2016 with revised tariffs.
Egypt-Sun Initiative	• Designed and implemented by the Central Energy Efficiency Unit at the CoM. • Promotes the installation of combined efficient lighting and PV systems in government buildings. • Provides technical assistance to staff in different governorates. • 52 projects in 14 governorates were implemented during the period March 2014 to June 2015. • Helped governorates displace more than 2 MW capacity, with PV representing one-third.
UAE Rural Electrification Initiative	• Supported PV projects with the objective of electrification through small-scale projects with a total capacity of 32 MW • Included 6 942 stand-alone systems totalling 2 MW in villages that had no electricity, and 8 centralised systems totalling 30 MW, as well as street lighting and several hybrid PV-diesel systems.

Notes: kW = kilowatt; CoM = Cabinet of Ministers.

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; MOERE (2017), Full Scale Program for Renewable Energy in Egypt.

Concentrated solar power

The first solar thermal integrated combined-cycle power plant was constructed in the Kuraymat area with a total capacity of 140 MW, including 20 MW as a solar component and 120 MW as a gas-fired combined-cycle plant, funded primarily by the Global Environment Facility. The total area of the integrated solar field is about 644 000 square metres (m^2), with a total solar collector area of 1 920 m^2 containing 53 760 mirrors.

The total electricity generated from the power plant was 164 GWh/year in 2015/16. Accordingly, the total annual reduction in conventional fuels as a result of utilising solar energy in the Kuraymat power plant is estimated at about 10 000 tonnes per year, and consequently avoided CO_2 emissions are estimated at about 20 000 tonnes.

In 2015, EETC and the NREA initiated a tender for a new concentrated solar power (CSP) plant through the BOO system with a capacity of 100 MW. However, offers have yet to be received. Separately, a study financed by GIZ (the German development agency) in November 2013 suggested boosting electricity output by adding CSP facilities at existing Egyptian power plants. This would enhance the supply from, and effectively start to "hybridise", those largely gas- and oil-fired plants (EGHLJC and EgyptERA, 2013).

Solar water heating

In the early 1980s efforts were directed towards the development of SWH applications in industry. As a first step, the MOERE imported 1 000 SWHs of 100 to 500 litres per day capacity and tested selected samples in different types of application, as well as renting others to the public.

This initiative resulted in the establishment of several private-sector companies for the assembly and manufacture of SWHs in Egypt. Moreover, the Ministry of Housing and Urban Communities issued a decree in 1986 for the mandatory use of SWHs in new cities, which resulted in the installation of solar water heaters equivalent to 800 000 m^2 coverage. However, as a result of the highly subsidised energy prices and the mismanagement of the dissemination process due to the lack of experienced personnel and awareness, the market went into decline until 2013.

By 2013, the New Urban Communities Authority (NUCA) had started introducing SWHs in new cities in co-operation with EU countries. Currently, there are 22 companies listed in the registry of the Federation of Egyptian Industries (FEI) with a scope of activities including the production and/or the import of solar thermal technology. About 12 to 14 of those companies are currently involved in manufacturing, while the remaining serve as importers, such that the total installed capacity amounts to about 750 000 m^2.

Egypt has proven potential for the industrial application of SWHs in process heat and solar thermal systems as a result of several demonstration projects that were implemented in the food and textile industries in the early 1990s. Thus, a USD 5 million project was launched at the end of 2014 by the Ministry of Trade and Industry for small and medium-sized enterprises (SMEs), to promote low-carbon technologies, mainly solar thermal, for cooling and heating in industrial applications (UNEP, 2014).

Biomass

Egypt has large resources of biomass from agricultural waste, animal dung and urban solid waste. Agricultural waste totals about 35 million tonnes annually, 40% of which is used for feeding animals, the rest being available for energy purposes (equivalent to 5 Mtoe/year). Urban solid waste averages 0.5 kilograms per person per day, amounting to almost 10 000 tonnes per day in greater Cairo alone (GIZ, 2014).

Different biomass technologies have been demonstrated in Egypt, in particular for the production of biogas from animal waste in rural areas, as well as for the collection and briquetting of agricultural waste. Such technologies create jobs in villages and reduce the migration of young people to the big cities.

The Ministry of Environment, in co-operation with the Ministry of Local Development, is currently leading a programme for the treatment of municipal solid waste in large cities (GIZ, 2014).

The Bioenergy for Sustainable Rural Development Project (BSRD) (EEAA et al., 2013), led by the Egyptian Environmental Affairs Agency (EEAA), was initiated in 2009 and funded by the United Nations Development Programme and the Global Environmental Facility. The project aims at encouraging young graduates to become entrepreneurs, while providing special support to women and consideration to rural areas.

The project has achieved remarkable progress in developing and disseminating biogas digesters and establishing Bioenergy Service Providers (BSPs) to support the market penetration of bioenergy in the country. The resultant BSPs are companies that are founded to provide job opportunities for young graduates through on-site training on the construction, curing, feeding and gas production of biodigesters in rural areas.

During three years of its operation, the BSRD developed and operated 960 biogas units of different sizes in 18 Egyptian governorates. Twenty registered BSPs were established and spread across Egyptian villages, providing their services to more than 1 000 families. The BSRD is considering a FIT regulation for biomass systems similar to that for wind and solar issued by the Prime Minister in October 2014 (EEHC, 2016a).

3.4 Enabling framework for renewable energy

Egypt adopted its first renewable energy strategy in 1982, targeting the production of 5% of generated electricity from renewable energy resources by year 2000. However, this target was not reached due to the relatively high cost of renewable energy technologies and the heavily subsidised energy prices during this period.

In February 2008, following the emergence of the energy supply/demand gap in 2007, the SEC approved a new target: to source 20% of generated electricity from renewable energy sources by 2022. The SEC planned to meet its ambitious targets through the deployment of a variety of renewable energy sources, including 12% wind, 2% solar and 6% hydropower.

To realise these targets, the majority of the total capacity planned for installation is intended to be implemented by the government, with the remainder by the private sector. By January 2011, political instability, coupled with economic uncertainty, meant that the strategic renewable energy targets had not been implemented.

In January 2013, the Government of Egypt started developing a new 20-year strategy, the Integrated Sustainable Energy Strategy (ISES) 2015 to 2035, through a project funded by the European Union and implemented in co-operation with all relevant national partners. In October 2016, the SEC agreed to a new energy strategy for Egypt, under the TARES approved in 2016 (EU, 2015a).[9]

Energy targets

The sustainable development targets for Egypt as they relate to energy (Egypt Sustainable Development Strategy, Egypt Vision 2030, issued 2015) are:

Goal I – Ensuring security of supply

- The core objective is to ensure the availability of reliable energy supplies to satisfy the future development needs of the country through adoption of a more diverse energy mix and direct investment to provide a range of fossil fuels, renewable and nuclear technologies. Moreover, it includes rationalising the demand side and reforming energy subsidies without putting excessive financial costs onto citizens.

Goal II – Ensuring sustainability

- The core objective is to achieve both the technical and financial sustainability of the energy sector: ensuring a sufficient supply of diversified sources that can be utilised to deliver energy, and achieving financial sustainability by being able to fund the necessary infrastructure and operating costs by ensuring sufficient income to maximise efficiency in all operations.

Goal III – Improving institutional and corporate governance

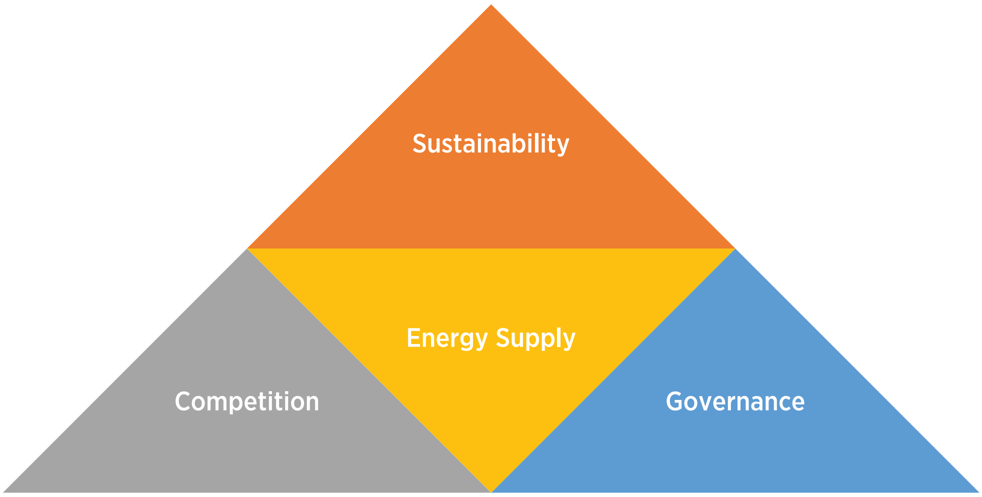
- The core objective is to modernise the current institutional structure of public enterprises to cater for a more commercial framework, by realigning the organisational structures of the EEHC, EGPC and their subsidiary companies, and introducing the necessary training assistance to responsible entities, along with action plans to enhance energy planning and energy efficiency.

Goal IV – Strengthening competitive markets and regulation

- The core objective is to establish an environment that can help build competitive energy markets as a key step in driving down costs and promoting market liberalisation to support greater transparency and efficiency within the electricity, gas and oil markets.

[9] TARES = Technical Assistance to Support the Reform of the Energy Sector for Egypt.

Figure 18. ISES 2035



Source: EU (2015a), "Integrated Sustainable Energy Strategy".

The energy strategy **agreed by the SEC** in October 2016, was based on:

- Data made available from both the petroleum and electricity sectors.
- The sustainable development report 2015 for Egypt (MOP, 2015).
- The study entitled "Combined Renewable Energy Master Plan (CREMP)", final form issued in December 2015.
- The "ISES 2035" report issued in November 2015 (EU, 2015a).

The ISES to 2035 integrated the findings from previous studies, including the CREMP, as well as the existing plans for the diversification of supply utilising both nuclear and coal. The ISES outlined several scenarios for the energy mix up to year 2035. The scenarios were assessed based on key issues in the Egyptian energy system, including the following:

- energy import dependence
- diversification of the primary energy supply
- diversification of electricity generation
- CO_2 intensity
- final energy savings considering the improvement in energy efficiency
- primary energy intensity
- total discounted subsidies
- total discounted system costs.

The value of the indicators, described above, for the year 2029/30 and for the "Most Likely" case of oil and gas production were used to perform the comparison among the scenarios. The cases represent a medium-/long-term perspective of the energy system, allowing some time for changes to become apparent in the different scenarios. In this regard, eight scenarios were assessed and scored against each other and the scenario with the highest score, Scenario 4b, was selected. A detailed description of the different scenarios is described in Annex I.

The highlights of the targets in Scenario 4b are:

1. Renewable energy

- Supply 20% of generated electricity from renewable sources by 2022.
- Supply 42% of generated electricity from renewable sources by 2035.

2. Efficiency:

- Reduce energy use by over 8% by 2022 with a base year of 2006/07.

3. Climate action

- Egypt submitted its Nationally Determined Contribution (NDC) in September 2015.
- Achieve "High CO_2 mitigation levels" through measures including phasing out energy subsidies within three to five years and, potentially, a national carbon market with the aim of using renewables and nuclear power sources.
- Egypt ratified the Paris Agreement on 29 June 2017 and it entered into force on 29 July 2017.

4. Nuclear

- Install 4-5 GW by 2025/26.
- To account for 4% of installed power generation capacity by 2030.

5. Natural gas and oil products

- Contribute 49% of installed power generation capacity by 2030, decreasing from 90% in 2014/15.

6. Coal

- Source 15% of electricity generation from coal by 2030.

The average annual gross rate of TPES for the adopted scenario is shown in Table 8 below.

In Figures 18–20, the crucial indicators of the adopted energy strategy (based on Scenario 4b) are shown for the "Most Likely" scenario. Scenario 4b follows the least-cost approach where subsidies are eliminated after 2020 and different energy sources can compete under the given market structure, with coal and nuclear power plants competing with renewables directly.

However, in Scenario 4b an updated nuclear programme leads to the share of natural gas and coal in the primary energy supply plateauing under the current market structure.

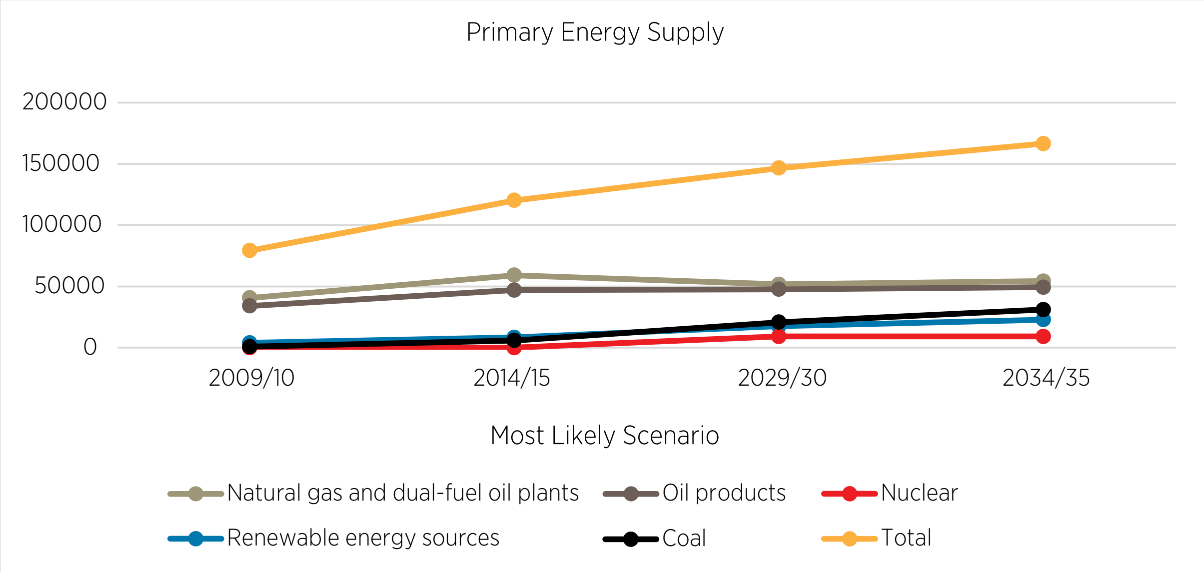
Table 8. Average annual growth rate of TPES for the adopted scenario

Average annual growth rates for the period 2009/10–2034 /35	GDP	TPES	Primary energy supply from coal	Primary energy supply from crude oil and petroleum products	Primary energy supply from natural gas	Primary energy supply from nuclear	Primary energy supply from renewable energy
Scenario 4b	**5.58%**	**3.00%**	**16.2%**	**1.5%**	**1.2%**	**21.5%**	**7.3%**

Note: Nuclear is available after 2026/27, so the annual growth rate is for period 2026/27–2034.

Source: EU (2015a), "Integrated Sustainable Energy Strategy"; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

Figure 19. Primary energy supply (ktoe) under Scenario 4b

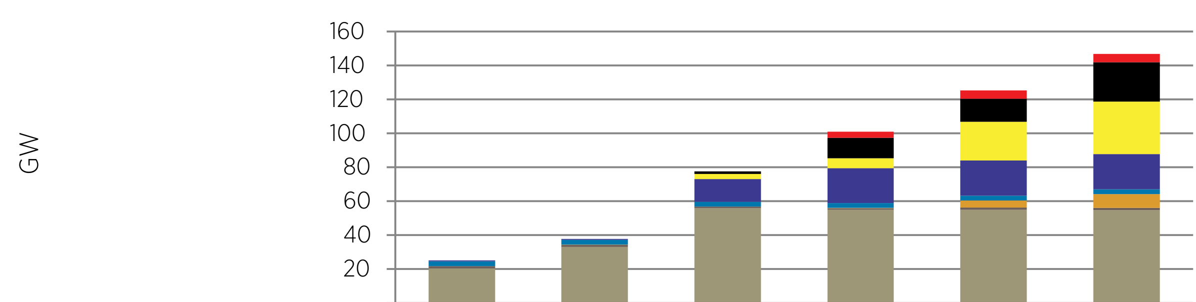


Note: ktoe = thousand tonnes of oil equivalent.
Based on: EU (2015a), "Integrated Sustainable Energy Strategy"; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

In the given Scenario 4b, renewable energy (including hydro, wind and solar) is expected to make up around 25% of the total installed electricity generation capacity in year 2019/20, whereas coal will make up 2.1%, as displayed in Figure 20.

However, with the introduction of nuclear in year 2025, the share of renewable energy sources in the electricity mix is expected to increase to 42% of the total installed capacity, where coal, natural gas and nuclear make up 15.8%, 37.35% and 3.27% respectively in 2034/35 (Figure 20).

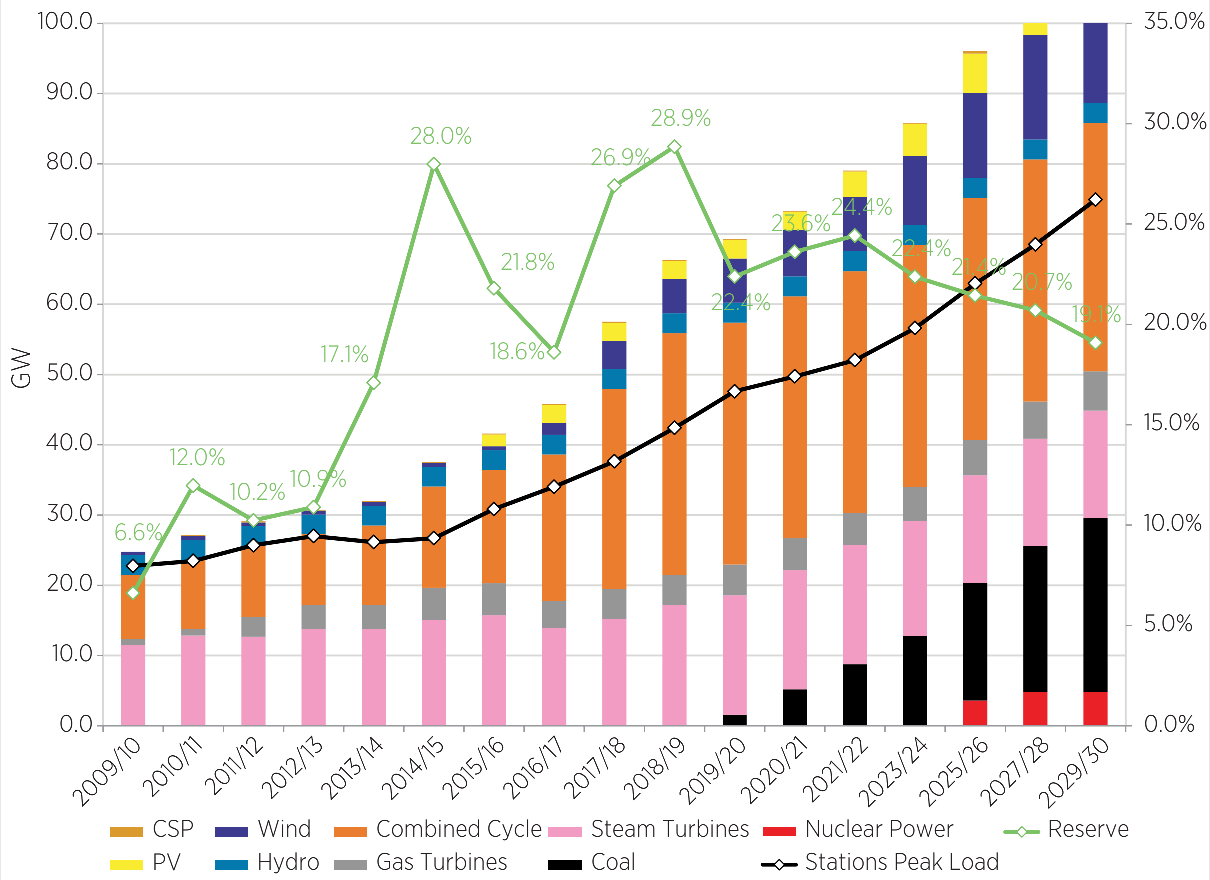
Figure 20. Total installed power-generation capacity under Scenario 4b



	2009/10	2014/15	2019/20	2025/26	2029/30	2034/35
Nuclear power stations	0.0	0.0	0.0	3.6	4.8	4.8
Coal	0.0	0.0	1.6	12.0	13.6	23.2
PV	0.0	0.0	3.0	5.9	22.9	31.0
Wind	0.5	0.5	13.3	20.5	20.6	20.6
Hydroelectric	2.8	2.8	2.8	2.9	2.9	2.9
CSP	0.0	0.1	0.1	0.1	4.1	8.1
Oil products	1.4	1.3	0.9	1.0	1.3	1.3
Natural gas & dual-fuel oil plants	20.4	33.0	55.9	54.9	55.0	54.8

Based on: EU (2015a), "Integrated Sustainable Energy Strategy"; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

Figure 21. Total installed capacity vs peak demand to 2035



Based on: EU (2015a), "Integrated Sustainable Energy Strategy"; MOP (2015), Sustainable Development Strategy: Egypt Vision. 2030; NREA (2013), CREMP; ISES (2016).

Renewable energy laws and regulations

The Egyptian government needed to endorse a new set of laws and regulations to facilitate the implementation of the 2022 and 2035 targets, in line with the ISES to 2035 as described above. The most crucial laws and regulations behind this national energy transition are highlighted in Table 9.

