



Clean Energy Transitions in North Africa

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About this report

Africa's energy future matters to the world. That is why the International Energy Agency (IEA) is substantially expanding its engagement with African regional partners and in African countries. Since 2019, the IEA has initiated a programme of work in the form of enhanced institutional engagement as well as an increase in technical activities in support of African countries' energy strategies and objectives.

The IEA aims to support African countries with their energy strategies and practices on clean energy transitions by sharing expertise to enhance data, inform decision-making and guide policy implementation. This engagement takes place in co-ordination with local, regional and other international entities. The aim is to support a sustainable and accelerated development through a varied mix of technologies, help achieve Sustainable Development 7 (SDG 7), promote increased energy security and affordability, and accelerate the development of clean energy systems across Africa.

Building on this framework, this report identifies pathways and recommendations to accelerate clean energy transitions in five North African countries (Algeria, Egypt, Libya, Morocco and Tunisia). Its aim is to take stock of the region's current energy trends and illustrate policy-relevant best practices that help advance decarbonisation of the region's energy systems. The report highlights key policy recommendations and opportunities to enable policy makers to build future energy systems based on the deployment of clean, affordable and efficient energy sources and practices.

The IEA will present this report's findings during a virtual regional event in September 2020. The event will convene regional policy makers and stakeholders for an exchange on pathways, best practices, success stories and lessons learned recommendations to accelerate clean energy transitions in North Africa. The event seeks to foster enhanced political will for ambitious clean energy transitions and to promote robust interregional stakeholder dialogue that will inform and guide national policy makers in their quest to implement high-impact policies in their respective countries.

This report is part of a wider IEA initiative that seeks to foster efforts towards clean energy transitions in Africa by promoting best practices and lessons learned for

regional collaboration. The initiative covers three African regions: North Africa, the Horn of Africa and the Sahel region. Its aim is to support African policy makers in their efforts towards achieving more sustainable energy production and use across their energy systems. Each report will look at one of these three regions in detail to take stock of energy sector conditions and frame pathways based on best practices as well as lessons learned. This series of reports will be disseminated in technical workshops gathering multiple stakeholders from the focus regions.

This analysis is supported through the IEA Clean Energy Transitions Programme, with particular thanks to the contribution of the Ministry of Foreign Affairs of the Netherlands.

The overarching high-level objective of this series of reports and events is to enhance knowledge and evidence to inform policy makers on accelerating clean energy transitions in Africa. In doing so, the initiative can help accelerate transitions and stimulate progress towards United Nations SDG 7 (to “ensure access to affordable, reliable, sustainable and modern energy for all”) in the targeted African regions.

As the Covid-19 crisis affects economies and energy systems across the world, the IEA aims to support African countries in their efforts to face the crisis. In that light, the IEA convened a virtual Ministerial Roundtable on 30 June 2020, co-chaired by the Minister of Petroleum and Energy of Senegal, to take stock of the effects of Covid-19 and its economic reverberations across Africa’s energy sector. The roundtable discussed the nascent impacts across the energy sector in order to assess what actions can be taken to ensure that energy investments in Africa remain a priority towards economic recovery.

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Table of contents

Executive summary	8
Key findings.....	10
Covid-19: Context	14
References.....	18
1. Regional overview	19
References.....	22
2. Clean energy transitions and SDG 7 in North Africa	23
Status of SDG 7 in North Africa.....	23
SDG 7.1. Enhancing energy access.....	25
SDG 7.2. Accelerating growth of renewables.....	33
SDG 7.3. Improving progress on energy efficiency.....	51
References.....	62
3. A changing role for hydrocarbons	65
Translating resource endowments into sustainable economic growth.....	65
A dynamic upstream with reduced emissions.....	67
References.....	71
4. The water–energy–food nexus: Opportunities for productive energy transitions	72
Key policy recommendations.....	77
References.....	80
5. Strengthening the climate resilience of energy systems	82
Climate change challenges clean energy transitions.....	82
Governments can strengthen resilience to climate change.....	85
Key policy recommendations.....	85
References.....	87
Annex: Country profiles	89
Country profile: Algeria.....	89
Country profile: Egypt.....	90
Country profile: Libya.....	91
Country profile: Morocco.....	92
Country profile: Tunisia.....	93
Abbreviations and acronyms	94
Units of measurement.....	95

List of figures

Figure 1	Energy sector investment in North Africa, 2015-20	16
Figure 1.1	Total final consumption by fuel and per capita, 2000 and 2018.....	21
Figure 1.2	Electricity generation mix in North Africa, 2000 and 2018	21
Figure 2.1	Access to electricity in North Africa – rural and urban population with access and evolution of access rates by country	27
Figure 2.2	Access to clean cooking in North Africa – share of cooking fuels and evolution of access rates by country.....	28
Figure 2.3	Trends in renewables contribution to final energy consumption in North Africa	35
Figure 2.4	Trends in renewable energy capacity in North Africa, 2009-19	36
Figure 2.5	Renewable electricity in 2008 and 2018 in North Africa (left) and by country (right).....	37
Figure 2.6	Trends in renewable generation capacity and generation in North Africa in WEO STEPS and Africa Case	39
Figure 2.7	Key characteristics and challenges in the different phases of system integration...	40
Figure 2.8	Annual VRE share and corresponding system integration phase in selected countries and regions, 2019	41
Figure 2.9	Renewable electricity capacity growth 2019-24 by procurement type	44
Figure 2.10	Energy intensity evolution in North Africa, Africa and non-OECD countries 2000-18 TES/GDP (toe per thousand 2015 USD PPP, index 2000 = 100)	52
Figure 2.11	Energy efficiency savings potential by sector in North Africa, under the Africa Case, 2019-30	53
Figure 2.12	Electricity energy efficiency savings in cooling in North Africa in the Africa Case, 2018-30	54
Figure 2.13	Energy consumption subsidies by country, 2019	55
Figure 3.1	Net income from oil and gas production in North African countries	66
Figure 3.2	Estimated average GHG emissions intensity of oil in selected countries, 2018	69

List of tables

Table 1.1	Energy-related plans and commitments by North African countries	22
Table 2.1	SDG 7 and selected energy indicators for North Africa	25
Table 2.2	Renewable electricity capacity targets in North Africa	43
Table 4.1	Selected water, energy and food indicators in North African countries	73

List of boxes

Box 1	The IEA Africa Case	9
Box 2.1	Sustainable Development Goal 7	24
Box 2.2	Outlook for electric cooking in Morocco	33
Box 2.3	Renewable hydrogen and ammonia production in North Africa.....	47
Box 2.4	Closing the power sector investment gap in North Africa	48
Box 4.1	Water–energy–food nexus case studies in North Africa	76
Box 5.1	Climate change impacts energy systems: Hydropower in Egypt and Morocco	83
Box 5.2	Supporting a systematic assessment of climate impact on energy systems: The case of Egypt	86
Box 5.3	Integrating climate impacts consideration into energy planning: The case of Morocco	87

Executive summary

As the necessity of energy system transformation gathers pace at a global level, North African countries¹ are increasingly making efforts towards their respective clean energy transitions. Clean energy transitions offer opportunities for North African countries to transform their energy infrastructure in ways that can meet the region's growing energy demand, create much-needed jobs and promote equitable socio-economic development, diversify their economies, and build climate change resilience, all while achieving low-carbon, sustainable, inclusive economic growth. Decarbonisation pathways are also instrumental for North African countries to achieve their climate and economic development ambitions. The region's long-term economic development and climate policy objectives, encompassed in countries' nationally determined contributions (NDCs) and the United Nations' Sustainable Development Goal (SDG) 7 and set out in the vision of the African Union's Agenda 2063, will require a transformation in how energy is supplied and consumed across the region.

Projected growth in energy demand and a vast yet under-exploited abundance of low-carbon energy resources such as renewables, as well as the possibilities regarding energy efficiency, hold important potential for the region's future energy systems. The continued deployment of renewable energy technologies beyond the power sector into the heat and transport sectors, as well as the rollout of sectoral and subsectoral energy efficiency policies, with many low-hanging fruits, are ways forward. There are also opportunities for North Africa's important oil and gas sector to adapt and contribute to accelerating the region's clean energy transitions. Applying integrated multisectoral approaches to future energy sector planning could improve resource efficiency, productivity and security, which may change the scale and type of the energy technologies deployed in the region. In turn, this will require an important scaling up of investment in energy infrastructure and technologies. Furthermore, North Africa has been identified as one of the world's most susceptible regions to climate change. This vulnerability means that the region's energy infrastructure planning must be climate-resilient and regionally integrated to ensure energy security.

¹ The geographic scope of this report is Algeria, Egypt, Libya, Morocco and Tunisia.

This is more relevant than ever in light of the current Covid-19 crisis, which is substantially affecting energy systems around the world. While still ongoing, the crisis has already exacerbated energy challenges in the region. As North African countries plan on how to face these challenges, this report seeks to identify pathways and put forward recommendations to help accelerate the transition towards clean energy systems. Analysis and recommendations are based on the International Energy Agency (IEA) Africa Case scenario (Box 1), which shows that clean energy transitions in North Africa are possible in ways that achieve sustainable economic development objectives.

Box 1 The IEA Africa Case

The IEA produced an in-depth analysis of the African energy sector in 2019, analysing 11 countries in detail and assessing the outlook for Africa energy. The analysis is built around two possible scenarios: the Stated Policies Scenario, which reflects the IEA's assessment of today's policy frameworks and plans; and the Africa Case scenario, which reflects a more ambitious approach, achieving in full the Agenda 2063 and meeting key SDGs. The IEA Africa Case shows what actions are needed to achieve fast economic and energy transitions across African countries. As published in Africa Energy Outlook 2019, the Africa Case is a scenario in which the continent's own inclusive and sustainable vision for accelerated economic and industrial development as envisaged in Agenda 2063* are achieved. In this scenario, faster economic expansion across the continent is accompanied by the full achievement of key SDGs by 2030, including universal access to electricity and clean cooking, as well as reductions in premature deaths related to pollution. The Africa Case outlook shows that accelerated clean energy transitions can stimulate progress towards meeting SDGs 7.2 on renewable energy and 7.3 on energy efficiency in North African countries.

* Agenda 2063 was adopted in 2015 by the heads of state and governments of the African Union; it is the continent's strategic framework that aims to deliver inclusive and sustainable development.

Policy makers can play a vital role in promoting low-carbon solutions and clean, sustainable, affordable, reliable and resilient energy technologies that support countries' long-term economic and development ambitions. While still developing, the Covid-19 crisis has underscored the importance of a strong, resilient and sustainable energy sector. The crisis is affecting energy systems around the world, and presents North African countries with an imperative to re-evaluate energy strategies and accelerate clean energy transitions in planning their economic recovery. The report is structured to consider central aspects of clean energy

transitions, including SDG 7 subgoals, the oil and gas sector, interrelated water-energy-food nexus approaches, and climate change resilience, with key findings specified.

Key findings

Energy access: North African countries have already achieved near-universal access to electricity and clean cooking (SDG 7.1) thanks to effective public policies promoting major grid extensions, dedicated rural electrification programmes, and the expansion of gas networks and liquefied petroleum gas (LPG) distribution. Since 2000, 20 million people have gained access to electricity, with rural areas progressing faster than in other regions of the world, presenting a global best practice. Today, access to clean cooking has become almost universal across the region, with the vast majority of North Africa's population relying on either natural gas or LPG. Challenges remain, including the need to ensure affordable access, with a limited burden on public finance and with a reliable quality of service and supply. The Covid-19 crisis may cause millions of people to slide back into poverty. Ensuring that the poorest continue to be able to pay and do not lose access to essential energy services will be a key objective in the months and years to come.

Renewable energy: The goal to scale up renewable energy (or SDG 7.2) is set to be the driving force of North Africa's clean energy transitions. While renewable energy consumption remains largely untapped across the region relative to its potential, several countries have made substantial progress in developing their vast renewable resources. Over the last decade, renewable electricity in North Africa has grown more than 40%, driven by the rapid expansion of wind, solar photovoltaic and solar thermal. Renewables play a minor role in the transport sector across the region, with still few electric vehicles that can use renewable power and low levels of biofuels. Yet the region's abundance in renewable energy resources, among the highest potentials in the world, makes significant further development and growth possible, with a strong need to increase deployment beyond power and into industrial heating and transport sectors, including technologies such as green hydrogen. System integration practices will become important as systems accommodate higher shares of renewables. Within the region, the portfolio of policies has evolved as the technologies have matured and the costs have fallen. The current support systems based on long-term power purchase agreements provide investors with long-term certainty, coupled with an element of competition that drives cost-effectiveness. There is scope to accelerate deployment by increasing the level of ambition and developing policies that help address certain challenges. The latter include improved access to affordable financing, effective auction design, improved regulatory frameworks, and implementing cost-reflective energy tariffs. Especially in light of Covid-19-related decreases in investment, more capital needs to be mobilised

towards low-carbon generation in North Africa, particularly on generation capacity, transmission and distribution electricity networks, and strengthening of grids.

Energy efficiency: Progress on SDG 7.3, focusing on improving energy efficiency, has been stagnant across North Africa. Energy intensity improvements have not been as strong as in other parts of the world over the past decades. Yet energy efficiency improvements can both help to unlock a range of economic, social and environmental benefits, and play a major role in the post-Covid-19 crisis recovery period. Policy packages combining incentives, information and regulation can maximise the benefits from energy efficiency across North African countries, especially regarding certain “low-hanging fruit” opportunities in the industry, buildings and transport sectors and subsectors. The industry sector, for example, while not the largest energy-consuming sector, represents the largest energy savings potential by 2030 under the IEA Africa Case. Appliances, equipment and lighting also drive much of the residential and commercial energy consumption in North Africa. Opportunities for further action include the combination of minimum energy performance standards (MEPS), energy efficiency standards and labelling programmes, and incentives, which have proven to be effective policy measures in countries all over the world. While most North African countries have adopted MEPS and labelling, more work is needed to fully unlock the benefits of energy-efficient appliances. Governments can also incentivise energy efficiency to consumers through technology replacement programmes, e.g. investments in accelerated replacement or scrappage programmes for appliances. More important are the opportunities for job creation from energy efficiency for sustainable economic recovery. The latest IEA *Sustainable Recovery* report estimates that appliance replacement programmes would globally create between 7 and 16 jobs across for every million dollars spent. In industry, motor replacement, heat recovery or heat pump programmes could deliver substantial job creation while also achieving significant environmental benefits. The implementation of regulations, such as MEPS for motors and appliances, alongside incentive programmes can help to go beyond short-term impact and drive a longer-term transformation, locking in jobs, utility bill savings, and economic and environmental benefits. Energy efficiency is a key area to create jobs in short terms – especially in buildings - in larger and smaller North African cities where Covid-19 may cause unemployment.

Oil and gas sector: Oil and gas resources have long been a central element in the economic growth for North African countries, notably Algeria, Libya and Egypt. Oil and gas export markets are becoming increasingly competitive, for a combination of reasons. Owing to the impact of Covid-19 on global oil and gas demand and a surge

in global supplies, there is more than ever a compelling case for faster implementation of reform initiatives to achieve economic diversification and industrial development, including reforming inefficient and wasteful subsidies. While this requires broad-based efforts beyond the energy sector, putting in place a mechanism to ensure effective and transparent hydrocarbon revenue management is the essential first step. Maintaining upstream investment to ensure adequate production, especially for gas, also remains vital to provide stability for the economy. However, this needs to be accompanied by greater efforts to reduce the environmental footprint of oil and gas operations, given that the emissions intensities of oil and gas production in North Africa are among the highest in the world. Reducing methane emissions is particularly important. The combined methane emissions in Algeria, Egypt and Libya amounted to around 10 million tonnes in 2019, approximately 12% of global oil and gas methane emissions. The region also accounts for over 10% of the flared gas volumes globally, which represents a major wasted economic and environmental opportunity. The IEA estimates that some 40-55% of methane emissions in the region could be avoided at no net cost, meaning that there are ample, cost-effective opportunities to reduce the region's methane emissions.

Water–energy–food nexus: The interlinkages between water, energy and food production and consumption demonstrate the need to integrate a nexus approach and climate-smart agriculture in favour of security of resources in water-scarce, energy-intensive and agriculture-focused North African countries. Applying an integrated multisectoral approach to clean energy transitions in the region can illuminate opportunities to deploy clean energy technologies and to improve resource efficiency, productivity and security. A holistic view on improving efficiency offers up solutions to save energy, reduce emissions and improve resource use. Reducing water losses saves water and energy. Energy efficiency reduces energy demand and greenhouse gas emissions and saves water. Efficient irrigation saves water and energy. Additionally, increasing the efficiency of power plants and deploying advanced cooling systems reduces water demand. It is thus essential to factor water-related issues into energy policy decisions and focus on sound water management. Solutions include a greater shift towards renewable-based desalination. There is also a significant opportunity to increase the productivity of agriculture and reduce its energy intensity by replacing diesel-based irrigation systems with solar-powered ones.

Climate resilience: North Africa is one of the most vulnerable regions to climate change. These changing patterns of climate are likely to affect all stages of the entire energy value chain in the countries of the region, requiring the energy sector to

adapt. Because of these vulnerabilities, North Africa countries should ensure that climate-resilient energy practices and infrastructure are at the core of their clean energy transitions pathways. Enhanced climate resilience of energy systems can bring multiple benefits to the region. Resilient energy systems support the achievement of SDGs, ensuring uninterrupted energy supply against increasing climate hazards. Furthermore, resilient energy systems can minimise socio-economic costs from the shocks of extreme weather events, enabling the continuous provision of public services. Governments can enhance climate resilience by supporting a systematic and comprehensive assessment of potential climate impacts into energy systems. Based on the assessment results, governments can develop policies, regulations, incentive mechanisms and guidelines to integrate climate resilience considerations into central planning and encourage private investment in building resilience.

Covid-19: Context

The Covid-19 pandemic triggered an unprecedented economic shock with profound implications for energy systems around the world. While first and foremost a global health crisis, related confinement measures have had major implications for global economies and their energy sectors. It has highlighted how indispensable electricity is both in responding to the pandemic and in maintaining the daily functioning of integrated energy-dependent modern economies and societies. International Energy Agency (IEA) analysis based on the *Global Energy Review 2020* finds a historic drop in both global energy demand and carbon emissions. Although this crisis is still ongoing, the pandemic, lockdown and economic impact are certain to shape global energy policy going forward, including for North African countries. Reliable, affordable and secure power is essential for an effective response to the health crisis, for energy security, for economic activity and to power future economic growth. In this respect, clean energy transitions take up a vital place in planning countries' economic recovery, in all regions of the world.

At the time that this report was completed, the pandemic had not yet ended, but all five North African countries that are the focus of this report¹ had introduced movement restrictions and confinement policies that affected their economies. Services, tourism and industrial sectors, which are the main contributors to the regional economy, have been severely affected by Covid-19-related restrictions. According to the African Development Bank, regional economic growth is expected to see a decline of between -0.8% and -2.3% for 2020, depending on how long the pandemic lasts. The energy sector was affected by plummeting demand, as populations went into confinement and restaurants, shopping malls and, in some countries, factories closed down to prevent the spread of the virus. Countries such as Egypt and Morocco saw a drop in electricity consumption – Egypt's dropped by 12% and Morocco's by 14% – with shifting demand loads, mostly moving towards residential use. While resilient overall, the region's energy systems faced operational pressure from excess generation capacity. Another impact was that the economic crisis has made it difficult for some customers to pay their bills, reducing revenue for utilities. Some countries provided power for free, adding pressure on the financial health of utilities and state budgets. At time of writing, Morocco for example had

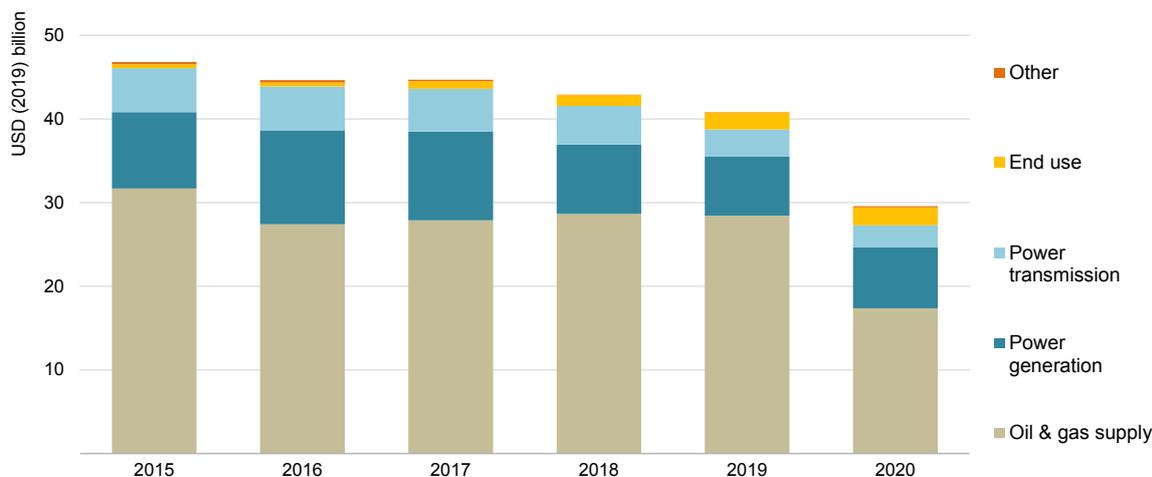
¹Algeria, Egypt, Libya, Morocco, Tunisia.

11 million outstanding electricity bills. Moreover, the crisis has led to delays in energy investment and planned projects due to slumps in the supply chain and demand.

The Covid-19-related shutdowns across the world have also severely affected the demand for oil, as transport and industrial activities ground to a halt with as many as 4.5 billion people around the world in confinement. This drop in demand, which peaked at a decline of over 20 million barrels per day in April, led to the oil price losing up to 70% of its value compared with the start of 2020. The historical collapse in demand and prices took a heavy toll on oil and gas revenues for North African producer economies such as Algeria and Libya, which depend on hydrocarbon exports to maintain foreign currency reserves, pay salaries and provide essential services to their populations, especially health care, education and sanitation. The net oil and gas income in Algeria and Libya fell by some 75-90%, putting severe strains on these countries' ability to counter the economic damages during the pandemic.

Meanwhile, IEA data warn of a decrease in energy investments in North Africa for both oil and gas as well as for the electricity sector in 2020, with worrying implications for clean energy transitions and security, as illustrated in Figure 1. Countries now face tighter credit conditions in accessing finance given restricted fiscal space, as recent events brought a repricing of risk across the global economy and energy sector. Furthermore, reduced revenues further impact utilities' ability to spend on expanding future generation capacity. This goes against the need to invest in energy systems of the future in terms of cleaner generation capacity as well as in resilient networks to carry growing energy demand of the future.

The crisis also affects other sectors as well as climate resilience. Expected impacts from confinement measures include supply chain issues such as reduced agricultural production and delays in transporting agricultural goods to demand centres. Fiscal limitations and drained budgets may in turn affect the ability to invest in projects related to the water-energy-food nexus or limit the deployment of new technology or upgrading of facilities. As one of the regions most vulnerable to climate change, North Africa's climate-related stresses are likely to continue with increased frequency and intensity. The adverse impacts of climate change on public health conditions, through for example more extreme weather events and more challenging living conditions, could further stress health care systems in North African countries that are already stretched to the limit due to Covid-19. Reliable energy services based on climate-resilient energy systems play a central role in protecting public health against the pandemic as well as climate change.

Figure 1 Energy sector investment in North Africa, 2015-20

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Source: [IEA \(2020a\), World Energy Investment 2020](#).

Energy investments in North Africa have decreased by 20% for 2020, while the need is much higher to carry expected energy demand growth.

The present crisis provides an opportunity for North African countries to re-evaluate energy strategies and accelerate their clean energy transitions. Countries can take advantage of the momentum from the crisis to build up a resilient, secure and clean energy sector that will help deliver a transformative economic recovery in a post-Covid-19 world. By accelerating transitions, the region can fully tap its energy sector potential to deliver a sustainable low-carbon economic recovery that creates much-needed new jobs and promotes long-term inclusive growth and socio-economic development.

The IEA recently published *Sustainable Recovery*, a World Energy Outlook Special Report, which provides a pathway of recommendations for just such a sustainable economic recovery. By putting clean energy transitions at the heart of their economic recovery plans, countries can boost their economies, create needed new jobs, and deliver a resilient and clean energy sector, while reducing emissions.

