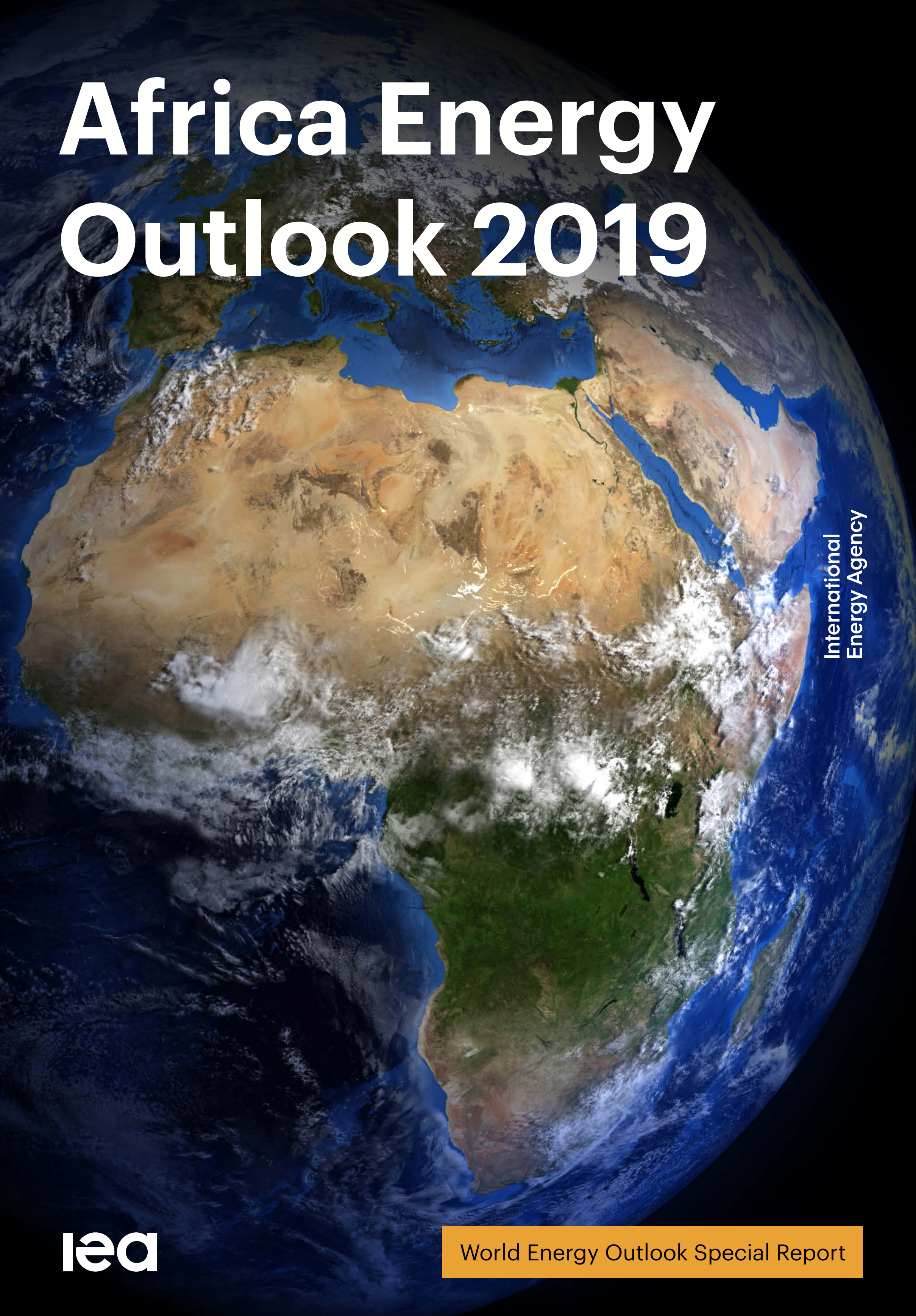
Africa Energy Outlook 2019

International Energy Agency



World Energy Outlook Special Report

Africa Energy Outlook 2019

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INTERNATIONAL ENERGY AGENCY

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As Africa's population rapidly expands and urbanises, its need for reliable and sustainable energy supply will become greater than ever. This energy is needed not only to drive the continent's economic development but also to provide modern energy services to the large numbers of Africans currently living without them. Africa is set to emerge as a key driver of global energy demand growth, one that is home to abundant reserves of fossil fuels, solar power and minerals that will be vital for clean energy transitions worldwide. And even though Africa has produced just 2% of global energy-related carbon dioxide (CO_2) emissions, the continent is disproportionately on the front line when it comes to the effects of the world's changing climate.

The International Energy Agency (IEA) has long paid close attention to Africa's energy sector. We have been working on energy access issues on the continent for nearly two decades, notably through our pioneering analysis in the World Energy Outlook series. This new special report is significant in its unrivalled breadth and depth, with a particularly granular focus on sub-Saharan countries.

Africa's growing urban populations will require ever more energy to power industrial production, air conditioning and expanding use of transport. In our Stated Policies Scenario, based on current and announced policies, African energy demand grows twice as fast as the global average over the next two decades. That includes an additional 500 million people who are expected to live in areas requiring some form of cooling. Despite a shift to modern and more efficient energy sources over this period, the continent's current policy settings aren't enough to put it on track to meet its development needs and provide reliable and modern energy services for all.

Effective energy policy choices are essential to deliver Africa's inclusive growth ambitions (such as those contained in the region's Agenda 2063 strategic framework), and to help meet other major sustainable energy and development goals. This is why we introduce the Africa Case in this report, a new scenario built around Africa's own vision for its future. It incorporates the policies needed to develop the continent's energy sector in a way that allows economies to grow strongly, sustainably and inclusively. Doing so does not mean African economies have to become ever more energy intensive. Africa stands on the cusp of a unique opportunity: the possibility of becoming the first continent to develop its economy primarily by using energy efficiency, renewables and natural gas – all of which offer huge untapped potential and economic benefits.

For example, Africa has the richest solar resources on the planet, but has installed only 5 gigawatts of solar photovoltaics (PV), accounting for less than 1% of global capacity. With the right policies, solar could become one of the continent's top energy sources. Natural gas, meanwhile, is likely to correspond well with Africa's industrial growth drive and need for reliable electricity supply. Today, the share of gas in sub-Saharan Africa's energy mix is among the lowest in the world. But that could be about to change, especially considering the supplies the continent has at its disposal: it is home to more than 40% of global gas discoveries so far this decade. Africa's rich natural resources aren't limited to sunshine and other energy sources. Its major reserves of minerals such as cobalt and platinum that are crucial for clean energy technologies mean the continent holds the key ingredients for global energy transitions.

This Africa Energy Outlook contains quantitative analysis of important factors influencing energy development in Africa. This includes detailed modelling of 11 sub-Saharan countries that enabled us to produce comprehensive, data-rich profiles from which we extracted important implications for Africa and the world. The profiles are a notable highlight of the report, providing a much greater level of detail than any other analysis of energy in Africa.

This report comes at an important time in the IEA's deepening engagement with Africa. It reflects the continent's increasing role in global energy affairs and the strengthening relationships between African energy decision makers and the IEA. South Africa and Morocco are now part of the IEA family. In May 2018, the IEA and the African Union Commission co-hosted their first joint ministerial summit at which African Union Commissioner Dr Amani Abou-Zeid and I signed a strategic Memorandum of Understanding to guide the two organisations' future collaborations. A second ministerial forum will be held in 2020.

I hope this new report serves as both an anchor for our new programme of work with African countries and also as a means to guide the continent towards a more secure and sustainable energy future.

Dr. Fatih Birol
Executive Director
International Energy Agency

This study was prepared by the World Energy Outlook (WEO) team in the Directorate of Sustainability, Technology and Outlooks (STO) in co-operation with other directorates and offices of the International Energy Agency. The study was designed and directed by **Laura Cozzi**, Chief Energy Modeller. **Stéphanie Bouckaert**, **Tae-Yoon Kim**, and **Kieran McNamara** were the principal authors. **Tim Gould**, Head of Division for Energy Supply and Investment Outlooks, provided essential guidance.

The other main authors were: **Lucila Arboleya Sarazola** (investment), **Yasmine Arsalane** (power), **Arthur Contejean** (energy access), **Timothy Goodson** (electricity demand and buildings) and **Molly A. Walton** (resource management).

Other key contributors were: **Thibaut Abergel** (cities), **Zakia Adam** (country profiles, data management), **Ali Al-Saffar** (urbanisation and industrialisation), **Bipasha Baruah** (gender), **Michela Cappannelli** (biogas), **Haoua Cisse Coulibaly** (policies), **Davide D'Ambrosio** (country profiles, data management and visualisations), **Amrita Dasgupta** (transport), **Chiara Delmastro** (cooling), **Marina Dos Santos** (policies), **John Dulac** (cooling), **Jinsun Lim** (climate impact on hydro), **Luis Munuera** (visualisation), **Paweł Olejarnik** (supply modelling), **Apostolos Petropoulos** (transport), **Andrew Prag** (climate impact on hydro), **Arnaud Rouget** (energy access), **Marcela Ruiz De Chavez Velez** (industry), **Andreas Schröder** (industry) and **Wilfred Yu** (power). The study also relied on support from across the entire WEO team. **Teresa Coon** and **Eleni Tsoukala** provided essential support.

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Further details on these events are available at www.iea.org/weo/events.

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Thomas A. Frankiewicz	US Environmental Protection Agency (EPA)
Amani Abou-Zeid	African Union Commission, Ethiopia
Olalekan David Adeniyi	Chemical Engineering Department, Federal University of Technology, Nigeria
Wisdom Ahiataku-Togobo	Ministry of Energy, Ghana
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Joseph Essandoh-Yeddu	Energy Commission, Ghana
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Dona Jean-Claude Houssou	Ministry of Energy, Benin
Samuel Igbatayo	Afe Babalola University, Nigeria
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Ken Koyama	Institute of Energy Economics, Japan
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Glada Lahn	Chatham House
Per Landberg	Norwegian Agency for Development Cooperation (NORAD)
Richard Lavergne	Ministry for Economy and Finance, France
David Lecoque	Alliance for Rural Electrification
Nikolaj Lomholt Svensson	Embassy of Denmark in Ethiopia
Emadeldin Ahmed Mahgoub	Agricultural Research Corporation (ARC), Sudan
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Simone Mori	ENEL
Isabel Murray	Department of Natural Resources, Canada
Rose Mutiso	Energy for Growth Hub
Glory Oguegbu	Renewable Energy Technology Training Institute (RETTI)

Karin Ohlenforst	Global Wind Energy Council (GWEC)
Sheila Oparaocha	ENERGIA/HIVOS
Moussa Ousman	Ministry of mines, Energy, and Hydraulics, Central African Republic
Isaiah Owiunji	World Wide Fund for Nature (WWF), Uganda
Cathy Oxby	Africa Green
Pak Yongduk	Korea Energy Economics Institute (KEEI)
Jose Ignacio Perez Arriaga	Comillas Pontifical University's Institute for Research in Technology, Spain
Lapo Pistelli	ENI
Jem Porcaro	Sustainable Energy for All
Elisa Portale	World Bank
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Amir Sadeghi	International Monetary Fund (IMF)
Papa Samba Ba	Ministère du Pétrole et des Énergies, Senegal
Thomas Scurfield	National Resource Governance Institute, Tanzania
Carsten Staur	Danish Ambassador to the OECD
Jessica Stephens	Africa Minigrid Developers Association
Robert Stoner	MIT Energy Initiative, United States
Dinesh Surroop	University of Mauritius
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Bob van der Zwaan	Energy Research Centre of the Netherlands (ECN part of TNO)
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Annexes

How Africa meets the energy needs of a young, fast growing and increasingly urban population is crucial for the continent's – and the world's – economic and energy future. One-in-two people added to the global population between today and 2040 is set to be African, and by 2025, Africa's population exceeds that of both India and China. The continent's urban population is set to grow by more than half a billion over that period, much higher than the growth seen in China's urban population during the country's two-decade economic and energy boom. These profound demographic changes are set to drive economic growth, infrastructure development and, in turn, energy demand.

Five years since its first special report on Africa, the International Energy Agency (IEA) has updated and upgraded its work in this new *World Energy Outlook Special Focus*. This reflects not only Africa's increasing importance in global energy affairs but also the deepening relationships between African energy decision makers and the IEA. This report, the most comprehensive to date, contains a unique richness of data and analysis. The centrepiece is a set of detailed, comprehensive outlooks covering 11 sub-Saharan countries[1] that were developed in consultation with our African partners.

Thanks to natural resource endowments and technology improvements, Africa could pursue a much less carbon-intensive development model than many other parts of the world have. The challenges and opportunities differ widely across a diverse continent. But renewables, together with natural gas in many areas, are poised to lead Africa's energy consumption growth as the continent moves away from the traditional use of biomass that currently accounts for almost half of final energy consumption.

Africa's energy prospects depend on the way that government policies shape investment flows and the availability and affordability of modern energy sources. Our analysis is based on two scenarios:

- The **Stated Policies Scenario** reflects our measured assessment of today's policy frameworks and plans, taking into account the regulatory, institutional, infrastructure and financial circumstances that shape the prospects for their implementation.
- The **Africa Case** is built on the premise of Agenda 2063[2], the continent's inclusive and sustainable vision for accelerated economic and industrial development. Faster economic expansion is accompanied by the full achievement of key Sustainable Development Goals by 2030. These include full access to electricity and clean cooking and a significant reduction in premature deaths related to pollution.

[1] These are: Angola, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania.

[2] 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.

Africa drives global trends, but a lack of access persists

Whichever pathway Africa follows, the continent becomes increasingly influential in shaping global energy trends. Growing urban populations mean rapid growth in energy demand for industrial production, cooling and mobility. Energy demand in Africa grows twice as fast as the global average, and Africa's vast renewables resources and falling technology costs drive double-digit growth in deployment of utility-scale and distributed solar photovoltaics (PV), and other renewables, across the continent. With the growing appetite for modern and efficient energy sources, Africa emerges as a major force in global oil and gas markets. As the size of the car fleet more than doubles (the bulk of which have low fuel efficiency) and liquefied petroleum gas (LPG) is increasingly used for clean cooking, oil demand grows by 3.1 million barrels per day between today and 2040, higher than the projected growth in China and second only to that of India. Africa's growing weight is also felt in natural gas markets and the continent becomes the third-largest source of global gas demand growth over the same period.

A critical task for policy makers is to address the persistent lack of access to electricity and clean cooking – and the unreliability of electricity supply. These have acted as brakes on the continent's development. Nearly half of Africans (600 million people) did not have access to electricity in 2018, while around 80% of sub-Saharan African companies suffered frequent electricity disruptions leading to economic losses. In addition, more than 70% of the population, around 900 million people, lack access to clean cooking. The resulting household air pollution from traditional uses of biomass is causing 500 000 premature deaths a year. It also contributes to forest depletion resulting from unsustainable harvesting of fuelwood, as well as imposing a considerable burden and loss of productive time, mostly on women.

The momentum behind today's policy and investment plans is not yet enough to meet the energy needs of Africa's population in full. In the Stated Policies Scenario, 530 million people still lack access to electricity and nearly one billion have no access to clean cooking in 2030. The continent's ambition to accelerate an industrial expansion continues to be hampered in many countries by unreliable energy supply. Only a handful of countries – including South Africa, Ethiopia, Ghana, Kenya, Rwanda and Senegal – are successful in reaching full access to electricity by 2030. Solid biomass remains a mainstay of the energy mix as a primary fuel for cooking as clean cooking policies lag population growth and premature deaths related to inhaling fumes from cooking end up only 2% below today's level by 2040.

The Africa Case points the way to a brighter future

The Africa Case outlines a way to lift these constraints, starting with the achievement of full access to modern energy by 2030. In the case of electricity, this would require tripling the average number of people gaining access per year from around 20 million today to over 60 million people. Grid expansion and densification is the least cost option for nearly 45% of the currently deprived, mini-grids for 30% and stand-alone systems for around a quarter.

LPG is used by more than half of those gaining access to clean cooking in urban areas across sub-Saharan Africa, while in the rural areas, home to the majority of those without access, improved cookstoves are by far the preferred solution. Electrification, biogas, ethanol and other solutions also play important roles.

A focus on energy efficiency can support economic growth while curbing the increase in energy demand. In the Africa Case, although the size of the continent's economy in 2040 is four times larger than today, efficiency improvements help limit the rise in total primary energy demand to just 50%. As a result, even though economic growth in the Africa Case is significantly stronger than in the Stated Policies Scenario, energy use is actually lower. This is linked to an accelerated move away from solid biomass as a fuel and the increased efficiency of charcoal production and use – and to the wide application of electrification and energy efficiency policies. These include fuel economy standards for cars and two/three-wheelers, more efficient industrial processes, building codes and efficiency standards for appliances and cooling systems.

Renewables push ahead to power Africa's brighter future

Rising electricity needs, especially in sub-Saharan Africa, require a major expansion of the power system. Electricity demand today in Africa is 700 terawatt-hours (TWh), with the North African economies and South Africa accounting for over 70% of the total. Yet it is the other sub-Saharan African countries that see the fastest growth to 2040. Electricity demand more than doubles in the Stated Policies Scenario to over 1 600 TWh, and reaches 2 300 TWh in the Africa Case as electricity supports an increasing range of residential, service and industrial uses. Most of the additional electricity demand stems from productive uses and middle- and higher-income households.

Renewables account for three-quarters of new generation, with a key question being how fast solar will grow. Africa has the richest solar resources in the world, but has installed only 5 gigawatts (GW) of solar PV, less than 1% of the global installed capacity. In the Africa Case, solar PV overtakes hydropower and natural gas to become the largest electricity source in Africa in terms of installed capacity (and the second largest in terms of generation output). With additions across the entire region, solar PV deployment between today and 2040 averages almost 15 GW a year, matching the average annual deployment in the United States over the same period. Wind also expands rapidly in several countries that benefit from high quality wind resources, most notably Ethiopia, Kenya, Senegal and South Africa while Kenya is also at the forefront of geothermal deployment.

The development and reliability of Africa's electricity sector will be shaped by progress in improving power infrastructure, within and across borders. Supporting a tripling of the electricity demand as envisaged in the Africa Case requires building a more reliable power system and greater focus on transmission and distribution assets. A key priority is targeted investment and maintenance to reduce power outages, a major obstacle to enterprise, and to decrease losses from 16% to a level approaching advanced economies (less than 10% today). In addition, some large power-sector projects – especially for hydropower – require regional integration to go ahead: they would not proceed if assessed only on domestic needs. That means building up the regulation and capacity to support Africa's power pools and strengthen regional electricity markets.

Africa needs a significant scale-up in electricity sector investment in generation and grids, for which it currently ranks among the lowest in the world. Despite being home to 17% of the world's population, Africa currently accounts for just 4% of global power supply investment. Achieving reliable electricity supply for all would require an almost fourfold increase, to around $120 billion a year through 2040. Around half of that amount would be needed for networks. Mobilising this level of investment is a significant undertaking, but can be done if policy and regulatory measures are put in place to improve the financial and operational efficiency of utilities and to facilitate a more effective use of public funds to catalyse private capital. Developing the technical and regulatory capacity to support sector reform policies, as well as Africa's own financial sector, is also critical to ensure a sustained flow of long-term financing to energy projects.

Natural gas can be a good fit for Africa's industrial growth

Natural gas is facing a potential turning point in Africa. In North Africa, gas already meets around half of the region's energy needs, but in sub-Saharan Africa, it has thus far been a niche fuel. The share of gas in the energy mix is around 5%, among the lowest in the world. The future could be different. There have been a series of major discoveries in recent years, in East Africa (Mozambique and Tanzania), Egypt, West Africa (Senegal and Mauritania) and South Africa, which collectively accounted for over 40% of global gas discoveries between 2011 and 2018. These developments could fit well with Africa's push for industrial growth and its need for reliable electricity supply.

Developing gas infrastructure will be a major challenge because of typically small market sizes and concerns about affordability. Nonetheless, the rapid deployment of renewables leaves room for gas to grow as a flexible and dispatchable source of electricity. Outside the power sector, the successful industrialisation foreseen in the Africa Case rests upon the stable provision of energy, including for energy uses that are hard to electrify. Gas could be well suited to these roles and, if it is not available, the alternatives in many cases would be other, more polluting fossil fuels. Much will depend on the price at which gas becomes available, the development of distribution networks (including small-scale liquefied natural gas (LNG) distribution), the financing available for infrastructure and the strength of policy efforts to displace polluting fuels.

In our projections, Africa becomes a major player in natural gas markets as a producer, consumer and exporter. Gas production more than doubles to 2040 in the Stated Policies Scenario. It rises further in the Africa Case, to support higher demand from power and industry. The share of gas in Africa's energy mix rises to around 24% in 2040 in the Africa Case (close to the global average today). However, the growth in production is considerably higher than the rise in demand, and Africa – led by Mozambique and Egypt – emerges as a major supplier of LNG to global markets.

Energy transitions bring mixed implications for Africa

Development models in Africa that are highly dependent on hydrocarbon revenues are coming under increasing pressure. Africa has abundant natural resources and the associated revenues could be an important motor for development. However, changing global energy dynamics mean that resource-holders cannot assume that their oil resources will translate into reliable future revenues. This year's outlook incorporates higher shale oil production in the United States, which is providing very strong competition for lighter African crudes. Accelerated energy transitions would result in lower demand and prices for hydrocarbons and cut sharply into future revenues. Our analysis underscores the need for strategic thinking on future investments, transparent resource revenue management and efforts to reform and diversify economies.