> The New Electricity Law of 2015 allows direct contractual relations between suppliers and end users

Table 9. Overview of renewable energy support policies, legislation and regulations

Legislation	Type
Law No. 102 of the year 1986 establishing the New and Renewable Energy Development and Usage Authority (as amended in 2015)	• Establishes the NREA. • The NREA has the primary role in promoting and developing renewable energy in Egypt.
The Constitution of the Arab Republic of Egypt, 2014 (Article 32)	• To gain optimum benefits from renewable energy, promote its investments, and encourage R&D, in addition to local manufacturing.
Renewable Energy Law (Decree Law 203/2014)	• To support the creation of a favourable economic environment for a significant increase in renewable energy investment in the country.
Cabinet Decree No. 1947 of the year 2014 on Feed-in Tariff	• Establishes the basis for the FIT for electricity produced from renewable energy projects and encourages investment in renewable energy.
Prime Ministerial Decree No. (37/4/15/14) of the year 2015	• Regulations to avail land for renewable energy projects.
New Electricity Law No. 87 of 2015	• To provide legislative and regulatory frameworks needed to realise the electricity market reform targets.
Investment Law No. 72 of the year 2017	• Ensures investment guarantees and amendments as of May 2017. • Establishes a new arbitration centre for settling disputes. • Codifies social responsibility. • Instigates foreign investment in Egypt.

Note: R&D = research and development.

Based on: EEHC (2016a) Egyptian Electricity Holding Company Annual Report 2015/16; EgyptERA (2016b), Issuance of Electricity Law No. 87 of 2015; EU (2015a), "Integrated Sustainable Energy Strategy"; MOERE (2017), Full Scale Program for Renewable Energy in Egypt; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

Table 10. Institutions involved in renewable energy schemes

Institution	Competitive bids		IPP	FIT				Net metering
	EPC	BOO		0–0.2 MW	0.2–0.5 MW	0.5 ≤ 20 MW	≥20–50 MW	
MOERE/EEHC	X	X	X	X	X	X	X	X
NREA	X	X	X	X	X	X	X	X
EgyptERA	X	X	X	X	X	X	X	X
EETC	X	X	X			X	X	X
Distribution companies				X	X	X		X
Ministry of Investment and International Cooperation	X	X	X			X	X	X
The National Centre for Planning State Land Uses	X	X	X			X	X	X
MOF	X	X				X	X	
Governorates		X	X		X	X	X	X
Developers	X	X	X	X	X	X	X	X
Financing agencies	X	X	X			X	X	X

Based on: EEHC (2016a) Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; MOERE (2017), Full Scale Program for Renewable Energy in Egypt; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

Table 11. Institutions involved in renewable energy scheme

Institution	Competitive bids		IPP	FIT				Net metering
	EPC	BOO		0–0.2 MW	0.2–0.5 MW	0.5 ≤ 20 MW	≥20–50 MW	
MOERE/EEHC	• Overall co-ordination and facilitation							
NREA	• Propose the project after making the necessary studies • Prepare the necessary documents and approvals • Prepare the financing methods • Mobilise required funds • Responsible for formulating the contract agreements with the qualified contractor	• Qualification of bids for project construction • Land allocation		• FIT evaluation, technical and economic assessment		• Qualification of bids for project construction • Land allocation		• Possible land allocation • Qualifying process for the service provider
EgyptERA	• Issue the licences and revise the proposed project tariff • Set the transmission fees	• Issue the licences and revise the proposed project tariff • Set the transmission fees		• Propose the tariff and regulation for the approval of the CoM • Propose the tariff and regulation for the approval of the CoM		• Propose the tariff and regulation for the approval of the CoM • Issue the necessary licences • Propose the tariff and regulation for the approval of the CoM • Issue the necessary licences		• Issue the regulation
EETC	• Sign the PPA and loan agreement as a provisional guarantee • Priority dispatch of renewables					• Qualification of bids for project construction	• Qualification • Prepare the necessary connection for the projects • Pay energy cost to producers	

Table 11 continued

Institution	Competitive bids		IPP	FIT				Net metering
	EPC	BOO		0–0.2 MW	0.2–0.5 MW	0.5 ≤ 20 MW	≥20–50 MW	
Distribution companies				• Prepare the necessary connection • Make the necessary payment to producers • Pay energy cost to the producers				• Prepare the necessary connection • Make the necessary payment to customers
Ministry of Investment and International Cooperation	• Facilitate the necessary approvals for the project • Establish special purpose vehicle (SPV) company					• Facilitate the necessary approvals for the project • Establish SPV company		• Provide special tax conditions for importing the required equipment
The National Centre for Planning State Land Uses	• Land allocation through NREA or other public entity.					• Land allocation		• Possible land allocation through NREA or other public entity.
MOF	• Issue the required guarantees for the loans or PPA with EETC			• Finance the project or give special tax conditions for importing the required equipment				
Governorates	• Land allocation			• Land allocation				• Possible land allocation
Developers	Develop the project							
Financing agencies	Finance the project							

Based on: EEHC (2016a) Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; MOERE (2017), Full Scale Program for Renewable Energy in Egypt; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

3.5 Renewable energy support schemes

Within the regulatory framework described above, the following schemes are applied for the implementation of renewable energy projects in Egypt:

Competitive bidding

In the early 1990s, the NREA started the competitive bidding process for renewable electricity generating capacity for government projects. In 2009, EETC launched the first auctions for large-scale private projects using the BOO scheme where the NREA secured the land and data on resources. In the following years, a number of other tenders were launched by EETC: 200 MW of solar PV in 2013; 250 MW wind, 200 MW solar PV and 100 MW CSP in 2015 (Eversheds and PricewaterhouseCoopers, 2016).

As a result of the declining cost of renewable energy sources, in 2017 Egypt moved to the auction mechanism (competitive bidding) for large-scale solar and wind projects. Auctions for large-scale solar PV projects were announced, to be carried out under state-owned EPC contracts with the NREA, or under a BOO scheme with an IPP through PPA agreements with EETC. In this regard, EETC issued a tender for a 600 MW of PV capacity in the West of Nile area in December 2017.

BOO scheme with PPAs

As of July 2015, the IPP scheme was adopted by the Egyptian power sector and EgyptERA issued the relevant regulations and contracts to provide developers with the necessary level of certainty. The generated electricity is sold directly to either the end users or the distribution utilities depending on the scale of the consumer. In the situation where surplus electricity is generated, it is consumed to satisfy the developer's own electricity demand (EU, 2015a). The IPP scheme alleviates upfront costs for project development and ensures continuous investment due to increased competition.

EETC has announced bidding processes for wind, solar PV and CSP projects with a total capacity of more than 1 000 MW through the BOO scheme in Gulf El Zayt, including consortiums with Italgen, Lakela and Engie-I (EEHC, 2016b). In addition, 100 MW of CSP and 1 000 MW of solar PV projects under three competitive bidding schemes, as well as a 600 MW project under direct negotiation, have all been approved by the Cabinet.

The aforementioned 600 MW solar PV BOO plant will be completed under direct negotiation and was approved by the Cabinet in December 2017. In this context, EETC will be the off-taker of electricity under the usufruct agreement with the NREA for a project lifetime of 25 years (Eversheds Sutherland, 2017).

As Egypt continues to develop tenders under the auction scheme through either private or public finance and ownership, to ensure an effective use of this tool the NREA and EETC would benefit from adopting the guidelines in IRENA's Renewable Energy Auctions publication (IRENA and CEM, 2015). The report provides elaborated context-specific design scenarios, with in-depth analysis of capacity- and energy- driven auctions, while highlighting country-specific best practice examples. IRENA's guidelines can further aid EETC in developing and evaluating the technical and financial specifications for upcoming projects, such as the current 200 MW PV facility at Kom Ombo. Auctions are an effective policy tool to aid Egypt in achieving its 2022 and 2035 targets in a cost-effective manner.

Box 1:

The rise of renewable energy auctions

More than 70 countries had adopted auctions to procure renewables by the end of 2016. (IRENA, IEA and REN21, 2018; and IRENA, 2017g).

The widespread adoption of auctions reflects their proven effectiveness in expanding renewable energy deployment, particularly in developing countries, often at record-breaking prices due to heightened competition. Auctions have allowed for real-time price discovery and reduced information asymmetry between the public sector and private finance from investors and developers. The 2015 guidebook on the design of auctions analyses the design elements, provides elaborated context-specific design scenarios and highlights country-specific best practice examples, thus bringing down the cost of renewable energy technologies (IRENA, 2017h; IRENA and CEM, 2015).

Auctions have led to record-low prices globally, including countries in the Middle East and North Africa. In 2016, Morocco awarded wind contracts at an average of USD 30 per megawatt hour (MWh), while the United Arab Emirates (Abu Dhabi emirate) achieved an average of USD 24.2 per MWh for solar PV. However, the factors behind the prices achieved in different markets are important to note. Auction prices reflect a combination of country-specific conditions (e.g. resource availability and cost of land, labour, finance), investor confidence, other renewable energy support policies (e.g. tax incentives, policies supporting a local industry) and the design of the auction itself (IRENA, 2017h).

Auctions have also gained popularity in different contexts in recent years owing to their flexibility of design. They can be tailored to the country-specific context and objectives. For example, auctions can be designed in a way as to maximise socio-economic benefits. Policy makers have realised the potential benefits of auctions in job creation and enhanced local content. In South Africa, auctions have been coupled with local content requirements to support the development of local industry. Auction requirements have allowed the country to increase its manufacturing capability from a minimal level of local content in the first round to around 45% in the fourth round for various renewable energy technologies (IRENA, 2017h).

FIT scheme

Consistent with creating a supportive environment for renewable energy applications, on 17 September 2014 the government approved a FIT scheme to encourage investment in electricity generation from renewable energy resources, particularly wind and solar, with the active engagement of the private sector in market development.

The FIT scheme aims to mobilise investment to achieve a total of 4 300 MW capacity over the period 2014-2018, including:

- 300 MW of small PV installations of less than 500 kW
- 2 000 MW of PV installations with a capacity ranging from 500 kW to 50 MW
- 2 000 MW of wind installations with a capacity ranging from 20 MW to 50 MW.

The second phase of the FIT scheme was announced by the Prime Minister's Decree No. 2532 dated 30 September 2016 and was implemented as of 27 October 2016. The duration of related PPAs was set at 25 years for PV projects and 20 years for wind projects. EgyptERA has put in place the required regulations and procedures for executing the relevant projects.

To ensure the bankability of the PPAs, under this second phase a greater share of the tariffs for wind and solar will be pegged to the fixed exchange rate of EGP 8.88/USD. The FIT for PV projects with installed capacities of greater than 500 kW will be charged in Egyptian pounds, such that 30% of solar PV project tariffs are based on today's pegged rate as against 15% during the first phase (exchange rate EGP 7.15/USD), while for wind projects the share of tariffs is 40%, as elaborated on in further detail in Tables 12 and 13.

Table 12. FIT for PV projects with installed capacities > 500 kW

FIT for PV projects > 500 kW
In the second phase: (30% of tariff value) X 8.88 (value of EGP at the time of tariff issuance in relation to USD) + (70% of tariff value) X (value of EGP at maturity time in relation to USD).
In the first phase: (15% of tariff value) X 7.15 (value of EGP at the time of tariff issuance in relation to USD) + (85% of tariff value) X (value of EGP at maturity time in relation to USD).

Source: NREA.

Table 13. FIT for wind projects with installed capacities > 500 kW

FIT for wind projects > 500 kW
In the second phase: (40% of tariff value) X 8.88 (value of EGP at the time of tariff issuance in relation to USD) + (60% of tariff value) X (value of EGP at maturity time in relation to USD).
In the first phase: (15% of tariff value) X 7.15 (value of EGP at the time of tariff issuance in relation to USD) + (85% of tariff value) X (value of EGP at maturity time in relation to USD).

Source: NREA.

Tables 14 and 15 present the second-phase FIT prices for PV projects and wind projects at selected numbers of operating hours.

Table 14. PV under Egypt's FIT Phase II

PV project description	FIT prices
Residential	1.0288 (EGP/kWh)
Installed capacity < 500 kW	1.0858 (EGP/kWh)
500 kW ≤ installed capacity < 20 MW	0.0788 (USD/kWh)
20 MW ≤ installed capacity ≤ 50 MW	0.0840 (USD/kWh)

Table 15. Wind under Egypt's FIT Phase II

Wind project description	Number of operating hours/year	FIT (USD/kWh)
Either 20 MW or 50 MW	2 500	0.0796
	3 000	0.0663
	3 500	0.0569
	4 000	0.0497
	5 000 and more	0.0400

Based on: EEHC (2016a) Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy"; MOERE (2017), Full Scale Program for Renewable Energy in Egypt; MOP (2015), Sustainable Development Strategy: Egypt Vision 2030; NREA (2013), CREMP.

The prices under the second phase of the FIT will only apply to those who have qualified from the first phase and for contracts signed on or after 28 October 2016. Financial closure was set at one year after signing for PV projects, 28 October 2017, while for wind projects, financial closure was set at 18 months, 28 April 2018.

Status of FIT implementation

For phase one, two developers of large-scale PV systems were able to achieve financial closure, while for phase two, 30 companies are close to obtaining their financial closure for their PV projects with total capacity of 1 465 MW by October 2017.[10] They have signed their PPA agreements with EETC and signed their land agreement with the NREA.

Distributed PV systems are mostly implemented by local companies that are representatives of foreign ones. Over 220 companies are licensed by the NREA, while only around ten of them are active in the field. The total capacity that has been installed on the basis of the FIT stands at about 1.7 MW, while those under installation may reach 12.4 MW.

The reason behind the limited total installed capacity is that the net metering scheme has yet to be effectively applied and FIT prices were insufficiently attractive for potential investors. This is supported by the fact that many have installed systems without relying on the FIT, instead relying on self-consumption. This has proved to be more beneficial to such users, as it cuts their consumption from the grid to a lower tariff segment.

[10] This section is based on consultation with the NREA, EETC and EgyptERA.

Egypt's shift to the auctions scheme will allow for further price declines and could potentially drive enhanced local content and job creation.

Other support mechanisms

The Prime Ministerial Decree No. (37/4/15/14) of 2015 was issued to allocate land for renewable energy projects through usufruct rights. In line with the decree, the government assigned about 7 600 km^2 in the Gulf of Suez, east and west of the Nile, Benban and Kom Ombo regions, of which about 5 700 km^2 are for wind projects (75% share) and about 1 900 km^2 for solar energy projects (25% share), as shown in Table 16.

T&D utilities are committed to offering priority dispatch for renewable electricity. In addition, an attractive mechanism has been developed to encourage the purchase of renewable electricity through the setting of tariffs for each category of consumption. Moreover, the applied customs on components and spare parts for the projects have been set at a discounted rate of 2% compared to the prior 5%, with a VAT rate currently set at 5% rather than 14%.

The following additional incentives complement the FIT implementation:

1. Provision of sovereign guarantees to projects above 20 MW that are awarded under PPAs between EETC, the MOF and IPPs.

2. Provision of soft loans at 4% interest rate for residential projects up to 200 kW, and up to 8% interest rate for projects ranging between 200 kW and 500 kW.

3. A decision to make EGP 2 billion investment for strengthening T&D grids to enable the transition towards smart grids.

In further support of renewable energy schemes, EETC proposed and discussed with both the NREA and EgyptERA a transmission code for the interconnection of wind projects. The code was approved by EgyptERA, in addition to the rules and regulations for the interconnection of solar PV systems with the low- and medium-voltage networks.

Table 16. Land assigned for renewable energy projects

Zone		Area (km^2)
Gulf of Suez (wind)		1 220
East Nile	wind	841
	solar	1 290
West Nile	wind	3 636
	solar	606
Benban (solar)		37
Kom Ombo (solar)		7
Total		**7 637**

Based on: EEHC (2016b), Egypt Renewable Energy Plan.

3.6 Policies to maximise local benefits

The deployment of renewable energy in Egypt presents considerable opportunities for socio-economic benefits and local value creation. Besides increasing energy security, enhancing energy access and mitigating climate change, renewable energy projects present opportunities along different segments of the value chain, including the sourcing of raw materials, manufacturing and assembly of components, construction and installation, and O&M. Building on its established wind market, Egypt's electricity sector has successfully localised 30% of overall wind farm requirements. A target of 70% by 2020 has been established, along with 50% for CSP plants.

For solar PV, only 30% of installed costs are spent on modules (and 10% on inverters) and the rest is on the balance of system. As such, 60% can be localised just through the balance of system which comprises construction works, mounting structures, cabling, etc. Following the installation of the project, considerable value is created in O&M.

As for manufacturing, Egypt has the potential to meet a local manufacturing content of more than 80% (EIB and IRENA, 2015). Egypt is considered an industrial leader in the Middle East and African markets, and it can leverage its mature steel, glass and cable industries to produce solar and wind components locally. For example, the three international float glass companies active in Egypt, Saint Gobain, Sphinx and Guardian, all have production facilities that can produce high-purity silica sand used for different industries including PV module production (EIB and IRENA, 2015). In parallel, Egyptian steel companies can supply the necessary support structures for modules.

Moreover, Egypt can advance its technical and human capabilities through policies that facilitate foreign domestic investments and joint ventures with multinational companies. For example, SWEG (Elsewedy for Wind Energy Generation) is generating local jobs through joint ventures in wind turbine and tower manufacturing and the production of cables and transformers (ElsewedyElectric, 2018). For onshore wind, one incentive for local manufacturing of bulky parts such as blades and towers is their high cost of transport and lower need for technological advancement[11].

Egypt produces half the components for its wind farms
Photograph: Shutterstock

[11] The potential for income generation and job creation for solar PV and onshore wind are analysed in IRENA's work on Renewable Energy Benefits: Leveraging Local Capacity (IRENA, 2017a, 2017b).

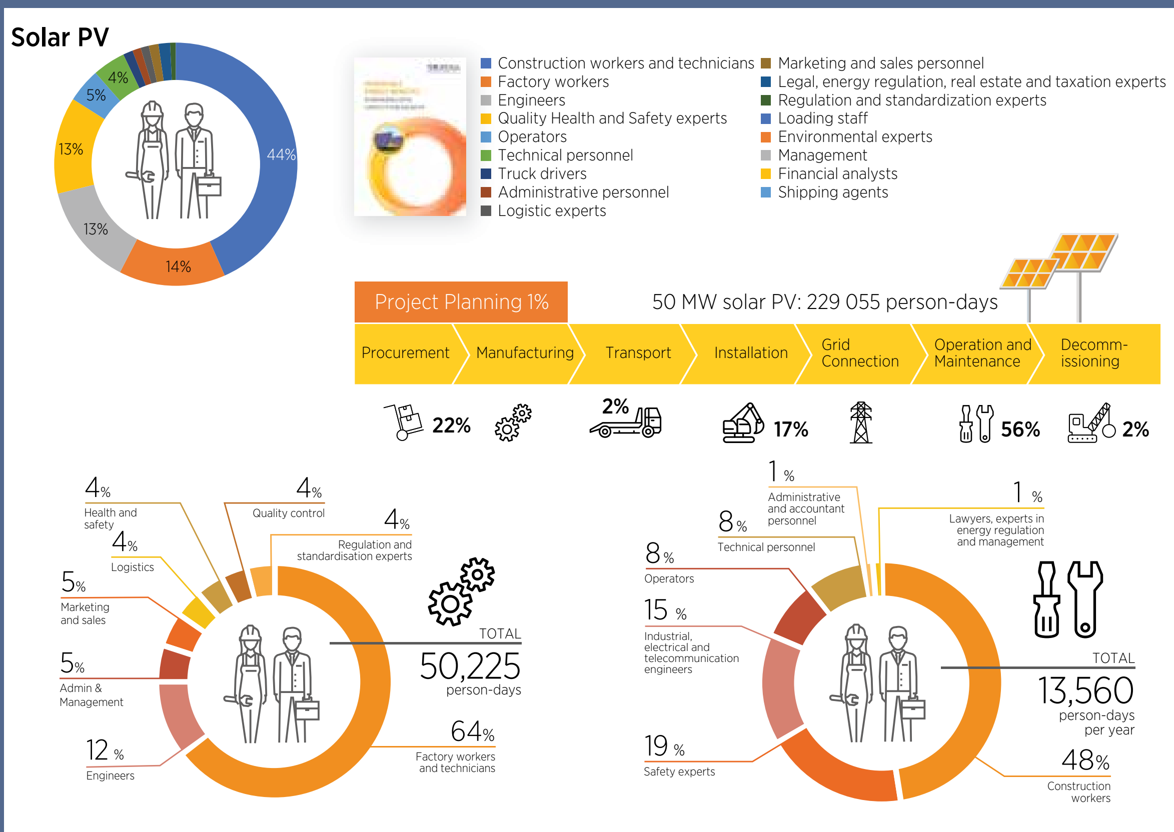
Box 2:

Leveraging local capacity for solar PV and wind industries

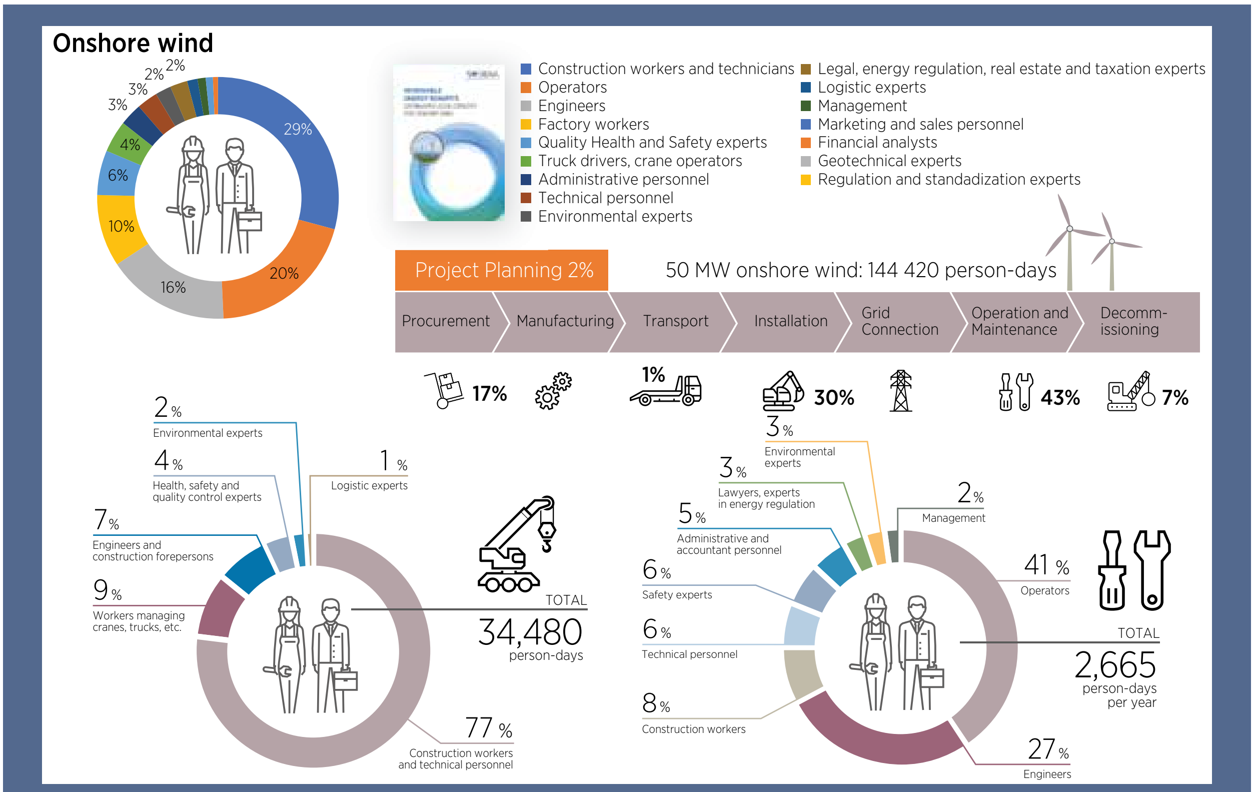
In designing policies to support value creation from the development of a domestic renewable energy industry, a deeper understanding of the requirements for labour, skills, materials and equipment is needed.