Countries can reorient economic stimulus packages to make clean energy transitions part of the architecture of their economic recovery plans. The region's vast untapped renewables and energy efficiency potential represents a major lever to ensure that the post-Covid-19 recovery unlocks the sustainable socio-economic benefits of a clean energy transition. This can be done by accelerating the build-up of low-carbon renewable energy and energy efficiency sectors as sources for economic growth and

job creation to support sustainable economic recovery. While all fuels and technologies have suffered during the crisis, renewable energy has been the most resilient of energy sources. The energy efficiency agenda, meanwhile, highlights vast potential for job creation across the region, especially in industry, buildings and transport. Both sectors can create jobs, support economic development, increase the competitiveness and resilience of local industry, and improve energy affordability, while freeing up funds for other parts of the economy including health, education, housing and transport. IEA estimates based on *Sustainable Recovery* (IEA, 2020b) place the worldwide job creation potential at 7 to 16 jobs per million USD invested in energy-efficient appliances, and 9 to 30 jobs per million USD invested in making buildings more energy efficient.

The Covid-19 crisis also underlines the strategic importance of broader reform initiatives to diversify hydrocarbon-dependent economies. The risks associated with undiversified economies have long been recognised, and the plunge in the global oil price during 2014 and 2015 was a wake-up call for many producer governments. However, many North African producers are still as dependent on hydrocarbon revenues today as they were several decades ago, and public finances are generally in worse shape than they were just five years ago, leaving these countries even less able to absorb the shock and invest in much-needed new low-carbon infrastructure. Economic transformation and diversified growth are essential not only to deal with the changing dynamics of global energy, but also to generate opportunities for growing populations at a time when large numbers of young people are increasingly entering the workforces of all African countries. The reform process will be complex and challenging, but a well-functioning oil and gas sector can be a durable asset for today's producers, providing some of the capital and expertise that can support more diversified and sustainable growth.

Despite the investment drop in 2020, maintaining energy investments at appropriate levels is key to ensuring the essential resilient energy systems of the future. Countries should prioritise investments in electricity generation capacity, power networks and also transmission, in order to guarantee the creation of energy systems that can support future economic growth. To that end, mobilising more capital towards low-carbon generation capacity and strengthening the transmission, distribution and grid infrastructure across North African countries are key. That will in turn require the continued strengthening of countries' policy and regulatory environments. More than ever, policy signals will be critical to attract private-sector capital needed to bridge the clean energy investment gap, and regional collaboration will be key to realising energy transitions that can power the recovery.

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1. Regional overview

The five countries that span North Africa have significantly different circumstances that influence their energy transitions pathways. The region includes large hydrocarbon producers and exporters (Algeria, Egypt and Libya), as well as countries that are heavily dependent on imports to meet domestic energy demand (Egypt, Morocco and Tunisia). The socio-economic and political contexts also vary widely. While per capita income in Libya is more than 55% greater than the regional average, a prolonged period of political unrest and conflict means that service provision lags; Libya is the only country in the region that does not have universal access to electricity. Despite their differing contexts, all five countries share similar challenges when it comes to climate change. Water stress is an acute and growing problem. Because of rapid population growth and depleting groundwater reserves, per capita water availability in Morocco is increasingly constrained; it has fallen by almost 80% since 1960. Rising sea levels are also a shared concern. In Egypt's Nile Delta, up to 15% of the most fertile arable land is already affected by increasing saltwater intrusion from the sea. Desertification is also a growing issue, as in Tunisia, where an estimated 95% of the arable land is affected by desertification to some extent. Given that the agriculture sector is one of the largest employers in Egypt, Morocco and Tunisia, future degradation could affect food security and livelihoods across the region.

The focus on transitioning to more sustainable energy systems has become an increasing priority for several North African countries, perhaps most notably Morocco, which set an example by enshrining sustainable development as a right for all its citizens in its 2011 constitution. There is considerable potential for improved sustainability across the region. Three countries, Algeria, Morocco and Tunisia, highlighted the role the energy sector could play in helping to meet their nationally determined contributions (NDCs) and have implemented measures to reduce the carbon intensity of their economies (Table 1.1); and all five countries have established renewables targets. However, progress has been uneven and, in Libya, where the security situation is precarious, progress has been adversely affected.

As well as the positive environmental benefits and local pollution reductions associated with such a transition, countries in North Africa that already have an established manufacturing base, such as Egypt and Morocco, could use a nascent domestic renewables industry to anchor further economic development. Egypt has

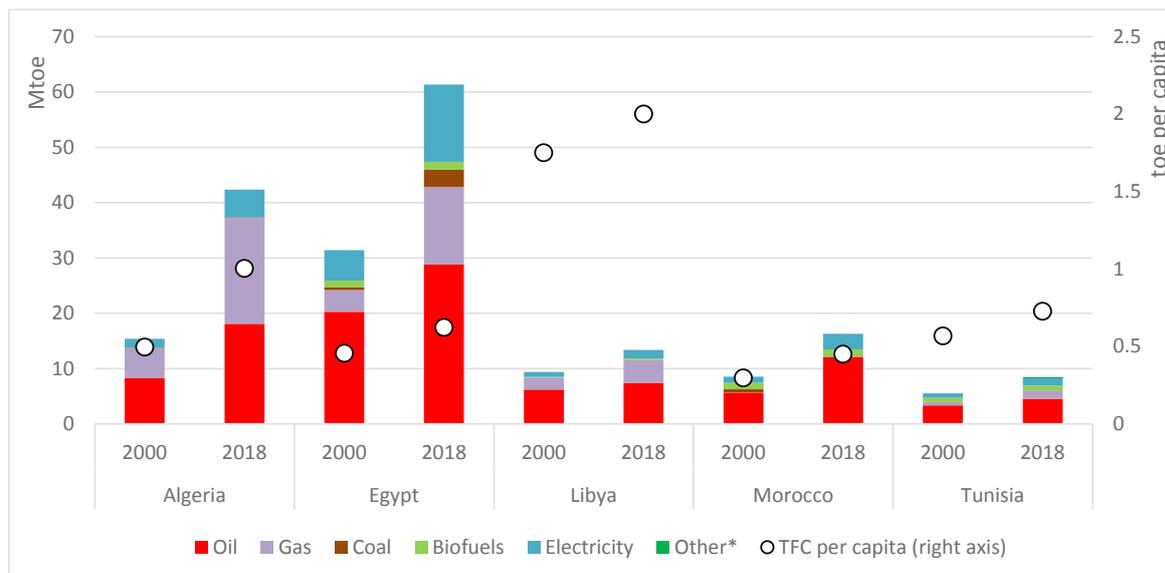
several of the industries necessary for the solar photovoltaic (PV) industry value chain already in place, including steel and glass manufacturing, as well as pump fabrication plants. Given the regional ambitions for increased renewable electricity, there is considerable potential for countries to take the initiative to become regional producers of the materials needed for this expansion.

The region's energy mix is dominated by oil, (Figure 1.1) which accounts for between 45% and 85% of final consumption across North Africa. This is not exclusively a story of meeting growing needs in transportation; in Morocco, for example, one-fifth of all consumption is accounted for by the residential sector, where liquefied petroleum gas (LPG) is used for cooking. Although the region has taken great strides to ensure access to modern clean energy, traditional biomass still plays a role in cooking in Algeria and Morocco (where 1.5% of the population rely on biomass as their primary cooking fuel). This adds an important gender perspective, as the burden for collecting wood and cooking with it falls mostly on women and girls, who disproportionately endure most of the negative health impacts associated with cooking using traditional biomass.

Electricity plays a relatively marginal role in all countries apart from Egypt (where it accounts for one-fifth of final end-use consumption, as seen in Figure 1.2). This compares to a global average of 18.9% of total energy consumption and presents a large opportunity for countries looking to transition to a more secure and sustainable energy future. The benefits are particularly strong in countries in the region that are not endowed with fossil fuel resources, particularly Morocco and Tunisia, where subsidised oil can be replaced by a range of substitutes.

The opportunities for improvement are not limited to increasing the sectors in which electricity can be consumed and replacing more polluting fuels, but also the way they are produced. North Africa's generation mix is marked by its reliance on fossil fuels. At 4.6% of the overall generation mix, renewables still play a small role that falls far below the global average of 25%. This is not commensurate with the available resources, as North Africa has some of the most favourable sites in the world for solar irradiance as well as significant wind potential in the coastal areas (Global Solar and Wind Atlas, 2020). North Africa has tremendous potential for increased renewables deployment, which could reduce dependence on imported fuels in Morocco and Tunisia while freeing up additional resources for export in Algeria. All five countries have long-term targets for increasing renewable electricity capacity. By 2030, Algeria targets 22 gigawatts (GW), Morocco 10 GW, Libya 4.6 GW and Tunisia 2.8 GW, while Egypt targets 54 GW by 2035.

Figure 1.1 Total final consumption by fuel and per capita, 2000 and 2018



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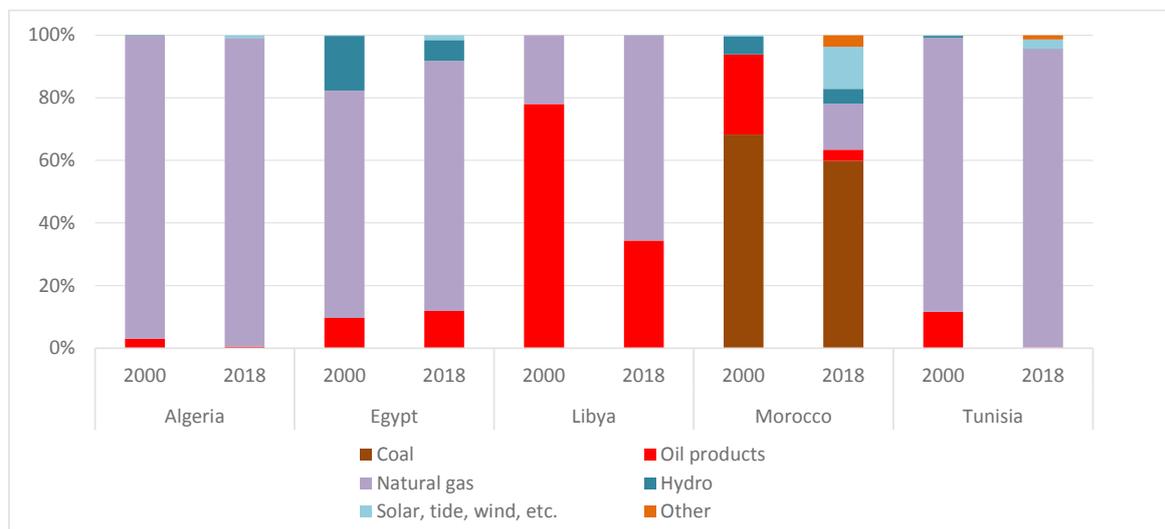
*Other includes solar thermal, geothermal, commercial heat, etc.

Notes: Mtoe = million tonnes of oil equivalent; toe = tonnes of oil equivalent; TFC = total final consumption.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#).

Oil and gas are the dominant fuels in North Africa’s energy mix.

Figure 1.2 Electricity generation mix in North Africa, 2000 and 2018



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Note: 2018 data are the latest comparable dataset. Egypt has since made significant renewable energy additions.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#).

The share of renewables in the power sector is low across the region.

Table 1.1 Energy-related plans and commitments by North African countries

Country	National plans and commitments
Algeria	<ul style="list-style-type: none"> • Aim to reduce greenhouse gas (GHG) emissions by 7% (unconditional)* to 22% (conditional), by 2030, compared with a business-as-usual scenario. • The National Programme for Renewable Energy and Energy Efficiency sets out a target for renewables to account for 27% of electricity generated by 2030.
Egypt	<ul style="list-style-type: none"> • The Integrated Sustainable Energy Strategy 2035 sets a target for renewables to make up 42% of the electricity mix by 2035.
Libya	<ul style="list-style-type: none"> • The Strategic Plan for Renewable Energies, 2018-30 sets a target of reaching 6.6 GW of renewable capacity by 2030.
Morocco	<ul style="list-style-type: none"> • Aim to reduce GHG emissions by 17% (unconditional) to 25% (conditional) by 2030, compared with a business-as-usual scenario. • Aim to reach over 52% of installed electricity production capacity from renewable sources by 2030. • The National Energy Efficiency Strategy aims to reduce energy consumption by 20% by 2030.
Tunisia	<ul style="list-style-type: none"> • Aim to reduce carbon intensity by 13% (unconditional) to 41% (conditional), by 2030 compared with 2010 as base year. • The National Renewable Energy Action Plan 2018 sets out a target for renewables capacity of 3.8 GW by 2030.

* Conditional targets and unconditional targets of NDCs.

Source: RCREEE (2019), Arab Future Energy Index 2019.

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2. Clean energy transitions and SDG 7 in North Africa

Accelerating clean energy transitions goes hand in hand with the achievement of Sustainable Development Goal (SDG) 7 in Africa, which aims to ensure affordable, reliable, sustainable and modern energy for all by 2030. North African countries have already achieved quasi-universal energy access (SDG 7.1) and should focus on improving reliability and affordability of energy supply. While renewables account for a small part of the region's mix, regional progress is set on SDG 7.2 by a few leading countries. Despite successful energy access and improvements on renewables, progress on energy efficiency has been stagnant across North Africa, necessitating further dedicated efforts to implement sectoral energy efficiency policies. Energy efficiency improvements (SDG 7.3) can help to unlock a range of economic, social and environmental benefits.

Status of SDG 7 in North Africa

Since 2015, when the international community defined and agreed on the SDGs, North Africa has made important progress towards reaching the SDG 7 targets. In terms of SDG 7.1, the region has already achieved virtual full access to electricity (with a 99% rate of access) and clean cooking (98% rate of access). Almost 20 million people in the region have gained access to electricity since 2000, and most households now enjoy access to clean cooking fuels. North African countries have also shown an important acceleration in the deployment of renewable energy technologies (SDG 7.2) in electricity generation, mostly in terms of solar and wind capacity. Meanwhile, improvements in energy efficiency have remained stagnant, indicating the need to increase the focus on progressing on SDG 7.3.

The progress achieved on SDG 7 in North African countries can inform access policies and renewables deployment elsewhere in Africa and globally. Yet additional efforts are needed to meet all SDG 7 goals (Box 2.1). In terms of energy access, although universal access in terms of connections is not threatened by the lockdown and other effects of the Covid-19 crisis, North African countries will need to improve the quality, reliability and affordability of the energy supplied to households to allow

them to sustainably reap the benefits of modern energy services. Further deployment of renewables is needed, in power generation but also beyond to sectors such as heat generation and transport. In addition, improvement on energy efficiency will be essential to North African countries' clean energy transitions, with many opportunities in the industry, buildings and transport sectors.

North Africa's carbon dioxide (CO₂) emissions account for 1.5% of the world total, up from 1.2% in 2010. With around 490 million tonnes (Mt) of CO₂, the region represents a large share of the energy-related CO₂ emissions in Africa, a continent where emissions are relatively limited, but nonetheless growing. Beyond CO₂, North Africa is responsible for almost two-thirds of the African nitrogen oxides emissions; nearly 50% of these emissions come from vehicle tailpipes, reflecting the relatively high number of cars on the road.

Making progress towards clean energy transitions across North African countries and meeting key SDGs by 2030 is achievable, as presented in the International Energy Agency (IEA) Africa Case (Table 2.1). This scenario developed by the IEA shows how the entire continent could achieve its inclusive and sustainable vision for accelerated economic and industrial development as envisaged in Agenda 2063. Faster economic expansion is accompanied by universal access to electricity and clean cooking, and reductions in premature deaths related to pollution. For North African countries, this scenario shapes a pathway where accelerated energy transitions stimulate progress towards meeting SDGs 7.2 and 7.3.

Box 2.1 Sustainable Development Goal 7

The UN SDGs serve as the blueprint for the sustainable development agenda, addressing global challenges including those related to poverty, inequality, climate change, environmental degradation, peace and justice. All 17 SDGs are interconnected. SDG 7, or the energy SDG, focuses on energy to "ensure access to affordable, reliable, sustainable and modern energy for all" (UN DESA, 2020), and serves as a guiding milestone for progress in energy development. Given the connectedness of energy, it has been named the "golden thread" of development connecting economic growth, social equity and environmental sustainability. Its subgoals are:

SDG 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services.

SDG 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix.

SDG 7.3: By 2030, double the global rate of improvement in energy efficiency.

SDG 7 provides a clear outline of objectives when it comes to improving energy access, sustainable energy and clean energy transitions. This report uses the SDG 7 framework in order to align with global development targets.

Table 2.1 SDG 7 and selected energy indicators for North Africa

	Historical data			Stated Policies Scenario		Africa Case	
	2000	2010	2018	2030	2040	2030	2040
SDG 7.1: Access							
Percentage of access to electricity	90%	99%	100%	100%	100%	100%	100%
Percentage of access to clean cooking	87%	96%	98%	99%	100%	100%	100%
SDG 7.2: Renewables							
Total final consumption (Mtoe)	70	113	142	198	238	187	218
Share of all renewables in final consumption	7.2%	5.4%	4.3%	5.7%	7.1%	8.5%	14.1%
Share of modern renewables* in final consumption	3.8%	2.9%	1.9%	5.0%	7.0%	8.4%	14.1%
SDG 7.3: Energy efficiency							
Total energy supply (Mtoe)	102	163	206	274	337	249	302
Energy intensity of GDP (toe/USD 1 000 [2015 PPP])	0.083	0.085	0.088	0.074	0.067	0.062	0.047
Average annual evolution		2000 2010	2010 2018	2018 2030	2018 2050	2018 2030	2018 2050
		0.3%	0.5%	-1.5%	-0.9%	-2.9%	-2.8%
CO₂ emissions							
Total CO ₂ emissions from fuel combustion (Mt)	246	390	492	627	719	539	545
Coal	15	14	33	29	26	7	9
Oil	151	227	238	311	321	286	255
Natural gas	79	148	220	287	372	245	282
Power sector	74	133	184	195	215	136	138
Final consumption	144	226	280	391	455	363	372

*Modern renewable energy: renewable energy excluding the traditional use of solid biofuels.

Notes: "North Africa" comprises Algeria, Egypt, Libya, Morocco and Tunisia. GDP = gross domestic product; PPP = purchasing power parity.

SDG 7.1. Enhancing energy access

North Africa has largely reached universal access to both electricity and clean cooking in recent decades, thanks to effective public policies promoting major grid extension, dedicated rural electrification programmes, and the expansion of gas networks and LPG distribution. Challenges remain in ensuring that access to energy services is guaranteed at affordable prices – with limited burden on public finance – and with a reliable quality of service. Overall, there are important lessons to learn from North African energy access success stories.

Status of energy access in North Africa

North African countries have achieved near-universal access to energy. Access to energy services in modern households include two components: first, access to electricity, with 99% of the population reached across the region as early as the late 2000s, and second, access to clean cooking facilities, which is the case for 98% of North Africa's population.

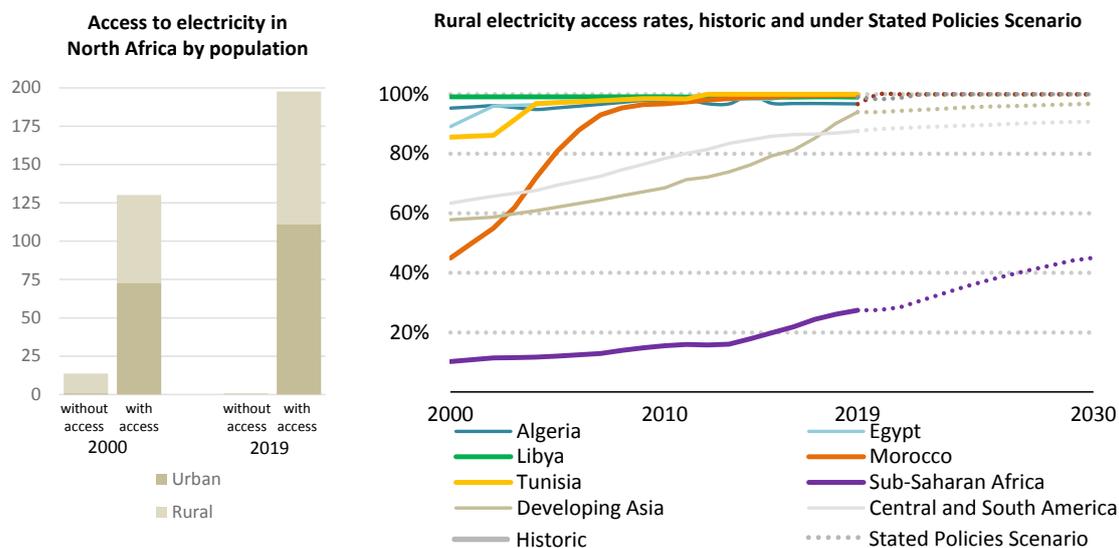
During the Covid-19 crisis and the subsequent lockdown measures, countries have deployed specific measures to ensure energy supply and to support power consumption. In Morocco, as well as in other regions of the world with a well-developed LPG sector, the government moved quickly to ensure continuity of supply during the crisis and has recognised LPG provision as an essential service. In other regions, similar measures for electricity have been instrumental in ensuring that households maintain access to service.

Access to electricity

North African countries reached quasi-universal access to electricity by 2010. Back in 2000, the average regional electrification rate reached 90% as urban households were provided access to electricity services across the region, but one-fifth of the region's rural population remained without power (Figure 2.1). Subsequently, 15 million people gained access to electricity between 2000 and 2015, mostly in the rural areas of Egypt and Morocco. Today, these zones are still home to the region's very last households without access to electricity. Algeria has counted on almost full electricity access for decades, while in Tunisia, universal access stems from progress achieved during the 2000s. In Libya, full access to electricity had been commonplace for all households since the IEA first published access statistics in 2000, but the effects of a prolonged period of political unrest and conflict has negatively affected access to reliable electricity.

Progress in electricity access across the region led to growing residential sector energy demand, which has significantly driven the growth in overall electricity demand. In 2018, per capita electricity demand reached more than 1 500 kilowatt-hours (kWh), double that of 2000, growing at an annual rate of 5%.

Figure 2.1 Access to electricity in North Africa – rural and urban population with access and evolution of access rates by country



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Source: [IEA \(2019a\), World Energy Outlook 2019](#).

20 million people have gained access to electricity since 2000 in North Africa. Progress in rural areas of North Africa was faster than in many other regions in the world.

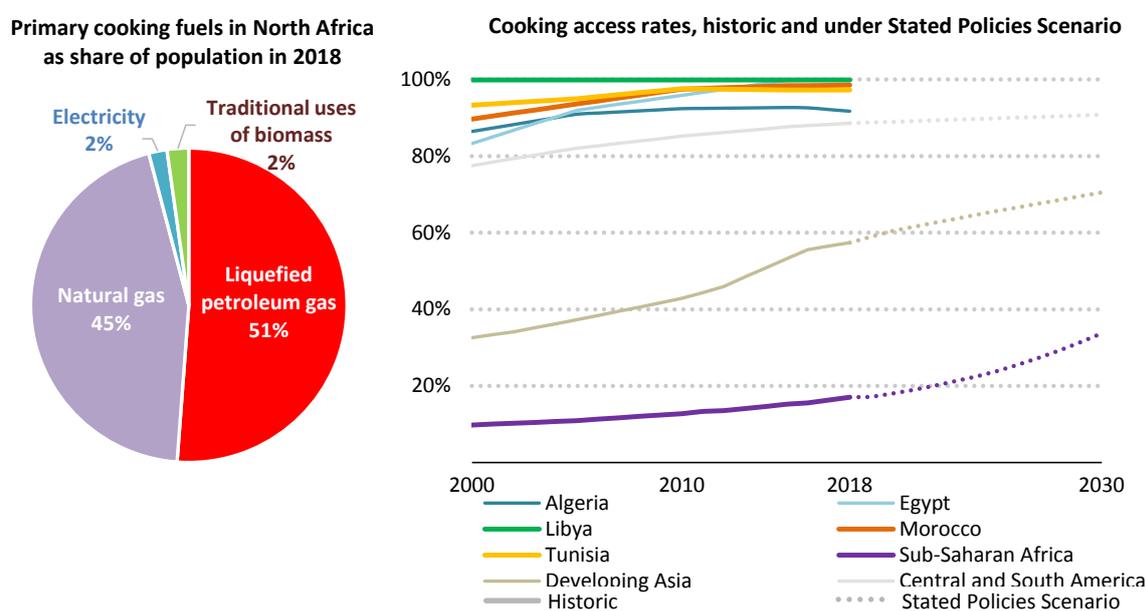
Access to clean cooking

In 2018, almost 98% of North African households had access to clean cooking fuels including natural gas and LPG (Figure 2.2). This represents important progress made since 2000, when 13% of North Africans, or 20 million people, mostly in rural areas, were still lacking access to clean cooking solutions. The majority of those lacking access – concentrated in Egypt and Morocco – relied on kerosene and traditional uses of biomass to prepare their daily meals.