Energy transitions are opening up new opportunities for a different set of strategic resources. Africa is home to many of the mineral resources that are critical in driving global energy transitions. The Democratic Republic of the Congo accounts for two-thirds of global cobalt production and South Africa produces 70% of the world's platinum. Rising demand for the minerals that can support global energy transitions offers an opportunity for minerals-rich countries in Africa, but responsible stewardship of these resources is vital. These supply chains are coming under increasing scrutiny, and adequate oversight will be needed to ensure that revenues produce visible positive results for local communities and that negative impacts on the environment are minimised.

Climate change matters in Africa, making resilient policy decisions critical

Africa has been a minor contributor to global greenhouse gas emissions, and this remains the case to 2040 in all our scenarios. To date, energy-related carbon dioxide (CO_2) emissions in Africa represented around 2% of cumulative global emissions. Although Africa experiences rapid economic growth, its contribution to global energy-related CO_2 emissions increases to just 4.3% over the period from today to 2040 in the Stated Policies Scenario. In the Africa Case, the continent's share of cumulative global emissions rises further by just 0.2 percentage points to 2040 despite an economy that grows even more quickly. Looking beyond CO_2, the transition away from the inefficient combustion of biomass for cooking in the Africa Case leads to same levels of greenhouse gas (GHG) emissions as in the Stated Policies Scenario as the increase in CO_2 emissions is offset by reductions in other GHGs (methane and nitrous oxide).

But Africa is in the front line when it comes to the effects of a changing climate on the energy sector. Today, Africa has some of the lowest ownership levels of cooling devices of any region, despite almost 700 million people living in areas where the average daily temperature exceeds 25 degrees. By 2040, this number approaches 1.2 billion as population expands and average temperatures increase with climate change. Without appropriate regulations on the type of equipment used for cooling, this would create a very strong increase in electricity demand. Increased frequency and intensity of extreme weather events such as droughts and floods is set to lead to more variability in generation output, notably hydropower. In Zambia, for example, a severe drought in 2015 led to a drop in output at the largest hydropower plant, resulting in power blackouts. Uncertainty over the impact of climate change on the region's hydrology underlines the need to build up a diverse power mix and enhance regional connections. Planning and investment decisions for energy infrastructure need to be climate resilient. Outside the energy sector, Africa's ecosystems already suffer disproportionately from climate change and are exposed to increased risks to food, health and economic security.

Policies will play a crucial role in determining Africa's energy future

Africa's energy future is not preordained: many pathways are possible, but effective policy choices can guide the continent to a more inclusive and sustainable energy future and accelerate its economic and industrial development. The choices that lead in this direction vary, reflecting the different resource endowments and starting points across a very diverse African energy landscape. Some have full access to modern energy services within their grasp, while others have much further to go, or are struggling with instability or a legacy of conflict. But there are reasons for optimism, both from the dynamism of Africa's energy sector and from the technologies that offer a cost-effective way to meet rising demand in a sustainable way. Whether and how African countries take advantage of these opportunities will depend in large part on the way that energy policies evolve. With the right institutional and policy foundations, a well-functioning energy sector can be the cornerstone of economic development and make a huge difference in the lives of Africa's people.

Five years after a first special report on Africa in the *World Energy Outlook-2014 (WEO-2014)* series, the IEA has updated and expanded its analysis of the energy outlook for the continent in this new report. The renewed focus on Africa in this year's *World Energy Outlook* reflects Africa's increasing importance in global energy affairs and the deepening relationships between African energy decision makers and the IEA. Institutionally, South Africa and Morocco have become IEA Association countries, and the IEA concluded a new strategic partnership on energy with the African Union in 2018.

At the heart of this *Special Focus* report are analyses at country level that break new ground and give important policy insights for global and African energy stakeholders. We carried out quantitative analysis of a number of important factors and used the results to develop modelling for eleven sub-Saharan countries for the first time. This enabled us to produce detailed, comprehensive, data-rich profiles for these countries and draw implications for Africa and the world. The profiles provide much greater granularity than the regional analysis carried out in the *WEO-2014 Special Report*. We draw on these profiles in the analysis and discussion in the chapters that follow, and present the detailed output of our analysis for each country in an easy-to-read graphic format in Chapter 6.

This introduction covers:

- **Context**: Africa's population is growing rapidly. Its economies have the potential to do the same, and their demand for energy is set to grow very fast. Africa is also an important supplier of energy and has seen major recent gas discoveries. At the same time it still faces significant challenges in terms of access to electricity and clean cooking for all.
- **Structure**: This *Special Focus* begins by looking at the energy landscape of Africa today and then moves on to look at a variety of future energy challenges.
- **Focus countries and country profiles**: The report looks at Africa as a whole, but focuses on sub-Saharan Africa, and on the eleven countries selected for detailed country profiles. These profiles reflect modelling capabilities developed for the first time for this report.
- **Scenarios**: We use the Stated Policies Scenario, as elsewhere in the *WEO*, and a new Africa Case developed for this *Special Focus* that reflects Agenda 2063, in which African leaders set out their vision for the future growth and development of the continent.

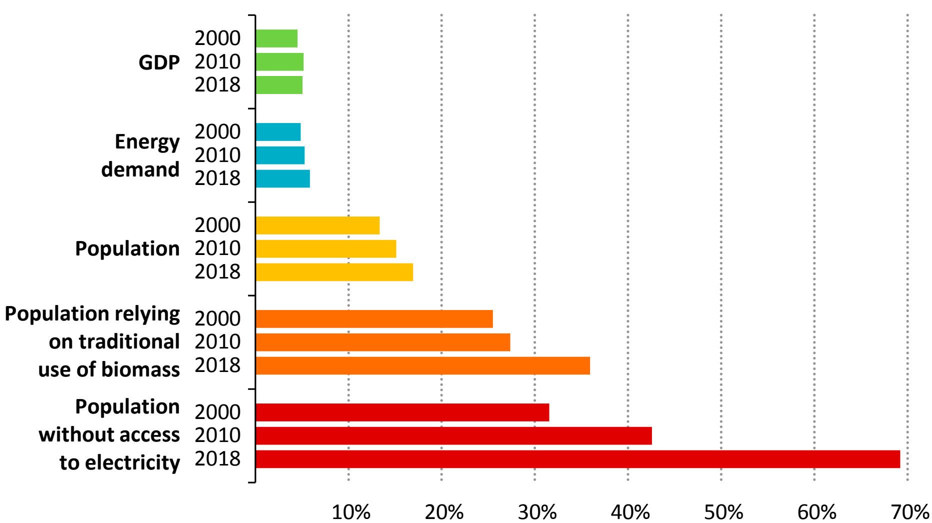
Context

In 2000, Africa's population of around 820 million accounted for about 13% of the world's 6.1 billion people. In 2018, this share had increased to around 17%, as its population expanded at more than twice the global rate. Africa has the world's fastest growing and youngest population. The last two decades have seen the number of people living in cities increase by 90% and this trend continues over the next two decades. By 2040, an additional 580 million Africans will be living in cities, an amount greater than the entire population of the European Union today, and a pace of urbanisation that is unprecedented.

Despite its large and growing population, Africa accounts for a very small share of global energy sector investment. In 2018, around $100 billion was invested in the energy sector in Africa, or about 5.5% of the global total. Of this, $70 billion was invested in fossil fuels and $13 billion in renewables. Another $13 billion was spent on electricity networks.

Africa accounts for a relatively small, but nonetheless growing share of the world's carbon dioxide (CO_2) emissions. In 2010, the continent accounted for 3.3% of global energy-related CO_2 emissions; by 2018 this share had increased to 3.7% or around 1.2 gigatonnes (Gt) CO_2. North Africa accounted for the largest share of the continent's energy-related CO_2 emissions, with 40% or around 490 million tonnes (Mt) CO_2 and South Africa accounted for 35% (420 Mt CO_2).

Figure I.1 ▹ Africa's share of selected global indicators



Africa accounts for a low share of the world's energy demand and a high share of the population without access to modern energy services

Africa is among the regions most exposed to the effects of climate change. Its ecosystems already suffer disproportionately from global climate change and future impacts are expected to be substantial. This will have implications for food security, migration and ultimately development. All African countries signed the Paris Agreement and, through their Nationally Determined Contributions (NDCs), they committed to contribute to the global effort to mitigate GHG emissions (IPCC, 2019). The majority of countries that have already enhanced the ambition stated in their NDCs in 2019 are in Africa.

The continent has made progress on metrics such as economic growth, income per capita, educational attainment, access to clean drinking water, child mortality and life expectancy. While the region is also home to a growing share of the world's energy-poor, new renewable energy technologies, innovative digital technologies and finance tools halted the growth in the number of people without access to electricity in 2013, giving new impetus towards achieving the UN Sustainable Development Goal 7 (access to affordable, reliable and sustainable modern energy for all by 2030). In East Africa, countries such as Kenya, Ethiopia and Uganda have made remarkable progress in providing modern energy services to millions over the past five years. Nonetheless, much remains to be done to deliver universal access to electricity, and in particular to expand access to clean cooking, where progress is being outpaced by population growth.

Africa's vast natural resources mean that low-cost clean energy technologies have plenty of potential. Solar is rightly seen as a huge opportunity for Africa, both at utility-scale and off-grid. Deployment is low today, but it is expanding fast. Recent new utility-scale capacity additions include the first phases of the 1.6 gigawatt (GW) solar photovoltaics (PV) park at Benban in Egypt and the 510 MW Noor solar concentrating solar power development in Morocco, both of which are among the world's largest of their kind. In East Africa, Kenya commissioned the 310 MW Lake Turkana Wind Power plant and the 185 MW Olkaria Geothermal Power Plant, both among Africa's largest in their respective technologies. Large-scale projects have successfully been confirmed in other countries and many more are under way in Angola, Ethiopia, South Africa, Senegal, Uganda and Zambia, among others.

There have been a number of natural gas discoveries, most notably in Mozambique and Tanzania but also in Egypt, Mauritania, Senegal and South Africa. These finds accounted for over 40% of global gas discoveries between 2011 and 2018 and the majority have occurred since our last focus on Africa in 2014 (Box I.1). The possible benefits are many: natural gas can provide the continent with an additional source of electricity for baseload and flexibility needs, it can supply feedstock for industrial growth and bring new export opportunities and revenues; and, when combined with the continent's huge renewable energy potential, gas can offer a new pathway towards the provision of modern energy services for all. In addition, many of the minerals essential to modern energy transitions are found in large quantities in Africa, including uranium and strategic metals and minerals such as cobalt, copper and platinum.

Box I.1 ▷ A retrospective assessment: Africa Energy Outlook 2014

The New Policies Scenario in the *Africa Energy Outlook* (IEA, 2014) provided a set of projections that were based on the policies firmly in place or planned at the time (the same principles that apply to this edition's Stated Policies Scenario). When we look back at those we find:

- Electricity access has progressed more rapidly than projected in 2014, as countries have stepped up their policy efforts in the meantime. A combination of lower cost renewable technologies and new business models helped to facilitate progress. In the case of clean cooking, progress was not as strong as projected in 2014.
- Since 2014, accelerated global deployment has made renewable technologies a much more cost-effective option to support Africa's energy and development objectives. The outlook for natural gas is also affected by new discoveries not just in Mozambique and Tanzania (covered in the 2014 report) but also in Egypt, Mauritania and Senegal and South Africa.
- Another consideration is energy prices. The 2014 report was written at a time when oil prices were relatively high and the focus of the analysis was on responsible and transparent management of revenues. Since then, the net income from oil and gas production has been very volatile, with the impacts of low fossil fuel prices amplified by domestic challenges in major producer economies. The combined net income from oil and gas production of the top-ten producing countries in Africa declined by 70% between 2014 and 2016.

Structure

The first part of this *Special Focus on Africa*, Chapter 1, analyses the changing dynamics and energy landscape of Africa today. It sets out the existing economic and demographic architecture, the continent's key energy demand and supply trends, the scale of its energy resources and assesses the factors that are likely to influence the future energy landscape.

The second part, consisting of three chapters, seeks to capture a sense of the continent's diversity by exploring in detail a number of themes, which touch on some of the most fundamental energy challenges facing sub-Saharan Africa. These include the outlook for energy demand, with a focus on urbanisation, industrialisation and access to clean cooking (Chapter 2); access to electricity and reliable power together with investment and financing for power supply (Chapter 3); and natural gas and resource management (Chapter 4). Woven through these themes are insights on gender and other forms of social inequality, which present major impediments for optimising economic and human development in African countries.

Chapter 5 sets out the implications for Africa and the global energy sector of the analysis contained in the preceding chapters. Chapter 6 presents a comprehensive profile of the energy sector not only in sub-Saharan Africa but in each of our eleven focus countries.

These profiles provide a snapshot of the energy sector in each and help identify not only the challenges ahead but also highlight the huge potential of the continent's plentiful natural resources.

Focus countries and country profiles

This special report covers Africa as a whole, but much of the detailed analysis and discussion focusses on sub-Saharan Africa and on the eleven countries highlighted in our country profiles: Angola, Côte d'Ivoire, Democratic Republic of the Congo (DR Congo), Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania. These eleven sub-Saharan countries are a diverse group: some are among the world's fastest growing economies while others are among the poorest in the world. Together, they represent three-quarters of sub-Saharan Africa's 2018 gross domestic product (GDP) and energy demand, and two-thirds of population. They also account for the majority of Africans without access to modern energy services. They are also home to a large share of the continent's abundant energy and mineral resources, with the potential not only to transform Africa, but also to make a substantial contribution to the world's energy transitions.

For the purpose of this *Special Focus*, North Africa, South Africa, ten additional sub-Saharan countries and the rest of sub-Saharan Africa have been modelled separately. Each of these countries and groupings was assessed on the basis of a number of factors including: demographics (population, urban population, age profile); economy (size and structure of the economy, GDP per capita, level of foreign direct investment, transport infrastructure); key energy indicators (total final energy consumption, energy consumed by end-use, consumption of energy per capita), scale of power sector (installed generation capacity, renewable energy capacity and potential, level of electricity exports and trade); the level of access to both electricity and clean cooking; fossil fuel resources; and the full range of energy and environment policies and strategies. For ten African countries (except South Africa), this led to the development of detailed modelling capabilities for these countries for the first time.

Understanding the scenarios

This *Special Focus* provides a framework for analysing the outlook for Africa's energy sector, particularly sub-Saharan Africa. It sets out what the future could look like based on different scenarios or pathways, with the aim of providing insights to inform decision making by governments, companies and others concerned with energy. The two scenarios assessed in this *Special Focus* are:

The **Stated Policies Scenario** provides a measured assessment of where today's policy frameworks and announced policies, together with the continued evolution of known technologies, might take the energy sector in sub-Saharan Africa in the coming decades. Given that announced policies are by definition not yet fully reflected in legislation or regulation, the prospects and timing for their full realisation are based upon our assessment of the relevant political, regulatory, market, infrastructural and financial constraints. This scenario does not focus on achieving any particular outcome: it simply looks forward on the basis of announced policy ambitions in various sectors.

The **Africa Case** is built on the premise of Agenda 2063 (Box I.2), and takes into account each country's own vision for economic growth, based on regional economic blueprints and typically incorporating an accelerated industrial expansion. Enhanced economic growth also increases the means to achieve the ambitions included in energy master plans and other policy announcements, so these are more fully realised than in the Stated Policies Scenario (Table I.1). The Africa Case also incorporates key sustainable development goals by 2030, including achieving full electricity and clean cooking access as well as significant reductions in pollution-related premature deaths. As a tangible representation of the Agenda 2063 vision, it presents a pathway to attain inclusive and sustainable economic growth and development.

Box I.2 ⊳ Agenda 2063: the future that Africa wants

In 2015, the Heads of State and Governments of the African Union adopted *Agenda 2063*. It sets out a vision for "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena". Closely linked to the United Nations Sustainable Development Goals, it is an ambitious vision and one which will require significant political will if its goals are to be realised.

Agenda 2063 builds on previous Pan-African initiatives, but is distinct in many respects: it sets out clear goals, implementation plans and targets alongside elements of accountability; it identifies key flagship programmes as well as monitoring and review mechanisms; and it proposes a clear resource mobilisation strategy. Successful delivery of Agenda 2063 is likely to depend on good governance, transparency and effective intra-African co-ordination, among other things. It will also depend on resources being available to implement it and in particular on the mobilisation of private sector resources.

Agenda 2063 emphasises the implementation of the Grand Inga Dam Project as a key development priority and a means to support regional power pools and help transform the continent from traditional to modern sources of energy. Energy-related targets contained in the framework for the first ten years include increasing access to electricity by at least 50% compared to 2013 levels and increasing the efficiency of household energy use by at least 30% before 2023.

The Africa Case sees an annual average rate of growth in gross domestic product (GDP) of 6% across sub-Saharan Africa, significantly higher than the 4.3% assumed in the Stated Policies Scenario. The population assumptions are held constant across the two scenarios (Table I.2); these are based on the medium variant of the United Nations population projections.

Table I.1 ▷ Real GDP growth assumptions by scenario
(compound average annual growth rate)

Country/Region	2000-2018	2018-2040	
		Stated Policies Scenario	Africa Case
North Africa	3.5%	3.6%	4.8%
South Africa	2.7%	2.5%	3.3%
Other sub-Saharan Africa	5.4%	5.0%	7.3%
Angola	5.8%	3.3%	5.3%
DR Congo	5.3%	5.5%	8.7%
Côte d'Ivoire	3.6%	5.3%	7.9%
Ethiopia	9.0%	6.5%	8.9%
Ghana	6.3%	3.9%	6.3%
Kenya	4.8%	5.9%	9.0%
Mozambique	7.1%	6.0%	8.1%
Nigeria	6.3%	3.4%	5.3%
Senegal	4.6%	6.5%	8.7%
Tanzania	6.5%	5.6%	9.3%
Africa	**4.3%**	**4.3%**	**6.1%**

Note: GDP in PPP terms, $2018.

Table I.2 ▷ Population assumptions

	Total population (million)		2018-2040	
	2018	2040	Delta (million)	CAAGR*
North Africa	196	263	67	1.3%
South Africa	57	71	14	1.0%
Other sub-Saharan Africa	1 034	1 761	728	2.5%
Nigeria	196	329	133	2.4%
Ethiopia	108	173	65	2.2%
DR Congo	84	156	72	2.8%
Tanzania	59	108	49	2.8%
Kenya	51	79	28	2.0%
Angola	31	60	29	3.1%
Mozambique	31	55	24	2.7%
Ghana	29	44	15	1.9%
Côte d'Ivoire	25	42	17	2.4%
Senegal	16	28	12	2.5%
Africa	**1 287**	**2 095**	**808**	**2.2%**

* CAAGR = compound average annual growth rate.

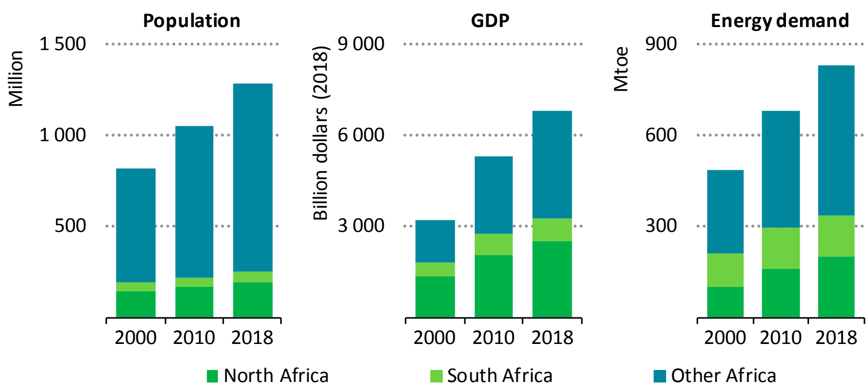
Africa today

Viewing Africa through a new lens?

S U M M A R Y

- The pace of change in Africa's energy sector has quickened, imparting to the continent a growing sense of confidence despite many setbacks. Africa's economy is also on an upward trajectory, with gross domestic product (GDP) likely to rise by around 4% this year. East Africa looks to be the fastest-expanding region today, led by Rwanda, Ethiopia, Kenya, and Tanzania. The way in which the energy sector develops will have a crucial influence on Africa's future.

Figure 1.1 ▷ Selected indicators for Africa, 2000, 2010, 2018



Africa's urban population is expanding fast while energy services and GDP struggle to keep pace

Note: GDP = Gross domestic product in PPP terms, $2018.

- The number of people gaining access to electricity in Africa doubled from 9 million a year between 2000 and 2013 to 20 million people between 2014 and 2018, outpacing population growth. As a result, the number of people without access to electricity, which peaked at 610 million in 2013, declined slowly to around 595 million in 2018. Recent progress has been led by Kenya, Ethiopia and Tanzania, which accounted for more than 50% of those gaining access. However, sub-Saharan Africa's electrification rate of 45% in 2018 remains very low compared with other parts of the world.

- Since 2015, only seven million people have gained access to clean cooking in sub-Saharan Africa, meaning that the number of people without access increased to over 900 million in 2018 as population growth outpaced provision efforts. Progress has been strongest in parts of West Africa such as Côte d'Ivoire and Ghana which have promoted liquefied petroleum gas (LPG). However, the problem remains acute and Sub-Saharan Africa is one of the only regions worldwide where the number of people without access to clean cooking continues to increase.