For solar PV, IRENA analysis shows that 56% of the total jobs are in O&M, 22% are created in manufacturing and 17% are in installation and grid connection. A large percentage of jobs created are for factory workers and technicians, which could help to alleviate unemployment in Egypt. Moreover, administrative, finance, legal and engineering jobs are created, which could be promising for college or university graduates struggling to find employment.

For wind, the bulk of the jobs created are in O&M (43%), installation and grid connection (30%), followed by manufacturing (17%). Notably, while jobs in manufacturing and installation are temporary, those created in O&M last throughout the lifetime of the project.



Based on IRENA (2017b), Renewable Energy Benefits: Leveraging Local Capacity for Solar PV.



Based on: IRENA (2017a), Renewable Energy Benefits: Leveraging Local Capacity for Onshore Wind.

The successful deployment of renewable energy depends on the existence of a workforce capable of undertaking activities through training and education policies. Since the mid-1990s, the NREA has organised and conducted a variety of training programmes on renewable energy resource assessments, technologies and applications for Egyptian, Arab and African groups. As of October 2017, the number of trainees exceeded 5 000, with individuals originating from universities and other Egyptian organisations to those from member countries of the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) and African countries. In the area of capacity building, the NREA conducted training for engineers and technicians for the newly established PV companies to obtain certification under the FIT regulation in accordance with both national and international standards.

Another initiative is the RENAC-OASIS Solar Academy Egypt (ROSAE), a partnership between the Renewables Academy (RENAC), Germany, and Oasis Renewable Energy (ORE). It has provided practically orientated training courses and capacity building in renewable energy for decision makers, consultants, engineers, installers and technicians since 2010.[12] Most recently, in 2018, the government launched a renewable energy curriculum at technical schools to encourage specialisation in renewable energy and training in solar and wind. The three-year certificate programme was developed by the Egyptian Ministry of Education and the US Agency for International Development (USAID) and aims to train over 300 technical school students.[13]

3.7 Testing and certification

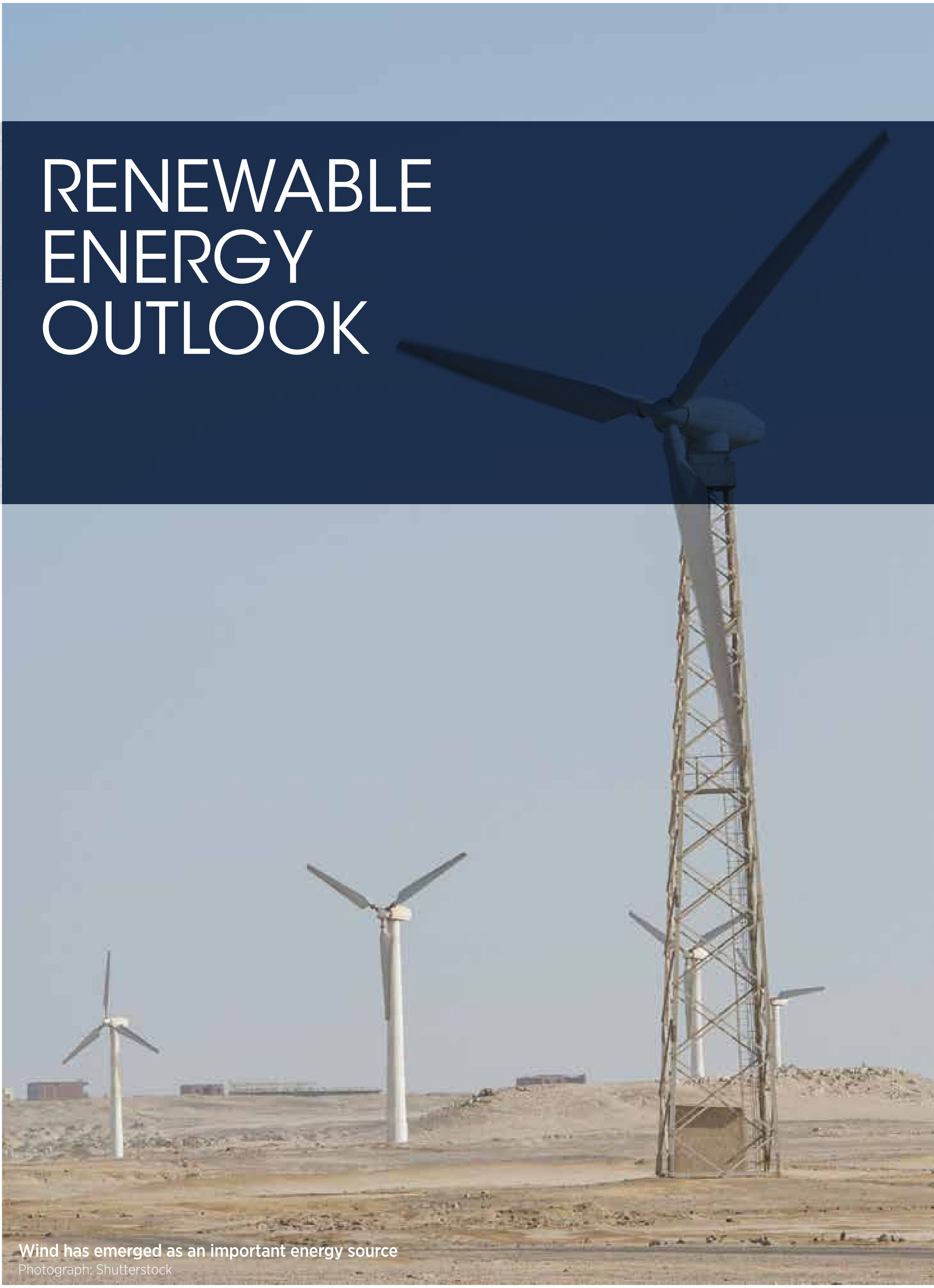
Since the establishment of the NREA in 1986, a set of indoor and outdoor testing laboratories has been in operation, covering most renewable energy and energy efficiency technology components, including laboratories for testing SWHs, solar concentrators, PV panels, system components, biomass digesters and gasifiers.

The NREA certifies SWHs, home appliances (refrigerators, washing machines, air-conditioning units, dishwashers) and lighting equipment for local manufacturers, as well as for the importers of equipment. The laboratories have an impact on the quality of equipment placed on the market and protect it from low-quality systems.

[12] www.renac.de/projects/current-projects/solar-academy-egypt-rosae/.

[13] www.al-monitor.com/pulse/originals/2018/02/egypt-launches-renewable-energy-curriculum.html#ixzz5FfXczpH1).

RENEWABLE ENERGY OUTLOOK



Wind has emerged as an important energy source
Photograph: Shutterstock

04

The previous chapters have outlined the energy context in Egypt, and provided a view on how the country's energy landscape is likely to evolve over the coming years based on government plans and targets and the country's energy strategy, ISES to 2035. However, Egypt's energy system is highly dynamic and the government would benefit from periodically re-evaluating longer-term energy goals to reflect changing market dynamics and priorities for the country.

Whereas the RRA approach focuses on analysing existing policy and institutional frameworks, IRENA's REmap analysis provides an outlook on the medium-term potential of renewable energy in the country. This REmap component, presented in this chapter, also highlights areas or sectors where the use of renewables could be scaled up.

The chapter focuses first on briefly presenting developments that are likely to occur in what is termed the Reference Case, which is based on current policies, market trends and forecasts. Next the chapter goes into depth on the accelerated potential of renewable energy beyond what is expected to occur in the Reference Case. These are called the REmap Options, addressing the end-use sectors of industry, buildings and transport, as well as power generation. The resulting high-renewables case is called the REmap Case.

The REmap analysis looks out to the year 2030, chosen as the standard assessment timeframe for REmap due to it being in the medium term, a common year for global efforts such as the Sustainable Development Goals, and a common year in Egypt for many national-level targets (for 2029/30). For more information about the REmap approach, methodology and sources, please see Annex II.

The steps to conduct the REmap analysis for Egypt that are presented in this chapter include the following:

A Reference Case to 2030 is developed based on the scenario results from the National Energy Model as presented in the report for Technical Assistance to Support the Reform of the Energy Sector for Egypt (TARES) (EU, 2015c). The result of the Reference Case presented here is a view of a baseline scenario, not specifically the ISES. This case represents possible developments in the energy system provided the government does not take additional measures to support renewable energy deployment.

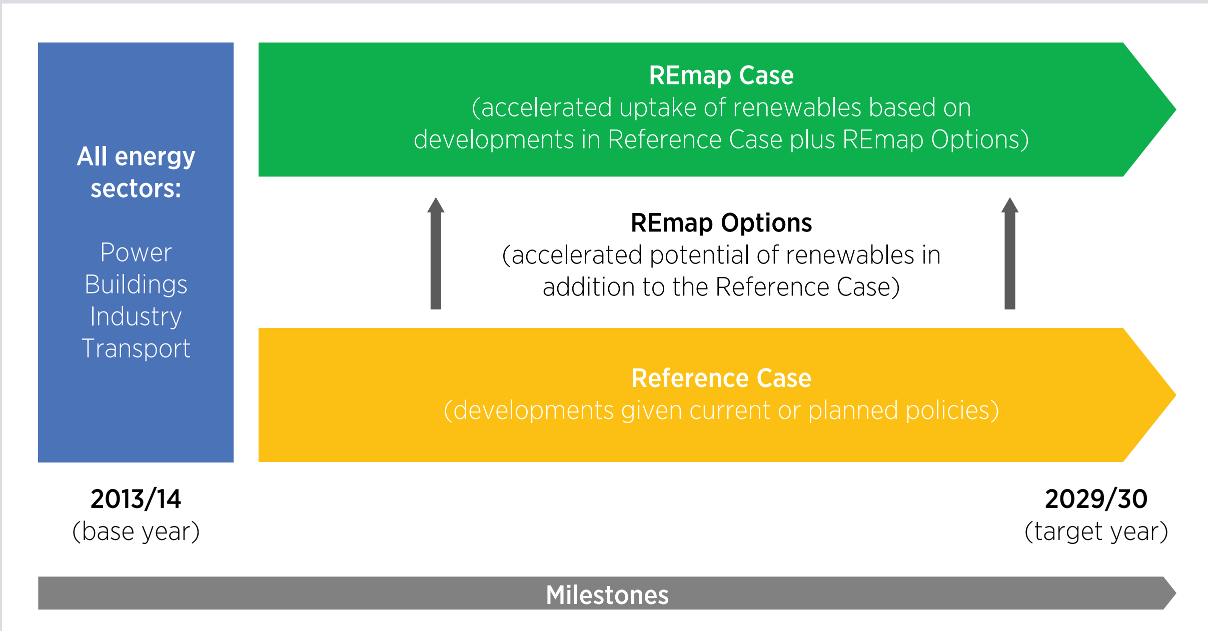
Additional renewable energy deployment options are then subsequently assessed. These are called the REmap Options and are based in part on country consultation, including analysis from an Egyptian energy expert from NREA loaned to IRENA to support the project and help in the identification of these options, and a validation workshop with Egyptian experts. Additionally, the TARES results for Scenarios 3b and 4 and IRENA analysis were also used (see Annex II for more information on sourcing).

The result of this options analysis is the REmap Case, which details the accelerated potential of renewables and what it would imply in terms of technological developments, costs and benefits. Importantly, the REmap Case also provides a view on where the additional potential of renewable energy outside the power sector lies, i.e. in the end-use sectors of buildings, industry and transport, and for energy services related to heat, fuels and other direct uses.

Finally, fuel prices were forecast based on existing literature and IRENA estimates, and technology cost and performance criteria (e.g. capacity factors) were estimated to reflect conditions particular to Egypt. The results of these options are then quantified in terms of their costs, investment needs, and benefits resulting from lower levels of air pollution, CO_2 emissions, and other impacts.

Figure 22 provides an overview of the key cases discussed in this chapter and the years that are highlighted.

Figure 22. Overview of REmap years and case descriptions



4.1 Reference Case

The Reference Case represents a perspective on energy supply and demand under a baseline scenario. This case represents likely developments in the energy market provided the government does not act to support the goals set out in the ISES. For the analysis, the Reference Case is based on the energy demand and supply scenario results from the TARES report (EU, 2015c), specifically the Baseline Scenario. However, the Reference Case has also been adjusted based on country feedback through direct consultation and during the validation workshop held in mid-2017. The Reference Case, therefore, reflects a baseline scenario view as of late 2017 – any new policies or development that have occurred past this date will not be reflected in the case.

The result is a Reference Case that provides a baseline off which the more aggressive renewable energy targets set forth in the ISES, and detailed in the REmap Case, can be quantified. Provided no supportive action is taken, the Reference Case is the case that potentially would occur given current market and policy developments in Egypt. Even if Egypt is firmly committed to achieving more assertive renewables goals, the Reference Case view is necessary as it allows the REmap Options assessment to provide a gap analysis and view on what key technologies will need to be supported to reach those goals, while allowing quantification of those technologies in terms of their costs, benefits and other impacts.

This chapter does not go into detail on specific developments in the Reference Case. However, some key changes in energy and economic indicators are discussed, and key shares and energy developments in the Reference Case are looked at in the sections that follow.

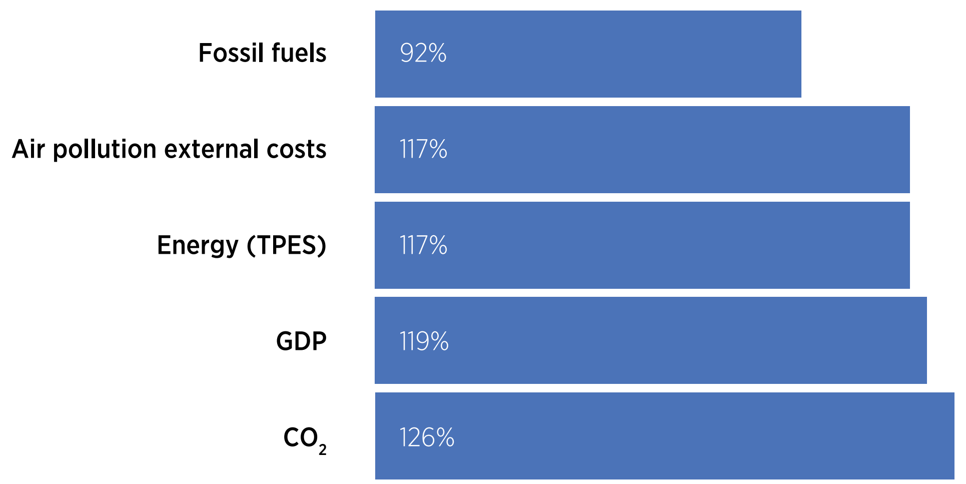
Economic and energy demand developments

- In the Reference Case, over the period 2014-2030, demand for energy increases by 117%. Fossil fuel consumption increases slightly less, by 92%. Demand for energy increases at a pace similar to overall GDP growth, which increases by 119% over the period, indicating no decoupling of energy demand growth and economic growth.
- The resulting growth in fossil fuel consumption sees increased imports of coal, natural gas and oil. The corresponding increase in energy-related CO_2 is over 126%, and external costs relating to air pollution from fossil fuels increase by 117% to a range of USD 13-53 billion annually by 2030.

Egypt is projected to see robust economic growth to 2030, with GDP increases averaging around 4% per year over the period. The result is an increase in GDP of 119% by 2030. Primary energy supply increases by 117%, from 62 Mtoe in 2014 to 133 Mtoe by 2030 (Figure 23). Demand for fossil fuels grows by 92%, with natural gas increasing the least at just 8%. Demand for oil products increases by 60% and coal's overall importance rises significantly with the emergence of 53 Mtoe of coal demand, up from below 1 Mtoe in 2014.

The Reference Case foresees GDP increases that are equal to growth in energy demand, with both increasing by around 120% to 2030; this points to no noticeable improvement in the energy intensity of the country's economy in the Reference Case, which indicates significant potential for improvements in energy efficiency in the country.

Figure 23. Increase in key economic and energy indicators, 2014-2030



Energy-related CO_2 emissions increase from 156 million tonnes (Mt) in 2014 to 354 Mt in 2030 – the largest increase of any indicator. This is driven by the significant growth in fossil fuel use, and outpaces total growth in TPES due to the emergence of coal power generation. The largest source of energy-related CO_2 is the power generation sector at 157 Mt, followed by industry at 78 Mt.

The greater use of coal brings with it not just higher CO_2 emissions, but also increased levels of air pollution. Additionally, the 63% increase in the use of oil, much of it in urban areas for transport, is particularly harmful due to its effects on local air pollution. Therefore, external costs relating to air pollution from fossil fuels – largely made up of adverse effects on human health –increase by 117% to 2030. Annual air pollution costs increase from a range of USD 6-25 billion in 2015, to a range of USD 13-53 billion by 2030. Most of the increases come from higher use of fossil fuels, in particular oil in transport, but also coal used in power generation.

Consequently, the overall picture of development in the Reference Case to 2030 shows that Egypt can expect significant growth in energy demand and the associated external costs that come with meeting that demand with fossil fuels.

Recent developments also provide views on how energy and power markets in Egypt could evolve. One is that growth in power generation capacity has outpaced demand for electricity. In 2017, power system capacity reached 45 GW, while maximum load during peak summer demand was in the order of 31 GW. Additionally, there have been recent discoveries of natural gas in deep-water fields. Both of these developments may influence energy-related policy making in the near term that could affect the Reference Case.

Renewable share and technology developments

- The share of renewables increases in all sectors in the Reference Case by 2030 except in the industrial sector. The largest increase in renewable share is in power generation. In the end-use sectors, the use of fuels and other direct uses of energy for thermal and transport uses see little or no change in renewable share. Overall, the share of renewable energy in TFEC grows from 5% in 2014 to 11% in the Reference Case.

- The only sizeable contributions of renewable sources in the Reference Case occur in the power sector. This sector sees total system capacity increase by over 250% to 117 GW, with growth in coal, natural gas, wind and solar PV. In the Reference Case both wind power and solar PV see sizeable increases, and the renewable share in gross generation increases to 25%.

In the Reference Case the share of renewables increases in all sectors except in the industrial sector (see Table 17); however, the only sizeable increase is in the power sector. Overall the renewables share in TFEC doubles to 11%. The renewable share of power generation increases from 9% to 25%; this increase is impressive given that the increase in gross electricity generation is around 125% to 385 terawatt hours (TWh). Therefore, renewable power generation increases from just 15 TWh (almost all of it hydropower) to 96 TWh by 2030 in the Reference Case. Total power system capacity increases by over 250% to 117 GW in 2030.

In the end-use sectors of buildings, industry and transport, the renewable share of fuels and direct uses of energy for thermal applications and transport sees little or no change (see Table 17). Industry has the highest renewable share of the three end-use sectors, with 10% in 2030, and sees small increases in bioenergy use in the Reference Case. However, due to the overall growth in energy demand in industry, the renewables share decreases from 11% to 10% over the period.

In the transport sector the share increases to 2% by 2030 due to the emergence of some liquid biofuels, but their contribution is minor compared to overall sector energy use, which is still dominated by oil. The buildings sector sees an increase in its renewable share from under 1% to around 1.5%, due to some growth in solar thermal for hot water and biogas for cooking. These shares all exclude electricity use. If the sectors are analysed including the share of renewable electricity consumed in them, the overall renewable share increases due to the fact that the proportion of renewables in electricity generation is significantly higher, at 25%, than the renewable proportion of fuels.