Today, a small share of the region's population, mostly in rural areas, still relies primarily on traditional uses of biomass for cooking. This has negative impacts on human health and the environment due to poor indoor air quality and pollution, as well as on livelihood opportunity costs resulting from the time spent on fuel collection. North African households that remain without access to clean cooking are distributed across Algeria, Morocco and Tunisia, representing around 2% of the region's population. While this is small compared with the 87% of the population of sub-Saharan Africa that lacks access to clean cooking, it is significant as it represents around 4 million people. According to IEA estimates, North Africa still counts around 4 000 annual premature deaths attributable to household air pollution. While some

households rely on solid biomass as their primary fuel, others may have access to more modern fuels and equipment but continue to use traditional biomass for a portion of their heating or cooking needs – a practice called fuel stacking. As a result, solid biomass still accounts for 7% of total residential energy consumption in North Africa. While this share has halved since 2000, additional research on household energy uses is needed to inform targeted policies and help further the phase-out of the traditional use of modern biomass in favour of modern cooking applications.

Figure 2.2 Access to clean cooking in North Africa – share of cooking fuels and evolution of access rates by country



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Note: Based on WHO Household Energy Database.
 Source: [IEA \(2019a\) World Energy Outlook 2019](#).

With almost half of the region’s population using natural gas and the other half LPG, access to clean cooking has been almost universal since 2010 and is higher than in other developing regions.

Access to affordable, reliable, clean and modern electricity and cooking brings an important gender perspective. When access to modern energy services is unavailable, it is often women and girls who bear the brunt of securing sources of energy, such as collecting firewood, and spend hours preparing and cooking meals. Thus, they are often subject to the negative health impacts associated with cooking using traditional biomass. Women and girls bear an opportunity cost that prevents them from partaking in economic or educational ventures. According to time-use surveys conducted in three countries of the region, women spend more than five

hours per day on unpaid work including cooking-related household tasks, and only one hour on paid work. By contrast, the vast majority of working time for men consists of paid work, despite the fact that in terms of total numbers of hours worked, they work on average one-fifth less hours compared with women (UNDP, 2015). Reducing women's time spent on household tasks such as cooking and collecting energy sources could help accelerate their economic empowerment, with overall spillover benefits for their communities.

Lessons learned on energy access in North Africa

North Africa's achievement of universal access to electricity is attributed to several factors. Lessons from North African countries confirm the need for government leadership; for adequate planning based on precise analyses of the situation; and for clear allocation of responsibilities at the national and local levels in order to gradually deliver electrification. Progress was realised through ambitious and well-designed public programmes and driven by the extension of national grid networks. In Morocco, the national electricity and water utility (Office National de l'Electricité et de l'Eau Potable [ONEE]) increased the rural electrification rate from 18% in 1995 to 97% in 2009 by implementing a utility-led model that focused on grid extension for the vast majority of households. For those in isolated or dispersed areas, access to electricity was provided by solar home systems based on a fee-for-service model. In Tunisia, progress in rural electrification was achieved thanks to a comprehensive strategy for rural development, integrating health and education services.

To provide continuous access to clean cooking, governments have to ensure affordable and long-term fuel supply for a significant part of the population. Over the past decades, North African countries implemented ambitious policies to drastically reduce the traditional uses of biomass and ensure access to modern fuels for cooking by leveraging available cleaner solutions and fuels. Today, the vast majority of households in North Africa rely on either LPG or natural gas for cooking. This trend nonetheless hides a few differences: in Morocco, for example, more than 90% of the population cooked with LPG in 2018, as LPG use is subsidised by the government. Likewise, for Tunisia LPG usage is widespread in more than 80% of households. Countries developed well-functioning formal markets following the so-called cylinder recirculation model, ensuring safety for consumers. Conversely, 60% of Algerian and Egyptian households rely on natural gas for cooking, given their countries' vast domestic natural gas reserves.

The provision of both LPG and natural gas for cooking required governments to secure supply, develop infrastructure and implement strategic plans through national co-ordination. The abundant supply of LPG in the region is sourced from North African countries and from external markets including the Middle East. These broad supply capacities offer opportunities to increase the penetration of LPG use among households and businesses, and to stimulate their uptake. For natural gas, the outlook varies between countries: Egypt alone accounts for 40% of natural gas demand of the entire African continent, while Algeria has historically been a large gas producer, exporter and consumer. In both countries, market penetration of gas in the residential and commercial sectors is already high and is set to remain stable.

Prioritising affordable and reliable access to clean energy

While the 2020 oil price crisis and Covid-19-related lockdowns did not directly reduce access to electricity and clean cooking, the resulting economic shock may have a stronger long-term impact. The economic crisis may push millions of people into poverty, affecting households' ability to afford modern energy services. For households to fully benefit from the value of energy access over the long term, it is essential to maintain and improve energy quality, reliability and affordability. Today, as governments are designing plans for recovery, ambitious policies could further expand access to sustainable energy sources and accelerate clean energy transitions while creating jobs and fostering economic growth. This can include measures to tackle the weight of subsidies in the public budget, as well as to increase the reliability of supply or to improve energy efficiency.

In past decades, energy access strategies in North Africa have been possible not only due to local resources such as natural gas and LPG but also thanks to public funding. The growth in consumption of both electricity and clean cooking fuels was supported by important subsidies, which have facilitated their affordability and enabled their wider uptake. While subsidies can help to support the uptake of energy services by the poorest households, they have also created substantial fiscal burdens for countries' public budgets. This interaction of subsidy policies with energy access has been a challenge for many countries, raising questions about fiscal priorities and social issues going forward.

Subsidies can incentivise wasteful consumption and weigh on national budgets. In 2019, the total bill for fossil fuel consumption subsidies¹ for Algeria, Egypt and Libya together exceeded USD 30 billion. Although most of this amount relates to oil and the transport sector, almost USD 10 billion went to electricity subsidies, including two-thirds for the residential sector (IEA, 2020a).

Reforming fossil fuel subsidy schemes can be done by introducing appropriate pricing mechanisms and maintaining gradual assistance to the poorest households. To do so, assessing the impact on commercial, industrial customers and households is a prerequisite. Social safety net programmes can help protect vulnerable households, while businesses need a well-defined subsidy phase-out plan with visibility on future energy prices in order to best adapt to, absorb or pass on the incremental costs. Examples of electricity price reforms exist in the region, and the current period of low oil prices offers a unique opportunity to pursue energy subsidy reform. With the sharp decline of global oil prices under the Covid-19 crisis, the cost of LPG is likely to remain low in the short term. In April and May 2020, LPG prices were down by around 40% compared with the 2019 average. This offers governments the opportunity to decrease their financial support to LPG consumption by reducing subsidies while keeping prices at the current level to maintain affordability.

In addition to subsidy reform, recovery packages can adopt complementary measures. In the case of clean cooking, natural gas and LPG can bring benefits beyond access. For example, in terms of emissions, they emit some of the lowest amounts of CO₂ equivalent (CO₂-eq) among cooking fuels that are available at scale, comparing favourably to alternative fuels such as biomass that are prevalent in the rest of the African continent. To reduce GHG emissions in the long term, biogas and bio-LPG are promising solutions as they could leverage existing distribution infrastructure and could draw on local agricultural resources. Similarly, renewables-based electric cooking can offer interesting opportunities to capitalise on existing power systems (Box 2.2). Increasing LPG penetration to reach remote populations and disincentivise fuel stacking could bring wider socio-economic benefits for the region. According to IEA estimates, every million USD invested in expanding LPG services could generate between 15 and 75 direct local jobs (IEA, 2020b).

¹The IEA estimates subsidies to fossil fuels that are consumed directly by end users or consumed as inputs to electricity generation. It relies on the price-gap approach, the most commonly applied methodology for quantifying consumption subsidies, which compares average end-user prices paid by consumers with reference prices that correspond to the full cost of supply.

Another challenge in North Africa's energy system is the reliability of power supply. Unreliable electricity is a constraint to the economy and to households in most countries. Technical electricity losses in North Africa are high – at almost 20% – and compare unfavourably with the average in other developing countries (9%) (IEA, 2019a). Losses are attributed to a combination of factors including poor operational performance on the part of utilities and electricity theft. The economic impact is serious: in sub-Saharan Africa, company losses can reach up to 8% of annual sales, and around 80% of firms reported suffering frequent electricity disruptions; in a number of North African countries, this number can go up to 25% (World Bank, 2020). Low-quality or unreliable electricity supply forces not only firms but also individuals to manage gaps in supply, turning to more polluting and expensive alternatives such as diesel generators. IEA analysis estimates that more than 10 GW of back-up generating capacity was available in the region in 2018, a figure that exceeds the total installed capacity from renewables (IEA, 2019b). In Egypt, above 10% of firms report to own or share a generator (World Bank, 2020). This has detrimental effects, including increased carbon emissions, poor air quality and lower economic competitiveness.

Improving electricity quality and reliability by reducing losses would bring large efficiencies, benefiting company competitiveness and development. In addition, the adoption of efficiency standards could improve the affordability of electricity services. Household consumption, which in 2018 accounted for 40% of electricity demand or 115 terawatt-hours (TWh), surpasses basic needs and is mostly dedicated to appliances, water heating and space cooling. For example, cooling equipment ownership increased by almost 50% over the last ten years, and households now own an average of 1.75 air-conditioning appliances. Demand from all air conditioners (from both the residential and service sectors) accounts for 7% of total electricity demand in the region and rose by nearly 30% between 2015 and 2019. Energy efficiency measures for appliances exist and can be easily implemented. They have the potential to cut consumer spending on electricity, limit the growth in demand and reduce GHG emissions.

Strengthening the reliability of the grid and the affordability of electricity should remain a priority in North Africa, and require significant investment. By 2025, USD 13 billion will be necessary on average each year to support new plants, refurbishments and network infrastructure, according to the Africa Case 2020-25 average (IEA, 2019b).

Box 2.2 Outlook for electric cooking in Morocco

The vast majority of Moroccan households have access to grid-based electricity and to clean fuels for cooking. Facilitated by government subsidies, 98.5% of the population has adopted LPG in the form of canned butane. However, hundreds of thousands of rural low-income households continue to cook with traditional firewood. This situation has led to a double challenge of decreasing the dependence on subsidised imported LPG and reducing the persistent use of unsustainable traditional biomass for cooking. The transition to sustainable, more accessible and more affordable cooking methods is a priority for the government.

Relying on traditional uses of biomass for cooking has negative effects on the environment in terms of forest degradation, on health owing to poor indoor air quality, and on the economy in terms of time and energy lost; and it disproportionately impacts women and girls. The persistence of reliance on wood stoves is due to the lack of physical access to the LPG distribution network and to affordability challenges: the cost of the canister, the equipment and fuel refills can be a considerable investment for the poorest. Cooking with LPG is cleaner and safer than traditional biomass. That is why its expansion has been supported by public policies and today represents Morocco's only remaining fossil fuel subsidy. Still, the subsidy bill comes at a high cost, standing at almost EUR 1 billion in 2017.

Electric cooking could help facilitate access to clean cooking while reducing the LPG subsidy costs. Recent innovations in electric appliances with energy-efficient pressurised cookers reveal new opportunities for electric cooking. These devices are increasingly user-centric, designed to ensure that they fit local cooking practices. Cost reductions of equipment could make them competitive versus alternative cooking fuels, including in off-grid rural settlements where they could be powered by stand-alone solar systems. Analyses in East Africa show that electric solutions based on solar PV plus battery systems have lower monthly costs than charcoal or LPG (Leach, 2019).

Further progress in electric cooking technologies associated with the declining costs of solar and storage energy systems could enable rural households to shift directly from traditional biomass to clean electric cooking. Beyond populations still without access, electric cooking could also be a relevant technology for grid-connected areas, where, if powered by clean sources, it would offer a sustainable and modern form of cooking.

SDG 7.2. Accelerating growth of renewables

Renewable energy generation is gaining ground in North Africa. The region is rich in renewable energy resources – notably wind and solar energy – which can not only provide electricity, but also contribute to wider energy needs in buildings, in industry and in transport. Increasing the contribution from renewables is an essential step in

the clean energy transition. First steps have already been taken to harness the wind and solar resources for power generation and for heating, with a number of countries in the region providing good examples of policies that create a strong enabling framework. Renewable energy sources have the potential to revolutionise energy supply in the region if the appropriate mix of policy measures are put in place.

Status of renewables in North Africa

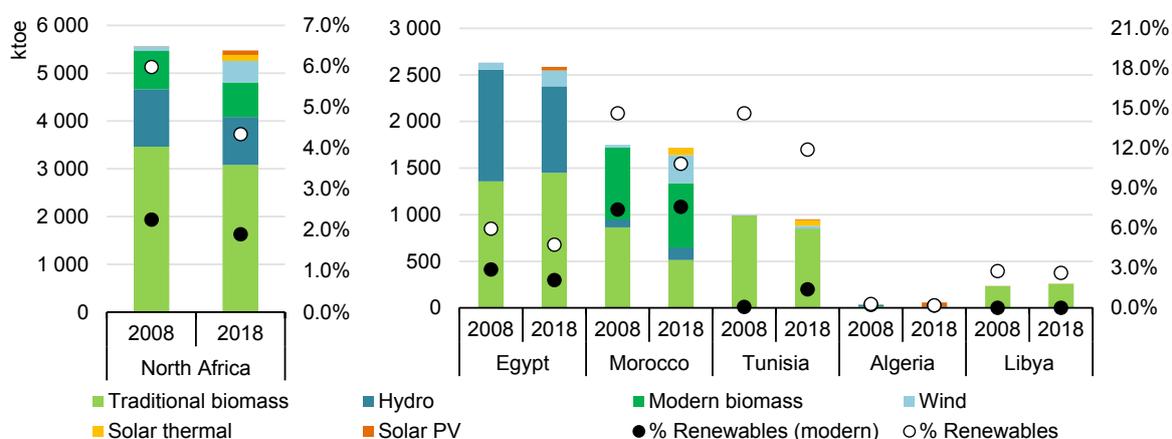
Renewables in final energy consumption

Renewable energy consumption in North Africa remains largely untapped relative to its potential. In 2018, renewables accounted for 4.3% of final energy consumption, down almost two percentage points from the levels observed ten years prior in 2008 (6.0%) (Figure 2.3). The decrease is due to both the declining use of traditional biomass use in Morocco and the upsurge in transport demand in Algeria and Egypt. Traditional biomass use is the region's largest source of renewable energy and is mainly used for heating and cooking in the residential sector. However, its consumption has been linked to negative health and environment impacts, and most policy objectives focus on decreasing its use (See Chapter 2, SDG 7.1.). The second-largest source of renewables in the region is hydropower, followed by modern bioenergy. Wind, solar thermal and solar PV have witnessed a rapid growth in the latest years mainly in Egypt, Morocco and Algeria.

Excluding traditional biomass use, the regional share of modern renewable energy in 2018 was 1.9%, but the shares vary significantly between countries ranging from less than 1% in Algeria to 7.6% in Morocco. The highest shares are in the region's net energy importers, Morocco and Egypt (and to a lesser extent in Tunisia), where one policy driver for renewable deployment has been energy diversification away from fossil fuel imports. Combined, these countries account for over 96% of the region's renewable energy consumption; however, they only account for 66% of total energy demand.

The sector with the highest penetration of modern renewables in North Africa is electricity, where renewables accounted for 6.9% of supply in 2018. Penetration has been slower in heat and transport; where modern renewables accounted for only 1.4% and 0.03% respectively.

Figure 2.3 Trends in renewables contribution to final energy consumption in North Africa



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Note: ktoe = thousand tonnes of oil equivalent.

Sources: [IEA \(2020c\)](#), [World Energy Balances](#).

The share of renewables in North Africa has declined in the last decade, due to modern renewables growing more slowly than total demand, and to a decrease of traditional biomass use.

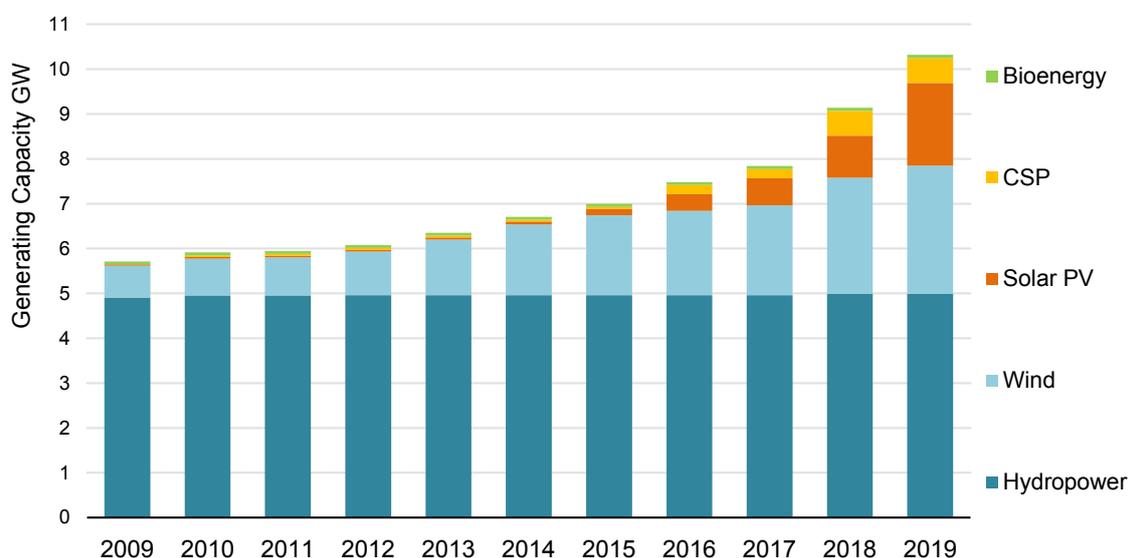
Renewables in electricity capacity and generation

Renewables electricity capacity trends have grown in particular in wind and solar PV, especially in recent years (2009-19), as shown in Figure 2.4 (IEA, 2020d). Hydropower capacity has remained constant at around 5 GW. Wind capacity has grown rapidly over the period, rising to 2.9 GW by 2019 (all capacity on- rather than off-shore). In 2019, solar PV capacity reached 1.9 GW, and concentrated solar power (CSP) capacity rose sharply as projects in Morocco came online, reaching 0.6 GW. Bioenergy electricity generation capacity remained low at 70 megawatts (MW) (all in Egypt).

Hydropower is the region's largest source of renewable electricity, with more than 80% supplied by Egypt, followed by wind led by Morocco, Egypt and Tunisia. Hydropower generation oscillates year-on-year because output depends on precipitation levels. As such, over the last decade hydropower generation has ranged between 15 TWh and 16 TWh due to rainfall variations in the region. Solar PV, the region's third-largest source, is almost entirely utility-scale and is the only technology

that exists in all countries while solar thermal, the fourth-largest source, is concentrated only in Morocco. Bioenergy, the smallest source, is only in Egypt (Figure 2.5).

Figure 2.4 Trends in renewable energy capacity in North Africa, 2009-19



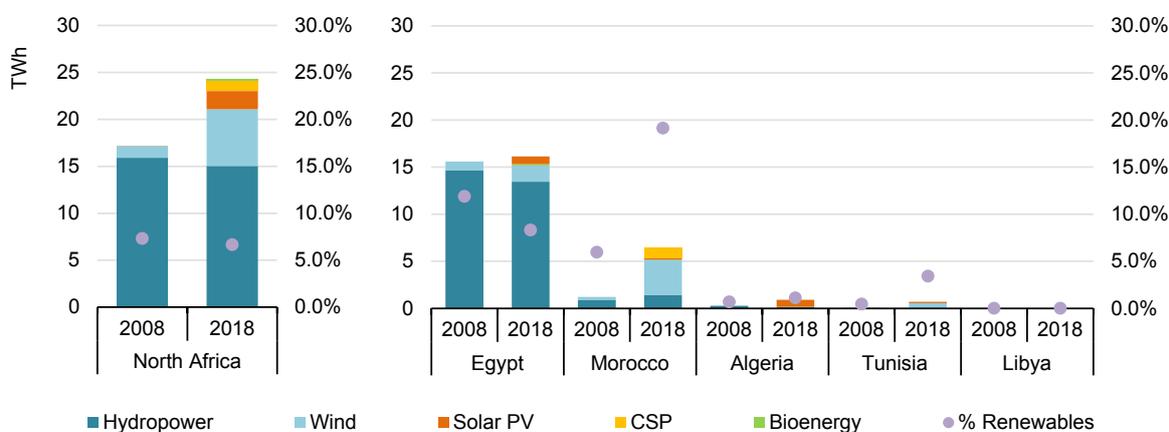
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Source: [IEA \(2020d\), Renewable Energy Market Update 2020](#).

Hydropower is the region's largest source of renewable electricity, but wind and solar are growing the fastest.

Over the last decade, renewable electricity in North Africa has grown more than 40% due to the rapid expansion of wind, solar PV and solar thermal. Three-quarters of the region's growth is from Morocco, driven by support policies targeting private investments such as competitive auctions among independent power producers (IPPs) and corporate power purchase agreements (PPAs). Almost 20% of Morocco's electricity supply is from renewables, the highest penetration in the region. The rest of the growth is from Egypt, Algeria and Tunisia driven by a mix of procurement methods such as feed-in tariffs (FITs); competitive auctions; unsolicited bilateral contracts; and utility engineering, procurement and construction contracts. However, despite the rapid increases in solar and wind generation, the overall share of renewable electricity declined from 7.3% in 2008 to 6.7% in 2018 because total power demand in North Africa has grown faster than renewables. In addition, lower hydropower output from less rainfall has also contributed to this decline.

Figure 2.5 Renewable electricity in 2008 and 2018 in North Africa (left) and by country (right)



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Source: [IEA \(2019e\), Renewables 2019: Analysis and Forecasts to 2024](#).

While wind and solar PV have strongly expanded in the region, the share of renewable electricity has remained stable over the last decade, albeit with strong differences across countries.

Heat and transport

The main renewable source used for heating in North Africa is biomass, principally through the “traditional” use of biomass for cooking and heating in simple fires and stoves (IEA, 2019d). In principle, North Africa has high potential for the use of solar heat for water heating. The solar heating market is developed to some extent, with solar heating capacity of some 679 megawatts thermal (MW_{th}) (and a collector area of 907 000 square metres [m^2]) in Tunisia (IEA SHC, 2020), 560 MW_{th} (750 000 m^2) in Egypt (IRENA, 2018) and 316 MW_{th} (451 000 m^2) in Morocco (IEA SHC, 2020). Renewables play a minor role in the transport sector across the region, with few electric vehicles that can use renewable power and low levels of biofuels (IEA, 2019e).

Outlook for renewables in North Africa

The IEA *World Energy Outlook (WEO)* has modelled the growth of renewables in the region to 2030 and beyond in two scenarios, the Stated Policies Scenario (STEPS), which reflects the IEA’s measured assessment of today’s policy frameworks and plans, and the Africa Case scenario, which reflects a more ambitious approach to economic transformation and meeting the SDGs (IEA, 2019a).

In each scenario, renewables electricity generation from wind and solar grows strongly by 2030. In contrast, the role of traditional biomass decreases as more modern sources are used to supply energy for cooking and heating in homes, businesses and industry. Overall the contribution from renewables to final energy consumption rises from 4.2% to 5.4% by 2030 in STEPS and nearly doubles to 8% in the Africa Case.