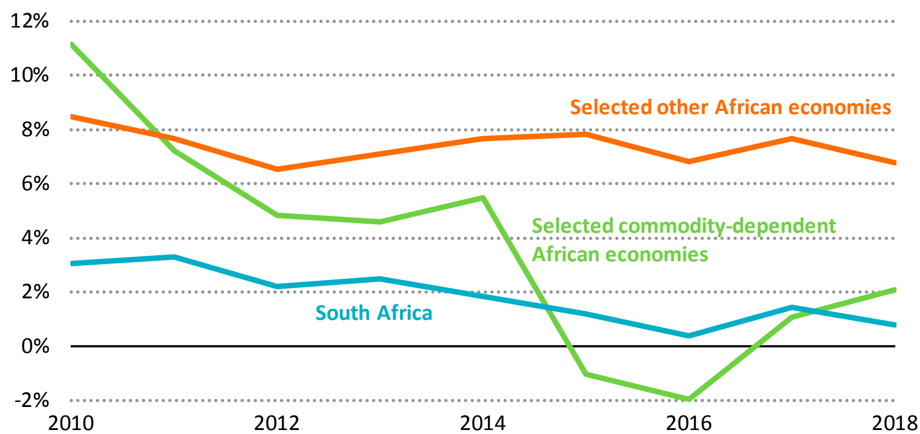
- Energy demand in Africa has been driven by the growing needs of North Africa, Nigeria and South Africa. There are also very strong regional variations. Countries such as Democratic Republic of the Congo (DR Congo), Africa's fourth most populous country, and Mozambique have seen their primary energy demand increase by over 50% between 2010 to 2018, whereas others such as Côte d'Ivoire and Ghana have witnessed only a gradual increase in energy demand (or even a decline).
- With a fifth of the world's population, Africa accounts for only 6% of global energy demand and little more than 3% of electricity demand. Average energy consumption per capita in most African countries is well below the world average and largely comparable to that of India. Bioenergy is the largest source of energy in Africa today, meeting 45% of primary energy demand and over half of final energy consumption.
- Africa has plentiful renewable energy resources and its economic potential is substantially larger than the current and projected power consumption of the continent. Bioenergy, hydropower, solar and wind power account for the bulk of the resources. East Africa also has rich geothermal resources. To date, limited use has been made of this vast potential: Africa has only 50 gigawatts (GW) of renewable capacity, mostly hydropower (36 GW). But this is changing: utility-scale projects have entered service in Egypt, Ethiopia, Kenya, Morocco and South Africa. Meanwhile, mini-grids, micro-grids and solar home systems are anchoring efforts to bring modern energy services and new sources of productive employment to remote populations, facilitated by digital technologies and payment tools.
- The future of natural gas in Africa is at an important juncture. Since 2010, there have been major gas discoveries in every part of the continent: immense finds in East Africa (Mozambique and Tanzania) were followed by more in Egypt, West Africa (Mauritania and Senegal) and South Africa. While Africa accounts for 6% of global gas production today, over 40% of global gas discoveries between 2011 and 2018 were in Africa. These resources offer new opportunities for Africa's energy and industrial development. The prospects for gas, however, hinge upon well-articulated strategies to bring the discoveries into production and build infrastructure to deliver gas to consumers at competitive prices.
- Africa is home to many of the minerals essential to the energy industry, for example, DR Congo accounts for almost two-thirds of global cobalt production. The continent also produces a large share of key minerals such as platinum (cars and fuel cells), chromium (wind turbines) and manganese (batteries), which will play a major role in powering the global energy transitions.

1.1 Context

1.1.1 Economic growth and industrialisation

Africa has experienced relatively low gross domestic product (GDP) growth since 2010, an average of 3.1% per year compared with a global average of 3.5% per year. GDP per capita in the continent is less than a third of the global average and in sub-Saharan Africa as low as a fifth of the global average. Two countries, Nigeria (17%) and South Africa (12%) account for a large portion of Africa's economic activity. Recent growth in some countries has been significantly influenced by their dependence on commodities. The greater this reliance, the more severe the impact of the 2014 commodity price decline; and the greater the fall, the more challenging the recovery (Figure 1.2). While countries such as Ethiopia, Kenya and Rwanda have successfully boosted growth through public investment and a growing services sector (AUC/OECD, 2018), Nigeria is only slowly pulling out of the recession that was triggered by a combination of lower oil prices and production outages associated with conflict (IEA, 2018a).

Figure 1.2 ▷ Annual GDP growth rates in selected African economies



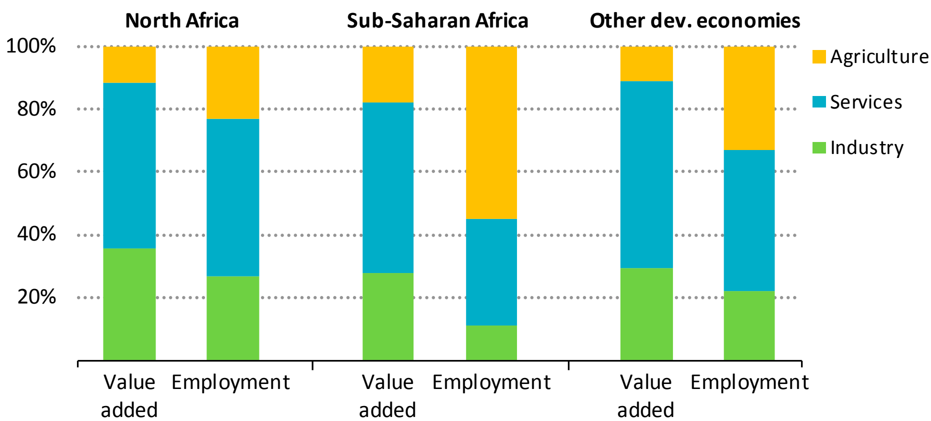
Commodity-dependent economies in sub-Saharan Africa have yet to recover fully from the commodity price fall in 2014

Note: Selected commodity-dependent economies are Algeria, Angola and Nigeria; Selected other African economies are Ethiopia, Kenya, Rwanda and Senegal.

Despite this, the overall sub-Saharan economy has expanded by more than one-third since 2010, reaching more than $4.3 trillion in 2018. Growth in Nigeria and South Africa has slowed, but GDP elsewhere is now growing at the fastest pace since 2013. GDP growth for the continent as a whole is forecast to accelerate to 4% in 2019, up from an estimated 3.3% in 2018, making it the second fastest-growing region in the world, after Asia. Some countries are growing much faster than this average. In Ghana for example, the International Monetary Fund estimates that GDP will rise by almost 9% in 2019, double the pace of emerging economies as a whole, and well ahead of world growth (IMF, 2019). Ethiopia, Côte d'Ivoire, Rwanda, Senegal and Tanzania all feature on the African Development Bank Group's list of the ten fastest-growing economies for 2018 (AfDB, 2019). Foreign direct investment (FDI) into Africa rose by 11% to $46 billion in 2018, reversing declines in 2016 and 2017 while FDI into sub-Saharan Africa increased by 13% to $32 billion (UNCTAD, 2019).

North Africa and South Africa are relatively industrialised, but other sub-Saharan African countries represent only a small share of global industrial production, and industry is hampered in many countries by unreliable electricity supply and high energy costs. The contribution of different sectors to GDP and employment varies significantly between individual economies, but for sub-Saharan Africa as a whole the relatively low share of employment in industrial sectors stands out. By contrast, services contribute 55% to the economy and a third of employment, while agriculture accounts for only 18% of GDP but well over half of employment (Figure 1.3).

Figure 1.3 ▷ Shares of value added and employment by sector in North Africa and sub-Saharan Africa, 2018



Agriculture accounts for a very large share of employment in sub-Saharan Africa even when compared to other developing economies

Incomes and personal wealth vary greatly across Africa, but sub-Saharan Africa is home to some of the world's poorest people. While global poverty rates have been reduced by more than half since 2000, and good progress is being made in many African countries such as DR Congo, Ethiopia and Nigeria, more than 40% of the population in sub-Saharan Africa continues to live below the poverty line on an income of less than $1.90 a day (UN, 2019a). Sub-Saharan Africa also remains one of the most unequal regions in the world. Half of the twenty most unequal countries in the world (measured by the Gini co-efficient) are in sub-Saharan Africa (UNDP, 2017). Average per capita incomes across sub-Saharan Africa range from over $10 000 in Mauritius and South Africa to less than $500 in the Central

African Republic, Madagascar and Niger. In 2018, average per capita GDP in sub-Saharan Africa was around $4 000 ($2018 at power purchasing parity) compared to about $3 700 in 2010. This represents an average annual increase of around 1% a year over the period. This compares with an average annual GDP per capita increase of 2.3% worldwide and 5.5% in developing Asia over the same period. The small size of the annual increase of per capita GDP in sub-Saharan Africa may seem hard to square with its faster GDP growth rate: the reason for the difference is that the population of sub-Saharan Africa grew rapidly over the period.

1.1.2 Demographics and urbanisation

In 2000, Africa's population of 817 million accounted for just over 13% of the world's 6.1 billion people. By 2018, this share had increased to around 17%, as Africa's population expanded at more than twice the global rate to reach almost 1.3 billion, of which almost 85% or 1.1 billion live in sub-Saharan Africa. Eleven countries account for almost two-thirds of sub-Saharan Africa's population today (Figure 1.4). The average age of the population of Africa is very young: in 2017, the median age was 17 while children under age 15 accounted for 41% of the population and 42% of the population of sub-Saharan Africa (UNDESA, 2019).

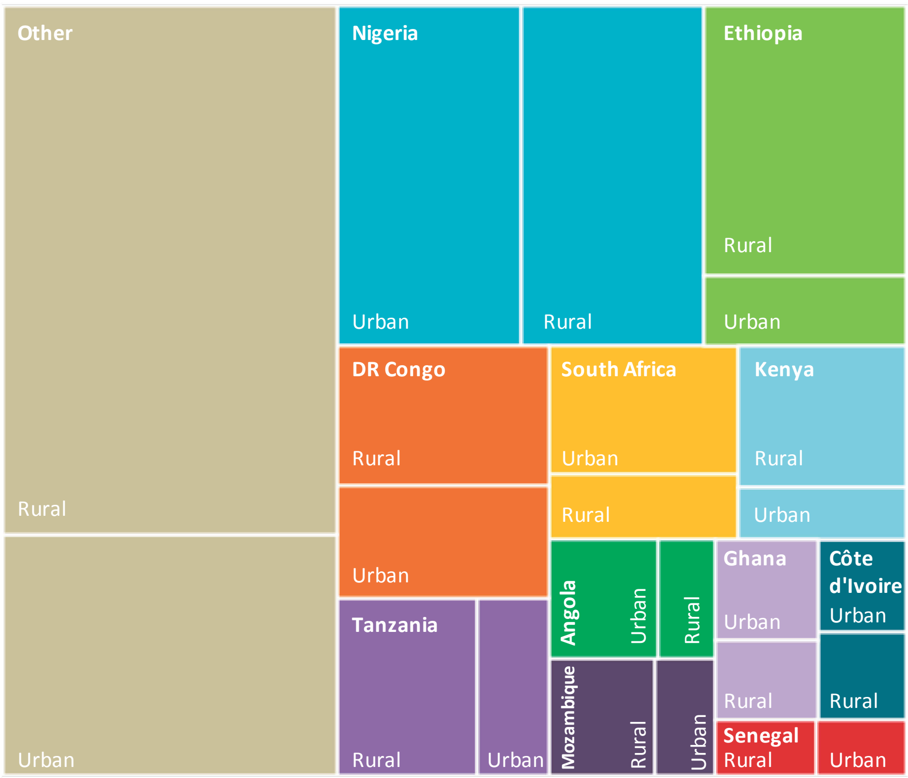
Almost 60% of Africa's population lives in rural areas although an increasing share is moving to the expanding urban areas. Africa already has two megacities in sub-Saharan Africa (Kinshasa and Lagos) and another in North Africa (Cairo). There are another five large cities on the continent with a population of between five and ten million each: Alexandria, Dar es Salaam, Johannesburg, Khartoum and Luanda (UNDESA, 2018).[1] Of these, Dar es Salaam and Luanda are likely to become sub-Saharan Africa's next megacities. The implications of an increasingly urban population for the energy sector are profound. In general, urban residents tend to consume more energy than those in rural areas, in large part because of differences in income levels. Smart urban planning and sustainable development offer a huge opportunity to shape patterns of future energy use. However, there are also likely to be major challenges arising from further strains on air quality, housing, transport, public utilities and sanitation (see Chapter 3).

The gender equality landscape in African countries is complex and sometimes contradictory, presenting both challenges and opportunities for the future. Nearly one-in-four households in Africa are headed by a woman: those in Southern Africa are most likely to be headed by a woman, while households in West African countries are least likely to be headed by a woman (Van de Valle, 2015). The percentage of women elected to parliament in many African countries, (e.g. Rwanda, Namibia, South Africa and Senegal) is among the highest in the world (IPU, 2019). Countries such as Mauritius, Seychelles and South Africa have female literacy rates on par with or exceeding those in many developing and emerging

[1] Large cities are generally defined as having between five and ten million inhabitants and megacities as having ten million or more inhabitants.

economies. Conversely, sub-Saharan Africa contains nine of the ten countries with the lowest levels of female literacy in the world. The complicated gender terrain in sub-Saharan Africa, evidenced by the existence of high levels of disparity between different groups of women as well as between regions and countries, has important implications for access to energy and for socio-economic development.

Figure 1.4 ▻ Share of urban/rural population in sub-Saharan Africa, 2018

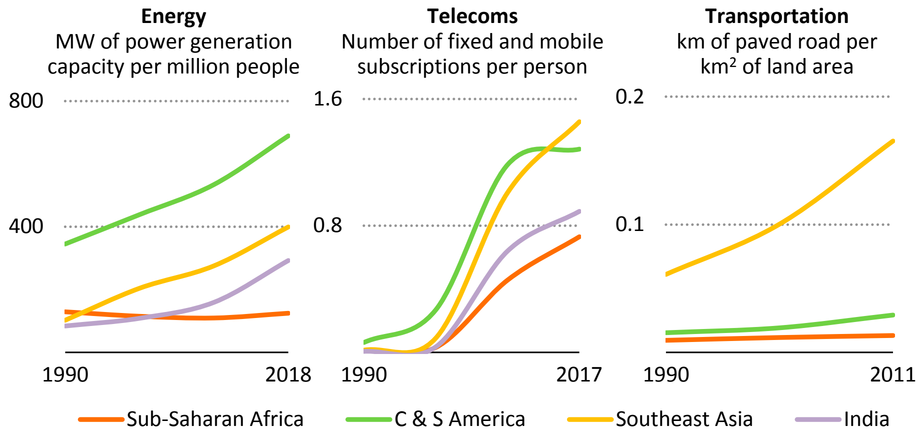


Eleven countries account for almost two-thirds of sub-Saharan Africa's 1.1 billion people today

1.1.3 Infrastructure and investment

Infrastructure is an essential building block for economic development and quality of life, but Africa, especially sub-Saharan Africa, lags behind other developing economies in virtually all aspects of infrastructure quality. Over the past three decades, the level of per capita power generation capacity in sub-Saharan Africa has remained flat, whereas in India and Southeast Asia (which had less generation capacity per capita than sub-Saharan Africa in 1990) it has grown fourfold. Sub-Saharan Africa has made relatively good progress on telecommunications infrastructure, but still compares unfavourably with other developing economies. Paved road network density has remained unchanged over the past three decades despite the growth in population and trade, owing mainly to continued under-investment in road expansion, maintenance and rehabilitation (Figure 1.5).

Figure 1.5 ▷ Infrastructure quality developments in selected regions



Slow infrastructure development in sub-Saharan Africa shows a stark contrast with progress in other developing economies

Note: C&S America = Central and South America; MW = megawatt.

Sources: International Telecommunications Union Statistics; World Bank World Development Indicators Database.

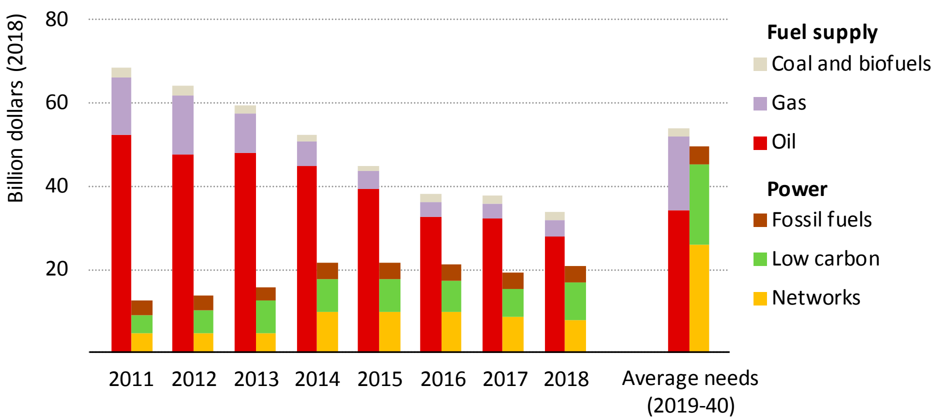
Making up the deficit of energy infrastructure in Africa will require a massive ramp-up in investment, but actual spending trends have been moving in the opposite direction. Energy supply investment in sub-Saharan Africa has dropped by over 30% since 2011[2], and oil and gas investments have more than halved because of low oil prices and investor concerns about regulation and security in major producing countries. Power supply investment registered strong growth until 2014, but has since stalled. The one bright spot has been rising investment in solar photovoltaics (PV), which is set to surpass that in hydropower for the first time in 2019, according to early data. Nonetheless, levels of spending still fall significantly short of what would be needed in the Stated Policies Scenario, particularly in the power sector (Figure 1.6).

Attracting capital for oil and gas projects in sub-Saharan Africa has generally been hampered by uncertainties around fiscal and regulatory frameworks - the design of local content rules has been a particular source of contention (Box 1.1). Moreover, difficulties in reaching agreement on contractual terms have often led to reliance in practice on a

[2] Energy supply investment includes capital spent on building infrastructure for fuel supply (extraction, processing and transportation of oil, gas, coal and biofuel) and power supply (generation, networks and storage).

handful of large companies that have the capacity to bear the risks. As a result, investment in oil and gas in sub-Saharan Africa has largely been driven by international oil companies. This contrasts with the prevailing trend in many other resource-rich countries where domestic companies, and in particular national oil companies (NOCs) take the lead. In those cases where sub-Saharan countries have established a NOC, they have generally not been effective in accelerating resource developments in the country due to their limited financial capacity and lack of technical expertise in handling complex projects (see Chapter 4). The lack of a competitive service industry is another constraint that has weighed on development costs. The limited attractiveness of the domestic market also means that most spending in oil and gas has been directed at export-oriented projects (e.g. upstream and liquefied natural gas) rather than projects geared towards domestic markets (e.g. gas pipeline, refineries).

Figure 1.6 ▷ Historical energy supply investment and average by sector in sub-Saharan Africa in the Stated Policies Scenario



Investments in fuel supply would need to increase by 60% from today's levels to meet needs; investments in power would need to grow by two-and-a-half times through to 2040

Investment in power infrastructure in sub-Saharan Africa has mainly been financed by state budgets with substantial contributions from international donors. Public and international development finance collectively accounted for over 90% of the capital committed to power infrastructure in 2017 (ICA, 2017). While public sources of finance have an important role to play, they are unlikely to be sufficient to address the significant investment gaps that exist, and need to be supplemented by private sector financing. Africa has so far had limited success in mobilising private finance. Between 2013 and the first-half of 2018, power sector investment based on private participation in infrastructure (PPI) models in sub-Saharan Africa amounted to around $4.5 billion per year on average, less than 10% of the annual needs between today and 2040. Most of the region's PPI investment has gone to a handful of countries with South Africa alone accounting for more than half.

Ultimately whether projects can attract financing depends on whether developers and investors believe that they will deliver adequate returns and the timely repayment of debt to lenders. This requires a sound investment framework (e.g. tariff schemes, institutional and regulatory structures) as well as a robust contracting framework (e.g. offtake agreements and financing structures) to manage risks around future cash flows (see Chapter 3). The role of public and development finance is also important: these sources can not only provide necessary capital, but also encourage private sector investment through targeted interventions such as risk sharing, liquidity support and take-out financing. Outside South Africa, public and development finance has not been very effective in catalysing private capital, suggesting that much more needs to be done to plug the investment gaps in power and energy infrastructure (see Chapter 5).

Box 1.1 ▷ Governance and policy frameworks

Good governance is closely correlated with faster growth, higher investment and faster poverty reduction. The World Bank Governance Indicators show that there was little to no progress in institutional quality across sub-Saharan Africa from 2000 to 2015 (World Bank, 2018). Progress was however recorded in many countries on perceived corruption. Côte d'Ivoire and Senegal, for example, are among the countries that improved their position on the Corruption Perceptions Index while, Angola, Nigeria, Botswana, South Africa and Kenya all displayed some promising developments (Transparency International, 2019).

Stable and effective governance and regulatory frameworks are crucial for increasing competition and attracting investments in the energy sector, and weak governance and regulatory frameworks at national and sub-national levels continue to impede performance in the energy sector. A key issue is the need for transparent and responsible management of hydrocarbon revenues (discussed in more detail in Chapter 4).