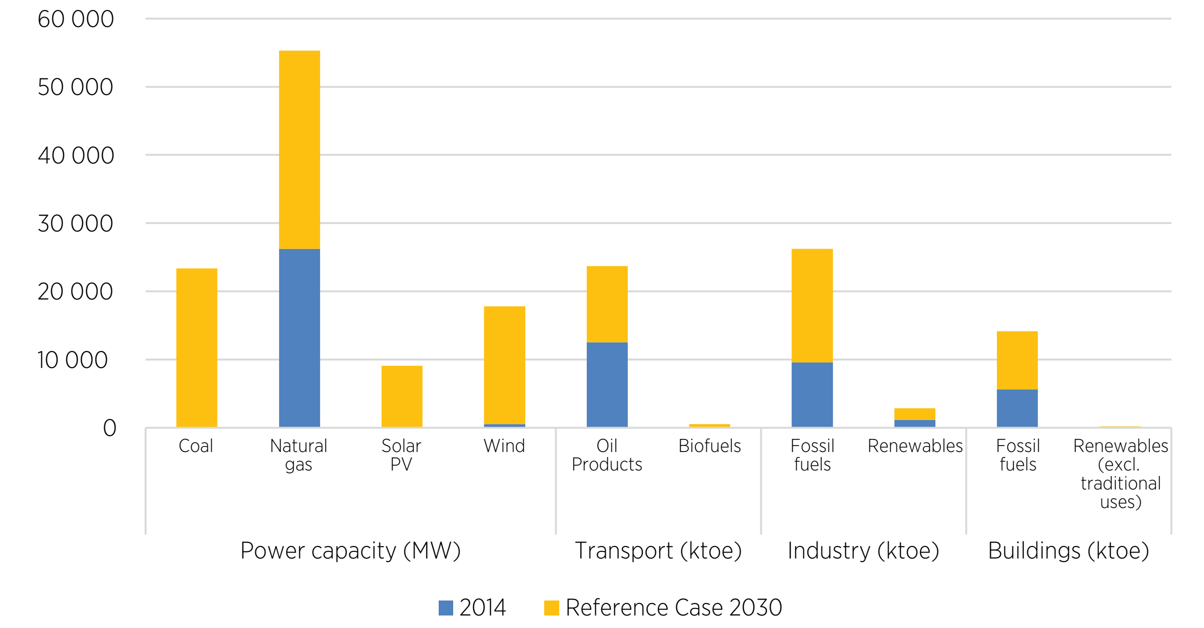
The power sector sees significant additions of generation capacity in the Reference Case. Over 20 GW of new capacity for each of coal and natural gas are installed, 18 GW of wind, and 9 GW of solar PV (see Figure 24).

Table 17. Renewable energy shares by sector based on current plans and policies

Type of energy use		Modern renewable energy share	
		2014 actual	2030 expected in Reference Case
Electricity generation		9%	25%
End-use sectors	Industry (fuels and direct uses, excluding electricity)	11%	10%
	Transport (fuels, excluding electricity)	<1%	2%
	Buildings (modern fuels and direct uses, excluding electricity)	<1%	1.5%
Total final energy consumption (TFEC)		5%	11%
Total primary energy supply (TPES)		4%	8%

Note: End-use sector shares (industry, transport and buildings) show the share of renewable energy in each sector's energy demand excluding electricity, i.e. fuels and other direct uses of energy. "Modern" refers to the share of modern renewable energy consumed in the buildings sector and overall energy (TFEC, TPES). Modern renewable energy is defined as including all forms of renewable energy except traditional uses of bioenergy (a notable part of energy use in the buildings sector).

Figure 24. Selected fossil and renewable energy supply developments in 2014 and in the Reference Case in 2030



Fuel demand growth is significant in the transport sector, increasing by 93%. Oil products remain the dominant fuel source, supplying around 98% of the sector's energy needs in 2030. Of the remaining 2%, liquid biofuels provide the largest proportion, largely bioethanol from sugarcane.

The industrial sector sees the largest increase in energy demand of any end-use sector, with almost 150% growth. Fossil fuel demand in the sector more than doubles, with a mix of coal, natural gas and oil products, and the sector sees a slight increase in the use of renewable energy due to the combustion of biomass residues, driven by the growing output of biomass processing industries such as sugarcane. Biogas from biomass processing wastes also contributes to the increase in renewable energy share.

Finally, the buildings sector sees a 135% increase in energy demand, and a very small increase in renewable energy use from limited solar thermal for hot water and biogas facilities for cooking.

4.2 REmap Case – accelerating renewable energy

This section discusses the REmap Case, which is an assessment of the accelerated potential of renewable energy in Egypt. The key findings relate to the REmap Options, which are renewable energy technologies and sources that have additional potential to be utilised or deployed on top of developments in the Reference Case. This section's main aim, therefore, is to outline where the additional potential of renewable energy lies in Egypt, both in meeting the aims of the ISES and also increasing renewables even further.

The REmap Options explore the potential to increase renewables across all sectors of Egypt's energy system – it uses a mixed approach aimed at maximising renewable energy deployment and looks at options in power, thermal, transport and cooking applications. It also quantifies the renewable options in terms of their costs, benefits and investment needs. More information on the approach to determining the REmap Options and sources is available in Annex II.

Drivers for renewable energy

The REmap Options identify areas across Egypt's entire energy system where additional potential for using renewable energy lies. The criteria for selecting these options are not based solely on cost, but also on additional motivating factors that incline governments to support increased deployment of renewable energy technologies. These factors can include efforts to improve energy security, promote domestic industry, and to reduce adverse health effects and environmental damage.

However, the REmap Options do show that renewables are in many cases the least-cost option for energy supply in Egypt. The cost case is even more appealing when considering benefits that arise from reduced air pollution and CO_2 emissions. As the costing section shows, the grouping of technologies identified in REmap not only reduce energy system costs as a whole – meaning lower overall energy costs for consumers – but also result in at least twice as many savings from reduced external costs due to lower levels of air pollution and environmental damage.

Fossil fuels carry price volatility risk, particularly where they are imported. Valuing this risk is difficult, but should be considered when evaluating energy system investments. The renewables identified in this section either have no fuel price volatility (such as for solar, wind or hydro resources), or in the case of bioenergy are based largely on the local agro-economy, which generally affords government more control over the market and certainty on how costs will develop over time.

Subsequently, energy security and diversification are a key driver of Egypt's energy policies. According to Egypt's ISES, the import dependence rate for fossil fuels reached 10% in 2014/15, and in the reference case scenario from that report, which is the basis of the Reference Case of this report, the share is expected to reach 50% in 2034/35. This indicates the crucial need for Egypt to enhance and expedite its efforts for the development of both energy efficiency and renewable energy.

The sections that follow go into more depth on what additional potential is available, in which technologies and sectors. They also quantify those technologies and sources in terms of their costs, benefits and investment needs.

Summary of REmap findings

- In the REmap Case the share of renewables increases across all sectors, with the largest increase in the power sector. Overall, renewable energy can provide 22% of Egypt's energy supply in TFEC in 2030, up from just 5% in 2014. Renewables in TFEC increase from 3.2 Mtoe in 2014 to 11.5 Mtoe in the Reference Case and to 21.7 Mtoe in the REmap Case by 2030 – a 600% increase in absolute terms over 2014.

- The renewable power mix moves from one dominated by hydroelectricity to a much more diverse mix of technologies that includes sizeable generation from solar PV, CSP and wind. While power generation from natural gas remains the largest generation source, the second-largest is solar PV, followed by wind and CSP. In the REmap Case by 2030, 53% of generation is supplied from renewable sources, a doubling over the share in the Reference Case and up from 9% in 2014.

- Renewables use in the end-use sectors is also important in the REmap findings, with around 10% of fuel use in all end-use sectors being met by renewables, including bioenergy and solar thermal.

- The REmap analysis identifies additional renewable energy potential across all sectors of the Egyptian energy landscape. However, the analysis shows that the largest potential, and where the largest growth occurs, is in the power sector. The power sector sees significant growth due to untapped potential, particularly for solar PV and CSP, but also for wind power. In both the Reference Case and the REmap Case, the share of renewable energy in TFEC that comes from renewable power is around two-thirds, with the remainder largely being renewable fuels and other direct uses in industry.

Overall, renewable energy can provide 22% of Egyptian TFEC, doubling the share in the Reference Case and up from just 5% in 2014 (see Table 18). At the sector level, the largest share is in the power sector where over half of electricity comes from renewable sources. Across the end-use sectors the share of renewable energy in fuels and direct uses varies from 9% to 12% (i.e. the share of sector energy excluding electricity). If end-use sectors also include electricity consumed in them, then the renewable share in each sector would be higher, at 19% in industry, 11% in transport, and 35% in buildings. The reason these shares increase when including electricity is because over half of the electricity supplied is renewable.

Table 18. Renewable energy shares in 2030 given different cases for growth of renewables

Type of energy use		Modern renewable energy share		
		2014 actual	2030 expected in Reference Case	REmap 2030
Electricity generation		9%	25%	53%
End-use sectors	Industry (fuels and direct uses, excluding electricity)	11%	10%	12%
	Transport (fuels, excluding electricity)	<1%	2%	10%
	Buildings (modern fuels and direct uses, excluding electricity)	<1%	1.5%	9%
Total final energy consumption (TFEC)		5%	11%	22%
Total primary energy supply (TPES)		4%	8%	22%

Note: End-use sector shares (industry, transport and buildings) show the share of renewable energy in each sector's energy demand excluding electricity, i.e. fuels and other direct uses of energy. "Modern" refers to the share of modern renewable energy consumed in the buildings sector and overall energy (TFEC, TPES). Modern renewable energy is defined as including all forms of renewable energy except traditional uses of bioenergy (a notable part of energy use in the buildings sector).

Looking at how these percentages translate into energy supply when viewed in final energy terms, several key findings are evident, as seen in Figure 25. Renewable power generation sees its relative importance grow, from making up around one-third of renewable energy consumed in 2014 to over two-thirds in REmap in 2030. The renewable power mix also changes, moving from one dominated by hydroelectricity to a much more diverse mix of technologies that includes the majority of generation coming from solar PV, CSP and wind. In fact, while power generation from natural gas remains the largest generation source, the second-largest is solar PV, followed by wind and CSP. Overall, renewable power generation in the country increases over tenfold, from just 16 TWh in 2014 to 186 TWh in REmap in 2030.

Despite the significant potential of renewable power, however, renewable energy use must also be considered in buildings, industry and transport. In these end-use sectors, energy is needed in the form of fuels and direct use for thermal, cooking and transport applications. In fact, in final energy terms these energy needs make up just under three-quarters of energy demand, and in primary energy terms they make up around 60% of energy demand. Therefore, a holistic view of energy is needed, taking account of the potential of renewables for heat, fuels and other direct uses.

Despite Egypt's arid environment, bioenergy is still an important source in end-use energy applications due to its ability to be used for heat and transport fuel. Bioenergy is the primary renewable source for heat and fuels in the end-use sectors in 2014, and remains so in the Reference Case. In REmap additional potential for bioenergy has been identified and is detailed in more depth in the sector discussions later in this chapter. In the REmap Case bioenergy accounts for around 5% of TFEC in 2030, an increase from 3.5% in the Reference Case in 2030 and 2.5% in 2014.

Solar thermal is also an important source of renewable energy in the end-use sectors of buildings and industry. The technology can provide domestic hot water in the residential sector, but also in subsectors including tourism and commercial uses. In industry, solar thermal systems can provide low-temperature heat and pre-heating or other process heat uses. The Reference Case does see a slight increase in solar thermal systems in the buildings sector, providing, however, just 0.6% of sector energy. In the REmap Case sizeable additional potential has been identified, raising the share of buildings sector energy supply met with solar thermal to 2.7%, and introducing limited solar thermal in industry able to provide around 1.5% of sector energy.

The REmap Options also consider electrification technologies, largely in transport in the form of electric mobility and in the buildings sector for cooking and water heating needs. Electrification in Egypt also makes sense given the strong renewable power resources available in the country.

In total, the amount of modern renewable energy used in Egypt increases from 3.2 Mtoe in 2014 to 11.5 Mtoe in the Reference Case, and increases further to 21.7 Mtoe in REmap in 2030 – more than 600% above the 2014 level. This would lead to a quadrupling of the share of modern renewables in TFEC from 5% in 2014 to 22% in REmap.

Further developments by case are presented in Table 19. The table shows how power capacity and generation develop from 2014 to 2030 in both the Reference Case and REmap Case. It also details how the use of fuels and direct uses of energy in both the industrial and buildings sectors change, with specific focus on solar thermal and bioenergy. In transport it outlines how liquid biofuel supply develops, as well as electric mobility. It also outlines how the renewable energy shares change over the various cases. Finally, the table presents several key financial indicators. The sections that follow go into detail to explain how these developments occur at a sector level, and discuss in more detail what the costs and benefits are that arise from greater renewables deployment.

Figure 25. Renewable energy in TFEC, 2014, 2030

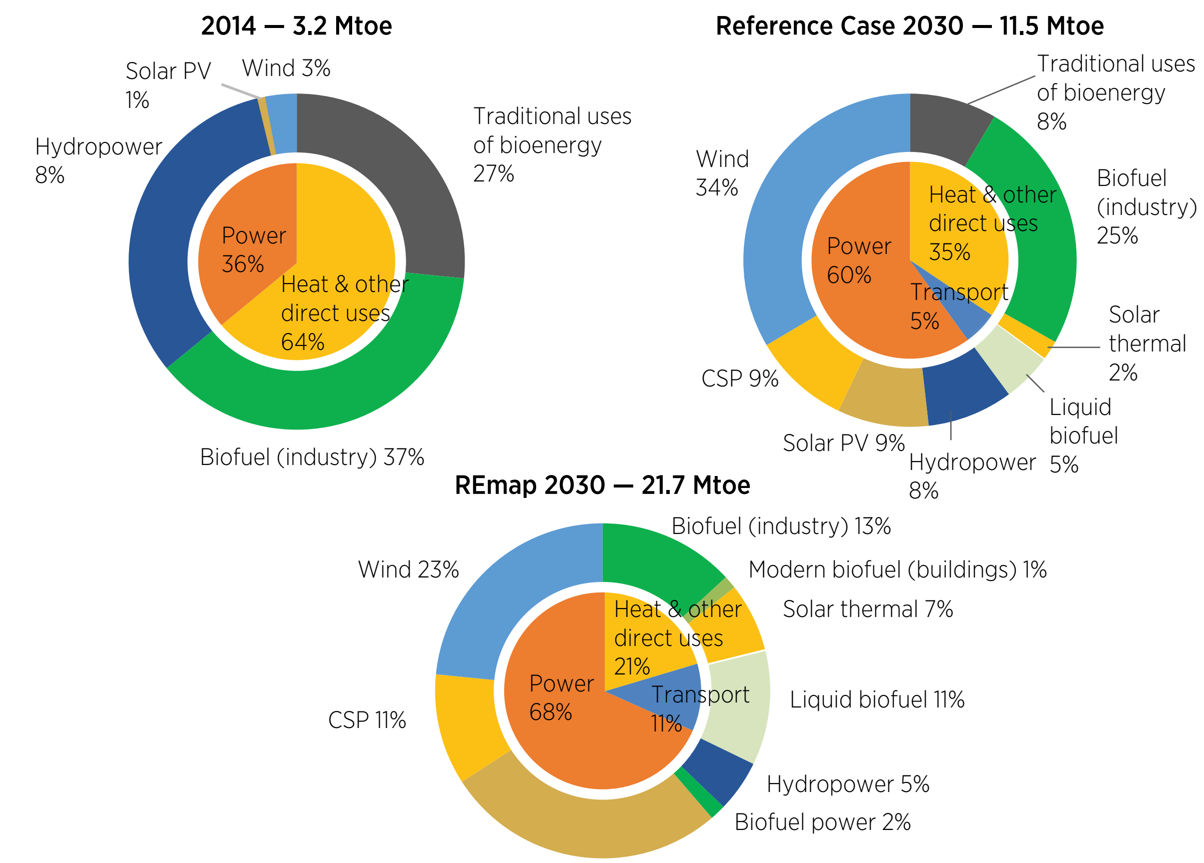


Table 19. Roadmap for scaling up renewable power in Egypt to the year 2030

Egypt			Unit	2014	Reference Case 2030	REmap 2030
Energy production and capacity	Power Sector	Total installed power generation capacity	GW	33	117	137
		Renewable capacity	GW	3	34	76
		Hydropower (excl. pumped hydro, domestic)	GW	2.8	2.9	2.9
		Wind	GW	0.55	18	21
		Biofuels (solid, liquid, gaseous)	GW	<1	<1	1
		Solar PV	GW	0.1	9	44
		CSP	GW	0.2	4	8
		Geothermal	GW	0	0	0
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	29	84	61
		Total electricity generation	TWh	172	385	348
		Renewable generation	TWh	16	98	186
		Hydropower	TWh	14	14	14
		Wind	TWh	1.3	55	64
		Biofuels (solid, liquid, gaseous)	TWh	0	0	5
		Solar PV	TWh	0.2	14	74
		CSP	TWh	0.6	15	29
		Geothermal	TWh	0	0	0
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	156	287	162
Final energy use - Direct uses	Building and industry	Total direct uses of energy	ktoe	17 474	44 672	43 437
		Direct uses of renewable energy	ktoe	2 021	4 055	4 595
		Solar thermal – Buildings	ktoe	0	214	930
		Solar thermal – Industry	ktoe	0	0	525
		Geothermal – Buildings and Industry	ktoe	0	14	14
		Bioenergy (traditional) – Buildings	ktoe	839	975	0
		Bioenergy (modern) – Buildings	ktoe	0	0	274
		Bioenergy – Industry	ktoe	1 183	2 852	2 852
		Non-renewable – Buildings	ktoe	5 664	14 171	13 048
		Non-renewable – Industry	ktoe	9 596	26 253	25 601
		Non-renewable – BF/CO	ktoe	193	193	193
	Transport	Total fuel consumption	ktoe	12 978	24 911	24 171
		Liquid biofuels	ktoe	0	547	2 389
		Conventional biogasoline	ktoe	0	547	239
		Advanced biogasoline	ktoe	0	0	0
		Biodiesel (conventional and advanced)	ktoe	0	0	2 150
		Biomethane	ktoe	0	0	0
		Non-renewable fuels	ktoe	12 978	24 364	21 782
		Electricity	TWh	1	2	6
		BEV – passenger (thousands)	1 000 units			637
		BEV – public (thousands)	1 000 units			10
		BEV – freight (thousands)	1 000 units			10
		2/3-wheeler electric (thousands)	1 000 units			1 429
Total final energy consumption (electricity, direct heat, direct uses)			ktoe	45 054	99 660	98 140

Table 19 continued

Egypt		2014	Reference Case 2030	REmap 2030
Renewable Share	in electricity generation	9%	25%	53%
	in buildings – final energy use, direct uses (modern)	<1%	1.5%	9%
	in industry – final energy use, direct uses	11%	10%	12%
	in transport fuels	<1%	2%	10%
	in TFEC (share of modern renewables)	5%	11%	22%
Other indicators	System costs (USD bln/yr in 2030)	N/A	N/A	-0.9
	RE investment needs (USD bln/yr [2010–30])	N/A	2	6.5
	Investment support for renewables (USD bln/yr in 2030)	N/A	N/A	0.6
	Savings from reduced externalities – air pollution (average) (USD bln/yr in 2030)	N/A	N/A	2.9
	Savings from reduced externalities – CO_2 (USD 50/tonne CO_2) (USD bln/yr in 2030)	N/A	N/A	5.2
	CO_2 emissions from energy (Mt/yr)	156	354	249

Notes: BEV = battery electric vehicle; BF/CO = blast furnace and coke ovens; N/A = =not applicable; yr = year.

Box 3:

Potential for bioenergy growth

Bioenergy accounts for a small share of Egypt's TFEC. Analysis based on a literature survey indicates that around to 2 000 ktoe of bioenergy was used in the country in 2014, which represents a little over 3% of TPES. IRENA statistics show a slightly higher value in 2015, at around 3 500 ktoe. The residential sector alone accounts for around 40% of the bioenergy use, mostly for cooking and heating. Most of that bioenergy is solid biomass in the form of agricultural residues, with some woodfuel and charcoal use. The remaining 60% is used in industry, where solid biomass is relevant in the food industry and the cement sector. In the food industry, the sugarcane sector is the most relevant where bagasse is used in co generation plants to supply the industry's internal heat and power needs.

In the cement sector, a little over 6% of thermal energy needs are supplied by so-called alternative fuels that include biomass, such as agricultural wastes (rice straw, cotton stalks, maize straw), dried sewage sludge and refuse-derived fuel (RDF), which is partly biomass in the form of the organic fraction of municipal solid waste (IFC, 2016). The use of bioenergy is negligible in transport and electricity generation.

Despite the limited use of bioenergy in Egypt and considering the restrictions imposed by land and water scarcity, some potential exists for growth in bioenergy use. The use of agricultural residues currently left in the field or burnt in an uncontrolled manner is one significant source of biomass resources that can be tapped. This would not only help improve bioenergy availability, but also mitigate local air pollution from the emissions produced during uncontrolled burning. Livestock wastes are another source, including animal and chicken manure. Also, the waste management sector could contribute to a greater extent, by incorporating energy recovery solutions into municipal solid waste disposal and wastewater treatment. In fact, the current use of RDF and dried sewage sludge in cement plants is an important step in that direction. Finally, there is the opportunity to develop dedicated energy crops in desert land, using reclaimed wastewater for irrigation. The analysis of different biomass sources from a literature survey indicates the existence of the following potential today:

- Agricultural residues: around 9 million dry-tonnes, which correspond to 3 250 ktoe/year, in the form mainly of rice straw and husks, corn stover, sugarcane straw and bagasse, and cotton stalks (based on FAO, 2017). This is additional potential supply, above current uses.
- Municipal solid waste: around 20 Mt per year, which translates to 3 820 ktoe/year (based on GIZ, 2014).
- Sludge from wastewater treatment plants: around 1 Mt per year, or 335 ktoe/year (based on Ghazy et al., 2011, and Said et al., 2013).
- Livestock manure: 120-240 ktoe if converted to biogas (based on UNDP/GEF, 2008).
- In addition, there is the potential for dedicated crops grown on reclaimed desert land using treated wastewater (based on El Diwany et al., 2008, and Fawzy and Romagnoli, 2016).