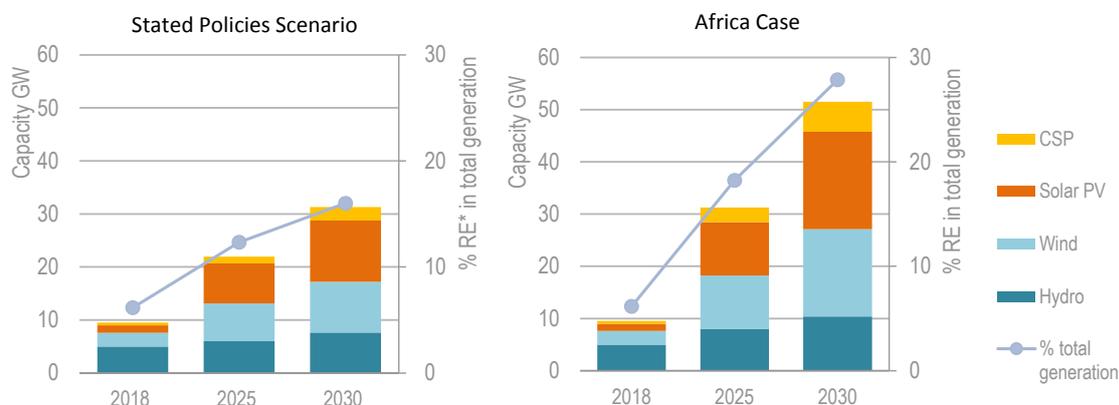
Figure 2.6 (left) illustrates how renewables electricity capacity is expected to grow from 2018 to 2030 under STEPS. Renewables grow strongly with overall capacity growing by a factor of 3.4 to 32 GW. Wind capacity grows by a factor of 3.7 to nearly 10 GW, that of solar PV by a factor of 8.4 to 12 GW and CSP by a factor of 4.6 to 2.6 GW. The proportion of renewables in total generation rises from 7.6% in 2017 to 16% by 2030.

Figure 2.6(right) also shows how renewables generation grows under the more ambitious Africa Case, with capacity rising by a factor of 5.5 to over 52 GW. Wind capacity grows by a factor of 3.7 to 17 GW, but is overtaken by that of solar PV, which rises 13.5-fold to 19 GW, while CSP grows tenfold to 6 GW. The proportion of total renewables in total generation rises to 28% by 2030.

This modelled contribution from renewables to energy supply in North Africa by 2030 is well below the long-term potential estimated by a number of studies. For example, the European Union's Intelligent Energy – Europe project BETTER, which was executed by a consortium led by the Centre for Energy, Environment and Technology (CIEMAT) between 2012 and 2015, quantified the so-called “realisable technical potential” in the long term (2050) (OME, 2015). This represents their estimate of the maximum achievable fraction of the overall technical potential, assuming that all existing barriers can be overcome and that there is strong political will.

In total, the study estimated the annual potential at some 34 100 TWh – nearly nine times the current electricity generation from all sources in the region. In addition, it highlights that the resources available allow for operation of the wind and solar plants at high utilisation rates, meaning that the power is produced at low cost. This opens up prospects of using renewable electricity to help reduce emissions from heating and cooling in buildings and in industry, and in transport, either through direct electrification or by using intermediates such as hydrogen (Box 2.3). Achieving higher levels of deployment would require ambitious targets, access to appropriate funding, and particular attention to system and market integration to ensure the power produced was effectively used either within the region or through exports.

Figure 2.6 Trends in renewable generation capacity and generation in North Africa in *WEO*STEPS and Africa Case



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Note: RE = renewable energy.

Source: [IEA \(2019b\)](#), [Africa Energy Outlook 2019](#).

Renewable power capacity is set to expand by a factor of three to five by 2030 depending on the scenario, with wind and solar PV accounting for approximately 75% of growth.

Implications for system integration and electricity security in North Africa

The importance of system flexibility

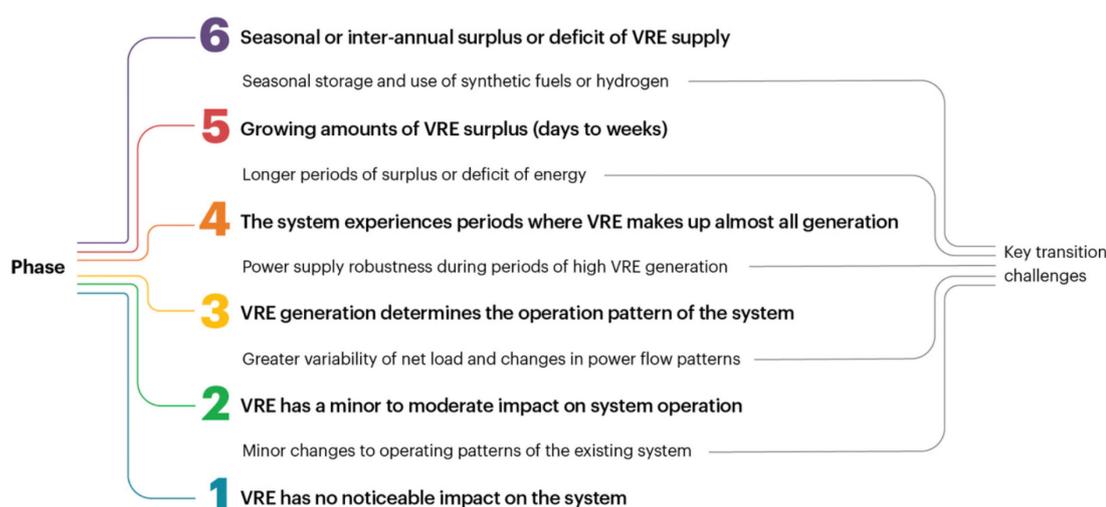
High levels of renewables generation from variable renewable energy (VRE) sources such as those foreseen for wind and solar PV generation in North Africa, as around the world, will pose new challenges to system planners and operators as the proportion of electricity provided by such plants increases. Increased power system flexibility² will be needed to ensure that the higher levels of VRE can be accommodated securely and efficiently in power systems as the percentage of VRE grows.

The challenges to the power system evolve as the level of VRE penetration increases and therefore requires a co-ordinated approach in order to increase power system flexibility. The IEA has developed a phase categorisation to capture the evolving

² Flexibility is defined as “the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply” (IEA, 2019d).

impacts that VRE may have on power systems, as well as related integration issues. The integration of VRE can be categorised into six different phases as summarised in Figure 2.7 (IEA, 2019d).

Figure 2.7 Key characteristics and challenges in the different phases of system integration



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Source: [IEA \(2019d\), Status of Power System Transformation 2019](#).

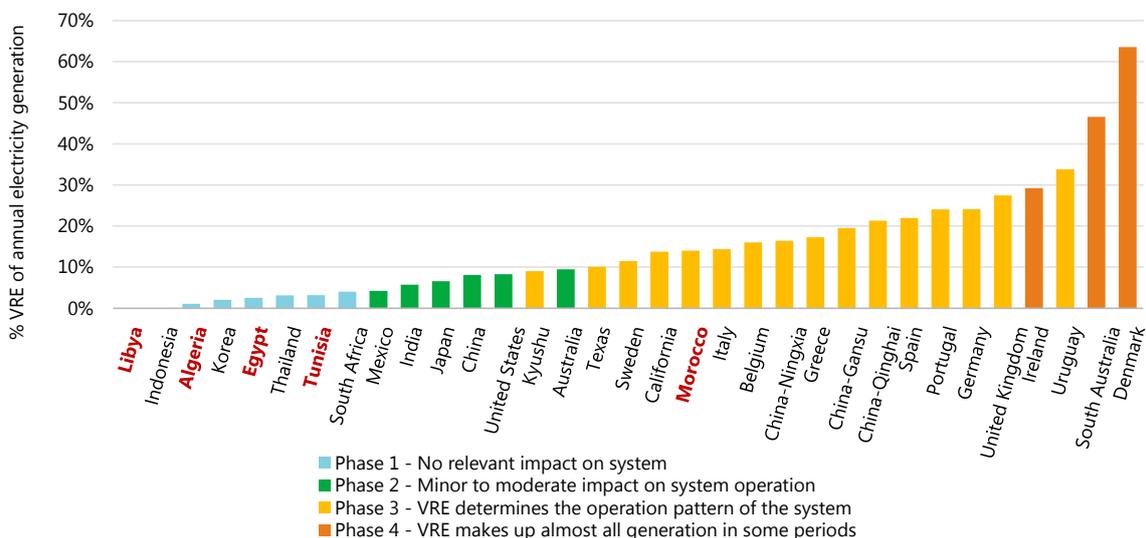
The challenges of system integration vary and can be classified into six phases, depending on the share of variable renewables and the overall flexibility of the system they are integrated in.

Figure 2.8 presents annual VRE shares and corresponding system integration phases for the five North African countries and other select countries and regions, showing the 2019 shares of VRE. Phase 4 is the highest VRE integration phase that has been achieved in a small number of countries and regions (e.g. Denmark, Ireland and South Australia) but most other power systems are still in Phases 1 and 2, with 5-10% shares of VRE in annual electricity production. In North Africa, Morocco had a 13% VRE share in 2019 placing it in Phase 3, while the remaining countries are all currently below 5%. Experience indicates that integration issues at current levels of generation should be manageable if best practice principles applied elsewhere are enacted.

Higher levels of deployment are expected across the region. In Morocco, the combination of solar PV and wind deployment is expected to take its share of VRE to more than 25%, which will place it firmly in Phase 3 of its deployment. For the region as a whole, if the deployment levels associated with STEPS or the Africa Case are achieved, levels will rise to 16% (STEPS) or 28% (Africa Case), with some individual

countries likely to go well above these levels. To integrate these higher levels effectively, further steps will need to be taken to secure system flexibility.

Figure 2.8 Annual VRE share and corresponding system integration phase in selected countries and regions, 2019



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Note: China = People’s Republic of China.

Source: [IEA \(2019e\)](#), [Renewables 2019: Analysis and Forecasts to 2024](#)

While to date, VRE sources have minor system impacts in most countries, high penetration in leading markets demonstrates that secure integration of high shares of wind and solar is possible.

There are four key categories of infrastructure assets that provide system flexibility: a) dispatchable power plants (both conventional and renewables); b) electricity networks and interconnections; c) energy storage; and d) distributed energy resources (DER), including demand-side response. Conventional power plants, electricity networks and pumped storage hydropower have historically been the primary sources of flexibility (IEA, 2019d). Furthermore, operational protocol improvements, which have occurred in VRE power plants and electricity networks, and with the advent of affordable DER and battery energy storage systems, are enabling the consideration of a wider set of flexibility options. Achieving this goal typically also requires changes to policy, market and regulatory frameworks (IEA, 2019d).

Owing to the size of the countries and the current state of the network, with high losses in some places, the deployment of VRE in North Africa would benefit from integrated generation and network planning, allowing the optimal placement of

resources across the network and reaping the benefits from reliability, economic and environmental perspectives. Taking into account that the deployment of VRE can often outpace that of other network infrastructure, this can limit the burden on the local transmission and distribution grid, which otherwise would lead to congestion and drive up the cost of delivered electricity (IEA, 2017a). The examples of Renewable Development Zones in South Africa and the solar park policy in India show how this approach can optimise the deployment of VRE (IEA, 2018a, 2019d).

Balancing supply and demand over a large geographical area can have a number of benefits including resource diversification, lessening of variability across a large geography and sharing of flexible resources. It also allows access to markets to export excess wind and solar production during periods of low demand, which can vary greatly across different regions, depending on both holiday and weekday conventions. The position of North African countries provides plenty of technical opportunities for greater interconnection, not just within these individual countries, but also with neighbouring regions such as Southern Europe and neighbouring power pools in West Africa (West African Power Pool) and East Africa (East African Power Pool) (ECDPM, 2019; European Commission, 2019; Foreign Brief, 2020; Daily News Egypt, 2020; PV Magazine, 2019a, 2019b, 2019c; Middle East Monitor, 2019). It must be recognised that such connections would involve complex geopolitical issues, which could take time to negotiate and reach mutually beneficial interregional agreements. However, the long-term objective for a better integration of electricity networks should be high on the regional policy agenda, to improve electricity security and achieve a reliable and cost-effective integration of renewables.

Renewables policy best practices in North Africa

North Africa's policy frameworks for renewable energy are mostly focused on electricity with ambitious goals to increase the share of renewables. All five countries have long-term targets for increasing renewable electricity capacity. By 2030, Algeria targets 22 GW, Morocco 10 GW, Libya 4.6 GW and Tunisia 2.8 GW, while Egypt targets 54 GW by 2035 (RCREEE, 2019) (Table 2.2).

These targets coupled with several support policies and enabling regulatory frameworks are expected to add more than 10 GW of renewable capacity by 2024, effectively doubling the region's installed capacity to over 20 GW. More than 75% of the growth is from support policies and regulatory frameworks that attract and enable private investment from IPPs. This includes competitive auctions, FiTs, unsolicited bilateral contracts between the IPP and the utility, and corporate PPAs

between producers and large consumers. The share of private investment increases to 88% when distributed PV policies encouraging self-consumption with remuneration for excess generation are included. The remaining 12% of new investment is by state-owned enterprises.

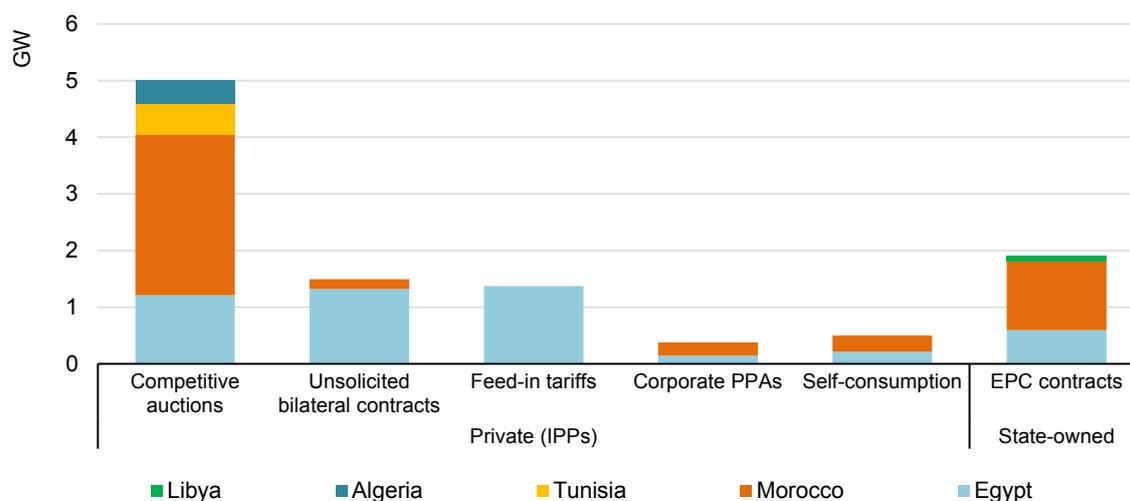
Table 2.2 Renewable electricity capacity targets in North Africa

	Algeria	Egypt	Morocco	Libya	Tunisia
Cumulative capacity (2019)	0.7 GW	5.5 GW	3.74 GW	0.01 GW	0.38 GW
Target	22 GW by 2030	54 GW by 2035	10 GW by 2030	4.6 GW by 2030	2.8 GW by 2030

Sources: [IEA \(2020d\), Renewable Energy Market Update 2020](#); RCREEE (2019), Arab Future Energy Index.

The largest amount of renewable capacity is from competitive bidding policies for long-term PPAs with state-owned utilities in Algeria, Egypt, Morocco and Tunisia. This policy accounts for almost half of the new capacity (5 GW) expected over the next four years for solar PV, onshore wind and CSP while at the same time helping to drive down costs in the region. In Morocco, IPP competitive auctions for CSP have decreased bid prices by 25% from USD 190 per megawatt-hour (MWh) for Noor I Ouarzazate (3.5 hours storage) in 2012 down to USD 140/MWh for Noor II (7 hours of storage) in 2015. Between 2016 and 2019, competitive auctions drove down solar PV bids from USD 49/MWh for Morocco’s Noor PV I to USD 24/MWh in Tunisia.

More than half of the auctioned capacity will come from Morocco, largely due to a successful institutional framework using a public-private partnership through the Moroccan Agency for Sustainable Energy (MASEN). MASEN is a dedicated “one-stop shop” government institution that provides the land and infrastructure for the projects, organises the auctions, and provides the permitting. It also uses an innovative dual PPA procurement model to optimise risk allocation between the private and public players (IEA, 2019g). The first PPA is a government-backed contract between a special-purpose vehicle made up of the winning bidding consortium and MASEN, and the second PPA is between MASEN and the state utility where the Government of Morocco funds the price difference between the winning bid and the lower electricity tariff set by the state utility (CPI, 2012). In addition, the contract’s provision of long-term visibility increases investor confidence, and MASEN’s role in obtaining concessional financing has been critical for decreasing the cost of capital. Since 2012, MASEN has procured around 1.5 GW of solar thermal and PV capacity, and as a result of its success, had its responsibility extended to include onshore wind and small hydropower.

Figure 2.9 Renewable electricity capacity growth 2019-24 by procurement type

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Source: [IEA \(2019e\), Renewables 2019: Analysis and Forecasts to 2024](#).

More than 75% of the region's utility-scale growth is from a mix of policies that have attracted private developers.

Government policies and institutions that help reduce the cost of financing are key to achieving renewable deployment in the region, particularly in Morocco. In addition to using concessional finance, MASEN also issued green bonds to finance the debt of 100 MW of Noor PV 1 projects in competitive auctions (IEA, 2019g). Approximately 1 GW of onshore wind in Morocco was financed with contributions from the German Development Bank (KfW) and the European Investment Bank. In Egypt, projects under the FiT were financed with USD 653 million from the International Finance Corporation and a consortium of nine international banks (Reuters, 2017). Limited access to local financing has been cited as a challenge for investors in Tunisia and Algeria's competitive auctions.

Enabling regulatory frameworks that allow private generation and sale of electricity is another policy practice that encourages renewable growth in the region. Unsolicited bilateral contracts between IPPs and the state utility, and corporate PPAs, are expected to drive another 20% of renewable capacity growth in the region by 2024 – due to Egypt's and Morocco's regulatory environments.³ Renewable capacity growth has also been driven by regulatory practices such as net metering⁴ and the

³ This forecast is from *Renewables 2019* (IEA, 2019e) and is prior to Covid-19.

⁴ In a net metering scheme, a PV owner receives an energy credit for any excess generation exported to the network during a specific period. This energy credit can be deducted from network electricity consumed on future bills at

purchasing of excess electricity that have increased the attractiveness of self-consumption. Egypt accounts for almost all of the region's grid-connected distributed PV, due to the economic attractiveness of solar PV self-consumption with the option to sell excess generation to the Egyptian Electricity Transmission Company (EETC). In Morocco, some of the first wind projects were developed by large industries such as cement factories for own use with the option to sell excess generation to ONEE thanks to Law 16-08. In 2020, Tunisia introduced regulations permitting corporate PPAs and net metering for the first time.

Key policy recommendations

North Africa has made progress on developing its renewable resources. Within the region, the portfolio of policies has evolved as the technologies have matured and the costs have fallen. The current support systems based on long-term PPAs provide investors with long-term certainty, coupled with an element of competition that drives policy cost-effectiveness. As experience grows, there is scope for more ambitious plans to drive cost-competitive renewables to higher levels of penetration in electricity supply (Box 2.4). Continuing development of the policies, coupled with an increasing level of ambition, can make the region a global centre of faster renewable energy growth if certain challenges are addressed.

Effective auction design is critical for de-risking investment and timely deployment. A transparent process is a must to attract investors and foster competition. An auction schedule outlining future plans with clear bidding rules and a transparent selection process is key to increasing investor confidence and attracting investment at the desired scale. Countries may consider designating dedicated institutions to hold auctions, earmarking land for tender, and arranging the permitting to reduce the cost and time associated with the bidding process for developers.

Improved regulatory frameworks can also facilitate faster growth, particularly for distributed PV. Small-scale generators currently are not able to access low- and medium-voltage grids in some countries. This prevents excess electricity from being exported and sold to third parties, which limits the economic attractiveness of the investment. Allowing grid access for small consumers through clear connection

another time. The period over which these energy credits can be used (e.g. one year, one month) strongly influences the economic attractiveness for PV investors.

rules, harmonised permitting procedures and transparent grid codes, as well as establishing tariffs with fair remuneration of excess electricity sold to the grid, could accelerate investment.

Implementing cost-reflective energy tariffs would also help improve the economic attractiveness of renewables. Many countries plan and have started to phase out end-user energy subsidies in recent years; however, despite the good resource potential, technologies such as distributed solar PV are still not cost-competitive in some places due to the suppressed end-user electricity tariffs. Reducing fuel subsidies may also help decrease the strain on national budgets. At the same time, any subsidy reduction or phase-out must be implemented very carefully in order to avoid excessive impacts on the most vulnerable parts of society.

Improving access to affordable financing: one of the biggest challenges for both large and small-scale deployment is access to affordable financing at scale. Apart from developing appropriate policies and regulations to reduce risks, overcoming these challenges requires a number of initiatives in the financial sector. Participation of development banks remains crucial to decrease risk and increase bankability of large-scale projects. At the same time a greater involvement of local commercial banks is also needed, including by diversifying financing models and products and increasing the capacity of commercial banks to fund renewable energy projects.

The very high technical and economic potential for renewables in the region means that there is also scope to go beyond sectors traditionally supplied by electricity: by increasingly providing transport energy through electricity, by extending the use of electricity for building use including cooling, and by expanding the use of renewables into the industry sector, which is still mostly powered with oil and gas.

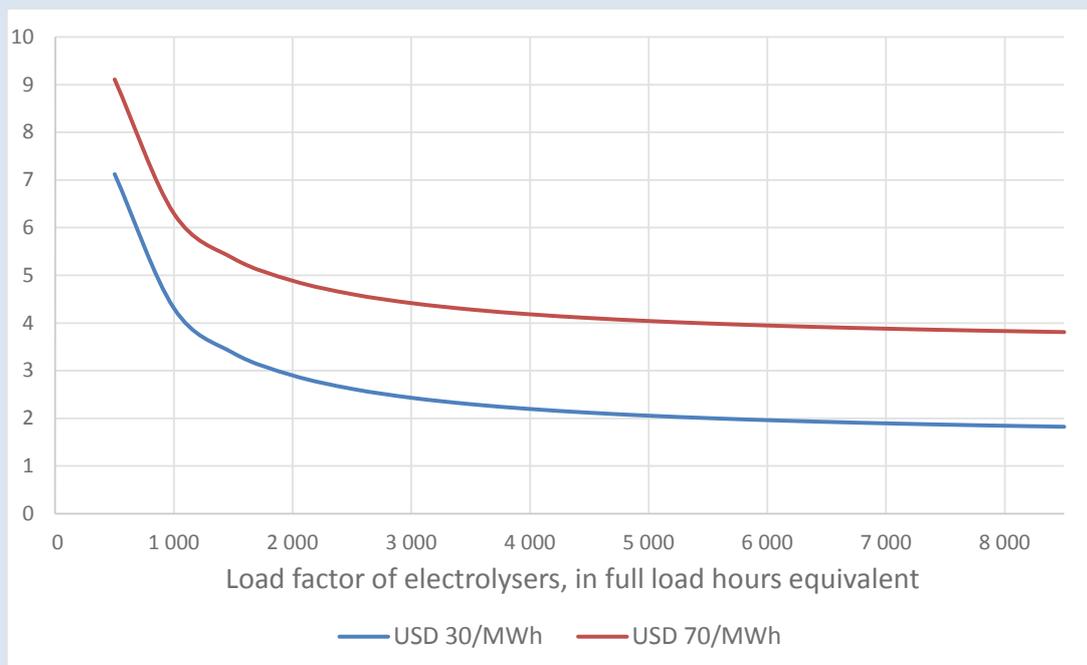
This could be achieved either through direct electrification of processes or by making use of energy sources based on renewable hydrogen, produced by electrolysis of water using solar or wind power. For example, renewable hydrogen has the potential to replace methane in the production of ammonia, one major industrial source of GHG emissions (Box 2.3). Renewable energy can be the driving force of North Africa's clean energy transitions thanks to its huge untapped potential (e.g. for solar and wind) (Box 2.4).

Box 2.3 Renewable hydrogen and ammonia production in North Africa

Hydrogen is widely used in a range of chemical processes, including ammonia production, as well as other industrial processes. Hydrogen is currently principally produced from methane, and its production is a major source of CO₂ emissions. Ammonia production alone is responsible for 420 Mt of CO₂ emissions, over 1% of global energy-related CO₂ emissions (IEA, 2017a).