1.2 Access to modern energy

Access to modern energy is a central pillar of efforts to reduce poverty and support economic growth in sub-Saharan Africa. Modern household energy services have two components: first, access to clean cooking facilities, where progress remains slow, with around 900 million people without access today; second, access to electricity, where there has been strong progress in several countries over the past decade but almost 600 million people in sub-Saharan Africa remain without access today (Box 1.2). Beyond households, gaining access to modern energy services is also essential for businesses, farmers and community buildings.

Box 1.2 ⊳ Defining and tracking household energy access

The IEA defines a household as having energy access when it has reliable and affordable access to both clean cooking facilities and electricity, which is enough to supply a basic bundle of energy services initially, and with the level of service capable of growing over time (IEA, 2019a).[3] We consider that this basic bundle of electricity services should encompass, at a minimum, several lightbulbs, phone charging, a radio and potentially a fan or television. Access to clean cooking facilities means access to (and primary use of) modern fuels and technologies, including natural gas, liquefied petroleum gas (LPG), electricity, bioethanol and biogas, or improved biomass cookstoves which deliver significant improvements[4] compared with basic biomass cookstoves and three-stone fires traditionally used in some developing countries. This definition of energy access serves as a benchmark to measure progress towards Sustainable Development Goal (SDG) 7.1 and as a benchmark for our forward-looking analysis.

The *World Energy Outlook (WEO)* electricity and clean cooking access databases are updated annually. They contain the most recent country-level data on the share of national, urban and rural households with electricity and clean cooking access for the 2000-18 period. The Access to Electricity Database sources data, where possible, from government-reported values for household electrification.[5] It takes into account connections to the main grid, and where available access through decentralised systems able to supply the basic energy services mentioned above. Despite their development benefits, "pico solar" products, mainly solar lanterns which may include mobile phone chargers, are considered to be below the minimum threshold to count as having access.

Access to electricity is considered to be binary (a household either has or does not have access) as the availability and quality of reported data limits the capacity to describe the level of service, reliability and affordability.[6] Within these limits, this *Special Focus*

[3] A full description of the *World Energy Outlook* energy access methodology can be found at www.iea.org/energyaccess/methodology.

[4] Most improved cookstoves currently in use have not been found to significantly improve household air pollution and thus are not considered as access to clean cooking. For our projections, only the most improved biomass cookstoves that deliver significant improvements are considered as contributing to energy access.

[5] The IEA Electricity Access Database, based on administrative data reported by ministries, differs from the World Bank Global Electrification Database, which derives estimates from household surveys. The IEA administrative data on electrification provides information from the perspective of supply-side data on utility connections and decentralised systems distributions, which in particular have the advantage of being updated annually. More information on the differences between databases can be found in the *Tracking SDG 7 Report*, which the IEA chaired in 2019, as one of the United Nations-appointed co-custodians of SDG 7 (IEA, IRENA, UNSD, WB, WHO, 2019).

[6] The World Bank's Energy Sector Management Assistance Program is undertaking surveys in several countries to measure energy access according to the "Multi-Tier Framework", a methodology that measures multiple attributes of the supply and use of electricity and cooking fuels; this initiative is helpful to map the current levels of access to affordable, reliable and modern energy, though assessment difficulties are likely to remain on a large scale.

integrates comprehensive analyses on the reliability of power systems, the level of energy demand from households, and the affordability of energy services, which are all important in ensuring that access to modern energy services delivers social and economic benefits (see section 1.3.3, and Chapters 2 and 3).

The Access to Clean Cooking Database comes from IEA analysis based on the Household Energy Database 2018, collected by the World Health Organization, which compiles data on reliance on primary cooking fuels at urban and rural level using national surveys. This is complemented by IEA's *World Energy Balances*, which contain data on residential energy consumption, as well as government sources of data.

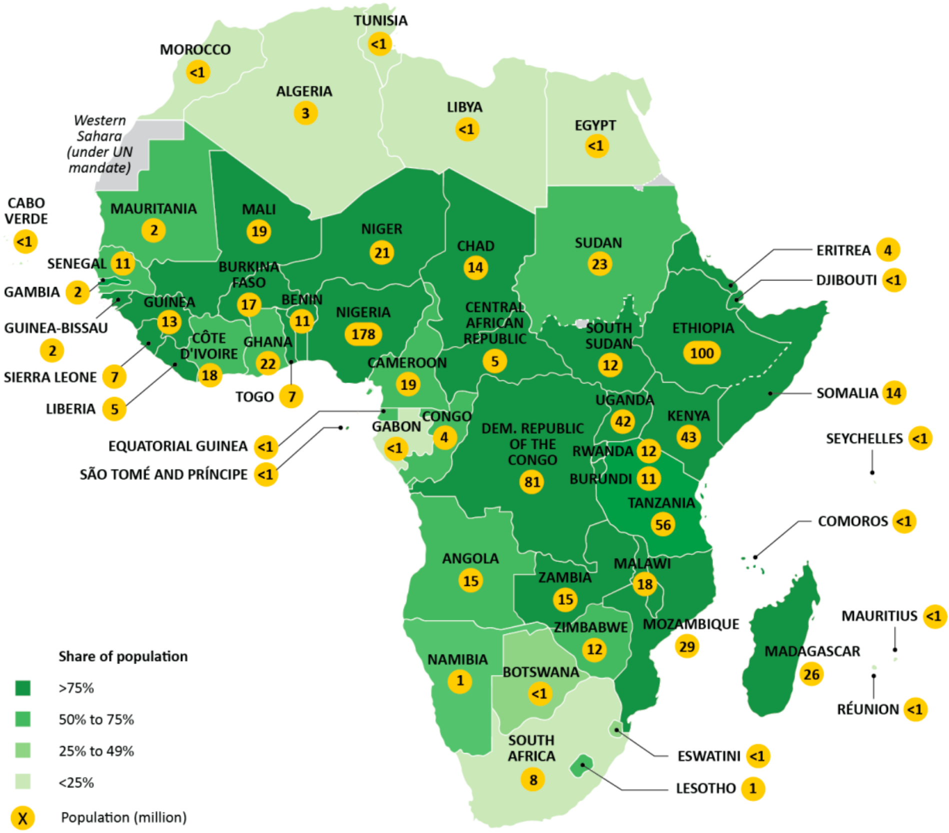
1.2.1 Clean cooking

Lack of access to clean cooking remains very acute in sub-Saharan Africa with access increasing only slightly from 15% in 2015 to 17% in 2018 (Figure 1.7). Progress has been registered in a handful of countries: West Africa has made the fastest progress since 2010, with almost 3 million people gaining access each year, followed by East Africa with nearly 1.5 million people per year. The number of people without access exceeded 900 million in 2018 as population growth outpaced efforts to provide access. Sub-Saharan Africa is the only region where the number of those without access continues to rise significantly, highlighting the urgent need for action. Almost 500 000 premature deaths per year are related to household air pollution from the lack of access to clean cooking facilities, with women and children the worst affected. Lack of access to clean fuels is also one of the most significant contributors in low-income countries to women's workloads, and poses a barrier to the economic advancement of women. It leads to women collecting and carrying loads of wood that weigh as much as 25-50 kilogrammes, which can also damage their health (UNEP, 2017).

Forest degradation, sometimes leading to deforestation, is another serious consequence of the unsustainable harvesting of fuelwood, mainly driven by inefficient charcoal production for cities (see Chapter 2). The forest area per capita in the sub-Saharan African region, a rough proxy for biomass potential available for consumption, is declining at an annual average rate of about 3%, almost double the rate seen in other developing regions. Biomass consumption outstrips the sustainable potential by the largest margin in Nigeria and Kenya. It is estimated that 27-34% of wood-fuel harvesting in tropical regions is unsustainable (FAO, 2018). Deforestation and the resultant shortage of fuel affect millions of people, especially women and children, who bear most of the responsibility for gathering firewood and cooking.

The shares of cooking fuels in sub-Saharan Africa (excluding South Africa) have remained relatively stable in recent years (Figure 1.8). Solid biomass – including fuelwood, charcoal and dung – is the most widely used fuel across the region (Box 1.3). Several governments, including Ghana, Cameroon and Kenya, are promoting LPG as a better alternative, largely in

Figure 1.7 ⊳ Population without access to clean cooking in Africa, 2018



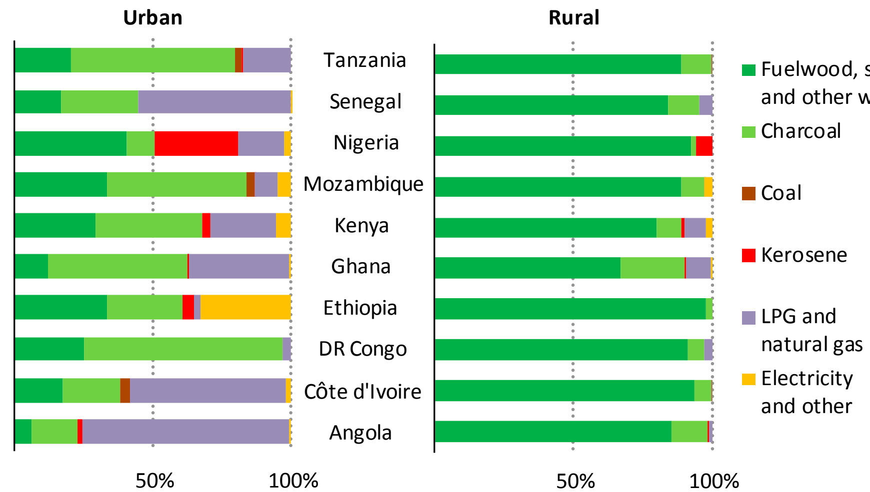
Around 900 million people are without access to clean cooking in Africa; in 32 countries more than 75% of the population is without access to clean cooking

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Sources: IEA analysis; World Health Organization (WHO) Household Energy Database.

urban areas. Ghana has been promoting LPG since 1989 and 24% of the population relied on LPG in 2018; as of December 2017, the government had distributed LPG cookstoves to 150 000 households in 108 districts under the LPG Promotion Programme launched in 2017. It intends to distribute them in all 217 districts of Ghana by 2020 (Asante, et al., 2018). In other countries, for example Nigeria, LPG uptake primarily displaces kerosene. Clean cooking has only increased by 0.7 percentage point since 2013 in rural sub-Saharan Africa, in part because supply chains for cleaner fuels lack the necessary scale to reach many rural communities.

Figure 1.8 ▷ Main fuels used by households for cooking, 2018



Use of clean cooking fuels such as LPG continues to increase in urban areas, but reliance on traditional use of biomass still dominates in rural areas

Sources: IEA analysis; WHO Household Energy Database.

Box 1.3 ▷ Traditional and modern uses of biomass

The various forms of bioenergy differ in terms of sustainability. Bioenergy feedstocks include different products and by-products from the agriculture, forestry and waste sectors (e.g. wood, charcoal, sugarcane, palm oil, animal waste) and there are many ways to use them to produce energy (heat, electricity and fuels).

In Africa, as well as developing Asia, solid biomass remains the largest source of energy used by households (in energy-equivalent terms) and is often burned as fuel in a traditional manner in inefficient and polluting cookstoves, using very basic technologies often with no chimney or one that operates poorly. This so-called "traditional use" of solid biomass is not sustainable and is associated with a range of damaging impacts to health and well-being. The volumes concerned are generally excluded when presenting shares of energy from renewable sources.

Solid biomass can also be used for cooking and heating in more advanced, efficient and less polluting stoves. It can likewise be used as a fuel in combined heat and power plants or transformed into processed solid biomass (pellets), liquid biofuels or biogas. These are classified as modern uses of bioenergy.

Bioenergy has the potential to contribute to the decarbonisation of the power, heat and transport sectors, bringing wider benefits in terms of rural development and diversification of energy supply. There are a number of potential concerns regarding sustainability that have to be considered when planning to use biomass, however, including deforestation, loss of biodiversity, lifecycle greenhouse-gas (GHG) emissions, land-use changes and air pollution linked to combustion. It is thus important that the potential benefits of using bioenergy are balanced against the sustainability considerations that are unique to each bioenergy supply chain application (see Chapter 2).

Several programmes support the diffusion of improved biomass cookstoves. Nonetheless, extensive analysis conducted by the IEA for *Energy Access Outlook 2017*, in collaboration with the International Institute for Applied Systems Analysis, showed that such programmes had limited success (IEA, 2017a). Improvements in pollutant levels from improved biomass cookstoves were often overstated, with virtually no biomass cookstoves on the market meeting WHO standards for exposure to household air pollution.

Conversely, while their reach has been limited to date, alternative biomass-based cooking fuels (such as bioethanol, biomass pellets, briquettes and biogas) are increasingly considered as viable alternatives to the unsustainable use of biomass. Where infrastructure and production can be efficiently developed, bioethanol in particular could prove to be not only safer but also cheaper than charcoal or kerosene. KOKO Networks, a company that focuses on promoting liquid bioethanol as a clean cooking fuel, recently launched 700 distribution points across Nairobi following a successful pilot project. Government support however will be essential to support production and distribution in many areas, especially in rural areas. In Ethiopia, for example, following initiatives such as Project Gaia, the government developed a National Biofuels Policy; promoting ethanol both for stoves and for blending with gasoline as a transport fuel, and production of ethanol now stands at around 40 million litres per year.

Very efficient electric cooking solutions are meanwhile increasing the attractiveness of electric cooking options (Couture and Jacobs, 2019). Increasing the efficiency of electric cooking could help merge initiatives on access to electricity and clean cooking by facilitating the integration of very efficient cooking appliances such as pressure- and slow-cookers in decentralised electric systems.

While clean cooking fuels and technologies are now more available, consumer awareness, accessibility and affordability remain significant challenges. The provision of clean cooking solutions does not guarantee that rural and urban communities will stop using traditional cooking methods. In Kenya, while only 26% of households said that charcoal was their primary cooking fuel, almost 70% were using it some of the time (Dalberg, 2018); and in an experiment testing several improved biomass cookstoves solutions some rural Kenyan households said that, although many of the proposed cookstoves allowed faster and more efficient cooking, they were much less flexible and adapted to their needs than traditional three-stone fireplaces (Pilishvili et al., 2016). Many poor and rural recipients of clean cookstove programmes thus continue to use traditional fuels and solutions for socio-cultural, economic and pragmatic reasons. Programmes to replace traditional but unsustainable fuel use are likely to succeed only if they are able to take account of these barriers to adoption in their design.

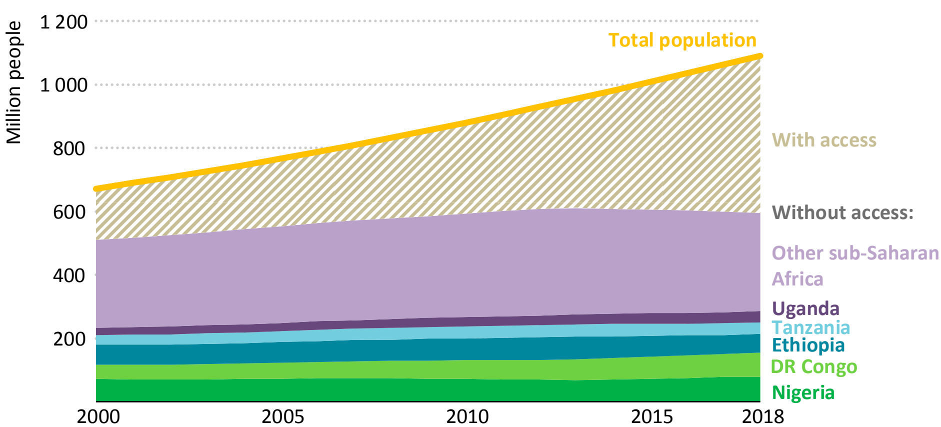
1

1.2.2 Electricity

More than two-thirds of people without access to electricity in the world today live in sub-Saharan Africa. North Africa reached almost universal access to electricity by 2018, but the electrification rate in sub-Saharan Africa was 45% in that year. Electrification levels in sub-Saharan Africa remain very low compared to the levels in other developing parts of the world, most notably the 94% rate reached on average across developing countries in Asia. Lack of electricity often obliges households, small businesses and community services that can afford it to use inefficient, polluting and expensive alternative solutions for essential services.

Despite the comparatively low access rate, sub-Saharan Africa has made progress with the pace of electrification accelerating over the past five years. The number of people gaining access to electricity for the first time more than doubled from 9 million a year between 2000 and 2013 to more than 20 million a year between 2014 and 2018, outpacing population growth for the first time. As a result, the number of people without access to electricity in sub-Saharan Africa peaked at 610 million in 2013, before slowly declining to around 595 million in 2018 (Figure 1.9). The region now faces a dual challenge: how to provide access to the 600 million currently deprived while at the same time reaching the millions born every year in areas without access to electricity.

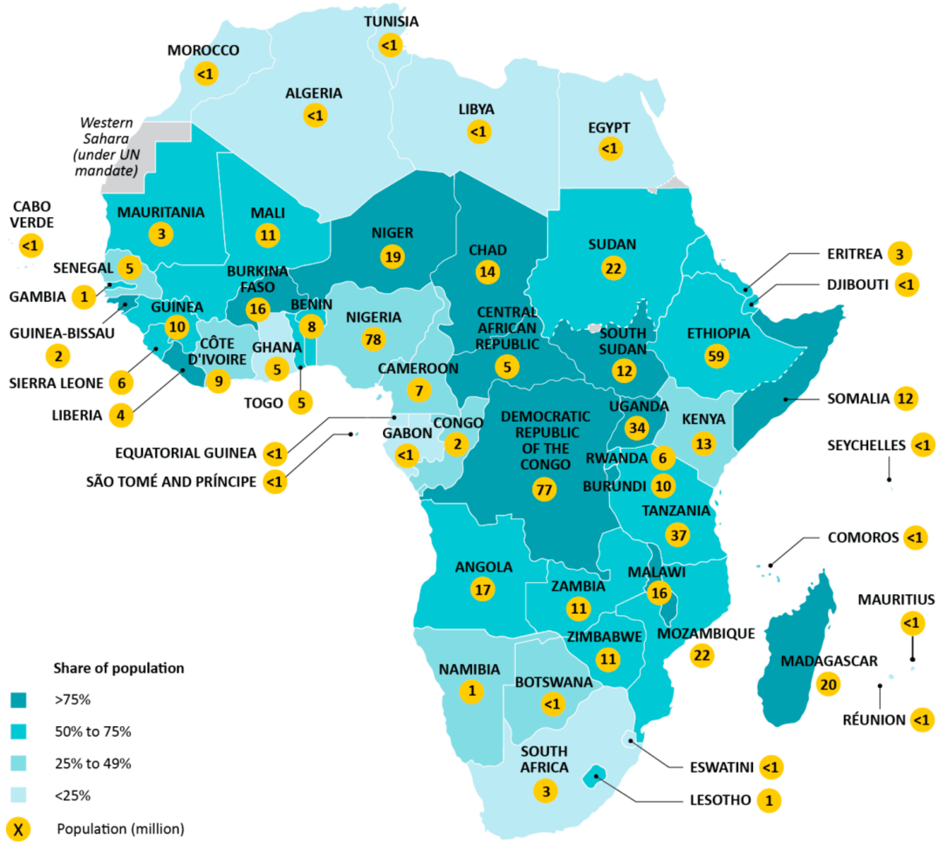
Figure 1.9 ▷ Electricity access by country in sub-Saharan Africa, 2000-2018



Population without electricity access has plateaued since 2013 thanks to the acceleration of connections; almost 50% of those without access live in five countries

About half of the sub-Saharan African population without access to electricity live in five countries: Nigeria, DR Congo, Ethiopia, Tanzania and Uganda (Figure 1.10). Conversely, Ethiopia, Tanzania and Kenya connected the highest number of people between 2014 and 2018, with these three countries accounting for more than 50% of those gaining access.

Figure 1.10 ⊳ Population without access to electricity by country in Africa, 2018



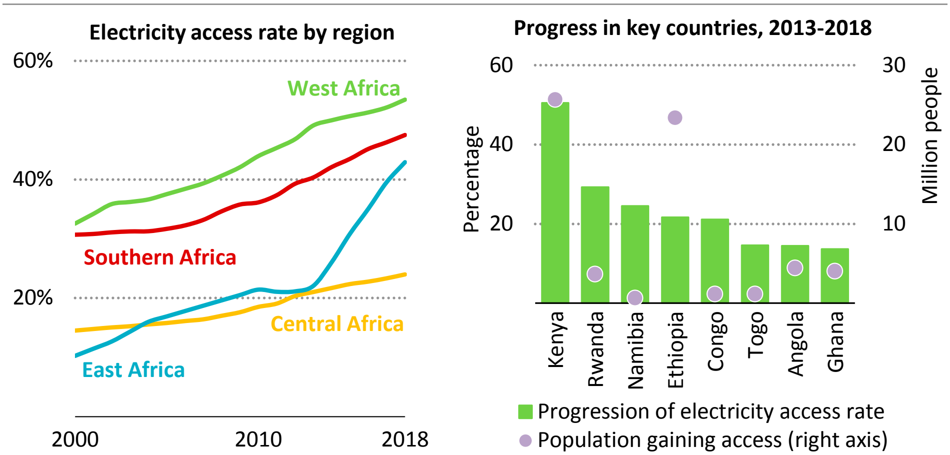
In sub-Saharan Africa 55% of people lack access to electricity; in thirteen countries, more than three-quarters of the population do not have access to electricity

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The energy challenges facing households vary significantly across Africa. In urban areas, on average, almost three-quarters of households have access to electricity, whereas in rural areas this figure falls to one-quarter. In remote rural areas and small cities not connected to a grid, finding affordable off-grid solutions and business models is key. But there are also many people living in informal settlements, with grid infrastructure nearby, that are not connected at all, or are connected illegally to the distribution grid, resulting in a revenue loss for utilities as well as exposure to hazards such as fires and risk of electrocution for those with illegal connections (see Spotlight on communities that live "under-the-grid" but without electricity). Getting or formalising grid access is often complicated not only by the high upfront connection costs for poor households, but also by the quality or absence of local distribution infrastructure. For households already connected, located mainly in urban areas, strengthening the reliability of supply from the grid and the affordability of electricity remains the priority (see section 1.3.3).