These estimates could translate conservatively into over 4 700 ktoe/year of bioenergy in the end-use and electricity generation sectors, which would more than double current bioenergy deployment. Said et al. (2013), for instance, estimate a significantly higher technical potential, equal to 9 960 ktoe/year.

One of the main challenges to realising such potential is development of adequate biomass supply chains. Most of the industrial facilities that can potentially use biomass for process heat and/or power generation are large-scale, centralised plants operating at economies of scale that require large energy flows to be brought from within and across national borders.

Consequently, the development of biomass supply chains has to be supported to ensure the delivery of reliable, high-quality and affordable biomass fuels to those industries that are willing to use biomass, while at the same time diversifying income streams for local farms without introducing potential risks. The development of such supply chains could benefit multiple users of different parts of the biomass feedstock.

Power sector

- Electricity generation more than doubles between 2014 and 2030. Renewable electricity generation grows significantly in both the Reference Case and REmap with large additions of solar PV, CSP and wind. The overall renewable energy share in power generation reaches 53% in REmap in 2030, doubling the 25% share in the Reference Case, and significantly higher than the 9% share in 2014.

- Power system capacity increases from 33 GW in 2014 to 117 GW in the Reference Case, and further to 137 GW in REmap. Natural gas remains the largest source of power capacity and generation; however, in REmap the second-largest is solar PV, followed by wind and CSP.

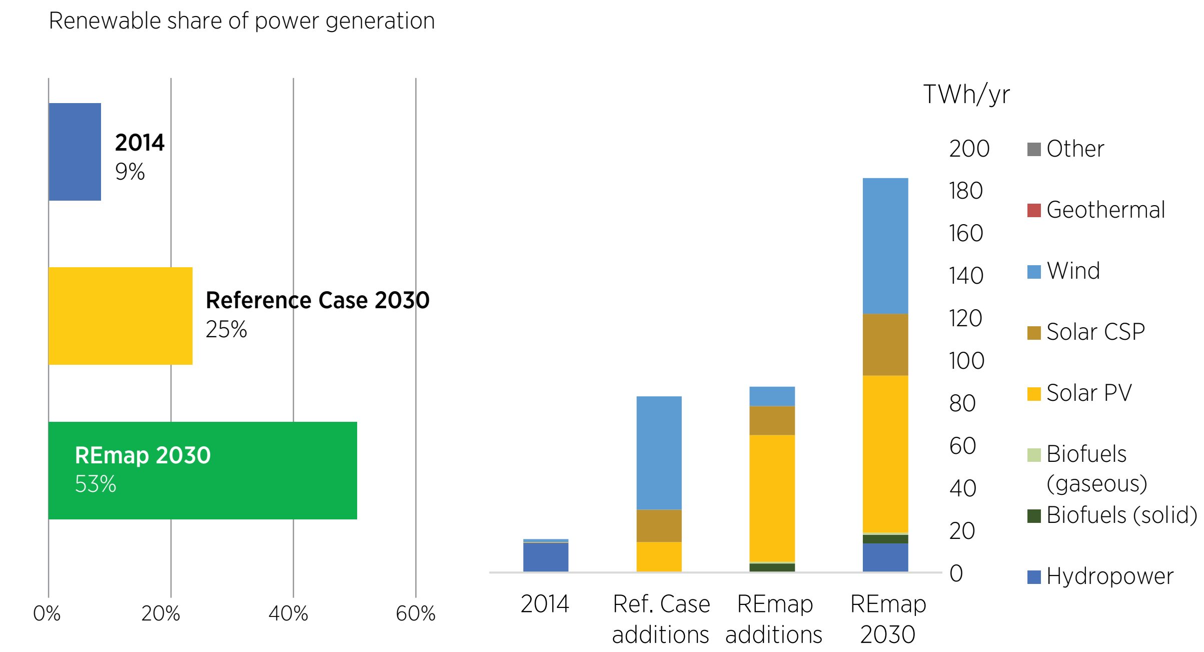
The power sector in Egypt sees significant changes by 2030. Electricity demand grows by almost 125% to over 385 TWh per year in the Reference Case. Over 80% of that increase is due to higher demand from the buildings sector, resulting from a growing population and demand for cooling and domestic appliances. To meet this growing demand, Egypt is exploring a wide range of technologies, from conventional to renewable.

Renewable power generation grows significantly in both the Reference Case and REmap Case. As can be seen in Figure 26, the overall renewable energy share of power generation reaches 53% in REmap in 2030, doubling the 25% share in the Reference Case and significantly higher than the 9% in 2014. The growth already occurring in the Reference Case is encouraging and points to the strong renewable resource availably in the country. However, the REmap Options show that significantly higher deployment of renewables could take place.

Power system capacity increases from 33 GW in 2014 to 117 GW in the Reference Case, and further to 137 GW in REmap. Natural gas remains the largest source of power capacity and generation; however, in REmap the second-largest is solar PV, followed by wind and CSP. The increase in system capacity in REmap is due not only to increased electrification in end uses, such as electric vehicles (EVs), but also to the lower capacity factor of solar and wind compared to conventional power plants, thereby necessitating more installed capacity.

The renewable power additions occurring between 2014 and 2030 differ between the Reference Case and the REmap Case (see Figure 26). The Reference Case sees over half of new renewable power generation come from wind, with the remainder split between solar PV and CSP, whereas in REmap the bulk of new generation is from solar PV. Under REmap, roughly half of the renewable power additions over the period come from solar PV. Total renewable power generation increases from 16 TWh in 2014 to 186 TWh in REmap in 2030.

Figure 26. Power sector renewable shares and generation, 2014, 2030



Under REmap, the largest new power source is solar PV, with 35 GW of additions on top of the 9 GW occurring in the Reference Case.

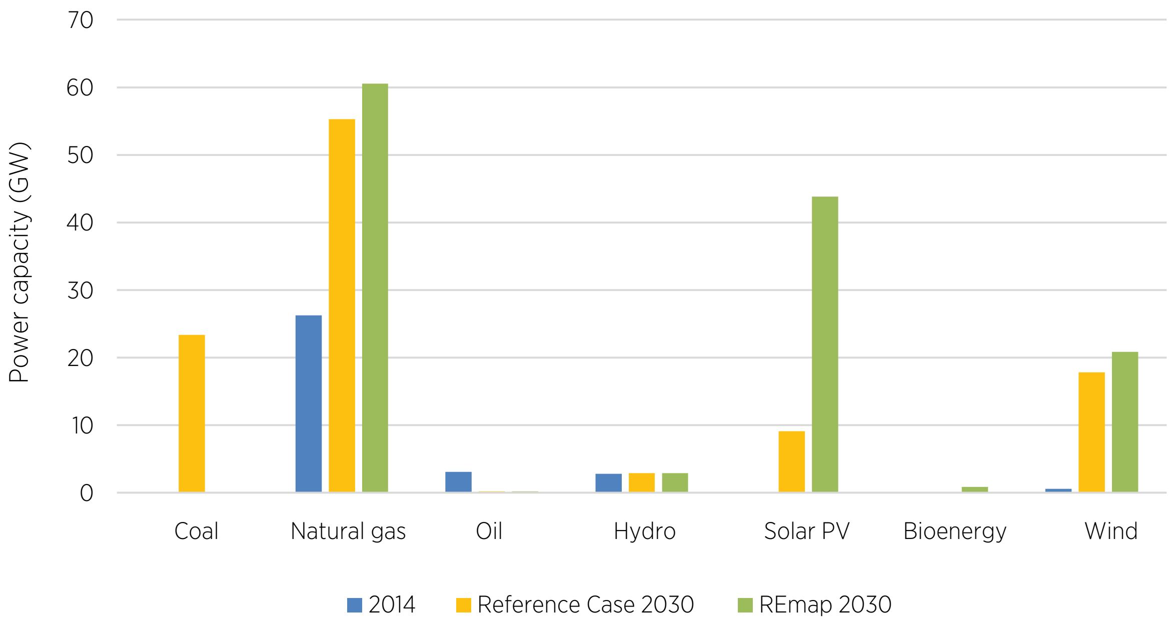
Wind power sees the largest additions in the Reference Case, with a total of 18 GW installed by 2030; additions from the REmap Options of 3 GW result in a total of 21 GW in the REmap Case in 2030. CSP grows by 4 GW in the Reference Case and a further 4 GW under REmap Options; however, the REmap Options see CSP additions that are largely coupled with storage.

Natural gas remains the largest generation source, and is subject to strong growth in the Reference Case, with additional capacity of around 20 GW.

The Reference Case also demonstrates strong growth in both coal and nuclear power, new entries into the Egyptian power generation fleet. However, the REmap Options largely replace these two power sources, adding a further 5 GW of natural gas-fired generation to help facilitate flexible generation in a power system with a high share of variable renewable power (Figure 27).

This significant growth in solar PV, CSP and wind is largely the result of rapidly improving market conditions for these power technologies (the costs for which are summarised in the cost and benefits section of this chapter) and the ability for new plants to be built quickly to meet the country's rapidly growing electricity demand.

Figure 27. Power sector capacity developments, 2014, 2030



The use of biomass for power generation is currently very limited in Egypt. The main exception is the use of bagasse in sugarcane mills to produce electricity in co generation systems. But given the availability of agricultural residues that are currently burnt in the field or unutilised, significant potential for growth exists. In particular, the use of rice residues (husks and straw) and an improvement in the energy efficiency of sugar mills could be interesting opportunities. Because of this, the REmap Options assume some small growth in co generation based bioenergy power; however, the contribution remains modest in the overall power system.

As an example of low-hanging fruit in Egypt's biomass-based industries, the sugarcane industry has the potential to maximise the generation of surplus electricity through the efficient use of biomass residues, which should be promoted. Older installations in existing plants often operate at lower pressures, with low thermal efficiency. Given the development of technology, and provided the right incentives are in place, retrofitting old plants and promoting the installation of the latest technology in new plants is a pathway that could be pursued.

For instance, investing in high-pressure boilers in steam co generation systems in the sugarcane industry could generate a potential 30 kWh per tonne of sugarcane in very low-efficiency systems, to 140 kWh per tonne of sugarcane in the most advanced (Mitr Phol, 2014). Promoting the use of modern installations that convert biomass to power at the highest efficiencies is a must and depends on appropriate incentive mechanisms being put in place.

The expansion of biomass-based IPPs is also an option. Abdelhady et al. (2014) investigated the potential of rice straw for energy production in Egypt and estimated that about 3 Mt of rice straw are disposed of by open burning in the field every year, causing environmental problems. In their study, they assessed the performance of a power plant fuelled by rice straw and found that it has significant potential to be used as fuel for power generation in the country. And the use of biogas produced from the anaerobic digestion of animal manure and wastewater treatment sludge could further boost the potential, as pointed out by Said *et al.* (2013).

If all the REmap Options were deployed, the share of variable renewable energy (VRE) (solar PV, wind and CSP without storage) in Egypt's power system would stand at 40% of annual generation in 2030. REmap does not analyse what types of flexibility measures might be needed in order to accommodate this amount of variable production capacity. IRENA has projects and analysis on the topic from other countries, regions and for general power system contexts. However, further study and analysis needs to take place for the Egypt results in order to provide a better understanding of how electricity end users, local grid and transmission operators, and government regulators can start to plan for a power system with increasing shares of VRE power technologies.

Renewable energy resources such as solar and wind are often operated differently from conventional power generation plants due to their variability. Depending on the share of VRE and the particular features of the power system, to guarantee an efficient and reliable supply of electricity these differences may prompt changes in the way the systems are planned and operated. The variability of VRE and limitations in forecasting its production with high accuracy can pose new challenges for the planning and operation of the power system. If high shares of VRE are to be integrated, the system must be able to deal with additional uncertainty and variability in its operation.

A recently published IRENA report, "Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies", part of AVRIL (Addressing Variable Renewable Energy in Long-term Energy Planning), explains the best practices in long-term planning and modelling to accommodate high shares of VRE (IRENA, 2017d). Requirements for VRE generators to support the stable operation of the system must be identified and established. One way is through updates to the existing grid codes. An IRENA report, "Scaling Up Variable Renewable Power: The Role of Grid Codes" (IRENA, 2016d), explains various aspects of grid connection code development, with country illustrations that might serve as a reference for Egypt's future grid code development as the VRE share increases.

Additional efforts include strengthening and expanding transmission infrastructure. Another method of increasing grid flexibility is the use of so-called "smart grids". A study on the topic (IRENA, 2013), details how effective deployment of smart grids can play a crucial role in smoothing the integration of higher shares of renewable power. Smart grids also support the decentralised production of power and enable the creation of new business models through enhanced information flow. Additionally, flexibility on the demand side is provided by consumer engagement and improved system control. A further IRENA report, "Smart Grids and Renewables: A Cost-Benefit Analysis Guide for Developing Countries" (IRENA, 2015), provides insights on cost-benefit analysis of smart grid systems in developing countries, which could be potentially applicable to Egypt.

In recent years and as early as summer of 2017, the MOERE agreed new contracts for the provision of smart meters. The aim is to help utilities improve the management and operation of the country's energy networks. The deal is part of an effort by the ministry to install up to 20 million smart meters in the next few years.

IRENA's publication on adapting market design to high shares of VRE (IRENA, 2017d) highlights that distribution companies will play a key role in the deployment and operation of grid-related infrastructure, such as EV charging stations in public areas or distributed storage. Egypt does not have explicit plans to see large-scale deployment of millions of EVs; however, REmap identifies significant potential, with almost 700 000 on the road by 2030. If Egypt were to develop a vehicle-to-grid scheme allowing EVs to participate in grid ancillary services such as frequency regulation, load shifting, demand response or energy management support in the home, those services could help enable increasing shares of VRE.

Planning for a future with higher shares of VRE needs to start today. To understand how this can be done, resources such as those listed in this section are a starting point for policy makers to better understand the broad scope of technology solutions, regulations and market approaches that address the issue. However, further study and analysis need to take place for Egypt so as to provide a better understanding of how electricity end users, local grid and transmission operators, and government regulators can start to plan for a power system with increasing shares of VRE power technologies. These studies can start by emphasising analysis of remote, rural or mini-grids, cities and regions, and demand response, smart metering or electric charging.

Buildings sector

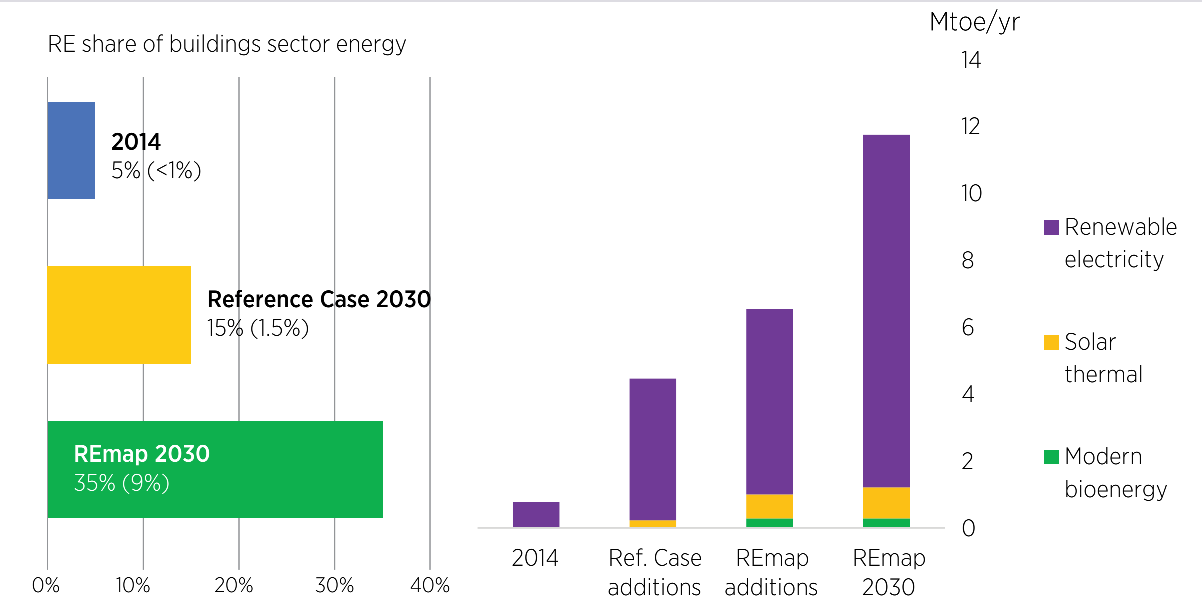
- The buildings sector sees energy demand growth of 135% over the period 2014-2030 in the Reference Case. Most of this increase occurs due to growth in electricity consumption, but also some increase occurs in natural gas and oil use. Traditional uses of bioenergy make a small contribution and remain unchanged in the Reference Case, meeting under 3% of sector energy needs. The renewable share does increase in the Reference Case, largely the result of increases in renewable electricity, but some addition of solar thermal and modern bioenergy is also seen.

- The REmap Options focus on three key end-use technologies: solar thermal, modern bioenergy and electric cooking. Modern bioenergy use, including biogas, and electricity for cooking are key residential applications, along with increased use of solar thermal for water heating. The share of renewables in energy demand for heating and other direct uses increases from 1.5% to 9% by 2030, while the overall renewable share in the sector when including electricity reaches 35% in 2030.

The buildings sector's energy demand in Egypt comprises a mix of electricity for appliances and cooling, some limited thermal needs for water heating, and the use of fuels for cooking. The sector sees strong growth in energy demand of 135% between 2014 and 2030 in the Reference Case. The majority of this growth comes in the form of electricity, used in appliances or for cooling, and natural gas and oil products (mostly LPG) used for cooking. The Reference Case sees little change in bioenergy use, with small amounts of bioenergy still being used in the form of traditional uses for cooking, and a small amount of solar thermal hot water. The result of these developments is little change in the share of renewables providing fuel for heating or cooking; however, when renewable electricity is considered the share does increase to 15%.

The REmap Options focus on three key end-use technologies: solar thermal, modern bioenergy and electric cooking. The main drivers are the use of modern bioenergy, including biogas, and electricity for cooking, and increased use of solar thermal mostly for water heating. In REmap, the share of renewables providing energy for heating and other direct uses increases from 1.5% to 9%, while the overall renewable share in the sector when including electricity reaches 35% (Figure 28).

Figure 28. Buildings sector renewable share and additions as TFEC, 2014, 2030



Note: The figure shows two renewable energy (RE) shares; the RE share of sector energy shows the share as a percentage of all energy consumed in the sector, including fuels, direct uses and electricity; the share in parentheses shows the RE share of final energy consumed in the sector excluding electricity, i.e. only for fuels and direct uses.

Solar thermal has been used for water heating in Egypt for decades, but has significant additional potential. REmap sees the addition of around 5.2 gigawatts thermal (GWth), or around 125 000 medium-sized systems. These are installed in buildings that have larger heating demand, such as hotels, commercial buildings and apartment complexes. Solar thermal systems in REmap can meet around 3% the buildings sector's energy demand.

The use of bioenergy in the residential sector is usually a matter of debate because statistics tend to be unreliable and difficult to obtain. A fair assessment of bioenergy use in this sector is essential, based on household surveys, in order to orient policy making. In general terms, however, traditional uses of solid biomass residues from farming and livestock are usually significant in regions with little access to affordable alternative cooking fuels such as LPG, biogas and electricity.

In such situations, the use of modern, clean cook stoves with improved solid biomass fuels (e.g. in the form of briquettes or pellets) can significantly improve the practice of solid biomass use for heating and cooking and, most importantly, reduce indoor air pollution, with strong improvements in health conditions. These modern cook stoves are up to four times more efficient compared with traditional cooking methods, reducing cooking times and indoor air pollution.

Cook stoves based on ethanol gels have also gained attention in recent years, with promising results in various African and Asian countries. Biogas is another alternative that, when implemented with the right long-term support to ensure adequate maintenance of the biodigesters, yields positive results. In the Reference Case there remains a small amount of traditional use of bioenergy, largely in rural, upper Nile regions of Egypt. In REmap most of the remaining traditional bioenergy is assumed to be replaced with modern solid biomass cookstoves, as well as some biogas units.

Electric cooking is a further option. This is a clear trend in developed countries, but uptake varies widely. The challenge for widespread deployment in developing countries is the need for a grid connection. Older electric coil technologies with 4 rings typically have 1.5 kW capacity and may require 0.5-1.5 kW during operation. New induction cooking technologies have dropped significantly in price in the last few years, and their efficiency is higher and electricity demand lower. Whereas electric coils need 2.0 kW to deliver 1.1 kW of heat (55% efficiency), natural gas has a similar efficiency of 50% and LPG has around 40% efficiency, induction efficiency is closer to 90%. Therefore, modern electric cooking technologies can be a means of reducing the use of LPG or other fuels and saving consumers money.

One of the largest sources of electricity demand in the buildings sector is for cooling. While almost the entirety of this increase in cooling demand will be met with traditional air conditioners, which are seeing increases in their efficiency, they still require significant amounts of electricity. Solutions do exist to meet cooling demand through novel technologies and approaches; for instance, district cooling is an option for new residential developments, large commercial users and hotels, where a centralised, high-efficiency cooling unit provides either chilled water or cooled air to numerous blocks or buildings. A recent IRENA study outlined in more detail the opportunity for this technology (IRENA, 2017d). Technologies such as cold storage can also be considered in certain cases. During the night or times when electricity is plentiful (from variable renewable power generation such as solar and wind), ice is produced, stored, and then used when cooling is needed and electricity is in short supply or costly.

Industrial sector

- The industrial sector's energy demand is the largest of all end-use sectors in Egypt and sees the largest growth in energy demand, with an increase of around 150% occurring between 2014 and 2030. In the Reference Case, 80% of this growth is met with fossil fuels, with most of the remainder being met by increased demand for electricity and slight growth in bioenergy. Overall the renewable share in the sector remains at historic levels of around 13% in the Reference Case.