It is also possible to make hydrogen by the electrolysis of water using renewable electricity. Recent developments that have shown how the costs of electricity from wind and solar PV can be reduced have opened up the prospect of making low-cost “renewable” hydrogen and so offer a way to significantly reduce industrial emissions. Analysis by the IEA has shown that the costs of hydrogen production depend critically on the cost of the electricity used, the efficiency and the rate of utilisation of the electrolyzers (IEA, 2019f).

Cost of electrolytic hydrogen production in function of load factor of electrolyzers and electricity generation costs



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Notes: kgH₂ = kilogramme of hydrogen. Assumptions: alkaline electrolyzers cost USD 700/kg (installed), lifetime 30 years, low heating value efficiency 67%, weighted average cost of capital 7%.

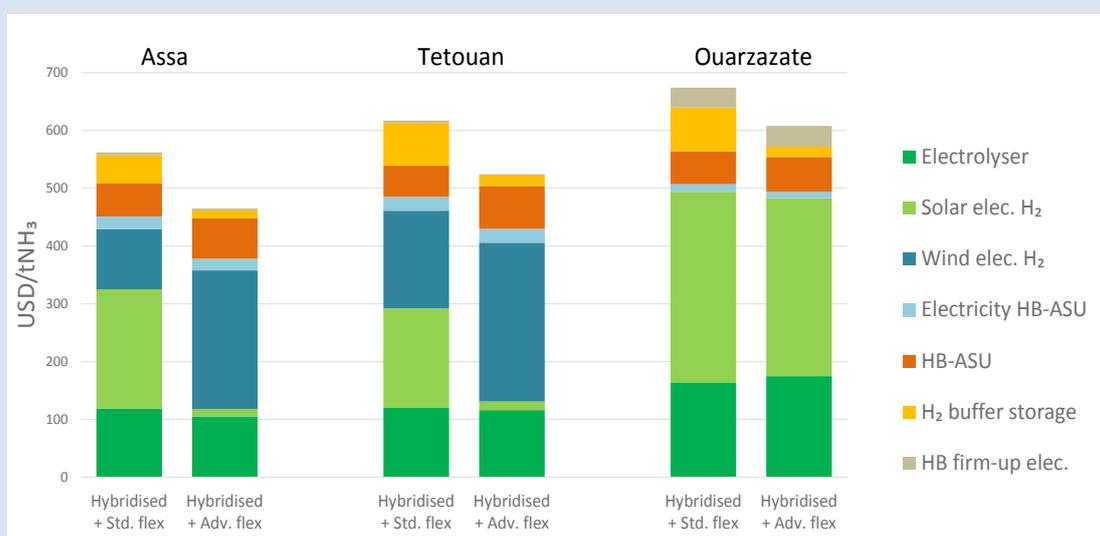
Source: Adapted from [IEA \(2017a\), Renewables in Industry](#).

The major cost component of hydrogen production at sufficient electrolyser load factors is the cost of electricity.

Sufficient load factors (above around 2 500-3 000 full load hours per year) for electrolyzers directly coupled with dedicated renewable electricity generation plants can now be achieved in areas with good wind and solar regimes – including in parts of North Africa. With renewable electricity generation costs around USD 30/MWh, this opens the prospect of making low-cost

hydrogen for ammonia and other industrial processes. To further explore this idea, the IEA analysed the costs of hydrogen and ammonia production at three sites in Morocco – Assa, Tetouan and Ouarzazate. The costs of hydrogen production were estimated between USD 2/kgH₂ and USD 2.7/kgH₂. This could allow ammonia production costs as low as USD 450 per tonne of ammonia (t NH₃) in the short to medium term, when wind and solar generation can be used in tandem and the ammonia plant allows for advanced flexible operation. These costs are comparable with long-term methane-based ammonia production costs of around USD 430/t NH₃. They would be competitive if methane-based ammonia production had to be coupled with carbon capture and storage (USD 610/t NH₃) or if a significant carbon tax was applied (leading to USD 700/t NH₃ at a carbon price of USD 120 per tonne of CO₂) to limit emissions.

Estimated costs of ammonia production at three Morocco sites



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Notes: HB-ASU = Haber–Bosch process - Air Separation Unit; Std flex = standard flexibility of the ammonia plant running between 60% and 100% of its nominal capacity; Adv. flex = advanced flexibility of the ammonia plant running between 20% and 100% of its nominal capacity.

Green ammonia can be produced at costs between USD 450/tonne and USD 600/tonne in Morocco, which is comparable with methane-based production in the long term, if externalities are considered.

Box 2.4 Closing the power sector investment gap in North Africa

The investment needed to supply electricity in North Africa is substantial and above the level of capital flowing into the region’s power sector before the Covid-19 pandemic. Given the impact of a rising population and economic growth on electricity demand, achieving the outcomes projected in STEPS by 2030 would require average annual power sector investment

(between 2026 and 2030) to increase by more than a fifth compared with the level of 2018, to around USD 16 billion per year. A higher income and more productive region, as in the Africa Case, would require increasing current investment levels by 34%, to an average of around USD 18 billion per year over the 2026-30 period. These long-term projections are likely to remain unaffected by the economic impacts of the Covid-19 pandemic, as the need for enhanced investment in electricity remains paramount in any scenario. In fact, the economic crisis that has unfolded during the pandemic intensifies the situation, as financing is even more constrained in the region given low fiscal space, increased cost of financing, and lower oil and gas prices (a key export of some countries in the region). Overall, power sector investments are set to decrease by 10% globally in 2020 – their lowest level in over a decade – with deep cuts in North Africa given its reliance on public funding.

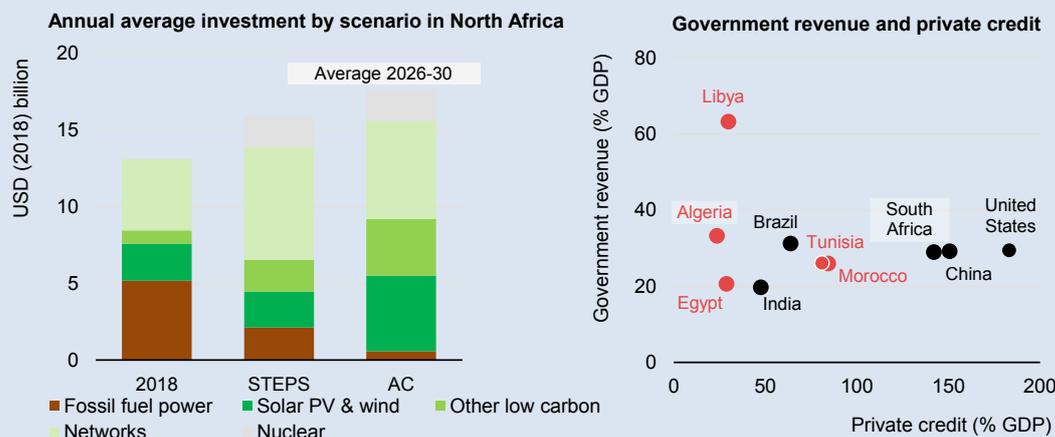
A substantial reallocation of capital, away from fossil fuels and towards low-carbon technologies and electricity networks, would also be needed under both pathways. Fossil-based generation, which in 2018 accounted for two-fifths of the annual capital spending, would drop to an average of 13% of annual spending under STEPS in 2026-30, and to 3% in the Africa Case – a much smaller share of power sector investments in the latter case. On the contrary, the share of low-carbon investments would need to increase to 40% in STEPS and 60% in the Africa Case, compared with a quarter in 2018. Investment in electricity grids remains relatively stable and central in both scenarios compared with 2018.

Mobilising more capital towards low-carbon generation in North Africa will require strengthening countries' policy and regulatory environments. Currently, most of the power infrastructure is financed by utilities – largely state-owned and vertically integrated – which at times face financial difficulty. While utilities in North Africa perform better on average than those in sub-Saharan Africa or the Middle East, they still experience important losses. According to a World Bank study (World Bank, 2018) the quasi-fiscal deficit (i.e. the hidden costs associated with financial, technical, commercial and labour-related inefficiencies) of utilities in Egypt represented 6.4% of GDP, in Algeria 2.3%, in Tunisia 1.4% and in Morocco 1.0% of GDP (estimates of other countries such as Libya were not included). To improve this situation, countries could continue pushing for reforms to improve utilities' overall efficiency and more cost-reflective pricing mechanisms, as well as better governance. Mobilising higher shares of private capital would also require market-oriented policies that promote competition paired with well-designed contracts (i.e. PPAs) – and in some cases implement reforms to allow for private-sector participation. This could help improve risk perceptions of investors and financiers, attract more private capital, and enable renewable investment at lower costs. More than ever, policy signals will be critical to attract the private-sector capital needed to bridge the investment gap.

Internationally, but also within North Africa, there are experiences to learn from to strengthen investment frameworks. For example, Morocco's renewable auction programme stands out as one that brought positive results. The country now has over 1.75 GW of installed solar PV and wind capacity, and around three-quarters of the renewable investment comes from the private sector. Support from development finance institutions (DFIs) was critical at the early stages to help structure the programme, as well as to provide mainly debt finance – thereby helping mobilising private capital. Another important success factor was the presence of an independent tender agency, MASEN, which helped bring visibility and credibility for investors.

Separately, Egypt has also shown progress in attracting private capital to renewables, with DFI support as well. In both cases, though, and as mentioned above, the financial viability of the utilities (off-takers to IPPs) and grid integration concerns emerge as challenges to further uptake of renewables.

Power sector investment needs per scenario



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Note: 2018 = current trends; AC = Africa Case.

The Africa Case requires an increase in current investment levels by 34%, reaching USD 18 billion per year over the 2026-30 period. Access to private credit in North Africa is more challenging than in other developing regions, especially in countries most dependent on fossil fuel revenues.

Given the long-lived and capital-intensive nature of power sector projects, the availability of long-term finance is also crucial to achieve the necessary investment. Capital is relatively constrained in North Africa, however, from both the public and private side. Access to private credit from local banks in North Africa compares unfavourably with access in developing economies or even other African economies such as South Africa, especially in the countries that are most dependent on fossil fuel revenues such as Algeria, Libya and Egypt. In addition, government revenues (as a share of GDP) are also relatively low compared with other economies, a particularly important point given the high level of public participation and financing in the energy sector. Libya is the exception, but its revenue dependence on the oil and gas sector is a factor of concern given the current environment where oil prices are at the lowest levels since the beginning of the 21st century. As 2020 is expected to be a year of low economic growth across the world, these concerns become more pressing, and public support even more critical.

High public revenues and fiscal means are important to support economies as a whole (from infrastructure financing, to health and education, and providing safety nets for the poorest households), and even more critical during a period of crisis. Yet government debt levels are relatively high – above 60% in Egypt, Morocco and Tunisia – and increasing in the case of Algeria (government gross debt jumped from 20% in 2016 to 38% in 2019, despite the recovery of commodity prices during the period). These levels will likely leave little room for strong economic stimulus (which may be needed if oil prices remain at low levels and as the Covid-19

crisis settles), and the overall situation makes it even harder and more expensive for governments to raise funds in the market. Thus, stimulus measures – which will likely be needed – will need to be very efficient and extremely well-targeted.

SDG 7.3. Improving progress on energy efficiency

Energy efficiency is essential for North African countries to achieve sustainable economic growth ambitions while limiting energy demand. Yet despite positive signals on energy access and renewables, progress on energy efficiency has been stagnant across North Africa, necessitating further dedicated efforts to implement sectoral energy efficiency policies. Clear opportunities and “low-hanging fruit” exist in the industry, transport and buildings sectors and subsectors to untap benefits from energy efficiency such as job creation, improved competitiveness and lower energy bills for households. Countries can combine a rollout of regulatory, information and incentive measures as well as best-practice policy recommendations that have proven effective in other countries and develop a tailored approach to unlock the benefits of energy efficiency in North Africa.

Status of energy efficiency in North Africa

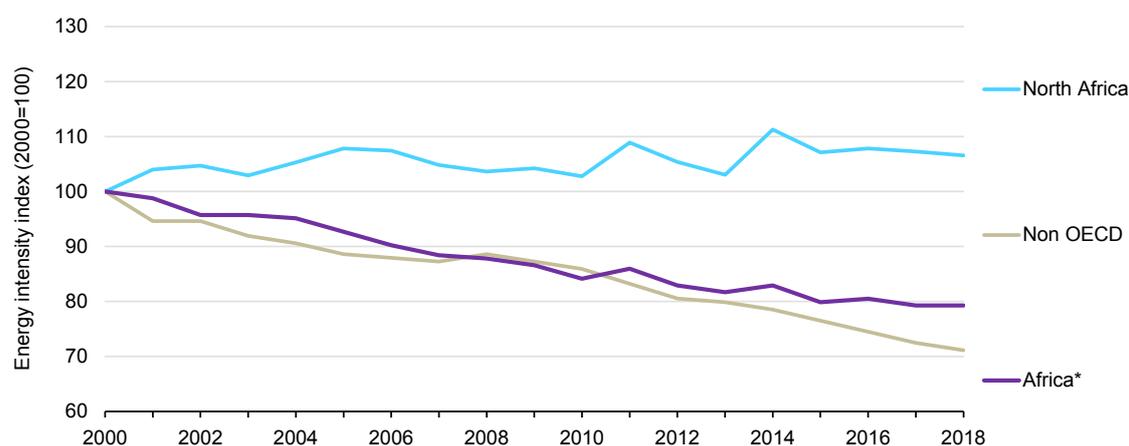
Despite positive signals on energy access and renewables, progress on energy efficiency – SDG 7.3 – has been stagnant across North Africa (IEA, 2020e). Instead of decreasing, the region’s combined energy intensity⁵ was 7% higher in 2018 than in 2000 (Figure 2.10). By comparison, energy intensity has been decreasing in Africa and non-OECD countries. These results varied across the region, however, as some countries performed better than others. Energy intensity increased in Egypt and Algeria by 16% and 4% respectively between 2000 and 2017; it decreased in Tunisia by 7 %, in Morocco by 4 % and in Libya by 1% over the same period. Reductions in energy intensity were even greater in other parts of the world and in particular in other non-member economies of the Organisation for Economic Co-operation and Development (OECD), where energy intensity shrank by more than 25% in 2017

⁵ Energy intensity is an indicator defined as the total energy supply divided by GDP and calculated here in toe per thousand 2015 USD PPP.

compared with 2000. This reveals the large opportunities for energy savings that energy efficiency could provide to the region (IEA, 2020c).

Final energy use in North Africa in 2018 was dominated by the transport and residential buildings sectors; transport represented 38% of final energy demand across the region and residential buildings represented 27%. In this respect, the North African region is comparable to OECD countries where transport represented 37% and residential buildings 21%. In comparison, on the rest of the African continent, overall residential buildings accounted for 64% and transport 16% of final energy use. Finally, industry represented 25% of final energy use in North Africa, 24% in OECD countries and only 13% in Africa overall.

Figure 2.10 Energy intensity evolution in North Africa, Africa and non-OECD countries 2000-18 TES/GDP (toe per thousand 2015 USD PPP, index 2000 = 100)



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* Africa: Geographical coverage includes Algeria; Angola; Benin; Botswana (from 1981); Cameroon; Republic of Congo (Congo); Côte d'Ivoire; Democratic Republic of Congo; Egypt; Eritrea; Ethiopia; Gabon; Ghana; Kenya; Libya; Mauritius; Morocco; Mozambique; Namibia (from 1991); Niger (from 2000); Nigeria; Senegal; South Africa; South Sudan; Sudan, United Republic of Tanzania (Tanzania); Togo; Tunisia; Zambia; Zimbabwe and Other Africa.

Source: [IEA \(2020c\). World Energy Balances.](#)

Energy intensity has remained stable in North Africa, while it has decreased in other regions, reflecting opportunities for energy efficiency in the region.

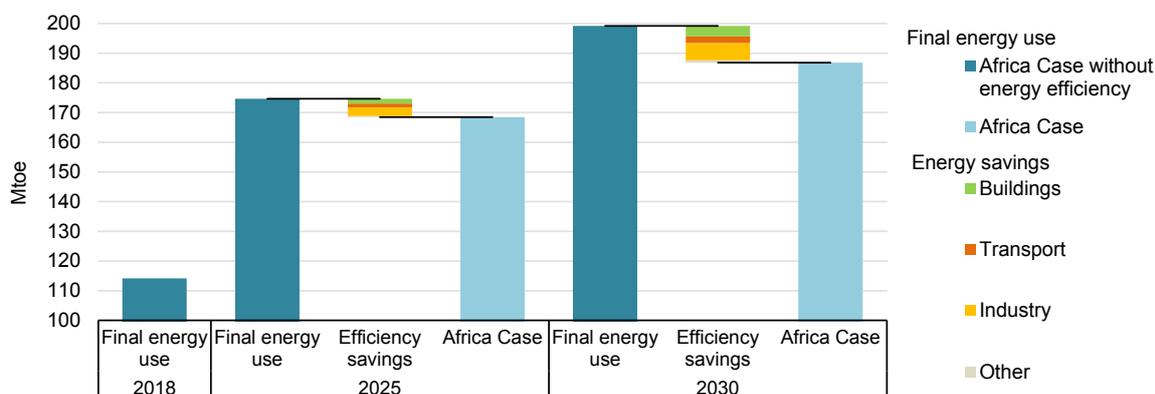
Outlook and opportunities for energy efficiency in North Africa

Energy efficiency is essential for North African countries to achieve sustainable economic growth ambitions while limiting energy demand. Growing the energy efficiency sector can create jobs, support economic development, increase the

competitiveness and resilience of local industry, and improve energy affordability, while freeing up funds for other parts of the economy including health and education. These benefits should drive the choices made in the post-Covid-19 crisis recovery.

Enhanced energy efficiency can reduce energy demand, and demand-side management will allow production capacity to be freed up, ensuring a more stable energy supply. In a region where intermittent renewable energy sources are growing, such as in North Africa, this will be key. The Africa Case shows that North Africa could be using up to 7% less energy (or 12 Mtoe) by 2030 if energy efficiency is increased. The main savings potentials are in the industry sector, accounting for almost half, followed by buildings (28%) and transport (19%) as can be seen in Figure 2.11.

Figure 2.11 Energy efficiency savings potential by sector in North Africa, under the Africa Case, 2019-30



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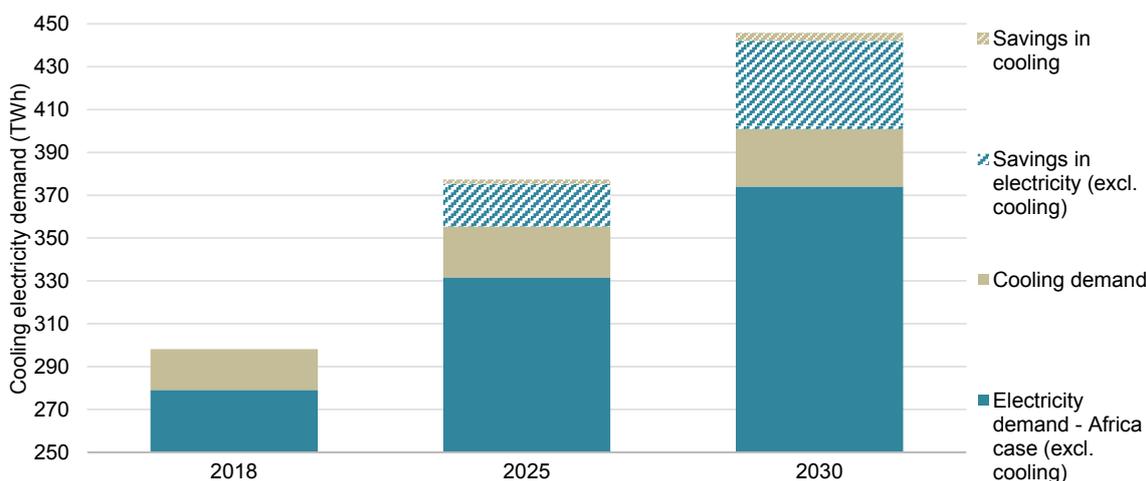
Source: [IEA \(2019a\), World Energy Outlook 2019](#).

The most cost-effective “low-hanging fruits” for energy efficiency in North Africa are in industry, buildings and transport.

Under the Africa Case, electricity demand in North Africa grows by almost 35% by 2030. More important, cooling demand increases by 40% (8 TWh) between 2018 and 2030, rising to a total of 27 TWh. This increase in demand for cooling is explained by the combined result of climate change raising the number of hot days across Africa, translating into a greater need for cooling, and on improvement in living standards, raising the number of air conditioners per capita. To illustrate the importance of energy savings and energy efficiency standards for the region, the Africa Case shows that cooling demand would be 14% higher again without efficiency measures (Figure 2.12).

Africa includes some of the world's hottest regions, but air-conditioner ownership is still typically below 5%. Consumption of electricity for cooling amounted to only 35 kWh per person on average in 2016. Even in Europe, which has a relatively mild climate, the average electricity consumed per person for space cooling is still more than all the electricity used per person in buildings in Africa, Brazil and Indonesia, which have much hotter climates and far greater cooling needs. Thermal mass is important for space cooling (and heating), as it holds temperature longer and creates a natural barrier between indoor and exterior temperatures, increasing thermal comfort. Traditional buildings with thick earth or stone walls with light colours, such as those in relatively hot Mediterranean and North African climates, rarely need to be cooled artificially (IEA, 2018b).

Figure 2.12 Electricity energy efficiency savings in cooling in North Africa in the Africa Case, 2018-30



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Source: [IEA \(2019a\), World Energy Outlook 2019](#).

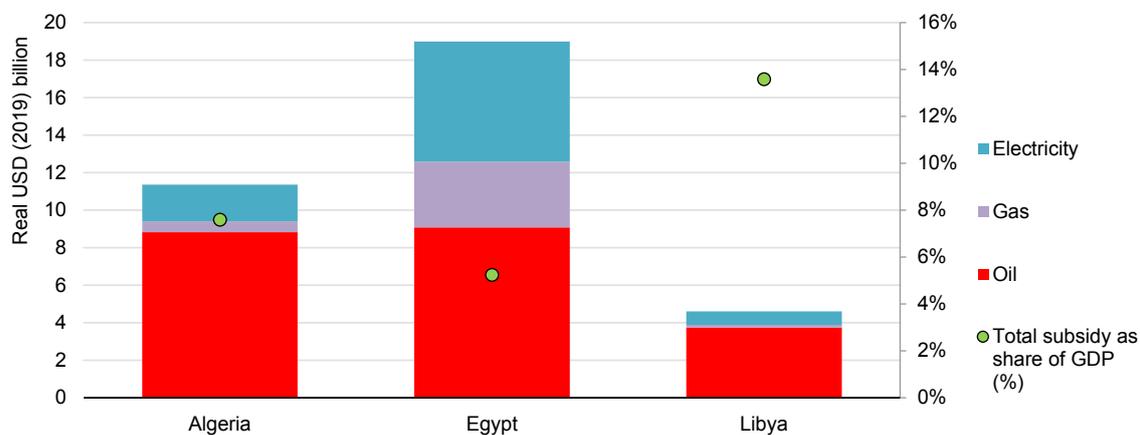
A warming climate and growing middle class are expected to increase demand for cooling. Energy efficiency measures are key to reining in cooling demand growth.

In the Africa Case, enhanced energy efficiency of the electricity sector will reduce energy demand by 11% by 2030. This will be key to alleviating peak demand, grid stress and production capacity needs. Meanwhile, subsidies for energy and fossil fuels remain high in the region,⁶ reducing the motivation to improve energy efficiency (Figure 2.13). These subsidies account for 5% to 13.5% of GDP, and represent a considerable amount in per capita figures in Egypt (USD 158/person), in

⁶ For the countries for which data were available.

Algeria (USD 305/person), and Libya (USD 661/person). This shows that energy efficiency could not only reduce consumers' energy bills, but also free up government subsidy expenditures for use in other sectors.

Figure 2.13 Energy consumption subsidies by country, 2019



IEA. All rights reserved.

Note: Data available only for Algeria, Egypt and Libya.

Source: [IEA \(2019h\), Value of fossil fuel subsidies in the top 25 countries.](#)

Energy efficiency presents the opportunity to reallocate funds from energy subsidies for energy consumption towards other sectors such as education or health.

Key policy recommendations

In order to untap energy efficiency benefits, policy makers should combine a roll-out of regulatory, information and incentive measures. Policy packages based on measures and best-practice policy recommendations proven effective in other countries can bring about rapid and long-term positive results to unlock energy efficiency opportunities in North Africa. Tried and tested measures and opportunities exist across multiple sectors including industry, appliances, buildings and transport.