East Africa stands out as a beacon of progress. It has more than quadrupled the increase in its electrification rate, going from an increase of around one percentage point per year between 2000 and 2013 to more than four percentage points per year from 2014 to 2018. It contains three strong performing countries in terms of electricity access rate progression: Kenya, Rwanda and Ethiopia (Figure 1.11). Kenya has performed best in recent years, with its access rate going from 25% in 2013 to 75% in 2018. Progress in Kenya is attributable to a combination of factors: a strong grid connection push through the Last Mile Connectivity Project; continuous support by government for decentralised systems expressed through exemption from import and value-added taxes for solar products and the adoption of international standards; and the development of a mature mobile payment infrastructure that enabled innovative business models and payment mechanisms to emerge. These factors allowed the country to increase grid connections by almost one million households per year (or more than five million people), and to provide more than 700 000 households with access to electricity through decentralised systems by 2018.

Figure 1.11 ▷ Electricity access progress in sub-Saharan Africa



Progress on electricity access has accelerated dramatically in East Africa since 2013

Progress has been much slower in Central Africa, but there are brighter signs in both West and Southern Africa, which achieved 53% and 48% access rates respectively in 2018. Early progress in Ghana demonstrated the need for an integrated approach that takes into account all possible solutions to achieve universal access. In 1991, the Ghanaian government developed the National Electrification Scheme, a master plan containing six five-year implementation phases to reach universal access to electricity by 2030 which was drawn up after a two-year National Electrification Planning Study. This scheme supported the use of main grid, mini-grid and renewables stand-alone systems according to which was most appropriate for a given area. Under its Self-Help Electrification Scheme, clearly stated contributions or commitments were expected from both the government and communities seeking to get connected to grid electricity. By 2018, 84% of the population had access to electricity, up from 45% in 2000.

Lessons from other countries confirm the need for strong 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 be able to achieve steady and effective progress. In Morocco, for example, the national utility (ONEE) increased the rural electrification rate from 18% in 1995 to 97% in 2009. It implemented a utility-led model that focused on grid extension for 95% of households and that used solar home systems to provide access to electricity for those in isolated or dispersed areas on the basis of a fee-for-service model. In India, a strong push from the government resulted in almost 100 million persons gaining access to electricity in 2018. The Saubhagya Scheme, which ran from October 2017 to March 2019, connected 26 million households to electricity for free; almost 99% of these connections were realised through the main grid, while mini-grids and solar home systems helped reach the remaining 1%, usually in remote areas.

While Morocco and India have provided access to electricity primarily through grid connections, the geography, demography and level of infrastructure provision in sub-Saharan Africa points towards the need for strategies specific to each country that integrate centralised and decentralised solutions to reach universal access. As such, governments in sub-Saharan Africa are increasingly allowing for flexibility in their policy design. In Nigeria, the energy ministry has developed a set of policies that cover a wide range of renewable systems as part of their efforts to reach remote populations across the country. The Rural Electrification Agency is currently implementing a large-scale strategy including energy service company-led and utility-led models to accelerate the rate of electrification through grid extension and green mini-grids, and is targeting market clusters, manufacturing centres, schools, universities and hospitals, for electrification using solar PV and hybrid solar PV-diesel systems.

The majority of progress over the past decade has been made as a result of grid connections[7], but the balance has been shifting. Provision of access by means of decentralised solutions has increased considerably since the IEA's *Energy Access Outlook* was published in 2017 (IEA, 2017a). Around 15 million people are now connected to mini-grids in Africa (ESMAP, 2019), while the number of people gaining access through solar

[7] Connections to the grid have been both formal and informal: in Côte d'Ivoire and Ghana, for example, one single formal metered connection can legally serve more than one household.

home systems in sub-Saharan Africa increased from two million in 2016 (IEA, 2017a) to almost five million in 2018 (IEA analysis based on sales data provided by the Global Off-grid Lighting Association). This route to energy access has been concentrated in a few countries: Kenya, Tanzania and Ethiopia accounted for almost 50% of new connections in 2018. In Ethiopia, 32% of rural households are connected through solar home systems (Padam et al., 2018) and in Rwanda around 15%. The market for solar home systems is largely made up of systems below 50 watts which provide access to energy services such as energy-efficient televisions and cooling fans.

The digitalisation of communication and financial services has been critical to the development of mini-grids and solar home systems markets. In some countries in sub-Saharan Africa, the widespread availability of mobile phones, mobile money accounts, and associated telecommunication and payment infrastructures have helped the development of a wide array of energy services (IEA, 2017b). Solar home system providers are offering customers affordable payment plans over several months or years, often with an initial deposit followed by daily payments that cost less than customers currently spend on kerosene (see Chapter 3). Mobile networks enable direct communication with customers and remote control of devices, enabling solar home systems to be disabled when the customer fails to pay. By means of such a scheme, the company Fenix International Inc. has brought affordable solar power to over 500 000 homes in several regions of sub-Saharan Africa with its ReadyPaySolar Systems (Fenix, 2019).

The relationship between electricity access and priorities such as local development and human capital is an important element of the United Nation's 2030 Agenda for Sustainable Development. The vast majority of rural households in Africa rely on agriculture, and integrating agricultural needs such as irrigation, agro-processing and storage into the design of electricity access business models and technologies can have a very positive impact. Cold storage powered by renewable energy supply, for example, could help reduce post-harvest losses, which are estimated at between 20% and 50% of food produced (depending on the food) in sub-Saharan Africa. Electricity can also play an important role in improving agricultural productivity through irrigation, as several successful examples of stand-alone solar water pumps show, provided that policy makers also tackle wasteful irrigation practices.

The absence of electricity access, or access only to intermittent supply, also deeply impacts the quality of services available to the population. In 2016 in sub-Saharan Africa, around half of lower secondary schools and 57% of upper secondary schools had no access to electricity (UNICEF Institute for Statistics, 2019). Moreover, in 27 sub-Saharan African countries, close to 60% of health centre facilities have no access to reliable electricity (Cronk and Bartram, 2018). Access to electricity is essential to a proper provision of essential services: in health centres, for instance, it supports the use of efficient modern equipment, the preservation of vaccines and medicines, and the ability conduct emergency medical procedures, for instance during childbirth.

S P O T L I G H T

What approaches can help communities that live "under-the-grid" but without electricity?

More than half of the urban population in African countries lives in informal settlements often lacking access to formal electrification services (Tusting et al., 2019). Furthermore, at least 110 million of Africa's 600 million people without electricity access live in informal urban settlements close to or directly under a grid (GTM Research, 2017). A 2017 World Bank study on infrastructure in Africa discovered that connection rates for populations living under-the-grid is lower than 50% in most countries in sub-Saharan Africa, with a few exceptions such as South Africa, Nigeria, Gabon and Cameroon. Depending on the data source, estimates for under-the-grid populations without access to legal electricity in other African countries range from 61% to 78% (World Bank, 2017a).

A few studies provide insights into the consumption of poor urban customers and the reasons why utilities are unwilling or unable to serve them despite the immense commercial opportunity they represent (Baruah B. , Energy Services for the Urban Poor: NGO Participation in Slum Electrification in India, 2010). The price of grid connection is one of the major barriers to connection. Typically, people who live in urban informal settlements are poor, with low incomes and low power demands, and connection prices are frequently unaffordable. Before the Last Mile Connectivity Project, the price of a connection in Kenya was around $400 per household (Lee, Miguel and Wolfram, 2016), nearly one-third the annual average per capita income and over three-times the mean of the willingness to pay of surveyed Kenyans. In Nigeria, 62% of under-the-grid households cite high connection costs as the major reason for not being connected to the grid (GTM, 2017). The Centre for Global Development estimates that there may be up to 95 million people living in under-the-grid areas in Nigeria, Kenya, Tanzania, Ghana and Liberia.

There is an urgent need for innovative approaches to provide affordable legal electricity to those living under-the-grid in African countries. A look at promising practices for providing legal access to electricity to urban poor consumers offers some guidance (Shrivastava, 2017). In 2009, Tata Power Delhi Distribution Limited (TPDDL) in India focused on connecting a particular segment of its customer base living in impoverished neighbourhoods. The most significant interventions introduced by TPDDL included reducing new connection charges to INR 350 (about $7 at the time), offering an affordable 24-month payment plan, waiving outstanding dues, reducing requirements for proof of identification and residency, relaxing commercial formalities on land rights and promoting insurance offerings for those with metered connections. Between 2010 and 2015, TPDDL's unique model connected 175 000 new rate-paying customers in 217 impoverished neighbourhoods near New Delhi. In the process, the utility doubled its customer base and increased its revenues fourfold.

Many of the features TPDDL adopted were replicated in Jamaica, Brazil, South Africa, Philippines and Kenya (in Kenya it was estimated in 2013 that more than three-quarters of off-grid homes are located within 1.2 kilometres of a power line) (Wolfram, 2013). In 2015, Kenya Power & Lighting Co. (KPLC) discovered through a survey that customer willingness to pay for an electricity connection upfront was only 57%. KPLC responded by instituting a subsidised connection fee of around $170 through the Last Mile Connectivity Project and an instalment-based payment plan that led to a thirty-fold increase in legal electricity connections in impoverished neighbourhoods in one year.

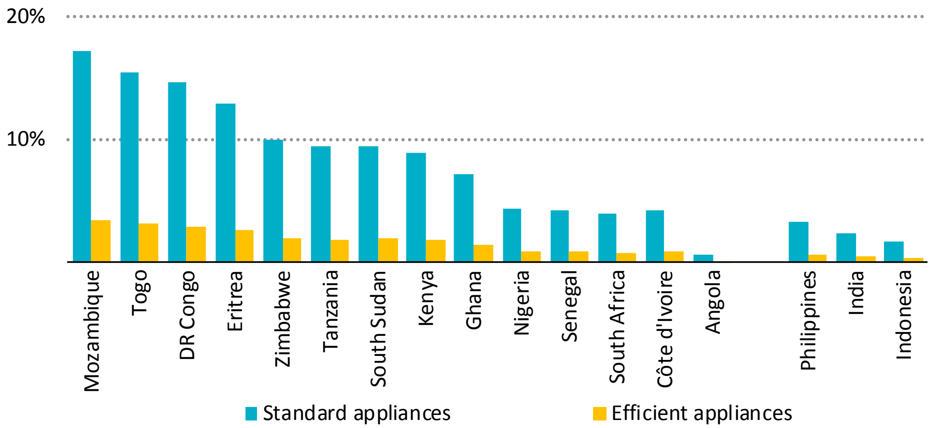
1.2.3 Affordability: energy prices and fossil fuel subsidies

Affordability remains a challenge when it comes to providing households with access and with modern energy services that they can use. The two central elements here are the cost of being connected and equipped (connection to the grid, acquisition of the decentralised system or the stove, appliances); and the cost of the energy used (i.e. electricity supply and cooking fuel refills). Making access to electricity and clean cooking affordable requires an understanding of the current payments made by households for similar services and of the structure of their income. For example, many households in rural areas relying on traditional use of solid biomass use a stove and a fuel which do not require significant capital outlay. As noted above, programmes which have proved to work on a large scale have had to respond to household concerns about capital costs either by subsidising the costs or by spreading payments over time to reduce the required capital outlay.

On the basis of electricity prices in several countries, it appears that paying for electricity to power a few basic appliances (four lightbulbs, a fan, a mobile phone charger and a television) would represent around 10% of the average income of the bottom 40% poorest households (Figure 1.12), while in Mozambique and Togo it would represent more than 15%. As a result of the high cost of power relative to income, electricity consumption rates per household in many sub-Saharan African countries are among the lowest in the world. The average household in most sub-Saharan Africa consumes less than 1 000 kilowatt-hours (kWh) of electricity each year, less than one-seventh of the average consumption of households in advanced economies. Other than South Africa, it is only in Angola that average household consumption exceeds 2 500 kWh, partly because the government subsidises tariffs.

There are actions that governments can take to improve affordability. Cross-subsidy schemes could help lower the costs of electricity for the poorest households. So could the promotion of highly efficient appliances. While such appliances tend to have higher upfront costs, we estimate that they could cut the proportion of income spent on electricity bills. Incentives could be provided to poorer households to encourage the purchase of more efficient appliances instead of or in conjunction with subsidies or cross-subsidies to reduce the price of their electricity. Digital payments could facilitate such schemes: around 90% of the 147 000 televisions sold by in the second-half of 2018 sold by solar home systems companies were through pay-as-you-go mechanisms, with more than 100 000 sold in East Africa (GOGLA, 2019).

Figure 1.12 ▷ Electricity expenses required to power basic appliances as a percentage of household revenues for the poorest 40%



Affordability of electricity remains an issue for many people in African countries. Efficient appliances can help keep costs down

Notes: Electricity consumption is based on a basic bundle of energy services, equating to around 500 kWh per household annually with standard appliances and 100 kWh with highly efficient appliances. This delivers four lightbulbs operating four hours per day, a mobile phone charger, a fan operating three hours per day and a television operating two hours per day. The household revenue is the average gross national income per household for the bottom 40% of households and is computed using the World Development Indicators.

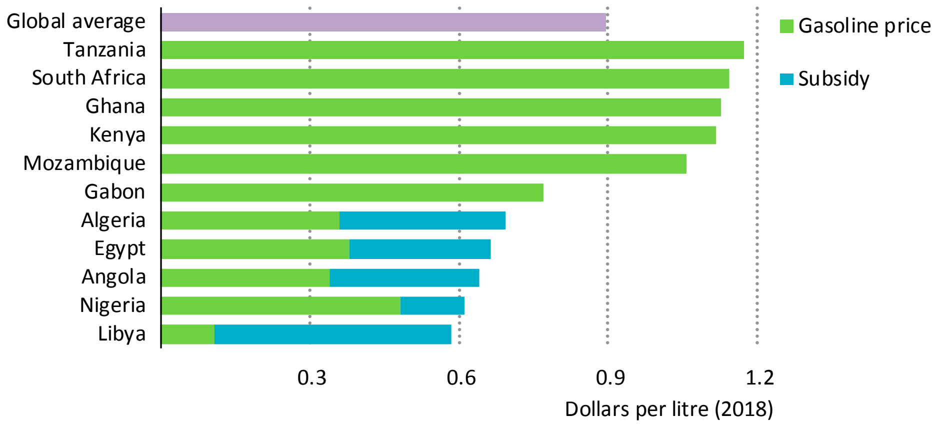
Sources: IEA analysis using World Bank World Development Indicators in some cases.

End-user energy prices vary significantly across countries in Africa, and reflect differences in domestic energy resources, levels of energy access, subsidies and taxes. Retail prices for road transport (gasoline and diesel), for example, are often higher than the world average (Figure 1.13) There are however exceptions: some major hydrocarbon exporting countries supply fuels to their domestic markets at prices lower than those in international markets. Some countries abstain from energy consumption subsidies in order to focus on other policy priorities. Instead of supporting gasoline and diesel prices, for example, Ghana prioritises subsidising kerosene and LPG as part of a strategy to promote switching away from the harmful and unsustainable use of solid biomass.

The interaction of subsidy policies with energy access is a challenge for many sub-Saharan African countries, raising questions about fiscal priorities and about how best to improve access to electricity and achieve sustainable development goals. Consumption subsidies for fossil fuels may once have seemed necessary for development goals, but renewables are increasingly cost competitive with other forms of generation, and many countries are now looking instead at an expansion of low-carbon electricity provision, both via centralised grids and on a decentralised basis (which avoid the costs of transmission and associated losses as well as incurring lower costs for distribution). The situation is different for clean cooking, where some of the viable alternatives to solid biomass are fossil fuels, in particular

LPG, but examples in India and in some African countries show how subsidies can quite effectively be targeted at specific sectors of the population, or limited to a certain number of LPG cylinders per month.

Figure 1.13 ▷ Gasoline end-user prices in selected African countries, 2018



Gasoline end-user prices vary substantially in African countries

For oil-exporting countries in Africa, many of which subsidise fossil fuel consumption, lower prices since 2014 have created strong pressure for pricing reforms to improve fiscal balances and to diversify economies which are highly dependent on hydrocarbons. However, the reform process remains unfinished business in a number of countries. Despite being a net exporter of oil, Nigeria imports most of the oil products consumed in the country (see section 1.3.3) and continues to supply them at subsidised prices; we estimated the value of these subsidies in 2018 at $2.9 billion section. Fossil fuel consumption subsidies are much more prevalent in North Africa, in particular in Egypt (with an estimated consumption subsidy bill of $27 billion in 2018), Algeria ($17 billion) and Libya ($5 billion).

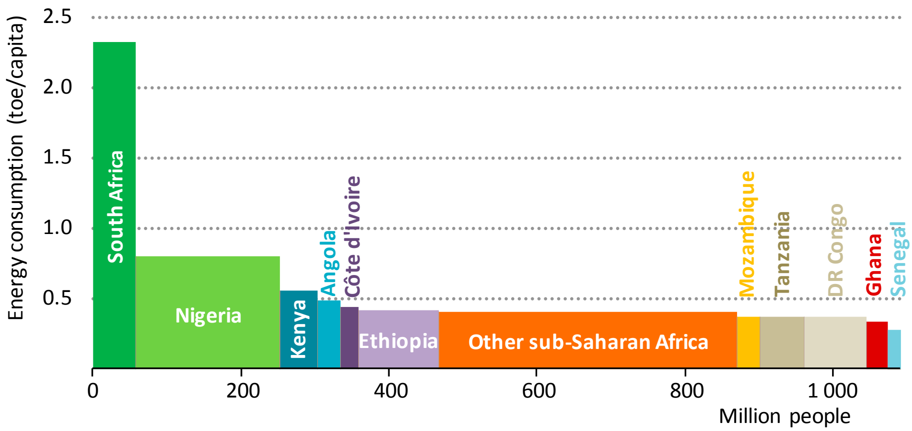
1.3 Energy trends in Africa today

1.3.1 Energy demand

Primary energy demand

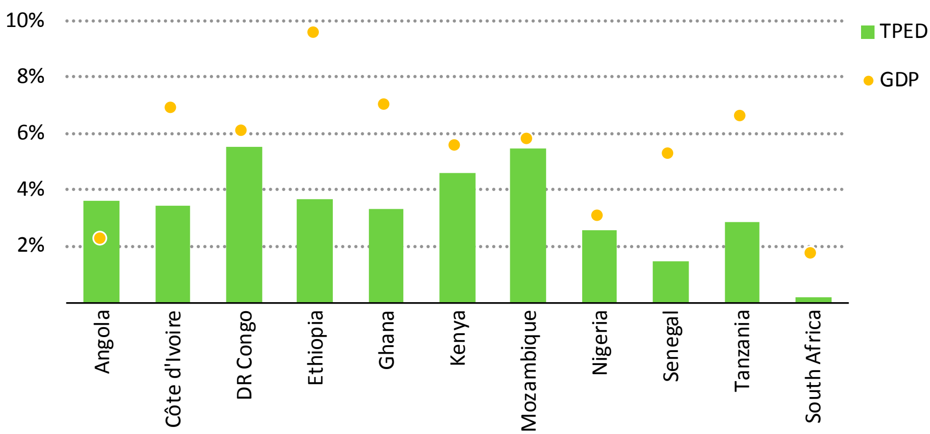
In recent decades, African energy demand has been driven by the growing needs of North Africa, Nigeria and South Africa. In 2018, primary energy demand in Africa was more than 830 million tonnes of oil equivalent (Mtoe): North Africa (24%), Nigeria (19%), and South Africa (16%) together accounted for almost 60% of this despite making up only 35% of the population. Average energy consumption per person in most African countries is well below the world average of around 2 tonnes of oil equivalent (toe) per capita and is broadly comparable to India's average of 0.7 toe/capita. In 2018, per capita consumption in sub-Saharan Africa was highest in South Africa at 2.3 toe/capita and in Nigeria at 0.8 toe/capita (Figure 1.14). Most other sub-Saharan African countries have per capita consumption of around 0.4 toe/capita and in most a large part of it consists of the relatively inefficient use of solid biomass.