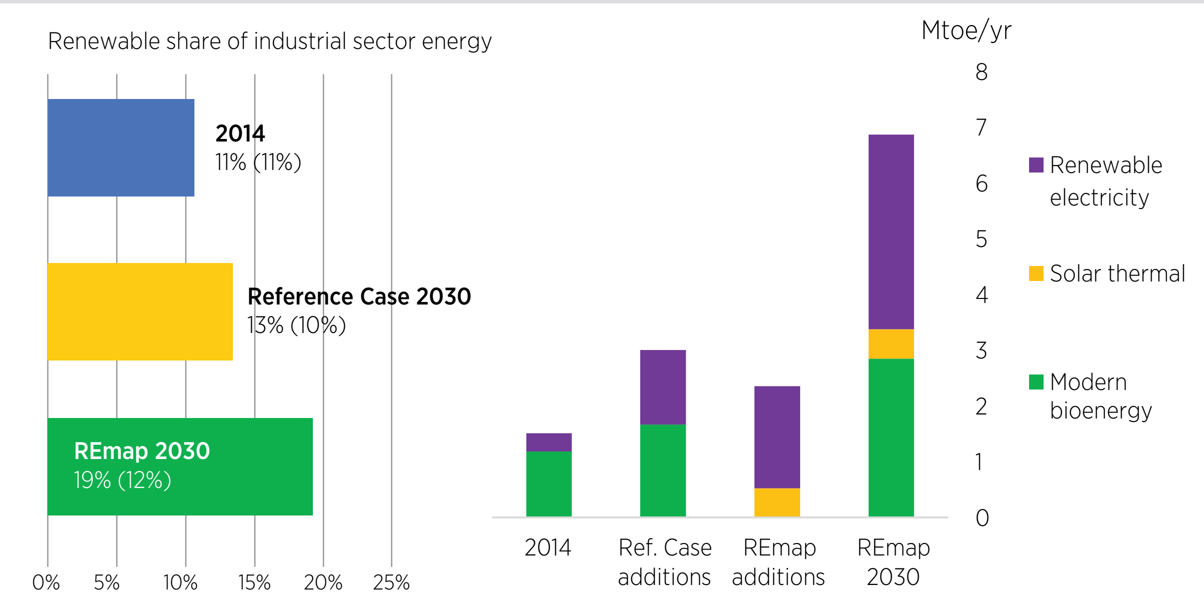
- The main technology deployed in the REmap Case is solar thermal used for industrial process heating applications and pre-heating. The share of renewable energy in the sector therefore increases marginally to 19%.

The industrial sector sees the largest energy demand growth of any end-use sector, with an increase of almost 150% by 2030. Fossil fuels meet 80% this growth in the Reference Case, with the largest increases in oil products, followed by natural gas and coal. The remainder of the increase in energy demand is mostly met with electricity, followed by small amounts of bioenergy. Over the period the renewable share, if viewed in terms of fuels and direct uses of energy, stays more or less constant at around 10% in the Reference Case (see Figure 29).

Broadly defined, the industrial sector requires energy in the form of electricity and fuels to combust for process heat. For heat, bioenergy is typically a key renewable solution due to its ability to be combusted for higher-temperature process heat; however, bioenergy supply is limited in the industrial sector in Egypt and therefore additional potential is not assumed in the REmap Case. The main technology assumed for increasing renewable heat in the REmap Options in industry is solar thermal, specifically, low-temperature technologies used mainly in food processing for pre-heating and drying, or other low- to medium-temperature uses in the textile and chemicals subsectors. However, these additions are limited to around 3 GWth of solar thermal systems, which could provide around 1.5% of sector energy.

However, there is a very active bioenergy market for industrial uses. The use of bagasse in co generation systems in the sugarcane industry is a good example, but the cement sector also currently plays a prominent role in the use of biomass as a substitute for fossil fuels in Egypt. Agricultural residues, RDF produced from municipal solid waste and sewage sludge from wastewater have been used successfully in some cement plants and there is potential to expand. Currently the cement sector satisfies a little over 6% of its thermal energy needs using alternative fuels such as agricultural residues, RDF and dried sewage sludge (IFC, 2016). However, the potential for growth exists as biomass resources are available and the rate of substitution could technically increase to higher levels (international experience shows rates of substitution as high as 40%). The International Finance Corporation (IFC) recently conducted an analysis of the sector in Egypt and assessed that in the worst-case scenario the share of alternative fuels could almost double, increasing to 13%, with potential to reach 30%. This would also benefit the development of more sustainable waste management solutions by incorporating added value to the collection and adequate processing of solid waste, agricultural residues and wastewater treatment sludge.

Figure 29. Industrial sector renewable share and additions as TFEC, 2014, 2030



Note: The figure shows two renewable energy shares; the "renewable share of industrial sector energy" shows the share as a percentage of all energy consumed in the sector, including fuels, direct uses and electricity; the share in parentheses shows the renewable share of final energy consumed in the sector excluding electricity, i.e. only for fuels and direct uses.

Transport sector

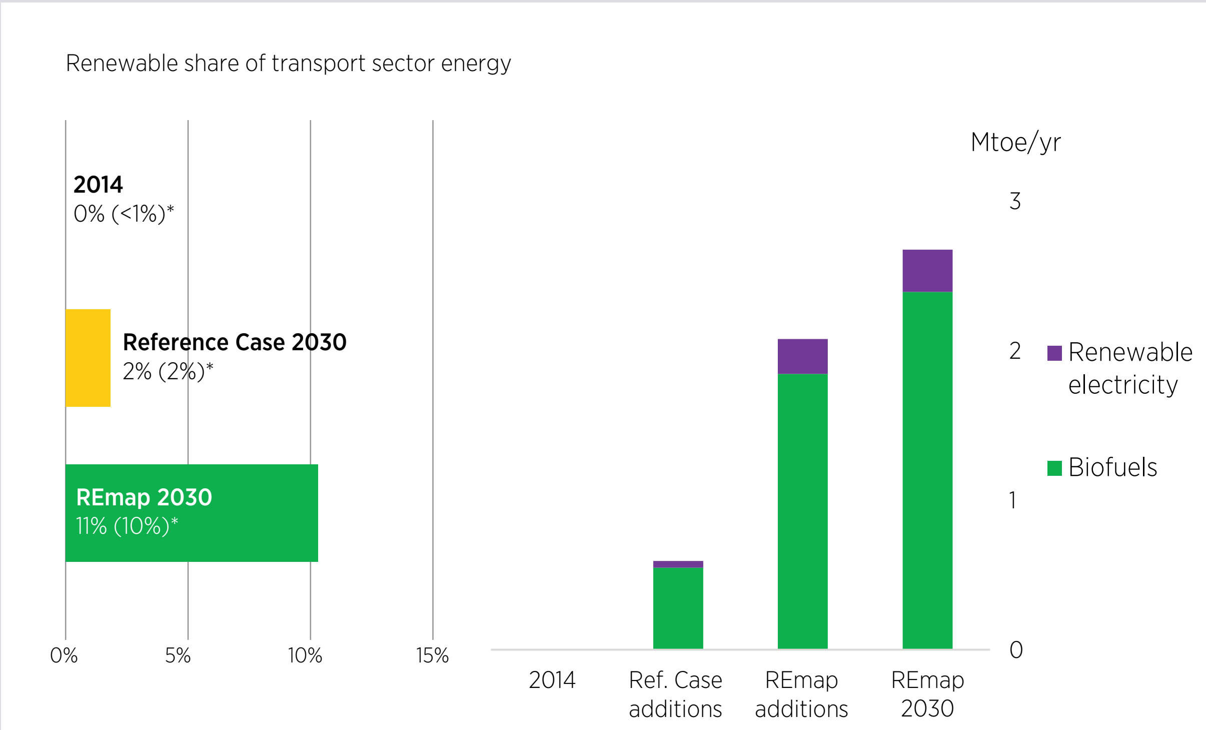
- The transport sector sees energy demand increase by 93% between 2014 and 2030. Oil products meet 95% of this increase in demand, with only small additions from liquid biofuels and electricity. The renewable energy share in the sector is just 2% in the Reference Case.
- REmap focuses on identifying the potential of EVs in various modes, and as a result the demand for electricity in the sector almost triples. The number of passenger EVs on the road by 2030 would total 700 000 and the renewable energy share in the sector would increase to 11%. REmap also assumes some additional liquid biofuels, namely biodiesel.

In Egypt, the transport sector sees strong energy demand growth, increasing by 93% with almost all of this increase met with oil products. The transport sector is traditionally the most challenging sector in which to increase renewable energy. In the Reference Case the fuel mix changes little. There is slight growth in liquid biofuels, providing around 2% of sector energy, and the use of electricity increases marginally.

Given the severe constraints on the availability of agricultural land and water resources, the development of bioenergy crops for liquid biofuel production faces significant challenges in the country and the use of biofuels in transport is not significant in Egypt. But alternative solutions could be pursued in an effort to reduce dependency on fossil fuels in gasoline and diesel vehicle fleets.

Given the vast amounts of desert land, the cultivation of energy crops on such terrain using reclaimed wastewater is an alternative option. In fact, positive experiences have been recorded in the use of treated wastewater that does not reach the required quality standards for other uses, for irrigation of non-edible crops in desert land (Wahaab, 2013). These include energy crops such as jatropha, which can be used

Figure 30. Transport sector renewable shares and additions as TFEC, 2014, 2030



Note: The use of electricity in transport technologies, such as EVs, is significantly more efficient than liquid fuels when viewed in final energy terms (right figure). If viewed in terms of activity, such as passenger kilometres, one unit of electricity can provide between two and four times the service compared to an electric fuel. The figure, therefore, vastly understates the impact of electricity in transport modes such as passenger road services, in which the REmap Options result in 25% of the vehicle stock being electric and providing around 40% of passenger service. The figure also shows two renewable energy shares; the "renewable share of transport sector energy" shows the share as a percentage of all energy consumed in the sector, including fuels and electricity; the share in parentheses shows the renewable share of final energy consumed in the sector excluding electricity, i.e. only for fuels.

for biodiesel production. Fawzy and Romagnoli (2016) and El Diwany et al. (2008) conclude that the production of biodiesel from jatropha in Egypt would have many environmental benefits, such as combating desertification, and fewer impacts compared to fossil fuel diesel. In view of the experimental results and economic assumptions, the prospects might be positive.

Another alternative would be the production of cellulosic ethanol. Cellulosic biomass residues from crop production, such as rice straw, maize residues and sugar cane residues, represent suitable candidates for ethanol production, according to Said et al. (2013) and Tewfik et al. (2013). Both studies conclude that crop residues, especially rice straw, would represent a good candidate as a renewable energy source in Egypt that could be used to produce ethanol and decrease the dependence on fossil fuels.

Biofuels are currently being researched as a way to resolve a municipal and agricultural waste issue rather than as an energy opportunity, such that energy is simply a by-product. In this regard, considerable potential is available for biofuels to be taken forward, as transport sector decarbonisation cannot solely rely on electricity. Embarking on liquid biofuels to power the aviation and heavy-freight sector could promote local industry, while also contributing to any energy security target. For these reasons REmap assumes that some liquid biofuel additions could take place. Around 90% of the liquid biofuel supply would be biodiesel, largely from jatropha, with the remainder from a combination of sugarcane residues. In total, around 10% of sector energy could be met with liquid biofuels.

REmap also emphasises electric mobility in transport. EVs are an emerging technology that could provide an important link with the power system when coupled with VRE such as solar PV or wind, from which Egypt will generate significant power. EVs are also a means to drive down levels of air pollution in urban areas. The Reference Case sees no meaningful increase in the number of EVs on Egypt's roads. However, REmap results in over 700 000 on the roads by 2030, representing 25% of the car stock and around 40% of passenger road activity, and providing 8 GWh of potential storage capacity.

EVs come in other forms besides cars; electric two- and three-wheelers are also deployed, particularity in urban areas, with REmap seeing over 1.5 million on the road. Additionally, larger EVs will also see adoption. Electric buses are emerging as a key public transport solution that has uses along certain transport lines within certain ranges, or where overhead charging, intermittent charging or end-point charging is possible. And light-freight vehicles for services such as package delivery or fleet uses also sees the adoption of forms of electric mobility.

4.3 Costs and benefits of renewable energy

The previous sections provided an overview of the potential for accelerated renewable energy uptake and discussed the technologies across all energy sectors. This section outlines the associated costs and benefits of higher renewables deployment and discusses the level of investment that would be required.

REmap assesses costs and benefits using a variety of indicators; these include:

- A substitution approach, detailing if there is an incremental cost or saving from a renewable energy technology compared to a substituted conventional technology. This view looks only at the associated cost of energy service, i.e. the relative cost of providing the same amount of energy from a renewable technology versus a conventional one. The sum of these costs shows whether there is an incremental energy system cost or saving.

- An externality assessment, which quantifies reductions in external costs due to lower levels of air pollution and CO_2 emissions.

- An assessment of the level of investment needed to deploy all the renewable energy capacity outlined in the Reference Case and the REmap Case; complementary infrastructure is not part of the assessment.

For more information about the approach and methodology, please see Annex I.

Costs and savings

- The REmap Options would reduce energy system costs by some USD 0.9 billion annually in 2030, equivalent to USD -7.0 per MWh. They also result in reductions in external costs of USD 8.1 billion annually on average in 2030. Therefore, the package of renewable technologies is both cheaper than the fossil alternatives and also results in significant reductions in external costs.

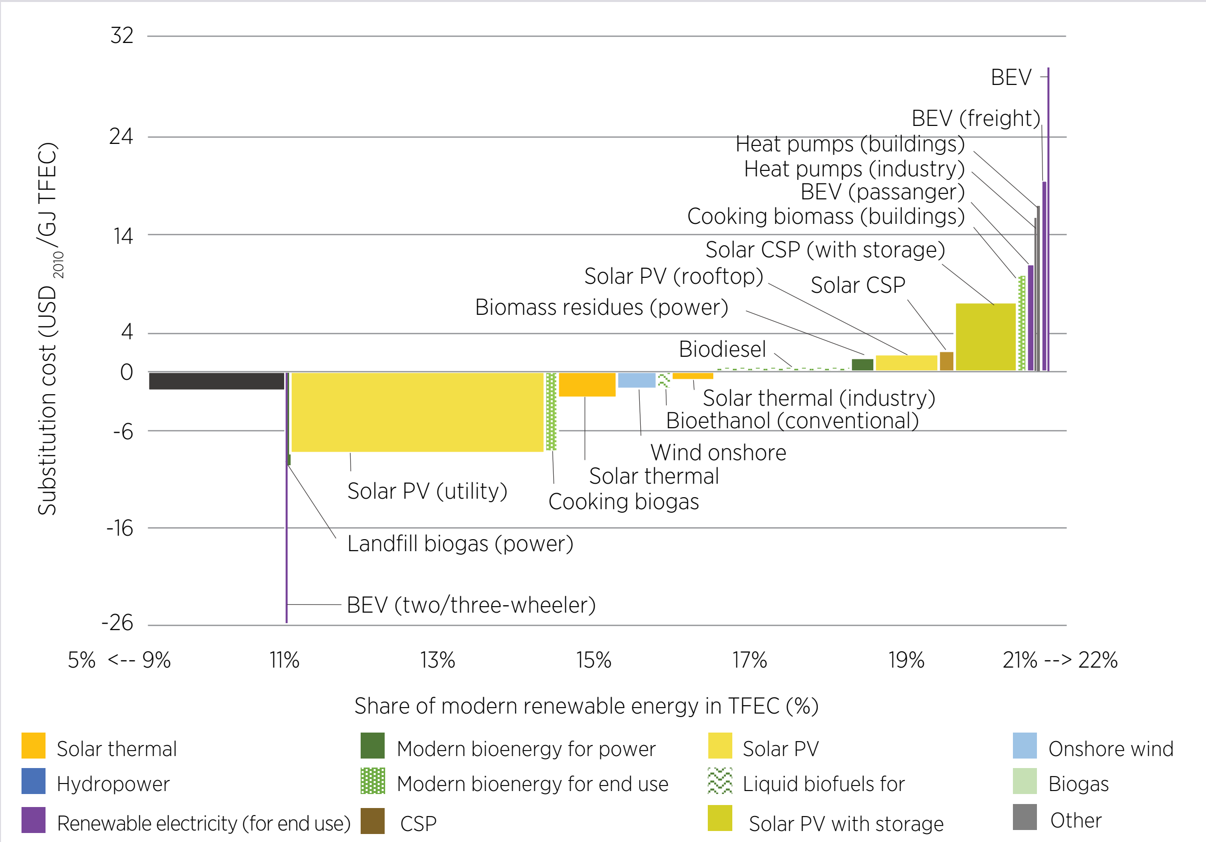
Substitution cost is a metric that compares the relative attractiveness of renewable energy technologies against conventional ones. These conventional variants are technologies that exist in the Reference Case and are replaced by renewable technologies in the REmap Options.

Substitution cost therefore measures the relative cost or saving from this substitution, i.e. how energy service cost would change if a renewable technology were deployed instead of a conventional one. It can be shown at the individual technology level using technology cost-supply curves as seen in Figure 31, or through other metrics such as marginal cost of CO_2 mitigation.

A variety of factors can affect the substitution cost, including the capital cost of technologies, their performance characteristics, the assumed discount rate (weighted average cost of capital) and fuel costs. The cost is also driven by the type of conventional technology substituted, i.e. if coal is substituted, which has low fuel costs, the substitution cost will likely be higher than if oil, with high fuel costs, is substituted.

The type of conventional technology substituted depends on factors that include the sector in question, the age of capital stock in operation, and planned new additions. Because of rapid energy demand growth in Egypt, this assessment only considers substitution of either a) capital stock reaching the end of its operational lifetime and in need of replacement, or b) new capital stock required over the analysis period. Therefore, no additional costs are assumed to account for early retirement.

Figure 31. Cost-supply curve for REmap Options, government perspective



Note: GJ = gigajoule.

The result of this substitution approach is shown in Figure 31. The figure is a cost-supply curve showing on the y-axis the substitution cost of the technology (average for a given renewable technology) (the REmap Option) compared to a conventional variant. The cost is shown in USD per GJ of final energy (3.6 GJ is equal to 1 MWh). On the x-axis is the share of renewable energy in TFEC. Therefore, the width of the bar directly corresponds to how much energy from that source is consumed as final energy. The larger the bar, the more energy consumed, and therefore the higher amount of capacity that is required.

The curve shows that Egypt increases the share of renewable energy in TFEC from 5% in 2014 to 11% in the Reference Case by 2030. The REmap Options double this share so that renewables reach 22% of TFEC by 2030. For the purpose of presentation, the Reference Case growth has been scaled to better show the REmap Option bars in the figure.

The average substitution cost of the grouping of renewable technologies, i.e. the REmap Options, is USD -7.0 per MWh (USD -1.9 per GJ in the figure), equivalent to a saving of USD 0.7 cents per kWh. This means that if the package of renewable technologies identified in REmap were deployed, the cost per MWh of final energy across Egypt's energy system would be USD 7.0 per MWh lower. However, this effect is across the entirety of Egypt's energy market and does not include either reduced externalities, which if internalised into energy prices would result in further savings, or in the possible need for increased investments in infrastructure. If only the power technology options are considered, they have an average substitution cost of USD -14.0 per MWh.

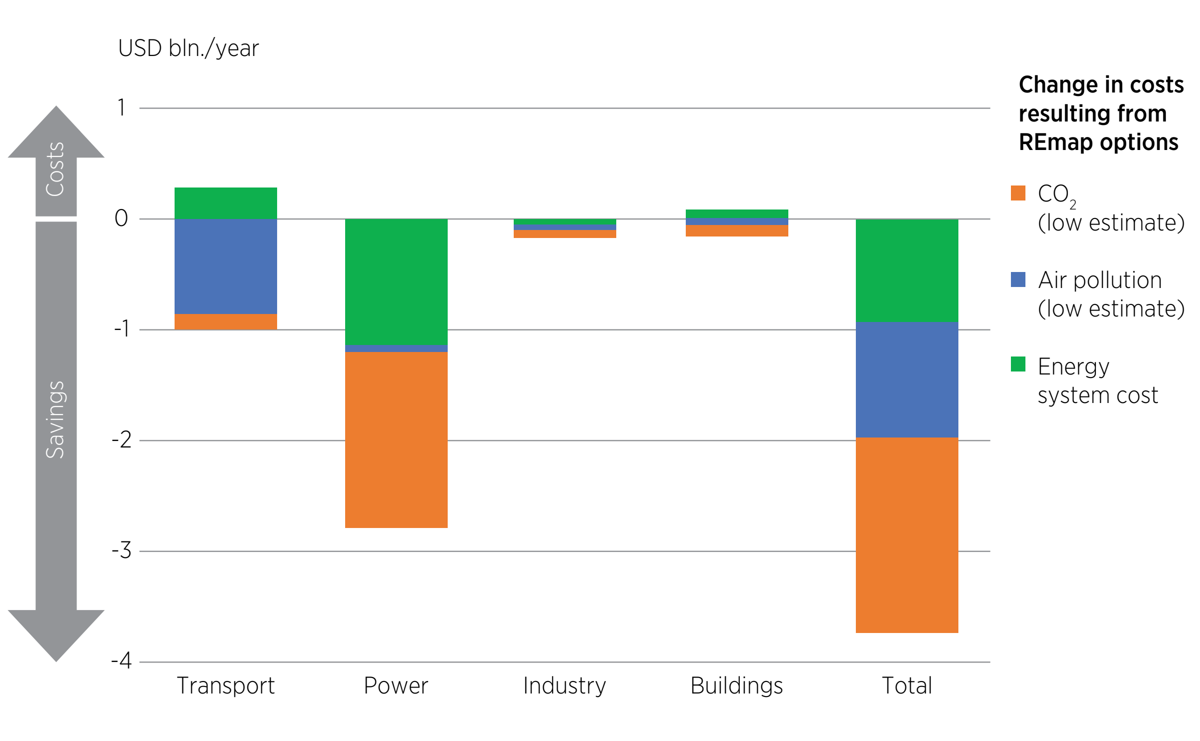
If specific technologies are examined, one sees how the cost-competitiveness of the REmap Options differ. The most affordable technologies include solar PV in the power sector and solar thermal hot water systems in buildings. The other source of cost-effective renewable potential is wind power; however, its potential is limited due to the significant growth already occurring in the Reference Case. In industry the potential of solar thermal heat for low-temperature applications (< 150°C) is competitive on cost; however, its potential is limited. CSP is an important technology for providing power that can be coupled with storage, and in the curve the substitution cost is positive for both CSP with storage and without.