Recommendations for the industry sector

While North Africa's industry sector is not the largest energy consumer, it represents the region's most important energy efficiency savings potential by 2030 under the Africa Case. In order to unlock savings rapidly and cost-efficiently, immediate action should strive to cover all industry subsectors.

Regulation and information

The efficiency level of electric motors is an important area of action for energy efficiency regulations in North Africa's industry sector. The application of minimum energy performance standards (MEPS) for motors can increase energy performance across multiple end uses such as pumps, fans and compressors. This should be the first step to tackle the wider motor-driven system, which presents even greater opportunities for efficiency gains beyond the individual motor unit, yet is more complicated to implement. Variable speed drives are commonly integrated with new high-efficiency electric motors but can also be retrofitted to existing electric motors, representing one of the most cost-effective efficiency measures available to countries. These measures would be greatly aided by the introduction of energy management systems (EMS) (IEA, 2017b), which ensure that energy uses are mapped, that energy saving improvements are identified, and that adequate data are collected and indicators established. A threshold (in energy use or employee number) could be set above which companies would be required to implement an EMS (such as ISO 50001). Companies below the threshold would be strongly incentivised to follow the same process.

Regulations and incentives should be paired with data reporting requirements. As a starting point, energy consumption by industry subsector should be reported. The goal is to be able to establish indicators for the key sectors that will enable benchmarking to set appropriate targets and help identify where the potential savings can be found. These measures will also enable governments to monitor policy effectiveness.

Incentives

In order to support the mandatory aspect of the recommended policies, incentives can be used to overcome barriers such as increased costs. These can take different forms such as tax rebates, grants, public investment or bulk procurement (e.g. for items such as electric motors, this could drive prices down if they are acquired in large volumes).

Case studies

There are currently no MEPS for motors in the North African region. Not only would their implementation improve energy efficiency, but also manufacturing motors could represent an economic opportunity as the industry sector grows. As sub-Saharan African countries continue their industrial development, North Africa could

become an exporter of efficient motors. Examples of this development model are Brazil and Mexico in Latin America, where MEPS are at a level required by many governments around the world (IE3 on a scale of IE1 to IE4, 4 being best, enabling them to become exporters of motors in the region. Other examples of countries having implemented MEPS can be found in both emerging economies and industrialised countries. The European Union (EU) introduced MEPS on motors at the IE2 level in 2011. The European Union's standards are now at the same level as Japan and Korea, which have all introduced MEPS since 2000 and already increased their stringency to the IE3 level. Australia/New Zealand, Brazil and China still have MEPS at the IE2 level, but are in the process of moving to IE3 soon. India implemented energy performance standards at the IE2 level in early 2018, although these are not yet mandatory (IEA, 2018c).

In terms of EMS, North Africa has started to implement policies following a similar path as the European Union. For example, Morocco passed measures mandating that industrial companies using more than 1 500 toe/year either carry out an energy audit or be ISO 50001 certified.⁷ In Tunisia, companies using more than 800 toe/year are required to carry out an energy audit.⁸ In Algeria, the threshold for the audit is 2 000 toe/year.⁹ As mentioned, EMS ensure that best practices are implemented across all energy uses and have proven to be highly cost-effective (IEA, 2017) in addition to providing multiple other sustainable benefits (IEA, 2014a).

Recommendations for appliances

Appliances, equipment and lighting drive much of the residential and commercial energy consumption in North Africa. The combination of MEPS, energy efficiency standards and labelling (S&L) programmes and incentives have proven to be effective policy measures in many countries all over the world. While most North African countries have adopted MEPS and labelling, however, more work is needed to fully unlock the benefits of energy-efficient appliances.

Regulation and information

Most countries in the region have national energy efficiency plans and have adopted MEPS and labels for appliances. Air conditioners, refrigerators and freezers, clothes washers, and specific lighting products are covered by energy efficiency labels. More

⁷ www.sgg.gov.ma/portals/O/AvantProjet/172/Avp_dec_2.17.746_Fr.pdf

⁸ www.anme.nat.tn/fileadmin/user1/doc/fr/Cahier_charges_audit_energetique_secteur_industriel2011.pdf

⁹ www.aprue.org.dz/documents/communication%20-seminaire%20du%2027-11-2017/Audit%20%C3%A9nerg%C3%A9tique%20dans%20le%20secteur%20industriel-APRUE.pdf

stringent MEPS could be put in place for major energy-using products, taking into account proven international best practice, such as for example MEPS for light-emitting diodes (LEDs). Stringency of MEPS should be regularly increased and other products using significant amounts of energy should be brought into the system once established. North African countries can ensure that appliances, equipment and lighting S&L activities are supported by a framework of monitoring, verification and enforcement; this is essential to ensure compliance, track progress and ultimately realise the energy savings of appliance energy efficiency policies. Governments should take advantage of regional co-operation, for all aspects of S&L programmes but especially for building monitoring, verification and enforcement capacity and jointly developing product testing infrastructure.

Incentives

A variety of incentives to support efficient appliances, equipment and lighting purchases exist in the region, including tax exemptions for materials needed to manufacture energy-efficient products and access to finance in Egypt, and public buildings retrofits in Morocco. Strengthening these efforts, for example through government-led public procurement programmes, grants and subsidies for business and consumers as well as financing schemes for manufacturing would ensure a faster and more successful market transformation.

Case studies

L'Agence Nationale pour la Maitrise de l'Energie (ANME) issued Tunisia's first energy label and MEPS for refrigerators in 2004. As most refrigerators were imported from Europe, Tunisia decided to test a number of adapted versions of the EU energy label, rather than apply a new design. The label format adopted through this process is similar to the EU label, but modified for the Tunisian context. For example, the letter scale was changed to numbers and the graphical displays can be read from right to left (as in Arabic) and left to right (as in French). This design enhances adoption by applying the bilingual Arabic-French system. The value of electricity saved by Tunisian consumers is projected to be about USD 0.01/kWh, which is significant given the current electricity tariff of USD 0.074/kWh. The success of the programme can also be attributed to the training and awareness-building campaigns that followed the S&L programme.

Recommendations for buildings

Improvements in buildings energy efficiency will help to support population growth, promote economic development and improve energy services in North Africa while minimising growth in energy demand. North Africa has the opportunity to develop a co-ordinated regional approach to delivering the next generation of efficient buildings and also improve the efficiency of existing buildings. North African nations share a similar climate and resources for building materials, creating the possibility to develop partnerships to promote innovative solutions and policies that support local industries and employment.

Regulation and information

Building energy performance codes represent the cornerstone of energy efficiency policies in buildings. They are an effective way to improve the minimum performance of new and existing buildings. They set long-term signals to developers and builders to meet or exceed minimum energy efficiency standards, delivering better energy services with less energy consumed and reducing consumers' energy bills over the building's lifetime. These codes have proven effective internationally. Over 50 countries have mandatory building energy performance codes for commercial and residential buildings, including Morocco and Tunisia. More than ten countries have voluntary commercial building energy performance codes, including Egypt, and about four countries have voluntary residential building codes. Algeria and Libya are yet to put in place building energy performance codes.

Building codes should generally include three key features: clear minimum energy standards across building types; a range of compliance options (from prescriptive to performance-based approaches) alongside a proactive compliance and training regime; and a regular process for updating the codes. Building energy performance codes usually deliver benefit-to-cost ratios of at least 1 to 3 over the lifetime of the buildings.

Buildings energy ratings, certification and labelling programmes are pivotal information programmes in driving improved energy efficiency performance in new and existing buildings. They are essential in helping developers, building owners, managers and tenants to benchmark their current performance and to identify opportunities for, and track, improvements. They help consumers to better understand the operating costs, comfort and environmental performance of the building they are looking to rent or lease, and help owners to demonstrate their investment in energy-efficient buildings.

Incentives

Incentives provide a “pull factor” to drive a shift in the market towards more energy-efficient buildings. Incentives can be crafted to target either the whole building, or specific technologies or end-use services. A wide range of incentives include: tax incentives; floor space incentives in the planning system; energy efficiency obligation schemes and grant programmes; finance and loan mechanisms – such as low-interest loans, on-bill or property-assessed clean energy (PACE)¹⁰ programme financing; government procurement setting minimum energy ratings for buildings developed, purchased or leased; and recognition programmes. Building improvement incentive programmes are likely to feature heavily in economic stimulus packages developed in response to the Covid-19 crisis because they result in the creation of large numbers of local jobs.

Case studies

Morocco sets an example of good practice on buildings energy efficiency within the North Africa region. The country has paired building energy performance codes to put minimum standards in place across building types together with a voluntary labelling system in order to provide consumers with better information on the energy performance of buildings, while helping building owners and developers who invest in more energy-efficient features to communicate the benefits and value of their investments. In October 2014, Morocco put in place a thermal regulation code and introduced minimum technical requirements for the thermal performance of new residential buildings and social housing, hotels, offices, educational facilities and hospitals. Thermal performance requirements have been tailored to each of Morocco’s six climate zones. These are complemented by a voluntary labelling programme for the thermal performance of buildings. Compliance with the thermal performance regulation can be achieved through a performance-based approach (modelled in energy consumption per square metre of floor space) or a prescriptive component based approach.

Recommendations for the transport sector

Transport represented the largest energy consumer sector in North Africa in 2018, accounting for 36% of final energy use. It is also the fastest-growing sector. Transport

¹⁰ PACE programmes help home and business owners pay for the upfront costs of energy efficiency initiatives, which the property owner then pays back by increasing property taxes by a set rate for an agreed-upon term ranging from 5 to 25 years.

ranges from one-third to almost two-thirds of TFC in countries across the region, with oil meeting almost all of the transport energy demand. In emerging economies, transport energy consumption is driven by rapid urbanisation and increased vehicle ownership and use of private vehicles, as well as lower occupancy of those vehicles. In North Africa the presence of transport fuel price subsidies exacerbates these effects. According to the Africa Case, the energy demand of the transport sector in North Africa increases by more than 40% from 2018 to 2030.

A key approach to addressing energy efficiency in transport is to frame the discussion around a broad conceptual hierarchy known as avoid, shift and improve, as highlighted below. Fuel efficiency standards have not yet been implemented in the region, presenting proven opportunities to improve vehicle efficiency. Challenges to implementing such measures include:

- Consumer preferences for larger cars with typically bigger engines. Underpinning these preferences are a) geographic factors such as long distances driven and climate, which can drive preferences for larger vehicles from the perspective of comfort and convenience; and b) fuel price subsidies.
- Financial and lifestyle factors providing incentives for keeping an existing vehicle on the road rather than purchasing a new one. This preference is supported by networks of small auto repair shops and availability of inexpensive but poor-quality replacement parts.
- Large purchase-price differential between less-efficient conventional vehicles and fuel-efficient vehicles such as hybrids (IEA, 2014b).

Globally, mandatory fuel economy standards have been essential in boosting the efficiency of road vehicles. The introduction and strengthening of such standards since 2000 reduced the use of oil for transport globally in 2017 by nearly 1.2 million barrels of oil per day (IEA, 2018c). Key measures to promote energy efficiency in the transport sector should therefore focus on mandatory fuel economy standards and on encouraging a more rapid turnover of vehicle fleet with a mix of regulatory and incentive measures. Examples include restrictions on imports of vehicles that are more than five years old (as is the case in Morocco), incentives to encourage fuel switching, and regulatory vehicle inspections. Others measures to decrease transport sector energy intensity in the region can include:

- **Avoiding** transport activity through policies influencing urban structures and increasing the time and money cost of driving.
- **Shifting** mobility towards less carbon-intensive modes e.g. facilitated through greater investment in public transport. Vehicle manufacturing

represents a key sector for economic development; besides South Africa, there is no significant vehicle manufacturing activity in the sub-Saharan Africa region. North African countries, which have infrastructure already in place, could become leaders in energy-efficient vehicle manufacturing. As an example, in 2016, Morocco started a consortium to develop a mobility ecosystem and promote electric vehicle development (ICCT, 2017).

- **Improving** standards progressively, which would ensure higher levels of energy efficiency performance over the future (as for example with the European energy efficiency standard).

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3. A changing role for hydrocarbons

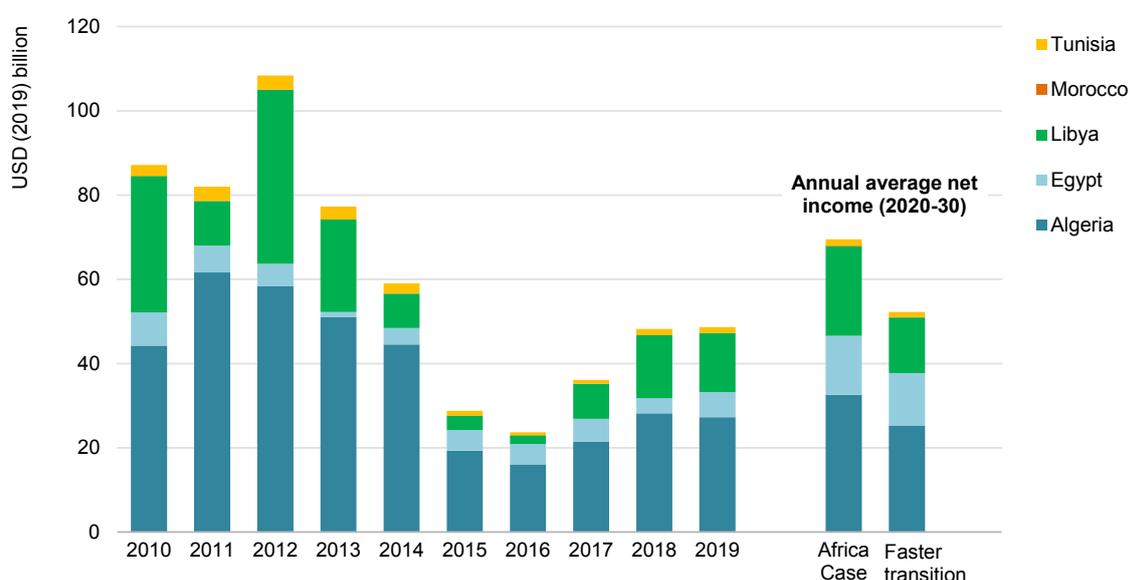
Oil and gas resources have long been a central element in the economic outlook for North African countries, notably Algeria, Egypt and Libya. As clean energy transitions accelerate, these countries are facing serious questions about their development models, which rely heavily on fossil fuels. Without fundamental changes, a long-term reduction in hydrocarbon income as a result of energy transitions would not only hamper the ability of governments to make the investments necessary to diversify their economies, but could also limit their capacity to respond to any potential periods of economic disruption. The oil and gas industry faces increasing demands to step up its contributions to emissions reduction. This section explores opportunities for North Africa's oil and gas industry to adapt and contribute to the region's clean energy transitions.

Translating resource endowments into sustainable economic growth

In many North African countries, the large-scale production and export of oil and gas provide vital income to finance their national budgets. However, North African producers remain among the least diversified economies in the world. For example, exports of oil and gas account for over 90% of total merchandise exports of Algeria and Libya, with the fiscal break-even oil prices for the two countries amounting to USD 130 per barrel for Algeria and USD 95/barrel for Libya (IMF, 2019). There are many examples of the dangers of overdependence on this narrow and volatile source of revenue. Since demand and prices for oil and gas tend to be highly variable – as shown most recently during the Covid-19 pandemic – export revenues are subject to large swings, with knock-on effects for the economies. This volatile and unpredictable income tends to lead to high levels of public spending during boom times, followed by periods of severe fiscal strain during downturns. This cyclical dependence could undermine the effectiveness of government efforts to promote economic growth and achieve structural transformation. For example, when oil prices lower and the economy needs a stimulus, the decline in government spending may further reduce domestic consumption, creating a vicious cycle.

The rollercoaster ride in oil prices since 2014 has exerted severe fiscal and economic strains on North African producers. The latest IEA analysis suggests that oil and gas income for some key producers could fall between 50% and 85% in 2020, compared with 2019, owing to the impact of Covid-19 and a surge in supply (IEA, 2020a). Growing global efforts to respond to climate change also pose major questions over the strength of long-term hydrocarbon demand. North African producers are increasingly heading towards a future where markets for their ample resources may not be guaranteed.

Figure 3.1 Net income from oil and gas production in North African countries



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Note: Net income from oil and gas production is defined as the difference between the costs of various types of oil and gas production and the value realised from their sale on either domestic or international markets.

Source: [IEA \(2019a\), World Energy Outlook 2019](#).

The accelerating pace of energy transitions raises serious questions about the durability of hydrocarbon income in North African countries.

In the IEA Africa Case, net oil and gas income for North African producers edges higher by 2030, although it remains lower than the level seen in the early 2010s. However, in the faster transition case (a case where global demand and prices are substantially lower because of stronger action in support of climate goals in the Paris Agreement), oil production in North Africa declines by nearly 30% and gas production remains stagnant between today and 2030. The average annual net oil and gas income in this case does not grow from today’s levels, undermining the ability to provide essential services to the countries’ populations (Figure 3.1). This

suggests increased challenges for the region when taking account of the region's growing young population and the need to create more jobs.

This scenario makes a compelling case for economic diversification and reform. Globally, many producers have recently announced reform initiatives aimed at reducing their dependence on hydrocarbon revenues. Kuwait is implementing a series of reforms to build a diversified economy under its Vision 2035: New Kuwait. In Saudi Arabia, broader economic reforms under its Vision 2030 have helped spur a notable increase in non-oil revenues.

While achieving economic diversification requires broad-based efforts beyond the energy sector, developing an effective and transparent revenue management mechanism would be the first step to counter commodity price volatility and diversify revenue streams. Some countries are investing revenues into a range of financial assets for the wealth of future generations. Others set aside a specific portion of revenues during boom times to cover budgetary shortfalls during lean years. Other countries channel revenues towards domestic development of infrastructure and industry to lay the groundwork for economic diversification. For example, Senegal's sovereign wealth fund has played an important role in scaling up solar PV installations using its oil revenues.

While there is no one-size-fits-all approach to allocate revenues generated from oil and gas, it is critical for both incumbent and emerging producers to take a hard look at the resilience of their resource production under different scenarios and devise productive ways to utilise the revenue, away from today's prevailing pattern where the bulk of the money is spent on subsidies or public sector wages. Whichever pathway a country follows, the mechanism should include arrangements to ensure oversight and transparency of resource revenue flows and expenditure. Changing energy market dynamics suggest that fundamental changes to the development model of North African producers may be increasingly unavoidable, more so than at any other point in recent history.

A dynamic upstream with reduced emissions

While the need for economic diversification remains crucial, a well-functioning oil and gas sector is an important point of departure for North African producers given the centrality of the oil and gas sector in their economies. Maintaining upstream investment to ensure adequate production, especially for gas, remains vital, partly to

provide stability for the economy but also to avoid the negative environmental impacts arising from supply shortages.

Most North African countries, except Morocco, rely heavily on natural gas to meet their rising energy needs. Natural gas accounts for half of the region's energy demand, well above the global average of around 22%. Over 90% of electricity in Algeria is generated from natural gas and 80% of the power generation capacity in Egypt is gas-fired.

In the IEA Africa Case, natural gas continues to play a vital role in North Africa as a major source of energy to meet surging electricity demand and support industrial growth. It gradually gives way to renewables in power generation, but increases its share further in industry and buildings. Overall, demand for natural gas in this case grows by 15% by 2030, continuing to satisfy around half of the region's energy needs. However, the region's ability to ensure adequate supply is less clear given that outputs in Algeria and Libya have stagnated over the past decade.

A failure to meet rising demand could cause social disruptions and trigger an increase in GHG emissions. Egypt, the largest gas market in Africa, provides a useful example. The country, a major exporter of gas, experienced a significant drop in domestic production in the early 2010s due to subdued investment, and became a net importer of gas in 2015. Declining domestic output caused repeated power outages and weighed heavily on industrial competitiveness. It also led to accelerated switching from gas to more polluting fuels, with negative GHG implications. Fuel oil consumption in the power sector saw a notable uptick and industrial consumers (e.g. cement factories) rushed to retrofit plants to allow switching to coal. Although the country has experienced a dramatic turnaround following the discovery of the large Zohr field in 2015,¹ this experience underscores the lasting importance of upstream reforms to attract investment to ensure adequate supply. In November 2019, Algeria started to respond to this pressure by approving a new hydrocarbons law, which aims to provide fiscal and contractual incentives for upstream investment.

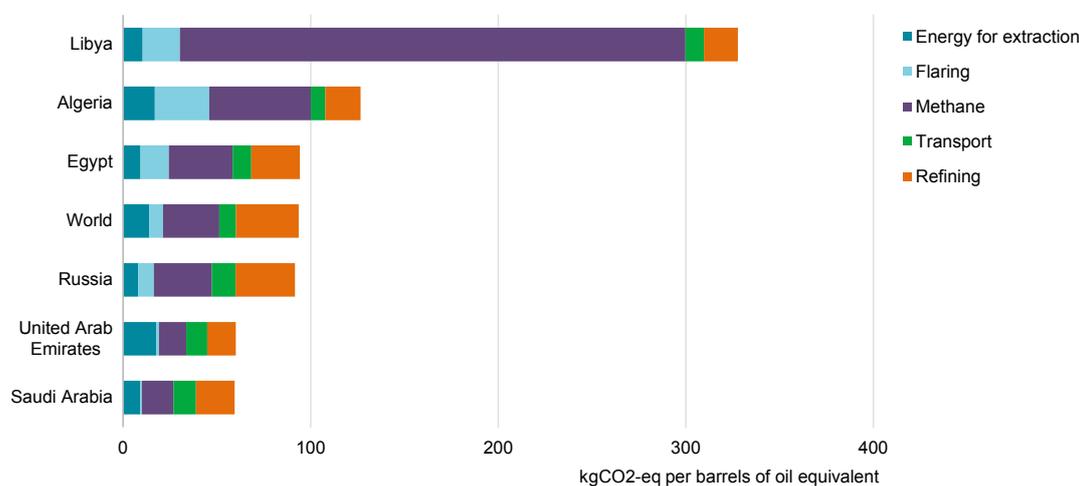
A reform of gas pricing is particularly crucial to incentivise upstream investment, prevent wasteful consumption and reduce fiscal burden. In Egypt, although the government raised domestic gas prices in 2014 in response to tightening supply,

¹ Production from the Zohr field started in 2017 thanks to the government's efforts to streamline and expedite the development process, and is being joined by several adjacent fields such as Nooros, Atoll, and the first and second phases of the West Nile Delta complex.

prices paid by power generators remain below the levels needed to incentivise new supply investment. Similar reforms would also be crucial for Algeria and Libya, where production has stagnated in recent years.

In addition, North African producers can do a lot more today to reduce the environmental footprint of their operations. On average, the extracting, processing and transporting of hydrocarbons to end users represents around 20% of the full life-cycle GHG emissions for oil and 25% for natural gas globally. These shares are higher for North African producers; the emissions intensities of oil and gas production in North Africa are among the highest in the world (Figure 3.2).

Figure 3.2 Estimated average GHG emissions intensity of oil in selected countries, 2018



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Notes: Russia = the Russian Federation. kgCO₂-eq = kilogrammes of carbon dioxide equivalent. Emissions from the combustion of the oil products are excluded.

Source: [IEA \(2019\), World Energy Outlook 2019](#).

The emissions intensities of oil and gas production in North Africa are among the highest in the world.

Crucially, above-ground operational practices (namely methane emissions, venting CO₂ and flaring) are responsible for the majority of GHG emissions from oil and gas operations. Reducing methane emissions is particularly important, as methane is a much more potent GHG than CO₂. According to the latest IEA estimates, the combined methane emissions in Algeria, Egypt and Libya amounted to around 10 million tonnes in 2019, approximately 12% of global oil and gas methane emissions (IEA, 2020b). Concerns are coming to the fore with the emergence of new, remote methods of detecting and measuring large methane emissions sources. For example,

in January 2020, satellites detected a number of large “methane plumes” coming from oil and gas facilities in Algeria. These plumes were caused by sources emitting over 25 tonnes of methane per hour, roughly equivalent to the CO₂ emissions from a 750 MW coal-fired plant (IEA, 2020c). Moreover, some 15 billion cubic metres (bcm) of natural gas output is currently flared in North Africa, just over 10% of total flared volumes globally. By way of comparison, North Africa accounts for 2% of global natural gas production. Besides the significant and damaging environmental consequences, this represents a major wasted economic opportunity.