Figure 1.14 ▷ Energy consumption per capita and population in selected sub-Saharan African countries, 2018



Excluding South Africa, per capita consumption in sub-Saharan Africa is 65% below the average for developing economies

Figure 1.15 ▷ Primary energy demand and GDP annual growth in selected sub-Saharan African countries, 2010-2018



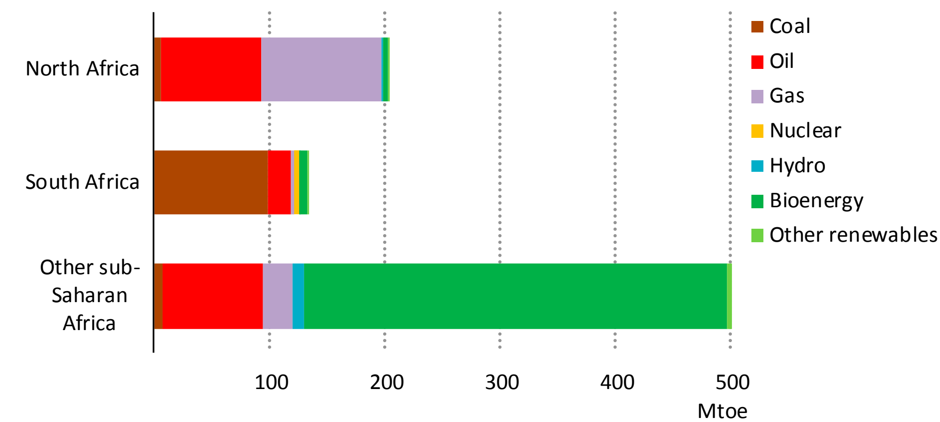
There is wide disparity between annual GDP growth and primary energy demand in many sub-Saharan African countries

Note: TPED = total primary energy demand.

The rate of growth in energy demand in sub-Saharan Africa has slightly slowed in recent years and remains lower compared to GDP growth (Figure 1.15). Between 2000 and 2010, energy demand increased at an annual average rate of 3%, but this slowed to 2.5% from 2010 to 2018, with very marked variations. Countries such as the DR Congo (Africa's fourth most populous country) saw their primary energy demand more than double between 2000 and 2018, whereas others such as Côte d'Ivoire, Ghana and Mozambique have witnessed an increase in demand of around half. The smaller increase in demand does not mean energy services didn't grow at the same rate: in the case of Côte d'Ivoire, the push towards LPG for cooking has resulted in a decline in solid biomass use, and this has produced large efficiency gains.

Traditional biomass is used mostly for cooking in Africa, but is also used in industry. It is by far the most widely used energy source across Africa, with the exception of North Africa, where oil and gas dominate, and South Africa, where the energy mix is coal-heavy (Figure 1.16). In sub-Saharan Africa, bioenergy's share in the overall energy mix has barely changed over the last 25 years, and it continues to dominate the primary energy mix, accounting for 60% of total energy use in the region (if South Africa is excluded, this share increases to almost three-quarters). There is no other region in the world that relies so heavily on bioenergy.

Figure 1.16 ▷ Total primary energy demand by fuel for selected African regions, 2018



With the exception of South Africa, the sub-Saharan Africa energy mix is dominated by solid biomass and oil

Fossil fuels represent almost 40% of the overall energy mix in sub-Saharan Africa and more than half of the African energy mix. Oil demand stands at almost four million barrels per day (mb/d). The transport sector accounts for most oil use (60%), but diesel is also consumed for back-up generators, kerosene or LPG within households for lighting and cooking, and a variety of oil products are used by industry (Table 1.1). Natural gas overtook coal as the third fuel in the African energy mix in 2015. Today, natural gas accounts for 16% of that mix, with nearly 160 billion cubic metres (bcm) consumed each year: almost 80% of this is consumed in North Africa and over 10% in Nigeria. Coal now accounts for 13% of the primary energy mix (compared with around a quarter globally), with consumption of almost 160 Mtce. South Africa accounts for the overwhelming majority of the continent's coal consumption, where it is used for power generation, industrial processes, transport (after coal-to-liquid conversion), and household heating.

Table 1.1 ▷ Total final consumption by fuel and sector in sub-Saharan Africa, 2018 (Mtoe)

	Industry	Transport	Residential	Other
Coal	12	0	5	5
Oil	9	69	5	13
Gas	9	0	0	0
Electricity	17	0	10	7
Bioenergy	18	0	281	13
Other renewables	-	-	0	0
Total	**65**	**69**	**301**	**38**
Share of total final consumption	*14%*	*15%*	*64%*	*8%*

Households

The affordability of basic services is an important concern in many African countries, where there are very low levels of appliance and vehicle ownership (Table 1.2). There are important disparities between urban and rural areas, reflecting their different levels of income (see section 1.2.3). There are also major inequalities within urban and peri-urban areas, where many people live in informal settlements under poor conditions as measured in terms of access to energy, sanitation and water services. While the situation has improved slowly over the last ten years, many households still lack appliances that could improve their quality of life, such as a fan (or even air conditioning) and a refrigerator: ownership levels of these appliances are far below the average of developing countries.

In many parts of Africa, ownership of a car remains a luxury, while ownership of two/three-wheelers is comparatively more common. The number of passenger light-duty vehicles is increasing in many countries as incomes rise, but the efficiency of the fleet is low as many are older vehicles imported second-hand from Europe and Asia (although some countries, for example Angola and Mozambique, restrict the importation of older vehicles). Public transport is also less developed in many places though it could play a pivotal role in boosting economic and social welfare in one of the world's most rapidly urbanising region. Rail networks are scarce, and many were originally built to meet the needs of extractive industries rather than to provide passenger services. In many parts of the continent, households rely on buses and minibuses to travel within or between cities. Providing safer and faster alternatives for transporting large numbers of people would be the first among the many benefits of investing in mass transport. There are a number of success stories in the region to inspire the further development of public transport (Box 1.4).

Table 1.2 ▹ Household size and average household ownership of key items in rural and urban areas in Africa

	Household occupancy (number of people)		Air conditioner (ownership per 1 000 households)		Car (ownership per 1 000 households)		Two/three-wheeler (ownership per 1 000 households)	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Sub-Saharan Africa	**3.8**	**5.5**	**68**	**11**	**125**	**21**	**129**	**96**
Angola	3.7	5.0	164	22	171	12	162	202
Côte d'Ivoire	4.0	5.6	25	10	64	8	161	220
DR Congo	4.3	5.9	9	8	43	1	79	38
Ethiopia	3.2	4.8	13	9	33	2	25	8
Ghana	3.1	4.1	119	33	126	44	91	132
Kenya	3.4	4.4	20	3	109	29	78	107
Mozambique	3.6	4.9	9	8	108	12	111	74
Nigeria	3.9	5.9	92	14	205	64	304	356
Senegal	6.4	11.3	19	9	25	14	112	104
Tanzania	3.8	5.5	16	9	59	14	115	111
South Africa	3.1	3.9	107	34	343	168	31	9
Other	4.1	6.0	62	8	42	1	77	37
North Africa	**3.7**	**5.5**	**235**	**58**	**147**	**57**	**60**	**106**

Box 1.4 ▹ A transport success story: Bus Rapid Transit in Dar es Salaam

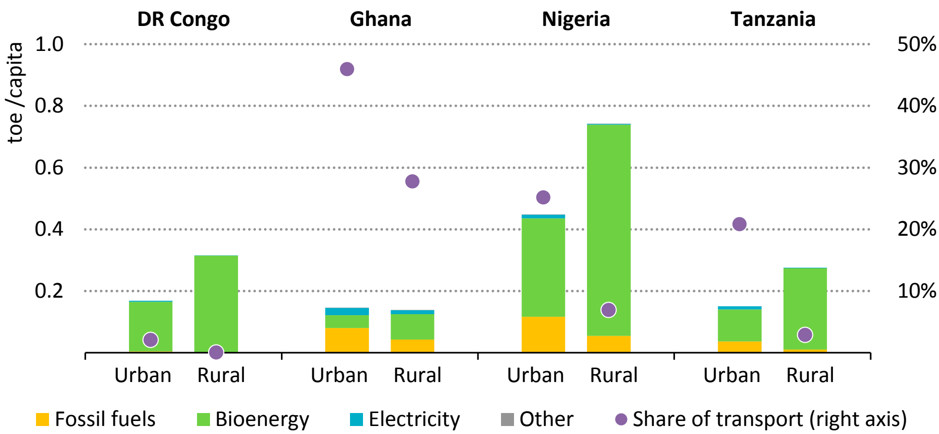
Dar es Salaam, Tanzania is growing at an unprecedented rate and is projected to become a megacity by 2035.[8] Most of the expansion has emerged on the edges of the city, compelling many commuters to travel very long distances to work. After years of struggling with an outdated and overcrowded transportation system that was extremely time-consuming to use, the city has introduced a new bus rapid transit (BRT) system which carries 200 000 passengers a day and has cut average travel times from the city centre to the terminus from two hours to 45 minutes each way. Recognised by the Institute for Transportation and Development (ITDP) as Africa's only "gold standard" BRT rating, this high-quality transit system of dedicated bus lanes offering fast, comfortable and cost-effective services at metro-level capacities is a potential model for other cities.

A similar initiative in Johannesburg in South Africa is called the Rea Vaya or "We are going" bus system. It runs on low-sulfur diesel and operates on predetermined routes in dedicated bus lanes, significantly cutting the time spent travelling through the congested streets. The system is reported by the World Resources Institute to have saved the country around $900 million so far by reducing travel time, improving road safety and reducing carbon emissions.

[8] A megacity is defined by the United Nations as a metropolitan area with a total population of more than 10 million people.

Households in Africa generally have a low level of energy consumption (Figure 1.17). Nonetheless, their overall energy use (including passenger transport needs) accounts for around two-thirds of final energy consumption. The share of households in final consumption is even higher in sub-Saharan Africa, where it reaches more than 70%, largely because of the extent of their reliance on inefficient solid biomass for cooking and poor quality cookstoves.

Figure 1.17 ▷ Urban and rural household energy consumption per capita and by fuel for selected African countries, 2018



Average household energy consumption varies between urban and rural and across countries, as does the fuel mix, though generally with a high share of bioenergy

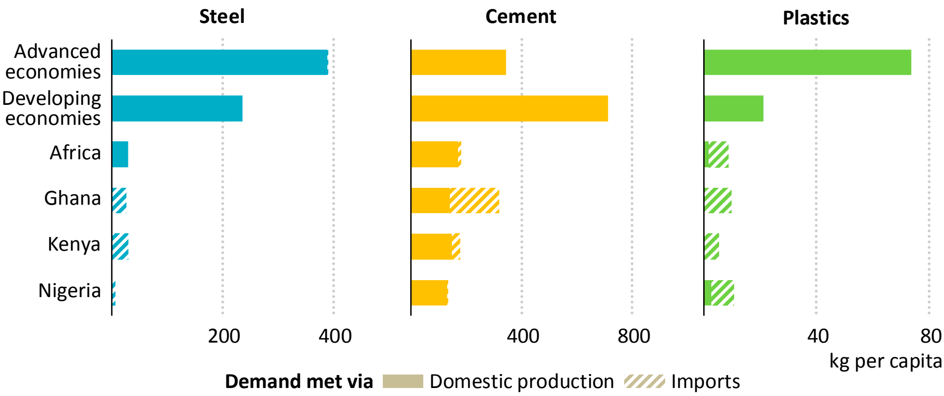
Productive uses

Productive uses, including industry, agriculture and services, account for around a quarter of total final consumption of energy in Africa. Industry employs only 13% of the workforce and generates only a third of GDP but it uses almost 70% of the energy that goes into productive uses. The services sector uses only limited amounts of energy even though it generates half of GDP. Agriculture employs half of the African workforce, but accounts for only 16% of GDP and less than 10% of energy for productive uses.

Agricultural productivity per hectare in sub-Saharan Africa is well below that of other regions in the world: this reflects low energy inputs, but also a lack of modernisation, limited use of irrigation to raise crops yields and unpredictable weather (IEA, 2017a). As a result, food production per capita has not changed significantly since 2000.

The lack of transport infrastructure acts as a brake on the development of the African economy. It hinders the development of trade within the continent as well as export (and import) of finished goods. Tackling this would help Africa to take advantage of opportunities arising from the new African Continental Free Trade Agreement (AfCFTA), which entered into force in May 2019. With the right enabling conditions, the AfCFTA has the potential to have a significant impact on the continent's development. The United Nations Economic Commission for Africa UNECA has predicted that by 2040 it will raise intra-African trade by 15-25%, or from $50 billion to $70 billion, compared to an Africa without the AfCFTA (UNECA, 2018a).

Figure 1.18 ▷ Per capita consumption of key materials, 2017



Per capita consumption of key materials such as cement, plastics and steel in Africa is low compared to developing economies elsewhere

Notes: Plastics consumption is based on 2015 data and includes key thermoplastic resins; developing economies elsewhere refers to Developing Economies less African economies in the group.

As things stand, sub-Saharan African countries represent a very small share of global industrial production: they are responsible for around 2% of global cement and aluminium production and less than 1% of steel production. As a result, Africa continues to rely on imports of many energy-intensive materials and manufactured goods (Figure 1.18).

1.3.2 Power sector

Electricity demand

Despite being home to almost a fifth of the world's population, Africa accounts for little more than 3% of global electricity demand and North African countries (42%) and South Africa (30%) represent nearly three-quarters of this. Africa's electricity demand is growing, but only at half the rate of developing Asian countries: it rose to 3% a year on average between 2010 and 2018, increasing from 560 terawatt-hours (TWh) in 2010 to around 705 TWh. The latter figure is equivalent to a fifth of electricity demand in Europe in 2018.

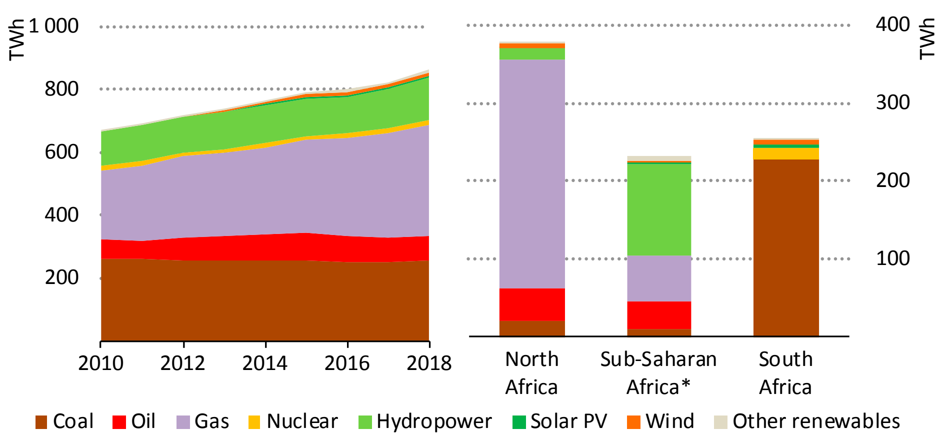
Electricity accounts for around 10% of Africa's total final energy consumption, but per capita electricity demand in Africa remains very low at around 550 kWh (370 kWh in sub-Saharan Africa) compared with 920 kWh in India and 2 300 kWh in Developing Asia.

Higher demand from the buildings sector accounted for almost 70% of the increase since 2010, largely, as a result of increased demand (more than 60 TWh) in residential buildings from appliances, water heating and cooling. Demand in heavy industry was largely stagnant over 2010-18 with lighter industries making up 90% of the almost 40 TWh demand increase across industry. South Africa alone accounted for more than 40% of African electricity demand from industry in 2018 although demand in the sector has been largely flat since 2010. Electricity use in transport remains very low across Africa, but is highest in South Africa, where parts of the rail network are electrified.

Electricity supply from centralised grids

Electricity generation in Africa increased to 870 TWh in 2018 from 670 TWh in 2010. Natural gas and coal (the latter largely in South Africa) accounted for 40% and 30% of generation output in 2018 respectively. Hydropower accounted for a further 16% and oil for 9%. However, there are large regional differences. In North Africa, for example, natural gas contributed more than three-quarters to power generation in 2018. South Africa in contrast is hugely reliant on coal and to a modest extent on nuclear power while in the remainder of sub-Saharan Africa, hydropower provides over half of generation output with oil and gas accounting for most of the balance. Although non-hydro renewables in sub-Saharan Africa (excluding South Africa) increased by 250% over the 2010-18 period, accounting for slightly more than 7% of all renewables and 4% of total generation output (Figure 1.19) in 2018.

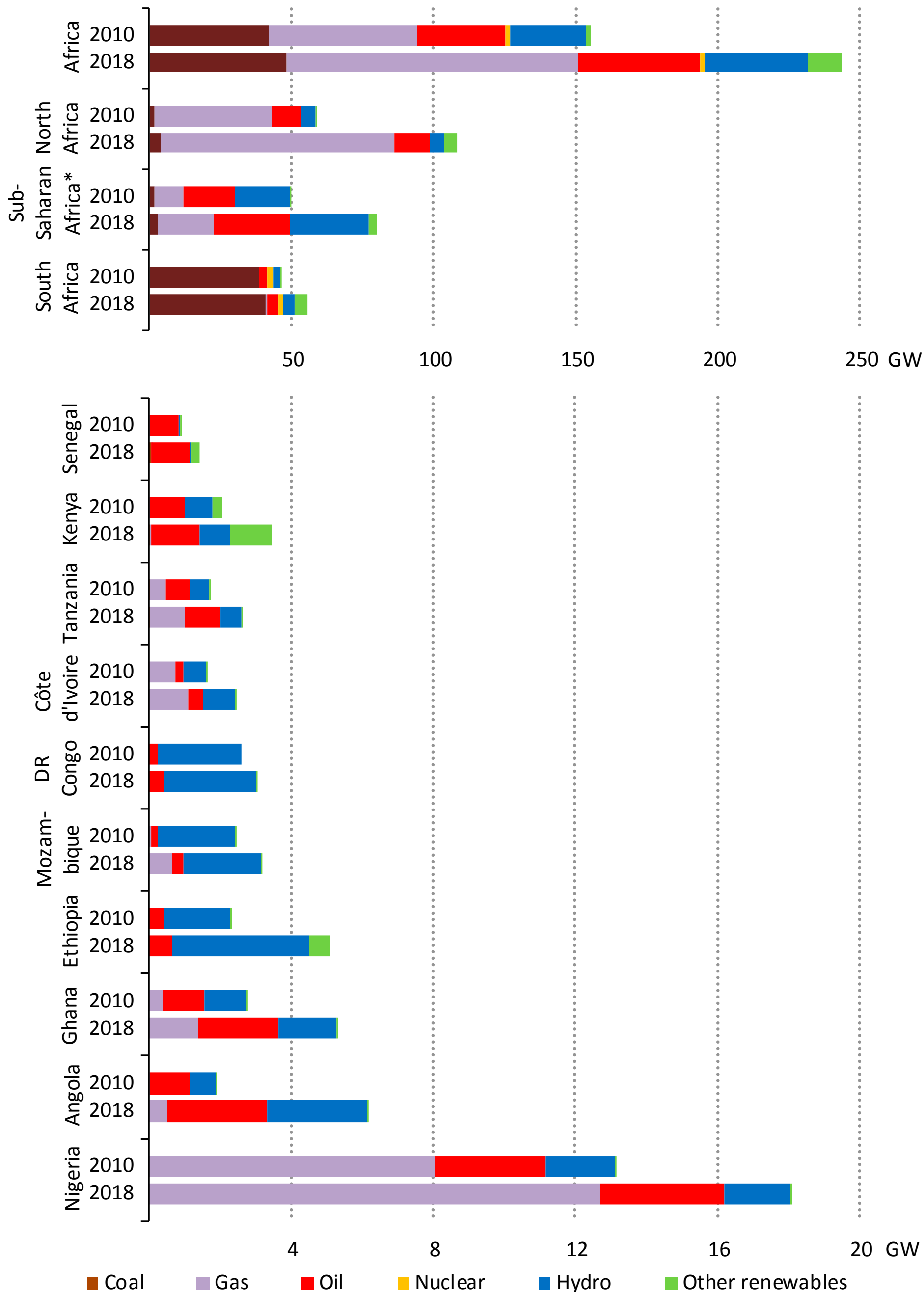
Figure 1.19 ▷ Electricity generation by fuel in Africa, 2010-2018 (left) **and in key regions in 2018** (right)



Natural gas fuelled most of the increase in electricity supply for the continent on the whole, but fuel shares varied by region and coal dominated in South Africa

* Excluding South Africa.

Figure 1.20 ⊳ Installed power capacity by fuel in selected regions/countries



Fossil fuels dominate the power mix but the role of non-hydro renewables is increasing

* Excluding South Africa.

Between 2010 and 2018, total installed generation capacity in Africa increased from around 155 gigawatts (GW) to almost 245 GW, or about a quarter of the capacity in European Union countries. South Africa and North African countries account for around 165 GW of this installed capacity. The capacity mix by fuel varies across the continent by country and region. North Africa accounts for almost 85 GW of Africa's 100 GW of gas-fired power plants, while the remainder is concentrated in Nigeria, Ghana, Côte d'Ivoire, Tanzania and Mozambique. South Africa accounts for 85% of the almost 50 GW of coal-fired capacity on the continent. Oil-fired capacity totals just over 40 GW; its relative importance varies greatly by country.

Renewable power capacity increased from 28 GW in 2010 to almost 50 GW in 2018. Hydropower is the largest source of renewable power by far and its capacity increased from 26 GW in 2010 to 35 GW in 2018, although its share in the overall generation mix has remained relatively constant at around 15%. Other renewable sources have started to develop but, for the moment, their share in generation and capacity is low. Although it has expanded in recent years, wind power development in Africa has been limited in scale compared to hydro with close to 5.5 GW of installed capacity in 2018, up from almost 1 GW in 2010. North Africa accounts for around 2.6 GW of this capacity and South Africa for around 2 GW. The growth of wind power in South Africa is in part a result of its Renewable Energy Independent Power Producer Procurement Programme that was launched in 2011 and has delivered close to 3 GW of new capacity over the past five years: notable projects include the Loeiresfotein and Khobab Wind Farms (140 megawatts each) which were commissioned in 2017. Countries such as Ethiopia, Ghana, Tunisia, Kenya and Morocco are making efforts to increase their wind deployment by adopting the independent power producers (IPPs) model (Greentech Media, 2019).