The transport sector technologies show a mixed picture. Liquid biofuels have positive substitution costs, as do EVs. EVs do not show significant potential in the curve; however, this is not because their deployment is limited, but rather the result of what is displayed in the curve. For one, EVs are highly efficient and are on average three to four times more efficient than internal combustion engines, meaning it takes one-quarter the amount of energy to deliver the same amount of passenger or freight service. Additionally, the curve only shows the share of renewable electricity consumed by those vehicles, i.e. around one-quarter of their electricity demand. Therefore, if all electricity consumed by EVs were shown, then the contribution would be four times larger. For these reasons this figure is not the best way of displaying the relative importance of EVs, or electric technologies in general. Also, as demand technologies they do not produce energy, but because of their importance in increasing the renewable share of energy in transport (by shifting energy consumption to the power sector where ample renewable technology options are available) and their beneficial effect on air pollution, they are shown in the curve.

Figure 32 shows how energy system costs and external costs are affected by the REmap Options at a sector level. When the substitution costs for the group of REmap Options are summed, they result in a perspective on how those renewable technologies affect energy system costs. The REmap Options in Egypt result in a reduction of energy system costs of USD 0.9 billion annually by 2030.

Energy system costs do not consider reduced externalities, which result from lower levels of air pollution and reduced CO_2 emissions. Lower levels of air pollution improve the conditions for human health and the local environment. Air pollution is a cause of ill health, particularly in cities, and results in early morbidity and mortality. CO_2 is a greenhouse gas, which is the main contributor to global warming, and numerous studies have examined its effect and determined a range for the social cost of carbon. REmap assesses both outdoor and indoor air pollution using a methodology developed specifically for the purpose (IRENA, 2016c), while CO_2 is assessed using a social cost of carbon ranging from USD 17 to USD 80 per tonne of CO_2.

Figure 32. Cost and benefits of REmap Options



Two sectors, transport and buildings, have incremental energy system costs resulting from deployment of the REmap Options. This means the groups of technologies identified in REmap for those sectors are more expensive on an energy service basis than the conventional alternatives. However, both the transport and buildings sectors see savings related to lower levels of air pollution, which in both cases are larger than the incremental energy system costs. The power sector sees significant savings both in terms of lower energy system costs and reduced externalities.

What is not quantified in this are the costs and benefits of reducing imports of oil and its products, such as diesel and petrol, and the larger macroeconomic benefits to jobs and GDP that would result from producing more of Egypt's energy needs locally.

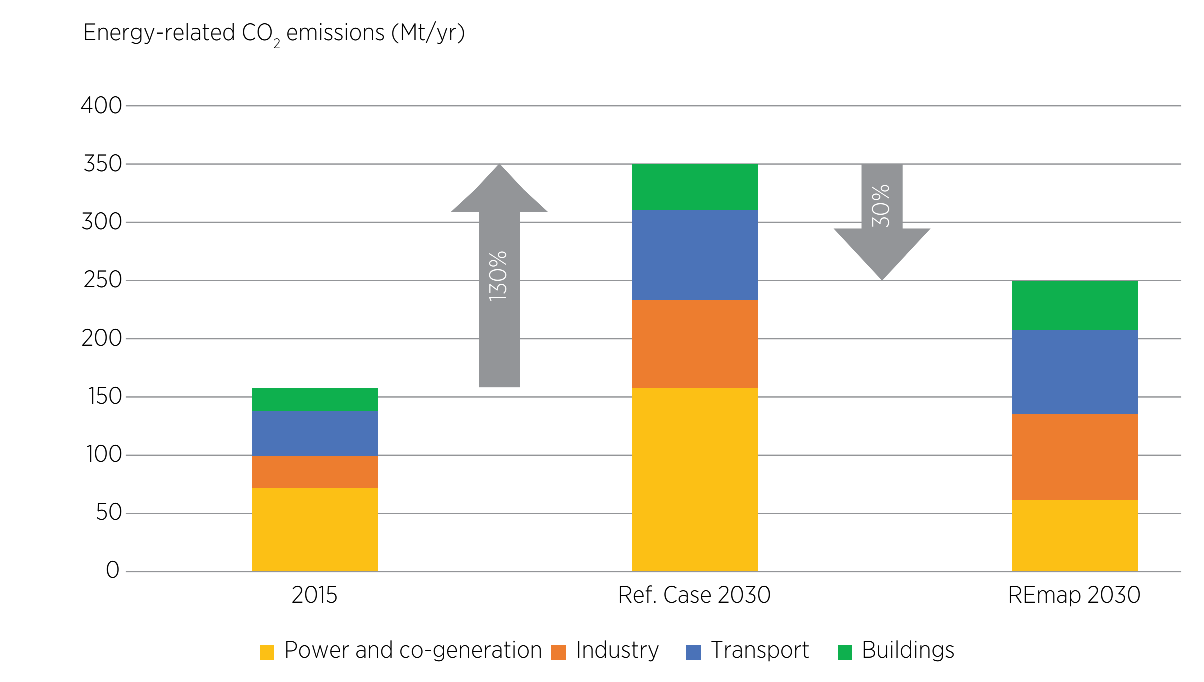
In total, the REmap Options result in a reduction in energy system costs of around USD 0.9 billion annually in 2030, equivalent to a reduction of USD 7.0 per MWh. Reductions in external costs due to reduced adverse effects of air pollution on human health and reduced environmental damage (social cost of carbon) are also significant. They would amount to at least USD 2.9 billion in reduced externalities in 2030 based on the low estimate, or USD 8.1 billion based on the average estimate. Therefore, when including both reduced energy system costs and reduced external costs, total savings to the Egyptian economy from the renewable technologies identified in the REmap Options are on average USD 9.0 billion annually in 2030 compared to the Reference Case.

Air pollution and CO_2 impacts

- External costs related to air pollution and CO_2 are important factors when considering the cost and benefit proposition of renewable energy. For instance, the REmap Options reduce external costs related to air pollution alone by between USD 1.1 billion and USD 4.7 billion annually by 2030.

- Energy-related CO_2 emissions increase by 130% in the Reference Case to 350 Mt by 2030, with the REmap Options slowing that increase to 60%, with just 250 Mt of energy-related CO_2 emissions in 2030 – a reduction over the Reference Case of 100 Mt annually.

Figure 33. Changes in energy-related CO_2 by sector, 2014, 2030



- Egypt will see a significant increase in energy demand of almost 120% by 2030. Therefore, similar increases in energy-related CO_2 are also seen, with an expected 126% increase in the Reference Case to 350 Mt annually by 2030 (see Figure 33). The REmap Case results in a decrease in energy-related CO_2 emissions of 30% compared to the Reference Case level. The REmap Options reduce the increase in CO_2 emissions from 130% to 60% over the period to 2030 (resulting in a 30% reduction in emissions in the REmap Case compared to the Reference Case).

When assessing external costs, the more directly measurable effect of fossil fuels is on local air pollution. External costs related to air pollution from fossil fuels, largely resulting from adverse effects on human health, increase from a range of USD 7-30 billion in 2014, to USD 12 48 billion by 2030 in the Reference Case.

Air pollution costs associated with oil use are highest, due largely to the effect its use in transport has in urban environments. The REmap Options provide significant benefits if renewable energy is deployed in transport, particularly by EVs in cities.

The second-largest source of external costs from air pollution is coal, largely in industry but also in the power sector. In total across all sectors the REmap Options reduce external costs related to air pollution by between USD 1.1 billion and USD 4.7 billion annually by 2030.

When considering reductions in external costs from reduced adverse effects of air pollution on human health and the environment and social damage from CO_2 (using the average estimate), total savings would be at least USD 3.8 billion (based on the low estimate), or USD 8.1 billion annually by 2030 (based on an average estimate).

Investment needs

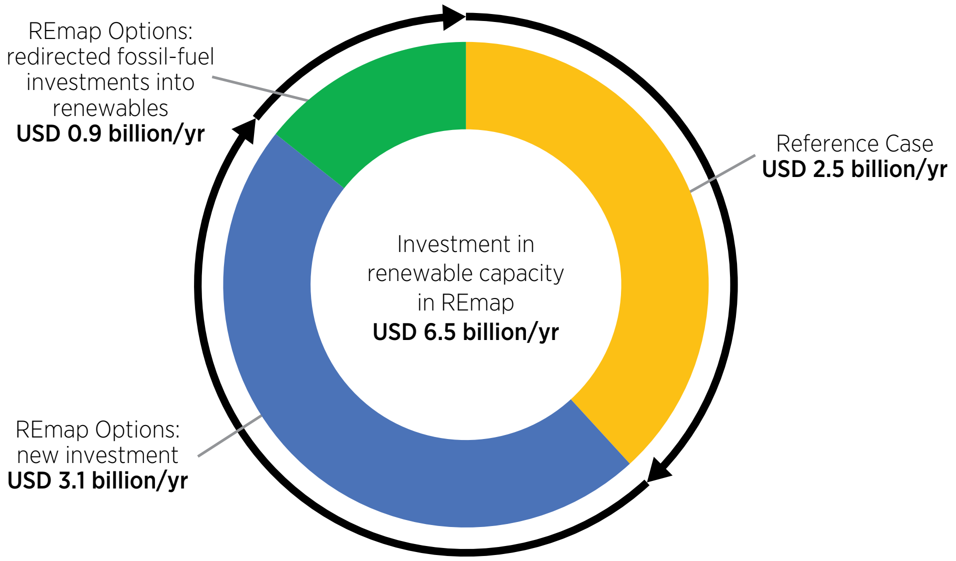
- Egypt will need significant investment in energy capacity by 2030 in order to meet the rising energy needs of the country, with demand expected to increase by almost 120% over the period. The Reference Case sees investment in renewable energy capacity averaging USD 2.5 billion per year to 2030. The REmap Options increase that average yearly investment by USD 4.0 billion, resulting in a total average investment need of USD 6.5 billion per year to 2030 in renewable capacity for power and thermal uses.

- Of the USD 4.0 billion per year incremental investment in renewable energy capacity resulting from the REmap Options, USD 0.9 billion per year would be investment redirected from fossil fuels to renewables.

Significant investment is required across Egypt's entire energy system due to the increase in demand for energy of almost 120% by 2030, encompassing electricity generation and transmission, capacity for thermal uses, cooling and cooking, and the transport sector.

During the period 2014-30, investment in renewable energy capacity in both power and thermal technologies would need to average USD 6.5 billion per year (see Figure 34) in order to reach the level of renewables identified in REmap. Of this total, USD 2.5 billion per year is expected to take place in the Reference Case. The REmap Options necessitate the mobilisation of an additional USD 4.0 billion per year in renewable energy investment, of which USD 3.1 billion would be new investment and USD 0.9 billion redirected from fossil fuel investment towards renewables.

Figure 34. Average annual investment in renewable energy capacity in the Reference Case and REmap, 2014-2030



KEY FINDINGS AND RECOMMENDATIONS

Wind farm in Egypt
Photograph: Shutterstock

05

Egypt has already achieved remarkable progress in developing an enabling policy, regulatory and institutional framework for the deployment of renewable energy, as well as gaining experience in implementation of a wide range of renewable projects, particularly for solar and wind electricity generation.

This chapter highlights the key barriers identified throughout the RRA/REmap process and the corresponding actions to overcome them, based on the following four pillars: institutional, legal and regulatory framework challenges; improving the market structure for renewables; mapping renewable energy resources and grid integration; and maximising the benefits of renewable energy deployment.

The adoption of these recommended actions would contribute to the widespread use of renewable energy through the implementation of government programmes that would ensure the realisation of the targets identified by the ISES to 2035.

5.1 Streamlining the enabling policy, regulatory and institutional framework

Challenges

The ISES to 2035 aims to ensure the technical and financial sustainability of the energy sector, while targeting energy diversification through renewable energy penetration as well as setting a plan for the gradual phase-out of energy sector subsidies by 2022. The selected scenario approved by the SEC in October 2016 envisages a 42% share of renewables in the electricity generation mix by 2035. The adopted strategic targets for renewables deployment are over 15 GW by 2022, 42 GW by 2030 and about 52 GW by 2035 according to Scenario 4b.

The successful realisation of such planned capacities would require concrete action by the government to address challenges that hinder accelerated deployment of renewable energy driven by the ambitious targets set in the strategy.

The ISES needs to reflect the response of the energy sector to economic developments at the national and regional level, particularly technological advances and innovation, as well as resource price levels. The best available data must be used, particularly to keep abreast of future cost learning curves for renewables and the rapid transformation being witnessed in power systems globally.

The ISES to 2035 has been developed based on a least-cost scenario, where renewable energy is envisaged to have a share of 42% of the installed capacity mix, with coal at 16%. However, since the strategy was developed in 2014, the electricity context has drastically changed, particularly with the rapid decline in the cost of renewable energy technologies.

The introduction of coal and nuclear, as envisaged in the strategy, would support the diversification of the existing energy mix and decrease the dependence on gas. Yet it would contribute less to the achievement of energy security, since the country would still rely on imports from international markets. With specific regard to the introduction of coal, this would hinder the country's efforts to achieve its climate ambitions and corresponding NDC, knowing that Egypt is highly vulnerable to climate change.[14]

With regard to nuclear energy, nuclear fuel production processes will require long-term planning and heavy financial investment. Given the declining cost of renewable energy technologies, the cost-competitiveness of nuclear technology in the Egyptian context may need to be re-analysed.

The main driver for the introduction of coal in Egypt's energy mix is a result of the 2014 electricity shortages, where energy policy makers were looking for a rapid solution to reduce Egypt's dependency on imported gas. Today, the scenario is subject to drastic change following the recent gas discoveries, coupled with the significant decline in the cost of renewables and rising environmental concerns over coal-fired generation.

Infrastructure limitations hinder the expansion of rooftop PV installations. Similarly, the inadequate space on building rooftops for SWH installation limits opportunities for market growth in Egypt, as most of the space available is utilised for water storage tanks and satellite dishes.

While the regulatory framework addresses electricity production systems using wind and solar, the strategy has not given sufficient focus to the exploitation of biomass potential. This is evident in the limited progress achieved on biomass mainly due to the limited availability of local capacity, along with the considerable cost associated with biomass-based electricity.

When considering energy-from-waste applications, the current framework consists of a recommendation from the relevant cabinet minister in the form of an indicative guiding electricity tariff for biogas/biofuel, which is expected to be issued soon.

A set of laws, regulations and implementation schemes has been adopted to create an effective enabling environment to promote the accelerated deployment of renewable electricity and encourage the participation of private investors. However, some difficulties have been experienced by developers and investors of renewable energy sources for electricity in the course of project implementation. This includes

[14] Egypt's NDC (2015) suggests that the country would lose 12-15% of the most fertile land in the Nile Delta as a result of sea water rise and salty water intrusion.

unavailability of contractual documents for projects at the time the FITs were announced.

Existing fuel subsidies for conventional energy sources create market distortions and do not allow renewable energy to compete on an equal level, thus hindering the smooth deployment of renewable energy technologies.

The initial FIT scheme for on-grid distributed PV systems was not found to be sufficiently financially attractive due to the prevailing currency exchange rate. As a result, many consumers preferred to use the net metering scheme. In the second-phase FIT scheme, started in October 2016, the tariff was increased to improve the financial feasibility of these systems.

The sector has a cadre of qualified, trained and experienced personnel. However, the capacity of the agencies in charge of power system planning is rather limited, particularly with respect to forecasting renewable energy sources for electricity generation and load for renewable energy sources, the calculation of capacity credit of renewable energy systems for electricity plants, and the integration of large-scale renewable energy systems into electricity systems.

The prevailing legislation has been able to stimulate the renewable energy market through a variety of support schemes (i.e. EPC, BOO, FIT, IPP and net metering), without any specific mechanism targeting on-grid or off-grid applications. Despite the strong and diversified institutional capacity of the sector, recent experiences have underscored the need to clarify specific roles of the concerned institutions and enhance their effectiveness in carrying out their respective roles, which would provide positive signals and confidence to the market and investors.

While the NREA has a clear leading role under the EPC scheme, its overall institutional responsibilities, including its role in land acquisition for renewable energy implementation, could be further clarified and simplified for all renewable procurement schemes (BOO, IPP, FIT and net metering). The administrative procedures regarding land registration for renewable energy developers are rather complex.

The ISES to 2035 has set a goal to achieve a liberalised electricity market, under which the NREA would be expected to primarily focus on its role as a facilitator of renewables-based projects while gradually phasing out its present role as a renewable energy project developer. The NREA's role as a developer has so far been given precedence, based on its current entitlement to land ownership for renewable energy projects, while also being the recipient of most of the soft loans attributed to these projects.

Recommended actions:

- Update the ISES to 2035, along with the associated policies, on a regular basis to incorporate developments in: technological advancements, particularly in renewable energy; availability and cost of imported and indigenous energy resources in the country; energy sector developments at the national, regional and international level affecting various economic sectors; and the geopolitical events in the region. Based on best practices and taking into account the rapid cost decline in renewable energy technologies, updating the strategy every two years is advisable (IRENA, 2016c).

- Within the process of the strategy review, consider the REmap scenario which suggests that 53% of power generation from renewable sources by 2030 is technically and economically feasible. This represents a doubling of the renewable energy share in the Reference Case and a rise from 9% in 2014, in line with Scenario 3 of the ISES to 2035. This is also recommended to provide a reference point for elaborating quantifiable and realistic targets for the upcoming NDC review process.

- Give specific emphasis in the next update of the strategy to accelerated deployment of biomass energy. In preparation for this, conduct a study to evaluate its potential. Develop a strong regulatory framework and associated support schemes to promote biomass investments.

- Reassess the feasibility of introducing coal and nuclear in the electricity supply mix in light of the concerns over energy security, the environment and climate raised by coal and nuclear, in addition to their cost-competitiveness vis-à-vis renewables.

- Establish the NREA as the national focal point for renewable energy in co-ordination with the relevant institutions, to develop and manage a centralised database for Egypt's renewable energy sector, including resource assessments, renewable energy targets, strategies, policies and regulation.

- Reposition and empower the NREA as a "one-stop shop" providing all permits and authorisations required from relevant institutions and administrations relevant to renewables investments, to ease renewable energy project development and the implementation process. This may include expediting the selection process of the developers under any of the renewable energy development schemes (EPC, BOO and FIT), issuing renewable energy generation licences, allocating the land for planned renewable energy projects, and handling the contractual process (connection agreements and PPAs) between the developers and EETC.

- Ensure that the process for phasing out fossil fuel subsidies is observed by relevant authorities in the government, as per the established timeline, to provide positive signals to renewable energy investors and avoid market uncertainty.

- Assess the feasibility of developing specific mechanisms to incentivise deployment of distributed renewables applications in public buildings.

- Establish a legal framework for solid waste management that focuses on the institutional responsibilities for collection and choice of sites for recycling and treatment of wastes; develop a mechanism with the MOERE to require local authorities to recycle organic waste.

- Develop specific capacity targets for the deployment of solar thermal systems. Explore different options for supporting accelerated penetration of solar thermal systems in the residential and industrial sectors. This may include: mandating real-estate project developers to deploy active and passive solar thermal systems in the design of new buildings and cities; integrating solar systems in the design of new industrial facilities through the identification of the most suitable production processes for the use of solar thermal systems; and replacing electric/gas water heaters with SWHs.

- Facilitate the transition towards the net metering scheme for distributed solar PV systems by lifting the existing ceiling for installed capacity which is, at present, required not to exceed the power contracted with distribution companies.

- Facilitate access to data and information for project developers with respect to: on-site solar and wind resource assessments; land allocation procedures; and the performance of existing renewable energy power plants under the harsh environmental conditions.

5.2 Improving the market structure for higher renewables uptake

Challenges

The current electricity market is the single buyer model. Given that most of the current renewable energy schemes depend on the state-owned off-taker (EETC), a transition process is currently under way to adopt new market rules as per the Electricity Law No. 87 2015, where direct contractual relations between suppliers and end users can exist. Allowing the transmission operator to conduct trading operations in addition to system operation and dispatching hinders this transition process.

With respect to the implementation of PPAs, EETC, as the off-taker of the power produced, has sometimes had difficulty in meeting its financial obligations for the power received, causing financial strain on electricity generation companies.

Commercial interest rates extended to SMEs are at rather high levels, currently at 18%, thereby discouraging SMEs from successful participation in the renewable energy market. Most existing financing schemes provided by multilateral or bilateral development institutions are not leveraged on by commercial banks. They have relatively low interest rates; however, they target large-scale renewable energy projects and are subject to international currency exchange rate fluctuations. The volatile exchange rates hinder larger funding opportunities from international financing institutions due to the limited ability of the Central Bank of Egypt to meet hard-currency reserve requirements.

Different biomass technologies have been demonstrated in Egypt, particularly in the production of biogas from animal waste for thermal uses in rural areas and the treatment of municipal solid waste in big cities. Remarkable progress has been achieved in developing and disseminating biogas digesters, establishing bioenergy service provider companies. Limited financial support schemes are available for off-grid solar and biomass electricity generation, as well as solar and biomass thermal systems (except for the Egysol).