The good news is that there are ample, cost-effective opportunities to reduce these methane emissions. For example, the IEA estimates that some 40-55% of methane emissions in these three countries could be avoided at no cost because the value of the captured methane is greater than the cost of installing the abatement measures (IEA, 2020b).

The abatement technologies that can prevent methane emissions are generally well-known and widely available; the challenge is to incentivise their deployment. There are multiple voluntary, industry-led efforts that have been established to tackle methane emissions around the world, but it is ultimately government targets, policies and regulations that will be essential to realise reductions at the scale and pace needed.

A number of countries around the world have recently established regulatory frameworks on methane, and these could be a useful guide for countries in North Africa similarly looking to reduce their methane emissions. For example, Canada’s new methane rule that entered into force from 2020 takes a bottom-up approach, with targeted interventions organised by component or activity (e.g. routing emissions to vents, replacing or controlling individual high-emitting components, and inspecting equipment for methane leaks). This approach differs from Norway’s use of an emissions tax to curb methane emissions, and Mexico’s new law, which empowers operators to choose how to achieve facility-wide emissions reductions from a pre-determined baseline. Whichever form a country adopts, there are certain elements that are common to most regulatory approaches, such as mandatory record-keeping and reporting requirements.

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4. The water–energy–food nexus: Opportunities for productive energy transitions

Water, energy and food underpin economic and social development. These sectoral interdependencies and their related challenges have important implications for water, energy and food security across North Africa. Water is essential for all phases of energy production, from fossil fuels to biofuels and power plants; energy use is vital for a range of water processes, including water distribution, wastewater treatment and desalination, as well as agricultural and supply chain processes. Food requires vast amounts of water and energy for production, processing, distribution, storage and disposal of products. Applying an integrated multisectoral approach to clean energy transitions in North Africa can illuminate opportunities to improve resource efficiency, productivity and security, which may change the scale and type of the energy technologies deployed in the region.

Status of the water–energy–food nexus in North Africa

The complexity of the water–energy–food nexus is evident in North Africa, as shown in Table 4.1 All five countries already face a high degree of water stress, and there is increased uncertainty about future water availability and the impact that climate change will have on water resources. Libya ranks as one of the most water-stressed countries in the world (WRI, 2019). Agriculture, made up mostly of small family farms, is a significant source of employment in the region and the largest user of water. Yet the region is also highly dependent on food imports, which account for 50% of their caloric consumption (AFDB, 2016). Total primary energy demand is dominated by oil and gas, which account for 43% (oil) and 51% (gas) of demand today. In the power sector, more than three-fourths of generation is natural gas-based. These challenges are all interrelated.

Table 4.1 Selected water, energy and food indicators in North African countries

	Total renewable water resources per capita 2017 (m ³ /inhab/yr)	Employment in agriculture 2019 (% of total employment)	Share of fossil fuels in total primary energy demand 2017
Algeria	282	9%	100%
Egypt	589	25%	97%
Libya	110	8%	99%
Morocco	811	38%	89%
Tunisia	400	15%	89%

Notes: m³ = cubic metres. A country is considered water scarce when it has less than 1 000 m³/inhab/year.

Sources: World Bank (2020), IEA (2020), FAO Aquastat (2020).

How this nexus is managed will have wide-reaching implications for the region’s ability to achieve the clean energy transition, meet its sustainable development objectives (notably SDG 2, SDG 6, SDG 7 and SDG 13) and ensure its resource security. If managed independently, these trends can strain countries’ social, economic and environmental systems, which can affect stability and development. An integrated approach can illuminate opportunities to improve resource efficiency, productivity and security, which may change the scale and type of the energy technologies deployed. It also allows for a broader and more durable view of local economic development – one that highlights the central role of women, who often bear the brunt of a lack of access, in developing long-lasting and sustainable solutions.

North Africa has high levels of non-revenue **water** – produced water that is lost before it reaches the customer as a result of leaks, bursts or theft. While data are poor, indicators show that the levels of water loss in the region are almost 25% on average, well above the 6% seen in some developed countries. It is estimated that in Algeria, water losses in its distribution network can reach 40% (Masmoudi et al., 2016). Reducing these losses plus curbing overuse from unmetered tariffs could bolster the region’s freshwater supplies and reduce the water sector’s energy consumption, which is required to pump, move and treat this water.

Rising water demand coupled with increasing uncertainty over water supply and diminishing water quality has led countries in North Africa to turn to more energy-intensive forms of water supply to narrow the gap between freshwater withdrawals and sustainable supply. By 2025, Algeria aims to meet 25% of its water needs via

desalination. Today, over 5 Mtoe of energy is used for North Africa’s water sector – a third of which is used for desalination and water reuse. Tunisia treats and recycles almost 25% of its treated wastewater, the highest in the region, and Morocco aims to reuse roughly 325 million m³ by 2030. Gas-fired thermal desalination is the dominant form of desalination in the region, though the use of membrane technologies, such as reverse osmosis (RO), is growing as costs decline. Morocco is currently building the world’s largest RO desalination plant powered by wind energy. A greater shift towards renewable-based desalination could lower the energy and carbon intensity of the region’s water supply while pairing RO technologies with co-generation¹ plants could help provide the storage and flexibility needed to support a greater uptake of renewables.

About another third of the water sector’s energy use goes towards groundwater pumping, including for agriculture. High levels of groundwater depletion and increasingly saline water – almost 30% of surface water in Tunisia is saline, for example – increase the energy required to provide fresh water in the region. Energy use for wastewater treatment today is low, but the sector offers an opportunity to generate more recycled water and energy. The energy embedded in wastewater can be recovered and turned into biogas, which can help offset energy needs at the plant or can be sold to the grid. The first wastewater treatment plant to implement energy recovery in North Africa was opened in 2011 in Marrakech. Another example from the region is the El Gabal El Asfar² wastewater treatment plant in Cairo – one of the largest plants in the continent. The plant services 2.5 million m³ of wastewater every day, serving 12.5 million people. In 2018 the plant was expanded to include an energy recovery facility that produces biogas from the plant’s waste sludge, which now meets up to 60% of the plant’s power needs.

Agriculture is not only the largest water user in North Africa, but is also a significant source of employment. Currently, there is a high reliance on rain-fed irrigation – it is estimated that less than 30% of North Africa’s cultivated lands are irrigated (You et al., 2010). Egypt is the exception as nearly all of its agriculture is irrigated. However, the region’s growing water scarcity, high variability of rainfall and limited land availability mean that irrigation is likely to become more widespread. Irrigated cropland can be two times more productive than rain-fed land, improving yields, and irrigation can help to manage fluctuations that occur from a dependence on precipitation (FAO, n.d.a). For example, just 8% of Tunisia’s agricultural areas are

¹ Co-generation refers to the combined production of heat and power.

² www.afdb.org/en/success-stories/egypts-gabal-el-asfar-wastewater-project-model-sustainable-development-35472

irrigated, but these areas account for 35% of its agricultural production and 20% of its exports (Chebil et al., 2019). In Morocco, roughly half of the country's GDP share from agriculture and 75% of its agricultural exports are from irrigated agriculture, which accounts for just 16% of cultivated land (World Bank, 2018).

Increasing irrigation, if not properly managed, can further impact the region's water scarcity and increase soil salinity. On average, the region has high water losses in agriculture (30%). In Egypt, the efficiency of farm-level water use is estimated to be as low as 50% (Nin Pratt et al., 2018). Moreover, the use of irrigation, especially groundwater irrigation, is often dependent on access to energy to pump and move water. Currently, energy inputs for agriculture in North Africa remain low, accounting for 5% of total final energy consumption for electricity and 3% for diesel, compared with India, another water scarce region, where shares are 17% for electricity and 5% for diesel. Increasing access to modern energy and irrigation will be important to help improve agricultural productivity. An emphasis on using cleaner sources of energy for irrigation, such as solar, irrigation infrastructure efficiency and the use of groundwater in a sustainable manner is vital to ensure that improvements in yield do not have adverse impacts. Recognising this, Morocco has developed a national plan to increase productivity from irrigated agriculture and optimise water use, which includes promoting solar water pumps (Box 4.1).

Compared with agriculture, the **energy** sector's water use is quite low, accounting for just 4% of total regional withdrawals – defined as the volume of water removed from a source – and less than 0.5% of its consumption – the volume that is withdrawn but not returned to the source. More than three-quarters of water withdrawals for the energy sector are for gas-fired power generation, which relies heavily on once-through cooling technologies. A majority of the water consumed by the energy sector in North Africa is for the production of oil. To meet the NDCs developed as part of the Paris Agreement, countries have begun to deploy low-carbon energy sources. The impact on the sector's water use will depend on the fuels, technologies and cooling systems used. Some renewables, such as solar PV and wind, require very little water. Others, for example the Noor I CSP plant in Morocco, which uses a wet-tower cooling system, still depend on water to operate. By comparison, its Noor II and III use dry cooling, which is expected to save around 3.6 million m³ of water (AFDB, 2014). Beyond just how much water is used by North Africa's energy sector, water-related climate impacts are affecting and will continue to affect energy production and reliability.

Clearly, the contours of the water–energy–food nexus vary by country in North Africa. Case studies (Box 4.1) can illuminate how different countries are confronting some of these problems and the policies and practices they are putting in place, offering potential solutions that can also contribute to their energy transitions.

Box 4.1 Water–energy–food nexus case studies in North Africa

Renewable-based desalination: While natural gas-based thermal desalination currently dominates in North Africa, the use of membrane technologies that use electricity, such as RO, is growing. Many countries looking to diversify and decarbonise their energy mixes have turned towards developing membrane-based desalination powered by renewables. In 2013, the United Arab Emirates launched a range of renewable energy desalination pilot programmes, including the first solar PV-powered RO desalination pilot at the Ghantoot desalination facility. Since 2018, the pilot plant using solar-powered RO has proven to be 75% more energy efficient than the thermal desalination technologies currently used in the country. Meanwhile, as part of its commitment to decarbonise, Morocco is constructing the world's largest desalination plant operating on wind power near the coastal city of Agadir. The 275 000 m³/day Douira desalination plant is expected to be finalised by 2021 and will meet the city's domestic water demand and provide irrigation water to almost 3% of the region's agricultural land, reducing pressure on aquifers in the area.

Sustainable use of wastewater: The level of collection and treatment of wastewater in North Africa is relatively high. Recycling and reusing this wastewater could provide a less energy-intensive way to tackle water scarcity. In 2015, Tunisia set an ambitious target to reuse 50% of its treated wastewater by 2020, with an emphasis on replacing freshwater use for irrigation. Today, the country reuses only 23% of its collected and treated wastewater, while Egypt reuses 18%, and Morocco reuses only 10%. Other parts of Africa provide examples of the benefits. Windhoek, the capital of Namibia, used public-private partnerships to become one of the world's first cities to produce drinking water from municipal wastewater. Open since 1968, the Goreangab water treatment centre produces 25% of the city's drinking water needs and supplies up to 23 000 m³ of drinking water per day by using ten-step multi-barrier technology that eliminates pollutants and contaminants.

Renewable energy irrigation technologies: Solar-powered irrigation technologies can displace diesel generators and LPG, reduce emissions, and improve access to water, increasing the resilience of agriculture. Morocco has implemented various sustainable agricultural programmes. Its Plan Maroc Vert (2008) set a target to conserve 1.4 bcm/year of water in part by converting its existing irrigation systems to localised systems, such as drip irrigation. Morocco also implemented a subsidy scheme in 2013 that covers 50% of the upfront cost of solar irrigation equipment for up to 8 000 small-scale farmers by 2025 as part of its National Solar Pumping Strategy Programme (UNDP/GEF, 2016). A solar pumping programme by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) helps scale up the adoption of solar PV-powered drip irrigation pumping systems in Morocco by creating a conducive framework for their uptake, including technical trainings for installers and operators, and institutional capacity building to structure and create high-quality markets

and jobs (FAO, 2018: 46). Another example is the Water Scarcity Initiative co-led by the Food and Agriculture Organization (FAO) and Egypt's Ministry of Water Resource and Irrigation; it uses solar power to lift irrigation water from the Nile and pump water for irrigation in the Nile Delta. Farmers and associations were trained on the use and maintenance of the solar irrigation systems. Today, Egypt is planning to scale up the use of solar energy to all other pumping stations in the Nile Delta.

Key policy recommendations

When looking at roadmaps for clean energy transitions, it has become ever more important to understand the linkages among these sectors, to anticipate future stress points and to implement policies, technologies and practices that soundly address the associated risks. The case studies above help illustrate some of the actions already under way in various countries. Below are some opportunities for further action – both overarching and sector-specific – that can help mitigate choke points, capitalise on synergies and ensure the region remains on track for a sustainable future.

Overarching policy recommendations:

Reduce silos between sectors and integrate policy making: Energy, water and food policy, technology and investment choices should take into account the needs of each of the others and identify potential synergies and efficiencies. A first step is to identify data gaps and take steps to fill them. Reliable, updated and complete data are essential to be able to model, forecast and manage resources and make informed decisions. A second is to quantify how much of each resource is used for the other sector and establish a baseline against which to measure the costs and benefits of change. A third focus is to continuously monitor and reflect progress on programme objectives and develop and share best practices across the region.

Improve efficiency: Reducing water losses saves water and energy. More stringent energy efficiency measures lower energy demand, reduce GHG emissions and save water. More efficient use of water for irrigation, such as drip irrigation, reduces the amount of energy needed to pump water and minimises water waste. Improving power plant efficiency and deploying advanced cooling systems can reduce water demand at power plants.

Reconsider subsidies: Underpricing of water and energy undercuts investment in more efficient infrastructure, disincentivises switching to alternatives and can lead

to unnecessarily high consumption levels. There should be a discussion on the rationale for and design of energy and water subsidies.

Include women at the centre of nexus solutions: Women are often best positioned to identify, champion and deliver energy and water access solutions. Women are also at the front lines of agriculture. Evidence suggests there are significant advantages in involving women from start to finish in the design of modern energy and water technologies and programmes, and empowering women to become more involved in the provision of energy and water services as they can help deliver appropriate solutions tailored to local conditions and needs.

Recommendations for the water sector:

Use desalination to increase the share of renewables in power generation: Pairing more co-generation plants with RO technologies instead of thermal technologies would allow for greater operational flexibility and for the system to be used as a demand response facility. It could help ensure an outlet during periods of excess electricity production, with water storage tanks also serving as energy storage. Additionally, a shift towards more renewable-based power is necessary for clean energy transitions and greater use of RO technologies can lower the energy and emissions footprint of desalination. While renewables-based desalination is currently limited and difficult to scale, North African countries should keep an eye on opportunities to implement this technology more broadly in the future.

View wastewater as a renewable resource: Countries can conduct feasibility assessments of existing wastewater treatment plants to assess the potential to generate biogas from wastewater. Where wastewater alone is not enough, facilities can look into commingling it with other waste via co-fermentation. An increased use of waste-to-energy technologies will require both the right regulatory framework and at least initially, fiscal incentives. Including the energy generated in wastewater treatment plants in renewable energy or climate programmes (and the associated tax credits or certification schemes) could encourage greater uptake. Wastewater can also be treated and reused, bolstering water supply and reducing water pollution, and by-products such as phosphorus and nitrate for fertiliser can be recovered. Increasing the rate of reuse would require, among others, clear national policy directives, a robust regulatory framework, incentives and educational campaigns to reduce misgivings about recycled water.

Recommendations for the agriculture sector:

Pair solar water pumps and irrigation systems with sound policy: Solar-based water pumps or irrigation systems are more reliable, cleaner and cheaper over the long term than diesel-based systems. Good policy is needed to ensure their sustainability. Innovative financing models or targeted subsidies can reduce barriers of high initial investment costs. Capacity building will be critical to ensure appropriate installation, operation and maintenance of pumps. Sound water management – including informed groundwater resource assessments, monitoring technologies and smart water metres, appropriate water pricing, and efficient irrigation technologies – will be essential to minimise risk of unsustainable water withdrawals and groundwater depletion. Finally, how the renewable energy produced by water pumps or irrigation systems could be go towards other productive uses should be considered as this may change the type of technology required.

Use renewable energy throughout the agri-food supply chain: The agri-food sector accounts for almost a quarter of global GHG emissions, and the FAO estimates that over a third of food supplies are lost or wasted in the Near East and North African region (FAO, n.d.b; Poore and Nemecek, 2018). Increased use of solar pumps, solar dryers, renewables-powered mini-grids and grid-based renewable energy can help ensure reliable and cleaner electricity for production, storage, food processing, marketing and retailing, thereby saving energy, emissions, food and water.

Recommendations for the energy sector:

Factor water use into energy transition policy decisions: The fuels or technologies used to achieve the energy transition could, if not properly managed, exacerbate or be limited by water stress depending on the location, availability of water and competing users. Technologies such as wind and solar PV require very little water, but others such as biofuels; CSP; carbon capture, utilisation and storage; or nuclear power can have more significant water demands. This underscores the importance of factoring water use into energy policy decisions. Plans for power generation that rely on more water-intensive technologies will need to take into account current and future water availability in the choice of sites and cooling technologies.

Use alternative sources of water: Where feasible, shifting to alternative sources of water can help reduce demand for fresh water and shore up the energy sector's resilience to drought or short-term water seasonality. For example, the power sector could increase its use of municipal wastewater, or brackish, sea or mine water,

ensuring the water is treated adequately to reduce corrosion, scaling and fouling of pipes and equipment.

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5. Strengthening the climate resilience of energy systems

North African countries are among the most vulnerable regions to the potential impacts of climate change. The increasing impact of climate change shows the need to build up a reliable energy mix and improve the resilience of existing and new energy systems. Adequate investment in resilient energy systems and infrastructure for the region will be vital. Clean energy transitions in North Africa need to incorporate planning and investment decisions that ensure their energy systems are climate resilient and secure.

Climate change challenges clean energy transitions

North Africa is one of the most susceptible regions to climate change. According to the *IPCC Fifth Assessment Report*, by the Intergovernmental Panel on Climate Change, the region's mean annual temperature has steadily increased over the past century and is likely to rise faster than the global average over the 21st century. Under the worst IPCC scenario (Representative Concentration Pathway [RCP] 8.5), the mean annual temperature of North Africa could reach almost 5°C above the 1986-2005 average by 2100, which is considerably higher than the projected average of global warming (3.7°C) (IPCC, 2014). Moreover, North Africa would also experience a reduction in annual precipitation. The Mediterranean region of North Africa, where precipitation has strongly decreased over the last few decades, is very likely to see a continuous drop in precipitation by 2100 (IPCC, 2014).

These changing climate patterns are likely to impact all stages of the region's energy value chain, changing fuel supply, affecting energy production, testing physical resilience of grids and assets, and altering demand patterns. Therefore, the region's clean energy transitions would require the energy sector to strengthen its adaptability and resilience to climate change.

The increasing share of renewables such as solar, hydro and wind to implement clean energy transitions in the region will require adoption of measures to enhance climate resilience, given that renewable energy technologies tend to be sensitive to a

changing climate (Ligtvoet et al., 2015). For instance, rising global temperatures have moderate but negative impacts on solar panel performance (Peters and Buonassisi, 2019). Erratic rainfall patterns directly exacerbate variabilities in hydropower generation (Box 5.1) and changes in wind speed can alter wind potential and even damage wind turbines if they are associated with cyclones and storms (Evans et al., 2018). Governments and utilities need to better understand these climate impacts on energy systems, and to take appropriate actions to enhance their resilience to the adverse effects of a changing climate.

Box 5.1 Climate change impacts energy systems: Hydropower in Egypt and Morocco

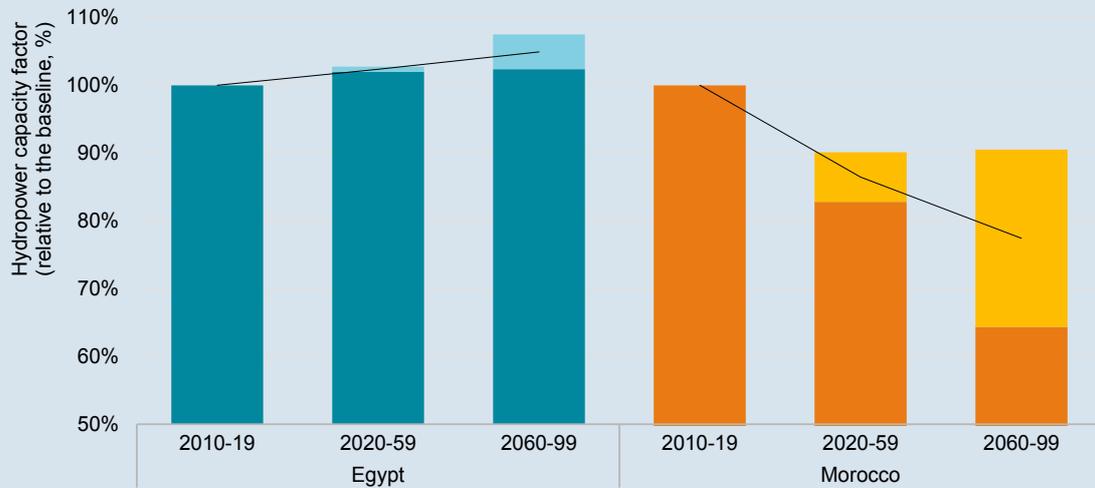
Hydropower in Africa is particularly sensitive to the adverse effects of climate change. Hydropower generation is directly affected by changing patterns in rainfall and rising temperatures in the region. Extreme weather events can also threaten the reliability and stability of hydropower generation. A recent IEA report (IEA, 2020) assesses potential climate impacts on hydropower plants in 13 African countries, including Egypt and Morocco, using two different scenarios that lead to a certain level of global warming, Below 2°C and Around 3°C. By comparing these two scenarios, the report aims to present how GHG concentration is likely to affect hydropower generation in Africa.

The report shows that a higher GHG concentration would exacerbate a geographical gap in climate impacts. Morocco is likely to experience a drop in its hydropower capacity factor during the rest of the century, while Egypt is likely to see an increase, benefiting from more frequent heavy rainfall. In the Below 2°C Scenario, however, the gap is comparatively small: the hydropower capacity factor in Egypt increases by 2% by the end of the 21st century, while in Morocco, it decreases by 10%. In the Around 3°C Scenario, the difference in climate impacts on hydropower is likely to be more marked: the mean hydropower capacity factor in Egypt during the period of 2060-99 would be 7% higher than that of the baseline period 2010-19 while Morocco would likely see a considerable drop in hydropower capacity factor of more than 30% in 2060-99 compared with the baseline.

Another impact of a higher GHG concentration would be the increased year-to-year variability in hydropower capacity factors, which can significantly damage reliable electricity supply. In a majority of cases, hydropower plants in Egypt and Morocco are likely to experience an increasing magnitude of fluctuation in their capacity factors for the remainder of the century. These hydropower plants will experience more fluctuation in capacity factor during 2060-99 than during 2020-59 under both climate scenarios.

If global GHG concentration is not regulated effectively, the variability in hydropower capacity factors is likely to be more accentuated. Hydropower plants in Egypt and Morocco present more substantial fluctuations in hydropower capacity factors under the Around 3°C Scenario than the Below 2°C Scenario.

Changes in hydropower capacity factor in Egypt and Morocco



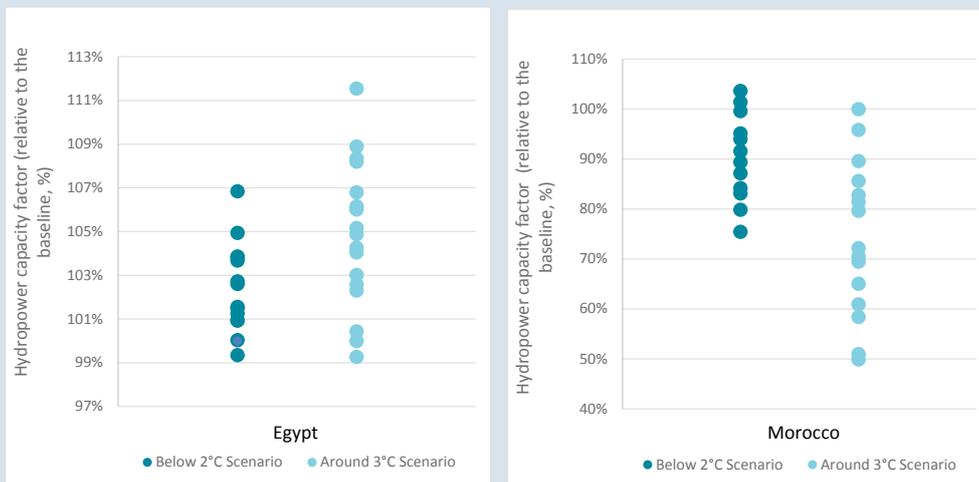
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Note: The areas that are lightly coloured indicate the gap between the projections of the Below 2°C Scenario and the Around 3°C Scenario

Source: [IEA \(2020\), Climate impacts on African hydropower.](#)

Morocco is likely to experience a significant drop in its hydropower capacity factor during the rest of the century, while Egypt is likely to see an increase. A higher GHG concentration would accentuate the spatial variation in climate impacts.