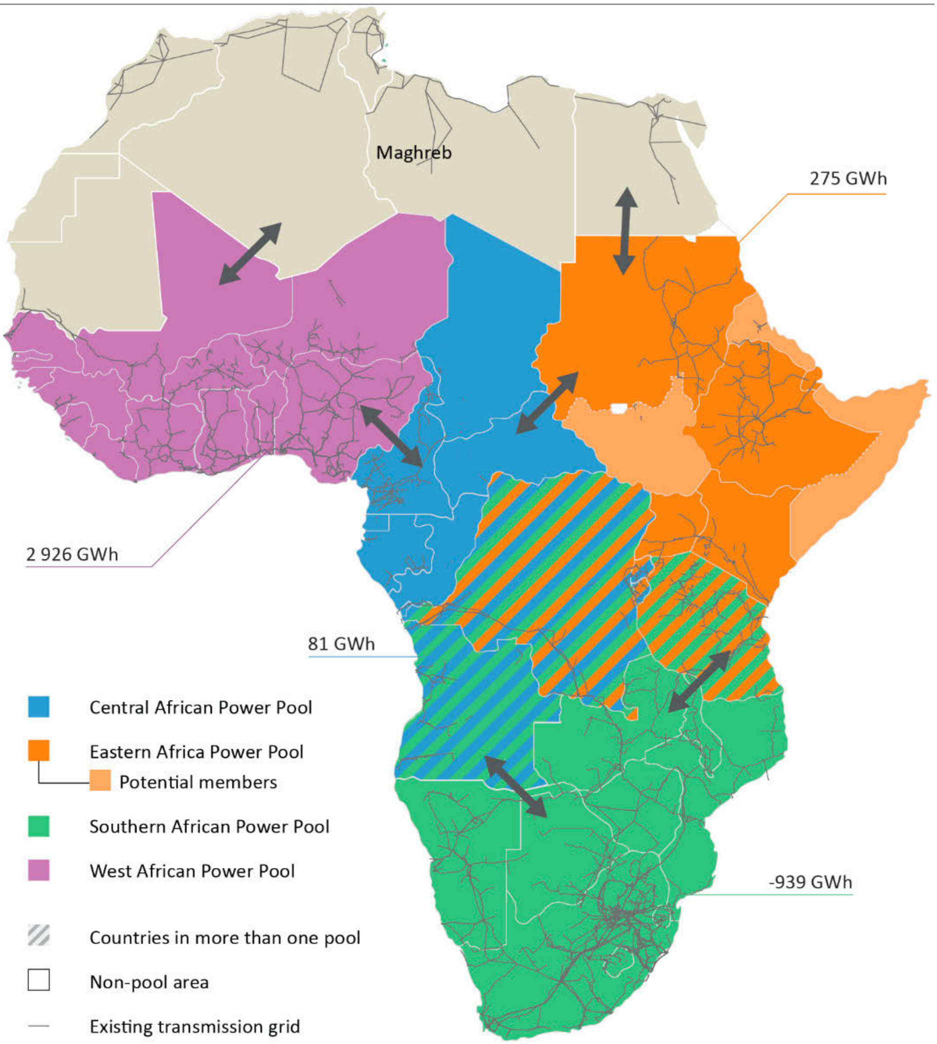
Solar PV installed capacity is around 4.5 GW. Capacity increased in 2019 when the 1.6 GW Benban Solar project, the largest utility-scale solar PV project on the continent to date, recently started service in Egypt. South Africa currently has close to 2 GW of installed solar PV capacity and a number of concentrating solar power (CSP) projects including the 100 megawatt (MW) Xina Solar One project and the 100 MW Ilanga-1 plant, which were commissioned in 2017 and 2018 respectively (IEA, 2018b). These projects brought the country's total installed CSP capacity to 0.4 GW, close to 40% of Africa's installed capacity of CSP.

Geothermal resources are generally concentrated in the eastern part of Africa where tectonic regimes indicate potential equivalent to more than 15 GW (Geothermal Energy Association, 2019). With excellent geothermal resources, Kenya has installed more than 600 MW of capacity: plans are underway to develop an additional 1 000 MW from three geothermal projects (Geothermal Development Company, 2019). Other countries in East Africa, including Ethiopia, Djibouti, Eritrea, Tanzania and Uganda are also looking to tap their geothermal resources.

Electricity trade

Africa is home to five regional power pools: Eastern Africa Power Pool (EAPP); Central African Power Pool (CAPP); Southern African Power Pool (SAPP); West African Power Pool (WAPP); and Maghreb Electricity Committee (COMELEC) (*Comité Maghrébin de l'Electricité*) (Figure 1.21). These pools vary greatly in terms of scale, governance and effectiveness.

Figure 1.21 ⊳ Electricity trade between power pools in sub-Saharan Africa, 2018



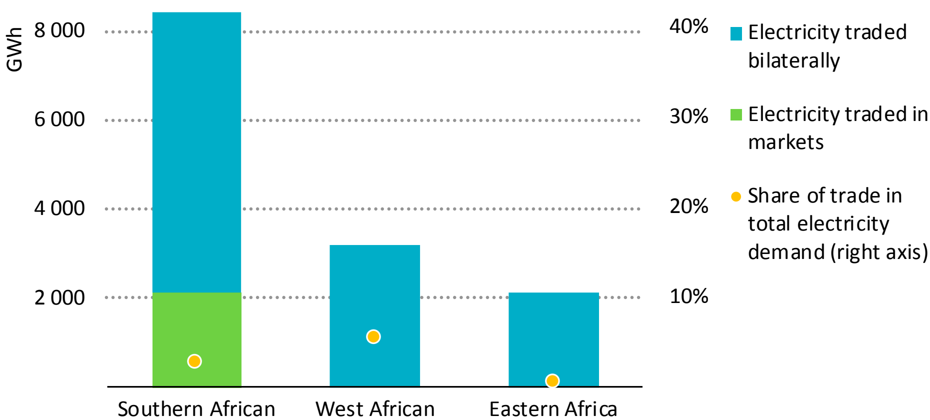
Regional power pools help to connect power generation sources across Africa

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Sources: World Bank (2017b) and AfDB's Africa Energy Portal (AfDB, 2018).

The SAPP has 17 members from 12 countries and operates four competitive electricity markets. Annual power trade amounts to around 3% of the member countries' demand, of which a growing portion is traded in the market. The COMELEC is relatively advanced while the WAPP and EAPP, both comparatively new, are making progress. The WAPP was established in 1999 and currently has 29 members, utilities and IPPs but remains underdeveloped compared with SAPP and COMELEC. The EAPP, established in 2005, comprises 11 state-owned utilities in Eastern Africa. The WAPP and EAPP have been working to harmonise their regulatory systems and develop market rules (e.g. standardised contracts and regional wheeling tariff methodology). Various transmission interconnections are under construction in EAPP, including an interconnection with SAPP (through a 400 kilovolt Tanzania-Zambia line). The CAPP was established in 2003 by utilities of eleven central African countries and is the least advanced.

Figure 1.22 ⊳ Power traded bilaterally and through competitive markets in the Southern African, West African and Eastern Africa power pools



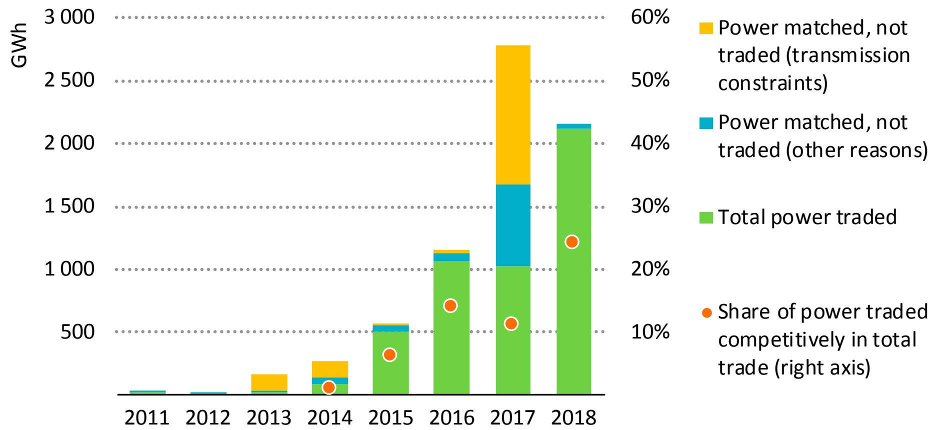
Power trade is low across the power pools and, except for the Southern African Power Pool, only bilateral trade

Note: GWh = gigawatt-hours.

Trade across the region remains low and is mostly realised through bilateral contracts (Figure 1.22). At present, in sub-Saharan Africa only SAPP has a functioning market. Some countries remain isolated from regional grids. Even where transmission interconnections exist, these are sometimes congested and need to be upgraded to facilitate trading. Around 1.8 TWh of electricity were matched in the competitive markets in SAPP in 2016/17, but were not traded because of transmission constraints (Figure 1.23).[9]

[9] Market players submit bids to buy and sell electricity in the wholesale market. When the power offered coincides with that requested, or vice versa, the electricity is said to be 'matched'. Yet, electricity can be matched but not traded, as technical constraints can come into play, like lack of transmission capacity to transport the matched electricity.

Figure 1.23 ▷ Electricity matched and traded in Southern African Power Pool and share of power traded in competitive markets, 2011-2018



Power traded in the competitive market has increased, though transmission constraints risk impeding further exchanges

Note: GWh = gigawatt-hours.

Source: SAPP annual reports (SAPP, 2019).

Most interconnections are state- or utility-owned and publicly funded. Transmission interconnections are capital-intense investments that require strong co-ordination among two or more governments and have high perceived risks, including risks related to transmission pricing. This makes it difficult for them to attract private sector finance, while domestic utilities are loss-making and have a low ability to raise funds themselves to finance these assets. This results in low investment and substantial delays. For example, the Zimbabwe-Zambia-Botswana-Namibia Interconnector (ZiZaBoNa) was initiated with the signing of an inter-utility memorandum in 2007 but has yet to reach financial closure. The situation looks set to improve with foreign donors such as the World Bank, the European Union, the European Investment Bank and US Agency for International Development Power Africa committed to providing financial and technical assistance for transmission interconnection projects, including the Cameroon-Chad Electricity Interconnection Project (PIRECT) and the 225 kilovolt (kV) interconnection of the electricity grids between Guinea and Mali.

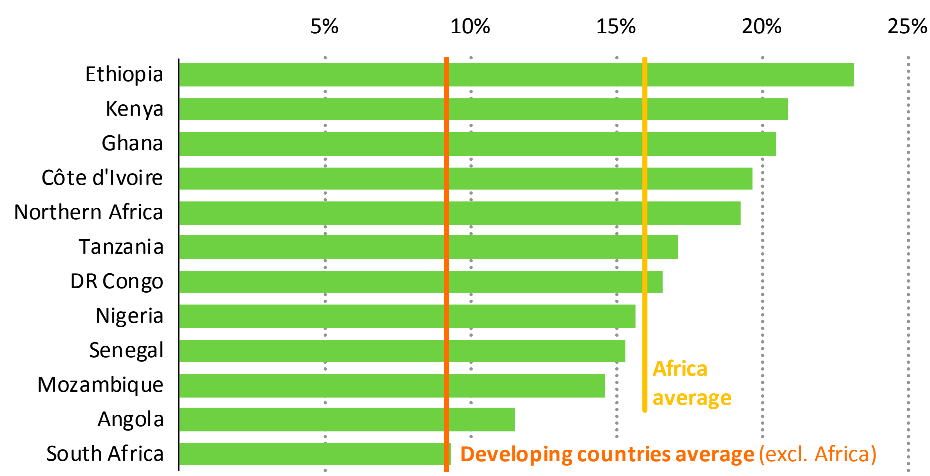
Regional power integration has the potential to reduce the level of infrastructure investment needed to meet demand by opening up a wider range of sources of supply (SAPP estimates savings in generation and transmission infrastructure of $37 billion over the 2017-40 period). It would also help to improve the resilience of countries energy systems by providing access to diverse and complementary markets, and help countries take advantage of economies of scale and realise large, low-cost projects that would not be justified based on domestic electricity demand alone. The potential benefits of the power pools mean that it makes sense to continue efforts to reduce investment risks and increase the bankability of projects, despite the challenges. This means improving transmission infrastructure and finding the right business model to scale up cross-border investments. Setting up a market in the EAPP and WAPP would allow countries to benefit from price differences within power pools, but will need improvements in trading regulations, wheeling methodology and regional grid codes.

Power system performance

According to World Bank Enterprise Surveys, unreliable electricity is perceived as a major constraint by almost 40% of firms in sub-Saharan Africa (World Bank, 2019). The vast majority of firms in sub-Saharan Africa experience electrical outages on a regular basis. In many countries, outages average 200 to 700 hours each year. In some countries they can be much worse than the average: A typical Nigeria firm experienced more than 32 electrical outages in 2018. These outages can vary in duration from less than one hour to more than a day, and in some countries they cost firms as much as a quarter of potential annual turnover and up to 2% of annual GDP.

Technical electricity losses are also high in Africa: in 2018, average losses amounted to 16%, which is almost seven percentage points higher than the average losses observed in other developing countries (Figure 1.24). The scale of these losses also varies significantly by region. In South Africa, average electricity losses were 9%. This is markedly lower than in other sub-Saharan Africa and North Africa countries, where electricity losses hovered between 17% and 19% respectively. Higher losses in these regions are a combination of a number of factors including poor operational performance on the part of utilities and theft of electricity from utilities. Reducing the level of losses would bring large efficiency gains.

Figure 1.24 ▷ Average electricity losses in selected African power systems today



Potential efficiency gains are possible by addressing the high levels of losses

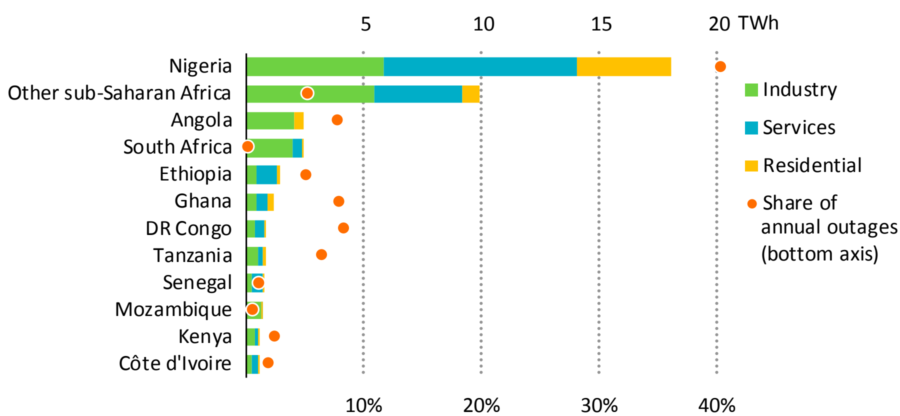
The frequent power outages in sub-Saharan Africa have resulted in a proliferation of stand-alone solar capacity and increased use of back-up generators to supplement the power needs of industry and households (Box 1.5). In Ethiopia, which depends on hydropower for much of its electricity generation, power rationing was in force during part of 2019 as a result of mechanical difficulties at dams and low water levels resulting from diminished rainfall (Africa Report, 2019). Kenya, South Africa, Zambia and Zimbabwe also experienced electricity price hikes or outages during the dry season in 2019 as a result of low water levels in hydropower systems. This may be a recurring problem if climate change results in lower rainfall.

Box 1.5 ▷ Use of back-up generators in Africa

The poor maintenance regime and ageing infrastructure in certain countries means that electricity outages are an everyday affair for many Africans. On average, many parts of countries such as Ghana and Mozambique experience outages once or twice a week. This has a direct impact on the daily lives of citizens and on the ability of the country to attract business, while the use of diesel fuel in back-up generators contributes significantly to emissions of CO_2 and air pollutant emissions.

IEA analysis estimates that 40 TWh of power was generated from 40 GW of back-up generating capacity in sub-Saharan Africa in 2018, which is equivalent to 8% of electricity generation. Nigeria accounted for almost half, generating 18 TWh of power from about 9 GW of back-up generation (Figure 1.25). Most back-up generation is used by businesses; households are often unable to afford the extra costs.

Figure 1.25 ▷ Electricity demand served by back-up generators and share of hours of electricity supply lost to outages in 2018



Unreliable power supply means that businesses and households turn to back-up generators in many sub-Saharan countries

Mini-grid and stand-alone systems

Grid extension is generally most cost effective when built to serve an area with a high density of demand. In more isolated (and often rural) areas, decentralised systems may be more cost effective. There are two main kinds of decentralised system: mini-grids and stand-alone systems.

Mini-grids are localised power networks, with infrastructure to transmit electricity within a defined service area. Generally, mini-grids provide electricity at a higher levelised cost than the main grid. Like any grid, mini-grids need a stable flow of power to function properly and often use either a small diesel generator or (increasingly) renewable-based power and battery systems for back-up. Mini-grids also require a certain demand threshold to justify the initial investment in the network, and therefore benefit from sizeable anchor loads provided by industrial and commercial customers or public buildings such as hospitals and schools. Mini-grids can be scaled up in line with rising demand, and eventually be connected to the main grid.

Electricity access can also be provided through stand-alone systems. These are systems not connected to a grid and typically power single households. Today, this market is dominated by diesel generators and solar PV systems (solar home systems). Stand-alone systems may be the most cost-effective option (from a system cost perspective) in sparsely populated and remote areas. Both solar PV systems and batteries can be built at different scales to match a need, which has led to innovative products coupling stand-alone generation with appliances. These products can be scaled up as power demand grows, and can supply a range of needs, from lighting and mobile phone charging to fans, televisions and sometimes refrigerators. Table 1.3 describes the main features of the mini-grids and solar home system markets and business models in sub-Saharan Africa.

The least-cost option to provide electricity access for a given area depends on its distance from the main grid, current and expected demand, and the lifetime of the assets needed for service delivery.[10] Least-cost options are generally identified in National Electrification Plans. Countries that have been successful in rolling these out tend to have plans that specify the technical, institutional and financial aspects of implementation.

There are around 1 500 mini-grids installed across Africa today and 4 000 more are planned; over half of them in Senegal and Nigeria, according to a 2019 World Bank market report (ESMAP, 2019). Demand has increased reflecting reductions in the capital costs of renewable-based generation. Policies and regulations have helped to promote investment and increase private sector participation.

Access through stand-alone systems has also been on the rise in sub-Saharan Africa, where East African countries are taking the lead. Almost five million people gained access to electricity through solar home systems in sub-Saharan Africa in 2018.[11] Many of these are

[10] The IEA and the KTH Royal Institute of Technology Stockholm have developed a detailed geospatial model determining least-cost technologies to achieve universal access to electricity in sub-Saharan Africa, which is presented in detail in Chapter 3.

[11] This figure is based on solar home systems of at least 8 W and does not include multi-lighting systems.

bought through the pay-as-you-go (PAYG) method, where private companies lease the solar products to customers who pay periodic instalment costs and can become owners once the loan is repaid. A market report prepared by a global association for the off-grid solar energy industry (GOGLA) and others shows that PAYG accounted for more than 80% of the value of sales (mostly solar home systems) made by the main private companies in the second-half of 2018.

Table 1.3 ▷ Features of mini-grids and solar home systems in sub-Saharan Africa

		Mini-grids	Solar home systems
Systems installed		1 500*	n.a.**
Capacity of systems		Installed capacity varies substantially by system and can range from a few kW to above a MW, depending on number of people supplied, demand and uses.	• Entry level: 11.0-20.9 watts (W) • Basic capacity: 21.0 - 49.9 W • Medium capacity: 50.0 - 99.9 W • Higher capacity: > 100 W***
Business models applied		• Private models, led mainly by private developers but also demand-driven (e.g. small industries). • Public models, led by utilities. • Co-operative models.	• Private models, led by private developers. • Some public programmes, led generally by rural electrification agencies.
Private business models	Description	• Mainly pay-as-you-go (PAYG). Private companies finance upfront investment costs and customers prepay for electricity. • Revenues depend on customer demand and tariffs levels.	• Mainly PAYG (e.g. lease-to-own: customer makes small deposit upfront and pays periodic instalments). • Revenues depend mainly on loan repayment rates.
	Tariff setting	Depends on regulatory framework and/or system capacity, including: • Set as per national uniform tariff. • Set according to system cost-recovery level and return on investment, often with approval from regulator.	n.a.**
	Ownership of assets	Mini-grids owned by developers or community.	Customer acquires solar home system by the end of lease period (lease-to-own model). Can also own it from the beginning (in cash-based models), though this is less common.
	Main risks	Regulatory risk (mainly around tariff setting and what happens when main grid arrives) and revenue risk.	Revenue risk (given customers have low and unpredictable income).

* ESMAP (2019). ** Data on number or cumulative capacity of solar home systems in the region is not available (n.a.). *** Categories as defined by GOGLA (2019).

Countries with clear targets, well-designed electrification strategies, and predictable policy and regulatory frameworks show a consistent growth in sales and uptake of stand-alone systems. Kenya and Ethiopia are cases in point. Tanzania was one of the first countries to promote stand-alone systems, but recent policy uncertainty has led to stagnation in sales. The commercialisation of these products has also been linked to business models that promote local job creation and training. "Solar Sisters" is an initiative that trains local women entrepreneurs to supply clean energy products to rural households and it is impacting the lives of women and local communities (Box 1.6).