Small-scale renewables projects receive limited interest from investors due to their rather small capacity and location in diverse regions across the country.

Recommended actions:

- Review the current terms and conditions of renewable energy PPAs to address concerns raised by investors, including putting in place standardised project document templates for renewable energy projects, which are being developed by IRENA and the Terrawatt Initiative and can provide solid guidance in standardising contractual procedures and documents as per international best practice (IRENA, 2016f).

- Encourage the bundling of several smaller-sized renewable energy projects through standardised project design to help achieve the required scale. In addition, this will help reduce project preparation and appraisal costs, and increase interest from the financial community, including private investors. Support from concessional lending schemes could possibly facilitate engagement of local financing partners, including domestic institutional investors.

- Explore the development of lending schemes specific to renewable energy projects that would enable the best use of limited concessional public resources (including those provided by development banks and institutions) to soften the terms of overall project financing.

5.3 Mapping renewable energy resources and their integration to the grid

Challenges

Several assessments of wind and solar resources have been conducted; yet they are not detailed enough to ensure the bankability of projects. Currently, the NREA is considering the possibility of making detailed resource measurements to further facilitate the implementation of renewable energy projects in a timely manner.

The installed capacity of the Egyptian power sector has been rapidly expanding during the last three years to overcome the shortage of electricity supply experienced in 2014. Total capacity is expected to reach 125 GW by 2030, including 42 GW of both large-scale and distributed on-grid renewable energy, these numbers reaching 147 GW and 52 GW respectively by 2035. Considering the planned deployment of renewable energy to 2035, electricity grid expansion and operations need to be carefully planned, taking into account the effects of VRE on system stability and efficiency.

Recommended actions:

- Conduct zoning of cost-effective areas with high potential for renewable energy project development, to feed into the power sector planning process. This will enable the accommodation of larger shares of renewable power in the electricity generation mix while aligning transmission system extension, expansion and upgrades accordingly. Based on the zoning outcomes, specific sites should be identified using available methodologies and high-quality mesoscale solar and wind time series. This will shorten the overall lead time for large-scale on-grid solar and wind investments.

- Consider inclusion of measurement campaigns as part of the tendering process. While this may enable the NREA to claim its initial expenses in relation to resource assessment, where measurement activities are conducted by the developer the NREA will be relieved from this responsibility. However, no local expertise would be developed within the NREA in respect of measurement, and the timely conduct of the process as well as the quality and transparency of data will need to be ensured.

- Undertake studies to identify viable options for improved power system flexibility to accommodate higher shares of VRE, including strengthening cross-border interconnections.

5.4 Understanding and maximising the benefits of renewable energy deployment

Challenges:

The ISES to 2035 does not address the potential for creating local jobs as a result of renewable energy deployment and lacks a national plan for that. In the current renewable energy context, the NREA is the main developer of renewable energy projects in Egypt, mainly supported through favourable financing instruments provided by development partners; however, for such renewable energy projects, imposing a requirement for a minimum level of local content hampers their bankability. Limited effort has been devoted to the development of domestic capabilities for different segments of the renewable energy manufacturing and service value chain.

The IRENA-EIB study, completed in 2015, finds that Egypt holds a comparative advantage in developing its local content for renewable energy projects, particularly downstream in the value chain. Several local players, including cable manufacturers and EPC contractors, have been active within the renewable energy market and hold a considerable market share for all renewable energy technologies (solar PV, CSP and wind). In this context, a local manufacturing share of 55% was achieved for the first CSP project developed in the country and local players believe that this could rise to 70% (EIB and IRENA, 2015).

Furthermore, the FIT scheme was not only able to create investment in different renewable energy sources, but also by 2017 the two phases of the scheme were able to provide about 6 000 direct and indirect jobs downstream in the value chain at the EPC stage, while also reducing harmful emissions by feeding 350 000 homes with clean energy (ENFRWC, 2017). Solar PV alone contributed 3 000 jobs (IRENA, 2018b).

The development of an Arab electricity market would facilitate tapping into the potential for electricity exports to regional, broader African and European markets. In turn, this would not only create a larger electricity market to benefit from economies of scale in renewable energy resource development, but would also stimulate the market potential of domestic manufacturing across renewables-based technologies.

The prevailing tariff structure does not allow for the segregation of the cost of service for electricity produced from renewables. Furthermore, it does not account for the benefits that arise through reduced environmental damage (and hence lower costs for externalities) based on increasing renewable energy use.

The current renewable energy context, where the NREA is the main developer of renewable energy projects in Egypt through funding from development partners, has constrained the development of R&D capacity to leverage local manufacturing potential. Under a soft loan scheme, the development partners do not allow minimum local content requirements to be imposed on the projects they fund. In the absence of a comprehensive action plan, limited efforts have been devoted to developing local capabilities with respect to renewable energy technologies, applications, marketing, financing and O&M of renewable energy systems. Increased involvement of the private sector, within the framework of joint ventures, would improve this situation by catering towards an increased local content in renewable energy projects.

The adoption of thermal biomass technology would facilitate switching fuel from natural gas to biomethane in gas-fired power plants, using rural and agricultural residues for pellet-making and briquetting, and switching to biomethane produced from rural residues and urban wastes to support local energy consumption. For some of the renewable thermal applications available, end users lack awareness of feasible renewable energy technology/application options, local suppliers and service providers, and the associated training needs to run such installations.

Recommended actions:

- Create a national master plan for the development of local job creation in the renewable energy industry, in collaboration with the Ministry of Trade and Industry, the MOF and the MOERE, with a specific set of actions defined for solar PV, CSP and wind energy technologies.
- Consider developing mechanisms, fully co-ordinated among all relevant stakeholders in the country, to promote local jobs in renewable energy, possibly supported by financial and fiscal incentive schemes.
- Encourage the establishment of joint ventures among industrial actors along the value chain to promote local jobs and knowledge and technology transfer across solar and wind technologies.
- Establish capacity-building programmes for supplier firms and incubators for enterprise creation.
- Develop adequate education and training programmes to ensure a skilled workforce for the renewable energy sector.
- Develop quality standards and corresponding certification schemes for the equipment and services (installation, maintenance, etc.) related to solar systems to ensure their reliability and long-term sustainability for final consumers.
- Enhance the availability of public information on renewable energy power systems and supplement it with more details on the legislation governing the renewable energy sector, as well as the tendering processes and grid codes (T&D); develop contract templates (land use, connection contract, network usage, IPP contracts with consumers, PPAs). This will require co operation between the NREA, EETC, distribution companies, EEHC and EgyptERA.
- Put in place a national action plan tailored to achieving a range of R&D capabilities on renewable energy to support technology development and provide a platform for public and private funding. The plan should be conceived on a collaborative basis among representatives from public authorities, universities and industry.
- Undertake regular and intensive capacity-building programmes to further develop the country's expertise in renewable energy fields, including: solar and wind energy resource assessments; planning, design and O&M of renewable energy power plants; installation and maintenance of distributed renewable energy power systems; and monitoring and evaluation of the performance of renewable energy power plants through certification schemes, including specific training targeting the improvement of the NREA's technical capacity.
- Develop technical know-how and training on different off-grid electricity applications, particularly with regard to water pumping, including remote tourist centres.
- Put in place an awareness-raising programme that encompasses, among other elements, public campaigns, education and training programmes tailored to different target groups, such as government entities, businesses and the public.
- Ensure decision makers in government and at a local level effectively communicate key messages on the strong business case for renewable energy in the country, as well as the wide range of socio-economic benefits of renewable energy deployment.
- Design and implement public awareness-raising campaigns, to be co ordinated by the NREA, aimed at the public in general, as well as focused campaigns aimed at professional groups (architects, engineers, developers and professionals in construction, hotels, industry and municipalities).
- Improve the understanding of the cost and benefits of end-user renewable energy applications, as well as the relevant technical and financial regulations and procedures for installing distributed renewable energy power and thermal systems (including rooftop solar PV systems and solar thermal systems for production processes and rooftop SWHs).
- Streamline communication with media and public information agencies on the socio-economic and environmental benefits of renewable energy.

ANNEX 1: Comparing national energy scenarios and different energy futures

The Integrated Sustainable Energy Strategy to 2035 for Egypt was developed on the basis of several economic and energy indicators in the Egyptian energy system, including energy import dependency, diversification of the primary energy supply, electricity generation, discounted subsidies and system costs. As shown in Table 20, comparison was made between nine scenarios: Baseline a and b, and Scenarios 1a, 1b, 1c, 2, 3, 4a and 4b. The "most likely case" of oil and gas production was used on the basis of a medium- and long-term perspective of the energy system. Table 20 presents the score of each of the indicators in the respective scenario. A score of 8 in one indicator shows that the scenario has the best performance for this indicator, while a score of 1 shows that the scenario has the worst performance. Tables 20 and 21 provide a brief description of the scenarios, along with the comparative results that facilitated the targets set for Egypt.

Table 20. Brief scenario description

Scenario		Description
Baseline "business-as-usual"	a	Level of subsidies is kept constant until 2035.
	b	Subsidies are reduced by 50% from 2015-2020 and are removed in 2025. Coal-fired plants are introduced in 2019/20, nuclear energy is applied and renewable energy is introduced.
Scenario 1	a	Same features as Baseline b; a renewable energy target of 20% is introduced.
	b	Delayed reference scenario of the CREMP.
	c	Minimum fuel scenario of the CREMP.
Scenario 2		Same features as Baseline b, with the delayed nuclear programme as in the Delayed reference scenario of the CREMP, along with the adoption of energy efficiency scenarios.
Scenario 3		High renewables policy in line with REmap Case.
Scenario 4	a	"Least-cost" analysis where subsidies are eliminated by 2020 and other sources are competing solely on relative cost.
	b (selected scenario)	Considers the introduction of a nuclear programme with two units operational in 2024/25 and 2026/27 respectively.

Note: ktoe = thousand tonnes of oil equivalent.

Based on: EU (2015a), "Integrated Sustainable Energy Strategy"; EU (2015b), "TIMES-EG Model Input and Analysis"; EU (2015c), "Scenario Results from the National Energy Model of Egypt".

Table 21. Scenario assessment results

Indicator	Baseline b	Scenario 1a	Scenario 1b	Scenario 1c	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b
Energy import dependency	1	2	3	6	4	8	7	5
Diversification of primary energy supply	6	8	7	5	3	1	2	4
Diversification of electricity generation	2	5	6	8	3	1	4	7
CO_2 intensity	1	2	4	7	3	8	5	6
Damage cost	1	2	5	7	3	8	4	6
Final energy intensity	1	2	3	4	5	8	6	7
Primary energy intensity	1	2	3	7	4	8	6	5
Total discounted subsides	1	3	2	4	5	6	8	7
Total discounted system cost	1	3	2	1	6	5	8	7

Based on; EU (2015a), "Integrated Sustainable Energy Strategy"; EU (2015b), "TIMES-EG Model Input and Analysis".

ANNEX 2: The REmap methodology, assessment approach and data sources

This annex details the REmap methodology and summarises the key assumptions and methods used for the Egypt analysis. REmap is a roadmap of technology options to increase the global share of renewables. It involves a bottom-up, iterative analysis of 70 countries (as of 2017). For selected countries, the analysis is deepened and detailed in in-depth country reports, working papers or other formats. This report is the second to summarise an in-depth REmap country analysis with a Renewables Readiness Assessment. Therefore, the REmap contribution to this report is limited to providing a perspective on energy use developments based on the REmap analysis that is presented in Chapter 4.

IRENA's engagement with Egypt on REmap began in early 2015. The results of an initial REmap analysis for the country were published as part of the 2016 global REmap report, "Roadmap for a Renewable Energy Future". In early 2016, the REmap team started to revisit the REmap analysis of Egypt and expand it to provide a more detailed assessment. This effort was aided by an expert officer seconded by the NREA to IRENA. This officer worked at IRENA's Bonn office for three months supporting the expanded and detailed assessment presented in this report. The results of this analysis were presented in Cairo in May of 2017 during the RRA and REmap workshop. Participants provided in-depth views and critique, and the analysis was subsequently revised. In September 2017, the revised analysis was again shared with the NREA and an IRENA consultant for further comment and feedback.

The REmap analysis for Egypt utilises IRENA's internally developed REmap tool, incorporating data and analysis done by IRENA and Egyptian experts for energy developments and renewable potential in the country. It provides assumptions and a standardised REmap approach for assessment of technologies in terms of their cost, investment and benefits.

The REmap analysis looks out to the year 2030 (consistent with the Egyptian calendar year 2029/30). The year is chosen as the standard assessment timeframe for REmap due to it being in the medium term, a common year for global efforts such as the Sustainable Development Goals, and a common year in Egypt for national-level targets (for 2029/30).

The REmap analysis starts by building the energy balance of a country, using 2014 as the base year of the analysis (2013/14), based on national data and statistics, other literature and sources. The country then provides its latest national energy plans and scenarios for renewables and fossil fuels, collated to produce a baseline perspective of the energy system, referred to as the Reference Case. This includes TFEC for each end-use sector (buildings, industry and transport) and distinguishes between power, district heating and direct uses of energy with a breakdown by energy carrier for the period 2014–2030.

Once the Reference Case is complete, the potential for additional renewable energy by technology is investigated for each sector. The potential of these technologies is described as REmap Options.[15] Each REmap Option replaces a non-renewable energy technology[16] to deliver the same energy service. The resulting case when all of these options are aggregated is called the REmap Case (or sometimes just REmap).

15 An approach based on options rather than scenarios is deliberate. REmap is an exploratory study and not a target-setting exercise.

16 Non-renewable technologies encompass fossil fuels, non-sustainable uses of bioenergy (referred to here as traditional bioenergy) and nuclear power. As a supplement to this report's annex, a detailed list of these technologies and related background data are provided on the REmap website.

Throughout this study, the renewable energy share is estimated in relation to TFEC[17] in general, but also occasionally as TPES to allow for comparison with targets or indicators that instead focus on primary energy. Modern renewable energy excludes traditional uses of bioenergy.[18] The share of modern renewable energy in TFEC is equal to total modern renewable energy consumption in end-use sectors (including consumption of renewable electricity and district heat, and direct uses of renewables), divided by TFEC. The share of renewables in power generation is also calculated. The renewable energy share can also be expressed in terms of the direct uses of renewables only. Renewable energy use by end-use sector covers the areas described below:

- **Buildings** includes the residential, commercial and public sectors. Renewable energy is used in direct applications for heating, cooling or cooking purposes or as renewable electricity.
- **Industry** (or industrial) includes the manufacturing and mining sectors, in which renewable energy is consumed in direct-use applications (e.g. process heat or refrigeration) and as electricity from renewable sources. It also includes agriculture.
- **Transport** can make direct use of renewables through the consumption of liquid and gaseous biofuels or through electricity generated using renewable energy technologies.

Metrics for assessing REmap Options

To assess the costs of REmap Options, substitution costs are calculated. This report also discusses the costs and savings of renewable energy deployment and related externalities due to climate change and air pollution. For this report there are three main indicators: substitution costs, system costs, and total investment needs.

Substitution costs

Each renewable technology has its own individual cost relative to the non-renewable energy that it replaces. This is explained in detail in the REmap methodology (IRENA, 2014a) and is depicted in the following equation:

Cost of Technology/ REmap options **USD/year in 2030** = Equivalent annual capital expenditure **USD/year in 2030** + Operating expenditure **USD/year in 2030** + Fuel cost **USD/year in 2030**

For each REmap Option, the analysis considers the cost of substituting a non-renewable energy technology to deliver an identical amount of heat, electricity or energy service. The cost of each REmap Option is represented by its substitution cost:[19],[20]

Substitution cost **USD/GJ in 2030** = (Cost of REmap options **USD/year in 2030** - Cost of substituted conventional technology **USD/year in 2030**) / Energy substituted by REmap options **GJ/year in 2030**

This indicator provides a comparable metric for all renewable energy technologies identified in each sector. Substitution costs are the key indicators for assessing the economic viability of REmap Options. They depend on the type of conventional technology substituted, energy prices and the characteristics of the REmap Option. The cost can be positive (additional) or negative (savings) because many renewable energy technologies are, or could be, more cost-effective by 2030 than conventional technologies.

[17] TFEC is the energy delivered to consumers as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually subdivided into transport, industry, residential, commercial and public buildings, and agriculture. It excludes non-energy uses of fuels.

[18] The FAO defines traditional biomass use as woodfuels, agricultural by-products and dung burned for cooking and heating purposes (FAO, 2000). In developing countries, traditional biomass is still widely harvested and used in an unsustainable, inefficient and unsafe way. It is mostly traded informally and non-commercially. Modern biomass, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry and relies on more efficient methods (IEA and World Bank, 2015).

[19] Substitution cost is the difference between the annualised cost of the REmap Option and the annualised cost of the substituted non-renewable technology used to produce the same amount of energy. This is divided by the total renewable energy use substituted by the REmap Option.

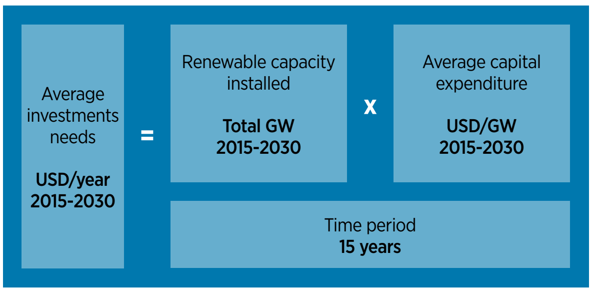
[20] 1 gigajoule (GJ) = 0.0238 tonnes of oil equivalent (toe) = 0.238 gigacalories = 278 kilowatt hours (kWh); USD 1 was on average equivalent to EGP 17.5 during the period of this analysis (mid-2017).

System costs

On the basis of the substitution cost, inferences can be made as to the effect on system costs. This indicator is the sum of the differences between the total capital and operating expenditures of all energy technologies based on their deployment in REmap and the Reference Case in 2030.

Investment needs

Investment needs for renewable energy capacity also can be assessed. The total investment needs of technologies in REmap are higher than in the Reference Case due to the increased share of renewables. On average, these have greater investment needs than the non-renewable energy technology equivalent. The capital investment cost in USD per kW of installed capacity in each year is multiplied with the deployment in that year to arrive at total annual investment costs. The capital investment costs of each year are then added up for the period 2015–2030. Net incremental investment needs are the sum of the differences between the total investment costs for all renewable and non-renewable energy technologies in power generation and stationary applications in REmap and the Reference Case in the period 2015–2030 for each year. This total was then turned into an annual average for the period.



Externality analysis

Externality cost assessments are considered looking at the impact of the REmap Option. They include health effects from outdoor air pollution (or indoor exposure to pollution in the case of traditional bioenergy), as well as effects on agricultural yields. In addition, the external costs associated with the social and economic impacts of CO_2 are estimated (IRENA, 2016e).

Further documentation and a detailed description of the REmap methodology can be found at www.irena.org/remap. Further details on metrics for assessing REmap Options can be consulted in the appendix of the 2016 global report (IRENA, 2016a).

Main sources of information and assumptions

The following key sources have been used to prepare the REmap analysis for Egypt:

- **Base year 2014:** Egyptian energy statistics provided by the government were used. Any gaps in data were filled using either IEA Energy Statistics or GlobalData.
- **Reference Case:** The report by the European Delegation of the European Union to Egypt Technical Assistance to Support the Reform of the Energy Sector for Egypt (TARES), "Scenario Results from the National Energy Model" (EU, 2015c) was used in part for the Reference Case, specifically the Baseline Scenario results; the Reference Case was also subsequently revised based on country expert feedback and consultation.
- **REmap Options:** The REmap Options are based on a variety of sources, including: country consultation and feedback from the NREA loaned officer seconded to IRENA; the May 2017 validation workshop; NREA feedback and consultation; TARES results for Scenarios 3b and 4; and IRENA analysis. Further analysis was based on IRENA studies exploring the potential of renewables in different sectors. These studies included: "Renewable Energy in Manufacturing" (IRENA, 2014b); "The Renewable Route to Sustainable Transport" (IRENA, 2016b); and technology briefs on EVs (IRENA, 2017e), biogas for cooking (IRENA, 2017f), liquid biofuel production (IRENA and ETSAP, 2017), solar heat for industrial processes (IRENA and ETSAP, 2015a) and solar heating and cooling for residential applications (IRENA and ETSAP, 2015b).

Key technology cost and performance:

Table 22 shows the key assumptions for the main technologies assumed in the buildings, industrial and power sectors for capacity deployment or substitution.

Table 22. Key technology cost and performance

Technology (in 2030)	Capacity factor (%)	Overnight capital cost (USD/kW)	O&M costs (excl. fuel) (USD/kW/yr)	Conversion efficiency (%)
Industrial sector				
Solar thermal	22	400	6	100
Heat pumps, low-temperature	50	400	10	400
Biogas heat, digester	70	200	5	85
Biomass, co-generation	50	900	25	80
Coal, boiler	80	300	8	90
Natural gas, boiler	80	100	5	90
Buildings sector				
Solar thermal, thermosiphon	18	150	4	100
Biogas, cooking	10	40	2	40
Heat pumps, geothermal	50	1 500	40	350
Biomass solid, cooking	10	15	1	30
Petroleum products, boiler	30	175	6	85
Natural gas, boiler	30	160	5	90
Electricity, boiler	30	150	4	85
Electricity, cooling	50	150	4	250
Petroleum products, cooking	10	10	1	50
Power sector				
Hydro	50	1 500–2 500	50	100
Wind, onshore	34	1 700	60	100
Solar PV, utility	20	1 000	10	100
Solar PV, rooftop	18	1 400	18	100
Bioenergy, co generation	70	2 750	70	80
Coal	79	1 300	52	38
Natural gas	60	1 000	40	55

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