Variability of hydropower capacity factors in Egypt and Morocco



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Note: Each dot represents the relative value of projected average hydropower capacity factor of the selected plants in each country every five years.

Source: [IEA \(2020\), Climate impacts on African hydropower.](#)

A higher GHG concentration is likely to intensify variability in hydropower capacity factors.

Governments can strengthen resilience to climate change

Resilient energy systems will support meeting the SDGs in North Africa addressing the projected impacts of climate change. As mentioned, North Africa has made strong progress on energy access in past decades. However, areas of improvement include quality and reliability of energy supply. Climate-resilient energy systems that ensure uninterrupted energy supply against increasing climate hazards will significantly contribute to providing reliable energy services.

Furthermore, resilient energy systems can minimise socio-economic costs from climate change. For instance, climate-resilient energy systems will support a fast recovery from extreme weather events, bolstering the continuous provision of public services with an uninterrupted electricity supply.

Therefore, governments need to play a central role in encouraging the energy sector to enhance resilience to climate impacts. Without the support from governments, private actors could have a limited incentive to implement resilience measures, because the benefits of investment in resilient energy systems are likely to be seen only after a few years or even decades. However, if energy systems remain vulnerable to climate impacts, it will bring large costs to society, while energy service providers would bear only a fraction of the entire socio-economic cost. Thus, governments need to send strong signals to the private sector to encourage investment in building with climate change resilience in mind.

Key policy recommendations

Support a systematic and comprehensive assessment of potential climate impacts on energy systems: There is no one-size-fits-all solution to enhance the resilience of North African energy systems because of the wide range of patterns and magnitude of potential climate impacts in the region. Instead, tailored policy measures based on systematic assessments of climate risks and impacts will help North African countries increase the resilience of their energy systems. The assessment should be based on scientific methodologies and established guidelines. Governments can provide technical support by commissioning research and making quality data and information available. Governments can also develop, support and implement capacity-building activities for the assessment (Box 5.2).

Box 5.2 Supporting a systematic assessment of climate impact on energy systems: The case of Egypt

The NDC of Egypt identifies climate risks and introduces its efforts to address climate impacts on its energy systems. The NDC points out that the increase in temperature, sea level rise and changes in rainfall patterns negatively affect energy supply and increase cooling demand in Egypt.

To enhance resilience to the adverse climate impacts, the government of Egypt introduced the action package for the energy sector. The action package emphasises the importance of climate impact assessment and capacity building for it. It focuses on:

- Conducting comprehensive studies to assess the impact of climate change on the energy sector, propose appropriate adaptation measures and estimate the economic cost of the proposed adaptation measures.
- Building institutional and technical capacities of different units in the energy sector on climate change issues.
- Supporting research and technological development to enable the electricity sector to deal effectively with climate change.

Source: The Government of Egypt (2017), The First Nationally Determined Contribution.

Mainstream climate resilience in clean energy transitions policy making:

Incorporating the assessed climate impacts into national policies for clean energy transitions helps countries develop climate-resilient roadmaps. For instance, Morocco's national plan to diversify the electricity mix in light of future climate conditions would improve the resilience of Morocco's energy systems and support clean energy transitions (Box 5.3). National strategies and plans underlining climate-resilient solutions will encourage project developers to incorporate climate risk and impact analysis as a regular part of energy projects, promoting technology development and investment in resilient energy systems.

Give the right signals to the private sector: An adequate level of rewards and penalties based on socio-economic costs-and-benefits analyses will encourage the private sector to align its interests with investments in climate resilience. Governments can introduce incentive mechanisms, regulations, standards and guidelines to promote climate-resilient energy systems. Countries can also share best practices across the region and support research and technological development to enable the energy sector to deal effectively with the impacts from climate change.

Box 5.3 Integrating climate impacts consideration into energy planning: The case of Morocco

By 2014, hydropower was the largest renewable source for electricity generation in Morocco. However, climate projections on rising temperatures and declining precipitation raised concerns about the long-term reliability of hydropower. Due to the changes in climate, hydropower in Morocco was projected to experience a significant drop in generation output and an increase in year-to-year variability of capacity factors by the end of this century.

Taking into account the future climate conditions, Morocco determined to diversify its electricity mix, reducing its reliance on hydro and raising the shares of other renewable sources. In 2015, the government announced a target to increase renewable generation capacity to 52% of the total installed power capacity by 2030, led by a significant increase of installed capacities of solar and wind. With the initiative of the government, the share of wind significantly increased from 3% in 2010 to 9% in 2017 while the share of hydropower in electricity generation fell rapidly from 15% to 5% for the same period (IEA, 2019a). Thanks to this diversification, Morocco's share of renewable energy remained relatively stable at around 14% from 2013 to 2017, despite a considerable decline in hydropower generation (IEA, 2019b).

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Annex: Country profiles

Country profile: Algeria

Energy data: Algeria						CAAGR	
	2000	2005	2010	2015	2018	2000-10	2010-18
Population (million)	31	33	36	40	42	1.5%	2.0%
GDP (billion USD 2015 prices and PPPs)	340	438	496	584	620	3.9%	2.8%
GDP per capita PPP (USD 2015 prices and PPPs)	10 955	13 212	13 798	14 711	14 671	2.3%	0.8%
Total energy supply (TES) (Mtoe)	27	32	42	56	61	4.4%	4.9%
TFC (Mtoe)	15	21	26	37	42	5.6%	6.1%
<i>By sector</i>							
Industry	2.8	3.7	5.2	5.8	6.8	6.4%	3.5%
Transport	5.8	8.3	10.7	15.6	15.3	6.3%	4.6%
Residential	4.7	6.6	6.4	10.2	12.8	3.1%	9.0%
Commerce and public services	-	-	0.2	0.5	0.6	n.a.	14.3%
Other*	-	-	1.8	1.7	2.3	n.a.	2.8%
Non-energy use	2.1	2.0	2.1	3.7	4.6	0.2%	10.1%
<i>By fuel</i>							
Coal, peat and oil shale	0.1	0.2	0.1	0.0	0.1	3.8%	0.0%
Primary and secondary oil	8.4	10.4	14.3	18.4	18.1	5.5%	3.0%
Natural gas	5.3	7.7	9.1	14.7	19.1	5.6%	9.7%
Biofuels and waste	0.1	0.1	0.1	0.0	0.0	-0.3%	-10.2%
Electricity	1.6	2.3	2.9	4.3	5.0	6.1%	7.1%
Electricity generation mix (TWh)	25.4	33.9	45.7	68.8	76.7	6.1%	6.7%
Coal, peat and oil shale	-	-	-	-	-	n.a.	n.a.
Primary and secondary oil	0.8	0.7	1.0	0.9	0.4	2.2%	-
Natural gas	24.6	32.6	44.6	67.7	75.5	6.1%	6.8%
Hydro	0.1	0.6	0.2	0.1	0.1	12.4%	-4.8%
Solar thermal	-	-	-	-	-	n.a.	n.a.
Solar PV, tide, wind, etc.	-	-	-	0.1	0.7	n.a.	n.a.
Energy consumption per capita (toe per capita)	0.9	1.0	1.2	1.4	1.4	2.9%	2.8%
Energy intensity of economy (toe per 2015 USD PPP)	79	74	84	96	98	0.6%	1.9%
CO₂ emissions from fuel combustion (MtCO₂)	62	77	96	130	137	4.5%	4.6%
CO₂ emissions per capita (tCO₂ per capita)	2	2.3	2.7	3.3	3.3	3.0%	2.5%
CO₂ emissions per GDP (kg CO₂ per USD 2015 prices and PPPs)	181	177	193	223	222	0.6%	1.8%
CO₂ emissions intensity of electricity production as an index of world in 2000							
World	100	101	98	94	89	-0.2%	-1.2%
Africa	124	120	117	113	108	-0.6%	-1.0%
Algeria	116	113	102	100	94	-1.3%	-1.1%

*Other includes agriculture, fishing and other non-specified sectors.

Note: CAAGR = compounded average annual growth rate; tCO₂ = tonnes of carbon dioxide.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#); [IEA \(2020\)](#), [World Energy Outlook 2020](#).

Country profile: Egypt

Energy data: Egypt						CAAGR	
	2000	2005	2010	2015	2018	2000-10	2010-18
Population (million)	69	76	83	92	98	1.9%	2.2%
GDP (billion USD 2015 prices and PPPs)	552	656	886	1 011	1 158	4.8%	3.4%
GDP per capita PPP (USD 2015 prices and PPPs)	8 015	8 690	10 700	10 939	11 762	2.9%	1.2%
Total energy supply (TES) (Mtoe)	41	62	74	81	96	6.1%	3.3%
TFC (Mtoe)	31	42	53	56	61	5.3%	1.9%
<i>By sector</i>							
Industry	9.9	13.8	14.5	14.3	17.5	3.9%	2.4%
Transport	9.6	10.2	14.9	18.3	18.0	4.5%	2.4%
Residential	7.3	8.8	11.7	14.0	14.0	4.8%	2.3%
Commerce and public services	1.2	1.9	2.4	3.2	3.5	7.2%	4.6%
Other*	0.3	2.1	2.7	1.5	1.5	24.9%	-7.2%
Non-energy use	3.2	5.2	6.6	5.0	6.8	7.5%	0.5%
<i>By fuel</i>							
Coal, peat and oil shale	0.4	0.5	0.4	1.1	3.1	-2.2%	31.1%
Primary and secondary oil	20.3	23.2	29.4	30.0	28.8	3.8%	-0.2%
Natural gas	4.0	9.1	11.0	10.5	14.0	10.7%	3.1%
Biofuels and waste	1.2	1.3	1.4	1.4	1.5	1.2%	0.6%
Electricity	5.6	7.9	10.8	13.4	14.0	6.8%	3.3%
Electricity generation mix (TWh)	78.1	108.7	146.8	172.8	194.1	6.5%	3.6%
Coal, peat and oil shale	-	-	-	-	-	n.a.	n.a.
Primary and secondary oil	7.6	14.5	19.8	38.2	23.1	10.1%	2.0%
Natural gas	56.7	81.0	112.3	118.8	155.2	7.1%	4.1%
Hydro	13.7	12.6	13.0	13.5	12.9	-0.5%	-0.1%
Solar thermal	-	-	-	-	-	n.a.	n.a.
Solar PV, tide, wind, etc.	0.1	0.6	1.7	2.2	2.9	28.7%	6.9%
Energy consumption per capita (toe per capita)	0.6	0.8	0.9	0.9	1.0	4.1%	1.1%
Energy intensity of economy (toe per 2015 USD PPP)	74	95	83	80	83	1.2%	0.0%
CO ₂ emissions from fuel combustion (MtCO ₂)	100	145	177	203	224	5.9%	3.0%
CO ₂ emissions per capita (tCO ₂ per capita)	1.5	1.9	2.1	2.2	2.3	3.9%	0.8%
CO ₂ emissions per GDP (kg CO ₂ per USD 2015 prices and PPPs)	181	221	200	201	193	1.0%	-0.4%
CO ₂ emissions intensity of electricity production as an index of world in 2000							
World	100	101	98	94	89	-0.2%	-1.2%
Africa	124	120	117	113	108	-0.6%	-1.0%
Egypt	65	89	79	93	90	2.1%	1.6%

*Other includes agriculture, fishing and other non-specified sectors.

Note: CAAGR = compounded average annual growth rate; tCO₂ = tonnes of carbon dioxide.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#); [IEA \(2020\)](#), [World Energy Outlook 2020](#).

Country profile: Libya

Energy data: Libya							CAAGR	
	2000	2005	2010	2015	2018	2000-10	2010-18	
Population (million)	5	6	6	6	7	1.5%	0.9%	
GDP (billion USD 2015 prices and PPPs)	125	161	195	99	131	4.5%	-4.8%	
GDP per capita PPP (USD 2015 prices and PPPs)	23 402	27 785	31 497	15 404	19 676	3.0%	-5.7%	
Total energy supply (TES) (Mtoe)	16	18	20	19	18	2.6%	-1.6%	
TFC (Mtoe)	9	11	13	11	13	3.6%	0.0%	
<i>By sector</i>								
Industry	1.5	1.6	1.5	1.7	2.1	-0.1%	4.1%	
Transport	3.7	4.3	6.1	5.1	5.7	5.1%	-0.9%	
Residential	1.5	1.7	1.5	1.1	1.5	0.1%	-0.7%	
Commerce and public services	-	0.4	0.8	0.2	0.2	n.a.	-17.6%	
Other*	0.1	0.3	0.2	0.5	0.5	7.1%	12.5%	
Non-energy use	2.6	2.2	3.3	2.5	3.5	2.5%	0.9%	
<i>By fuel</i>								
Coal, peat and oil shale	-	-	-	-	-	n.a.	n.a.	
Primary and secondary oil	6.2	6.6	9.2	6.5	7.4	4.0%	-2.7%	
Natural gas	2.1	2.1	2.2	3.1	4.2	0.3%	8.3%	
Biofuels and waste	0.1	0.2	0.2	0.2	0.3	5.5%	1.0%	
Electricity	0.9	1.6	1.7	1.3	1.5	6.9%	-1.5%	
Electricity generation mix (TWh)	15.5	22.7	32.6	37.5	34.2	7.7%	0.6%	
Coal, peat and oil shale	-	-	-	-	-	n.a.	n.a.	
Primary and secondary oil	12.1	16.3	17.2	17.2	11.8	3.6%	-4.7%	
Natural gas	3.4	6.3	15.3	20.3	22.4	16.3%	4.8%	
Hydro	-	-	-	-	-	n.a.	n.a.	
Solar thermal	-	-	-	-	-	n.a.	n.a.	
Solar PV, tide, wind, etc.	-	0.0	0.0	0.0	0.0	n.a.	3.9%	
Energy consumption per capita (toe per capita)	3.0	3.1	3.3	2.9	2.7	1.1%	-2.5%	
Energy intensity of economy (toe per 2015 USD PPP)	126	113	104	190	136	-1.9%	3.4%	
CO ₂ emissions from fuel combustion (MtCO ₂)	37	43	48	45	46	2.7%	-0.7%	
CO ₂ emissions per capita (tCO ₂ per capita)	6.9	7.4	7.8	7.1	6.8	1.3%	-1.6%	
CO ₂ emissions per GDP (kg CO ₂ per USD 2015 prices and PPPs)	293	267	247	458	347	-1.7%	4.3%	
CO ₂ emissions intensity of electricity production as an index of world in 2000								
World	100	101	98	94	89	-0.2%	-1.2%	
Africa	124	120	117	113	108	-0.6%	-1.0%	
Libya	189	170	129	122	120	-3.8%	-0.9%	

*Other includes agriculture, fishing and other non-specified sectors.

Note: CAAGR = compounded average annual growth rate; tCO₂ = tonnes of carbon dioxide.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#); [IEA \(2020\)](#), [World Energy Outlook 2020](#).

Country profile: Morocco

Energy data: Morocco						CAAGR	
	2000	2005	2010	2015	2018	2000-10	2010-18
Population (million)	29	30	32	35	36	1.2%	1.4%
GDP (billion USD 2015 prices and PPPs)	140	177	226	275	299	4.9%	3.5%
GDP per capita PPP (USD 2015 prices and PPPs)	4 850	5 821	6 998	7 942	8 289	3.7%	2.1%
Total energy supply (TES) (Mtoe)	11	15	17	20	21	4.5%	2.4%
TFC (Mtoe)	9	11	13	15	16	4.5%	2.6%
<i>By sector</i>							
Industry	2.2	2.5	2.9	3.1	3.3	2.8%	1.6%
Transport	2.7	3.3	4.5	5.3	6.0	5.2%	3.7%
Residential	2.1	3.0	3.3	3.8	4.0	4.6%	2.6%
Commerce and public services	0.8	1.3	1.1	1.2	1.3	3.8%	1.8%
Other*	0.5	0.7	0.9	1.1	1.2	6.4%	4.1%
Non-energy use	0.3	0.4	0.5	0.5	0.4	6.3%	-2.3%
<i>By fuel</i>							
Coal, peat and oil shale	0.5	0.0	0.0	0.0	0.0	-27.5%	-0.8%
Primary and secondary oil	5.7	7.5	9.6	11.1	12.1	5.4%	2.9%
Natural gas	0.0	0.0	0.0	0.1	0.1	1.7%	4.9%
Biofuels and waste	1.2	2.1	1.5	1.3	1.3	2.2%	-1.9%
Electricity	1.1	1.5	2.0	2.6	2.8	6.3%	4.1%
Electricity generation mix (TWh)	12.9	19.3	23.7	30.8	35.5	6.3%	5.2%
Coal, peat and oil shale	8.8	12.7	10.9	17.1	21.3	2.2%	8.8%
Primary and secondary oil	3.3	3.4	5.7	2.2	1.3	5.7%	-17.0%
Natural gas	-	2.0	3.0	5.8	5.2	n.a.	7.3%
Hydro	0.7	1.0	3.5	1.9	1.7	17.1%	-8.6%
Solar thermal	-	-	-	-	-	n.a.	n.a.
Solar PV, tide, wind, etc.	0.1	0.2	0.7	2.5	4.8	26.3%	28.1%
Other sources	-	-	-	1.3	1.3	n.a.	n.a.
Energy consumption per capita (toe per capita)	0.4	0.5	0.5	0.6	0.6	3.3%	1.0%
Energy intensity of economy (toe per 2015 USD PPP)	79	84	75	71	69	-0.5%	-1.0%
CO ₂ emissions from fuel combustion (MtCO ₂)	30	39	46	55	59	4.6%	3.0%
CO ₂ emissions per capita (tCO ₂ per capita)	1.0	1.3	1.4	1.6	1.6	3.4%	1.6%
CO ₂ emissions per GDP (kg CO ₂ per USD 2015 prices and PPPs)	212	221	205	201	197	-0.3%	-0.5%
CO ₂ emissions intensity of electricity production as an index of world in 2000							
World	100	101	98	94	89	-0.2%	-1.2%
Africa	124	120	117	113	108	-0.6%	-1.0%
Morocco	157	157	129	131	118	-1.9%	-1.2%

*Other includes agriculture, fishing and other non-specified sectors.

Note: CAAGR = compounded average annual growth rate; tCO₂ = tonnes of carbon dioxide.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#); [IEA \(2020\)](#), [World Energy Outlook 2020](#).

Country profile: Tunisia

Energy data: Tunisia						CAAGR	
	2000	2005	2010	2015	2018	2000-10	2010-18
Population (million)	10	10	11	11	12	0.9%	1.1%
GDP (billion USD 2015 prices and PPPs)	78	95	119	130	137	4.2%	1.8%
GDP per capita PPP (USD 2015 prices and PPPs)	8 081	9 397	11 151	11 599	11 849	3.3%	0.8%
Total energy supply (TES) (Mtoe)	7	8	10	11	11	3.5%	1.4%
TFC (Mtoe)	6	7	7	8	8	3.0%	1.6%
<i>By sector</i>							
Industry	1.6	2.0	2.0	2.2	2.2	2.5%	0.9%
Transport	1.3	1.5	2.3	2.2	2.6	5.7%	1.1%
Residential	1.5	1.9	1.8	2.1	2.2	1.7%	2.1%
Commerce and public services	0.5	0.6	0.6	0.6	0.7	2.0%	2.0%
Other*	0.4	0.4	0.4	0.5	0.5	1.0%	2.9%
Non-energy use	0.2	0.3	0.2	0.3	0.3	1.5%	4.6%
<i>By fuel</i>							
Coal, peat and oil shale	0.0	-	-	-	-	-100%	n.a.
Primary and secondary oil	3.3	4.0	3.9	4.3	4.5	1.5%	2.0%
Natural gas	0.6	0.8	1.5	1.3	1.6	9.3%	0.6%
Biofuels and waste	0.8	0.9	0.9	0.9	0.9	1.4%	-0.1%
Electricity	0.8	1.0	1.2	1.3	1.4	4.2%	2.5%
Electricity generation mix (TWh)	10.6	12.7	16.4	19.7	21.0	4.4%	3.2%
Coal, peat and oil shale	-	-	-	-	-	n.a.	n.a.
Primary and secondary oil	1.2	0.2	0.0	0.9	0.0	-43.6%	36.1%
Natural gas	9.3	12.3	15.7	18.0	20.0	5.4%	3.1%
Hydro	0.1	0.1	0.1	0.1	0.0	-2.4%	-12.9%
Solar thermal	-	-	-	-	-	n.a.	n.a.
Solar PV, tide, wind, etc.	0.0	0.0	0.1	0.5	0.6	19.8%	20.6%
Other sources	-	-	0.5	0.2	0.3	n.a.	-6.3%
Energy consumption per capita (toe per capita)	0.8	0.8	1.0	1.0	1.0	2.5%	0.3%
Energy intensity of economy (toe per 2015 USD PPP)	93	88	87	84	84	-0.7%	-0.4%
CO ₂ emissions from fuel combustion (MtCO ₂)	18	19	23	26	26	2.8%	1.5%
CO ₂ emissions per capita (tCO ₂ per capita)	1.8	1.9	2.2	2.3	2.3	1.9%	0.4%
CO ₂ emissions per GDP (kg CO ₂ per USD 2015 prices and PPPs)	225	205	196	198	191	-1.4%	-0.3%
CO ₂ emissions intensity of electricity production as an index of world in 2000							
World	100	101	98	94	89	-0.2%	-1.2%
Africa	124	120	117	113	108	-0.6%	-1.0%
Tunisia	108	88	90	87	80	-1.8%	-1.5%

*Other includes agriculture, fishing and other non-specified sectors.

Note: CAAGR = compounded average annual growth rate; tCO₂ = tonnes of carbon dioxide.

Source: [IEA \(2020\)](#), [World Energy Balances 2020](#); [IEA \(2020\)](#), [World Energy Outlook 2020](#).

Abbreviations and acronyms

ANME	L'Agence Nationale pour la Maitrise de l'Energie (Tunisia)
CAAGR	compounded average annual growth rate
CIEMAT	Centre for Energy, Environment and Technology (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas)
CO ₂	carbon dioxide
CNG	compressed natural gas
CSP	concentrated solar power
DER	distributed energy resources
DFI	development financing institution
EETC	Egyptian Electricity Transmission Company
EMS	energy management systems
EU	European Union
FAO	Food and Agriculture Organization
FiT	feed-in tariff
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
H ₂	hydrogen
IEA	International Energy Agency
IPP	independent power producer
IPCC	Intergovernmental Panel on Climate Change
KfW	German Development Bank (Kreditanstalt für Wiederaufbau)
LEDs	light-emitting diodes
LPG	liquefied petroleum gas
MASEN	Moroccan Agency for Sustainable Energy
MEPS	minimum energy performance standards
NDC	nationally determined contribution
OECD	Organisation for Economic Co-operation and Development
ONEE	Office National de l'Electricité et de l'Eau Potable
PV	photovoltaic
PACE	property-assessed clean energy (programme)
PPA	power purchase agreement
PPP	purchasing power parity
RCP	Representative Concentration Pathway
RO	reverse osmosis
S&L	standards and labelling
SDG	Sustainable Development Goal
STEPS	Stated Policies Scenario
tbd	to be determined
TES	total energy supply

TFC	total final consumption
UNDP	United Nations Development Programme
VRE	variable renewable energy
WEO	World Energy Outlook

Units of measurement

bcm	billion cubic metres
GW	gigawatt
kgCO ₂ -eq	kilogrammes of carbon dioxide equivalent
kgH ₂	kilogrammes of hydrogen
kWh	kilowatt-hours
ktoe	thousand tonnes of oil equivalent
m ²	square metres
m ³	cubic metres
Mt	million tonnes
Mtoe	million tonnes of oil equivalent
MW	megawatts
MWh	megawatt-hour
MW _{th}	megawatt thermal
tCO ₂	tonnes of carbon dioxide
TWh	terawatt-hours
toe	tonnes of oil equivalent
t NH ₃	tonnes of ammonia

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