Box 1.6 ▹ Impacts of clean energy entrepreneurship by women

Much of the existing research on access by women to renewable and clean energy technologies has focused on decentralised solar and bioenergy projects that disseminate technologies such as solar lanterns, improved cook stoves and solar home systems. Initiatives such as Solar Sisters, Envirofit, Barefoot College, Kopernik and Grameen Shakti have reached millions of low-income people in African and Asian countries using similar strategies.

In 2015, the International Center for Research on Women conducted a qualitative assessment in Tanzania to better understand whether and how being a Solar Sister clean energy entrepreneur impacts women's and men's lives at the individual, family and community levels. A secondary focus of the study was to reveal initial insights about the benefits experienced by customers as a result of using Solar Sister's clean energy products. Solar Sister's unique model of recruiting, training and supporting female clean energy entrepreneurs was found to create benefits for individual women and their households and communities by enhancing income and autonomy; business skills and leadership; equality and communication; household health and stability; child education; mobility and status; and community safety (Solar Sisters, 2019).

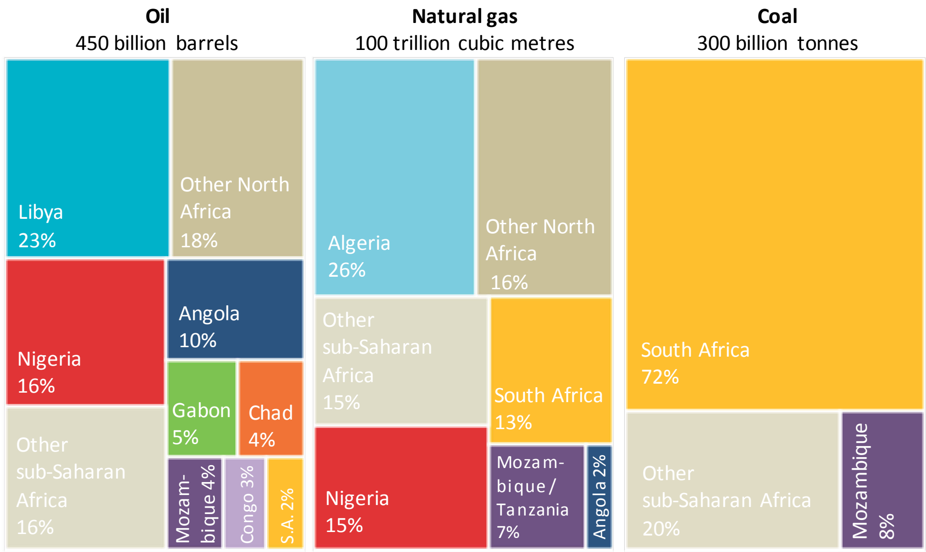
1.3.3 Fossil fuel resources and supply

Africa has large fossil fuel resources, with sub-Saharan Africa holding around half of the continent's oil and gas resources and nearly all of the coal resources. Remaining technically recoverable oil resources in Africa amount to some 450 billion barrels or around 7% of the world's oil resources. The 100 trillion cubic metres of remaining recoverable gas resources in Africa represent 13% of the world's gas resources. Coal resources are relatively small and concentrated in South Africa and, to a lesser extent, Mozambique (Figure 1.26).

Africa is also home to many of the minerals essential to the energy industry. It has around 20% of the world's uranium resources and 40% of the manganese reserves. It also produces a large share of key precious and base metals – for example, two-thirds of global cobalt production comes from DR Congo.

The continent's resource wealth has attracted interest from international companies. Between 2011 and 2014, Africa accounted for around 20% of global oil discoveries with six countries – Angola, Nigeria, Republic of the Congo (Congo), Ghana, Mozambique and Senegal – adding around 5 billion barrels of offshore resources. With major discoveries in Mozambique and Tanzania, Africa also accounted for around 45% of global gas discoveries during this period.

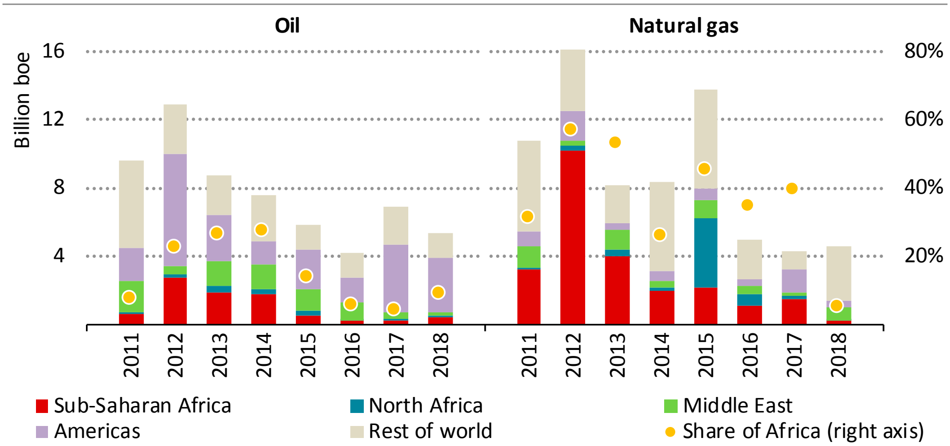
Figure 1.26 ▷ Remaining recoverable fossil fuel resources in Africa, 2018



Africa has abundant fossil fuel resources; sub-Saharan Africa accounts for around half of the continent's oil and gas resources

Since the fall in oil prices in 2014, oil exploration has fallen sharply, and Africa accounted for less than 10% of global oil discoveries between 2015 and 2018. There has however been a series of major offshore gas discoveries in Egypt (2015), Mauritania and Senegal (2015-17) and South Africa (2019) (Figure 1.27).

Figure 1.27 ▷ Global discoveries of oil and natural gas by region



Africa's share in global oil discoveries has fallen markedly since the oil price fall, but the region has seen significant gas discoveries

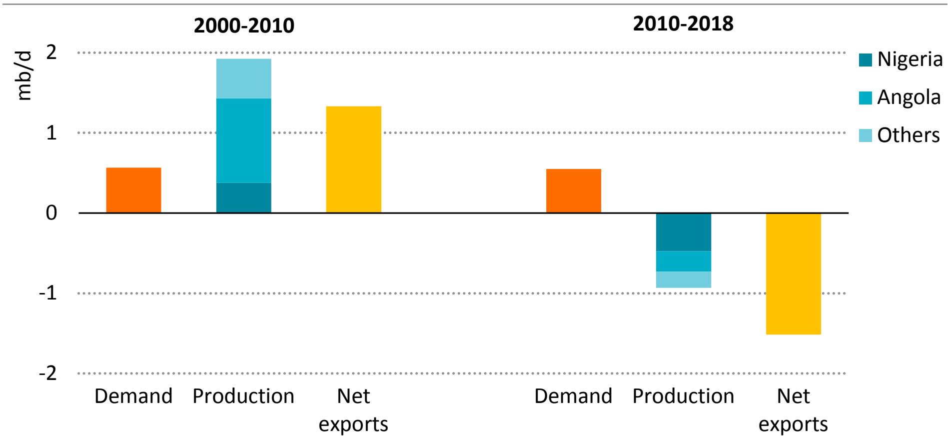
Note: boe = barrels of oil equivalent.

Oil

Oil production in Africa has seen major swings since 2000. In the early years after 2000, sub-Saharan Africa showed strong production growth as the expansion in Nigeria and Angola was joined by new producers such as Chad and Equatorial Guinea. The pace of production growth in sub-Saharan Africa was four-times faster than the global average and the region accounted for almost a quarter of global production growth between 2000 and 2010. This resulted in a 50% increase in net export volumes and, thanks to rising oil prices, a threefold increase in oil revenue.

However, sub-Saharan Africa faced a sharp reversal of fortune after 2010. Nigerian oil production started to decline from 2010 as regulatory uncertainties, militant attacks and the theft of oil took their toll, and Nigerian sweet crude oil also faced fierce competition from surging US tight oil output in export markets. Angola too struggled to keep up production levels as new investments failed to compensate for the rapid decline in maturing fields. Other producers such as Equatorial Guinea and Gabon also registered a gradual output decline. As a result, oil production in sub-Saharan Africa decreased by 15% from its peak in 2010 to 5 mb/d in 2018. Coupled with a 35% increase in domestic demand, this led to a 35% decline in net exports and associated revenue (Figure 1.28).

Figure 1.28 ▷ Changes in oil demand, production and net exports in sub-Saharan Africa

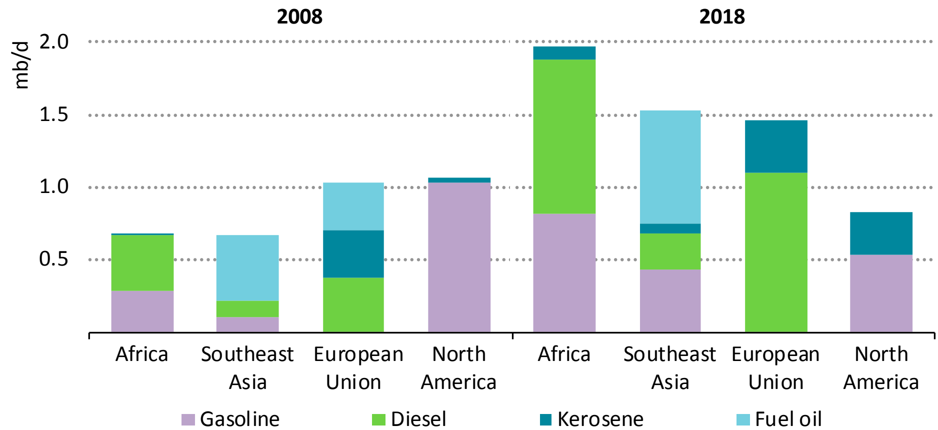


Coupled with the continued increase in demand, falling oil production in sub-Saharan Africa since 2010, led to a major drop in net exports

Major producers have recently managed to halt output declines. Nigeria's production has risen since 2016 as militant attacks in the Niger Delta have eased, but remains below the peak level reached in 2010. Long-standing issues holding back upstream investment, notably the uncertainties around the Petroleum Industry Bill, remain unresolved. In 2019, Angola succeeded in mitigating output declines due in part to the start-up of the Kaombo project, and the new government has initiated an overhaul of its oil and gas sector to stimulate investment, creating a new regulator, reorganising the role of Sonangol and streamlining investment procedures. In North Africa, output in Libya has been highly volatile given the instability and unrest there. Production registered a major drop in 2011 and remains well below 2010 levels. Output in Egypt has been in gradual decline since 2014 as investments have been directed towards natural gas developments.

Although Africa remains a major crude oil exporter, its growing oil demand and under-performing refining sector have combined to make it the world's largest importer of refined products. Africa holds 3.5 mb/d of refining capacity, which could theoretically serve three-quarters of its oil product demand, but it runs at low utilisation rates. On average, the utilisation rate was 58% in 2018; the rate was 25% in West Africa and just 9% in Nigeria.[12] African refineries tend to have fairly simple configurations, with low upgrading capabilities, and often suffer from poor maintenance. They also face growing competition from Asian and Middle Eastern refiners who are keen to export surplus diesel, and from European refiners who want to export excess gasoline. Poor refining performance has led to a growing deficit of refined products (Figure 1.29). Africa has now overtaken North America as the world's largest gasoline importer and is also the second-largest diesel importer after the European Union (IEA, 2019b).

Figure 1.29 ▷ Net imports of key refined products in selected regions



Growing demand for transport fuels and under-performing refineries have made Africa the world's largest importer of refined products

Natural gas

Africa's gas production increased rapidly in the 2000s, led by strong growth in Nigeria where the rise in oil production was accompanied by a large amount of associated gas, and in Egypt where shifting attention to gas use brought about threefold production growth. However Africa's gas production stagnated from about 2010. Egyptian production started to trend downwards until 2016 as unfavourable energy price schemes, mounting arrears to

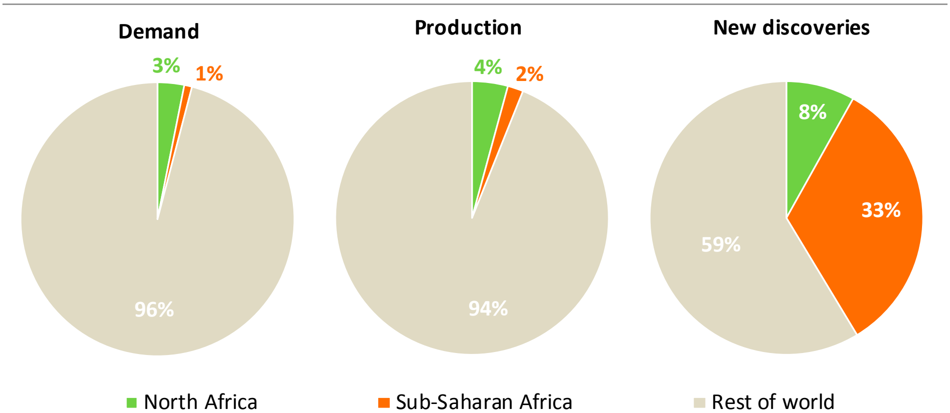
[12] Early data suggest that the utilisation rate dropped further to below 6% in the first-half of 2019.

international companies and social unrest caused a significant reduction in investment. Nigeria's rapid production growth also came to a halt as fiscal and legislative uncertainties weighed on investment. Algeria managed to maintain output levels, although its largest gas field, Hassi R'Mel, is already mature.

A series of major new gas discoveries seem likely to boost future gas production in Africa (Figure 1.30). The start of production at the large Zohr offshore field has already led to a turnaround in Egypt. A gas discovery on the maritime border of Mauritania and Senegal has been followed by a final investment decision (FID) on the Tortue liquefied natural gas (LNG) project. FIDs on new onshore liquefaction plants are coming to fruition in Mozambique to exploit the huge offshore resources in the Rovuma basin.[13] Total has also recently made a significant gas condensate discovery off the southern coast of South Africa, and the estimated volume of resources is over 20% of the world's entire gas discoveries in 2018.

Gas in Africa is at a critical juncture (see Chapter 4). Where resources are plentiful, it could provide the continent with additional electricity for baseload and flexibility needs, energy for industrial growth and a sizeable source of revenue. But whether that happens depends on countries with gas putting in place well-articulated strategies to turn the discoveries into production and to build infrastructure to deliver gas to consumers cost-effectively in a competitive global LNG market.

Figure 1.30 ▷ Share of Africa in global gas demand and production, 2018, and new discoveries, 2011-2018



Recent discoveries offer the potential to fundamentally change the role of gas in Africa

Coal

Coal production in Africa is dominated by South Africa, which accounted for 93% of the continent's output in 2018. Production in the main current producing region in

[13] Coral LNG reached a FID in 2017 and started construction in 2018. Mozambique LNG reached a FID in 2019 and Rovuma LNG by ExxonMobil is approaching a FID at the time of writing.

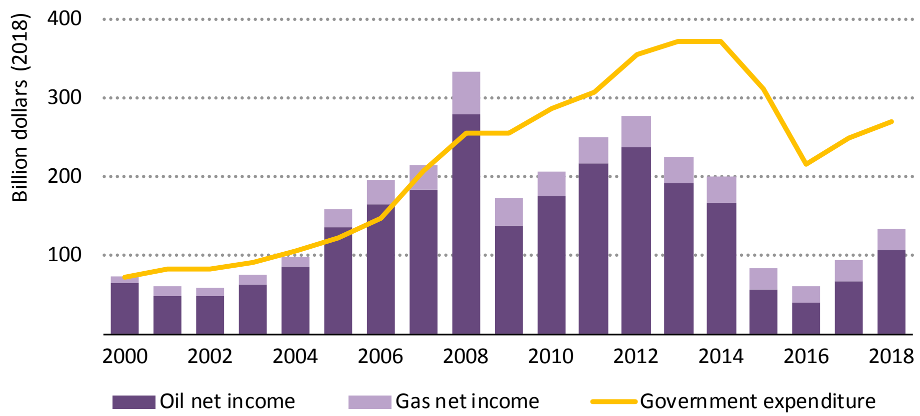
Mpumalanga province is starting to fall, and mining activities are now shifting to the northern Limpopo province on the border with Mozambique (IEA, 2018c). Around two-thirds of the country's output is consumed in domestic markets and most of the rest is exported via the Richards Bay Coal Terminal. Mozambique started coal production in 2010 and is the second-largest coal producer in Africa. Other countries such as Botswana and Zimbabwe are aiming to ramp up coal output, although building infrastructure – rail or roads – to connect production sites to demand or export centres remains a challenge.

1

Imperatives for resource producers

Energy resources have long been a crucial element in the economic outlook for Africa. There is a chance that recent discoveries will lead more countries to join the ranks of resource exporters. However, translating resource endowments into economic prosperity can be a daunting task. The net income[14] from resource production has been volatile over the past few decades and has tended to lead to high levels of public spending during boom times followed by periods of fiscal strain during downturns (Figure 1.31). This pro-cyclical spending has often undermined the effectiveness of government expenditure in promoting economic growth and structural transformation. Moreover, the rise of shale and the shift to clean energy also pose serious questions for development models that rely heavily on fossil fuels. It therefore is critical for both existing and potential producers to assess the resilience of their resource production and associated revenues and devise productive ways to manage and utilise resource income, a topic explored in more detail in Chapter 4.

Figure 1.31 ▷ Net income from oil and gas production and government expenditure in top-ten producers in Africa



Net income from oil and gas production in Africa has been volatile as the impacts of fluctuating commodity prices have been amplified by domestic circumstances

[14] 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.

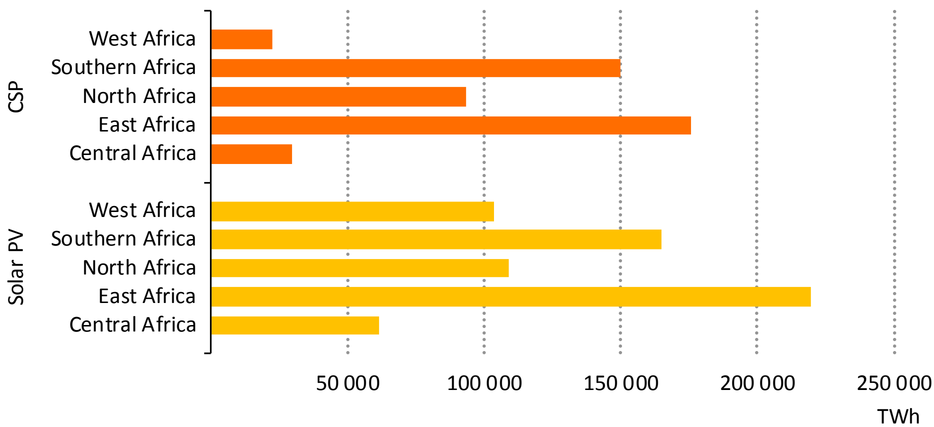
1.3.4 *Renewable resources and supply*

Africa is home to abundant renewable energy resources and its renewable energy power potential is substantially larger than the current and projected power consumption of the continent. Growth has been constrained, so far, by limited access to financing, underdeveloped grids and infrastructure, unstable off-taker financial arrangements and, in many countries, an uncertain policy environment (IEA, 2018b). Despite this, recent advances in renewable energy technologies and accompanying cost reductions mean that the large-scale deployment of renewable energy now offers Africa a cost-effective path to sustainable and equitable growth. In many parts of Africa, decentralised renewable energy technologies offer an economical solution for electrification in remote areas as well as for grid extension.

Solar

A study undertaken by the International Renewable Energy Agency (IRENA, 2014) assessed the theoretical potential of a range of renewable energy technologies in Africa (Figure 1.32). It estimated that Africa's solar PV theoretical potential could provide the continent with more than 660 000 TWh of electricity a year, far above its projected needs. East Africa was identified as having the highest theoretical potential (more than 200 000 TWh/year), followed by Southern Africa (more than 160 000 TWh/year).[15]

Figure 1.32 ▷ Solar energy resource potential per year in Africa



East Africa and Southern Africa contain the highest solar resource potential

Note: CSP = concentrating solar power.

Source: IRENA (2014).

[15] These potentials are purely theoretical potentials, with no techno-economic evaluation undertaken. These resource potentials, therefore, are subject to a significant reduction when economic parameters are applied.

Development of solar in Africa has been slow, with only around 4 GW of new solar PV capacity added between 2010 and 2018, more than two-thirds of it in sub-Saharan Africa. The main challenges and barriers that countries face include limited institutional capacity within government, lack of scale and competition, high transaction costs and the perceived high risk of such projects (World Bank, 2018). This has prompted the World Bank to start the Scaling Solar initiative to address these challenges by providing a "one-stop shop" to help governments mobilise privately funded grid connected solar projects at competitive costs.

IRENA also assessed the potential of CSP on the continent and estimated the likely potential as being around 470 000 TWh a year. Again, East Africa has the highest potential, followed by Southern Africa. Here too development has been slow with the exception of large solar CSP projects in Morocco and South Africa.

Hydropower

Hydropower has been the main renewable energy resource developed to date with around 35 GW of hydro capacity across Africa, with Angola, Ethiopia, DR Congo, Zambia, South Africa, Sudan, Mozambique and Nigeria each having 2 GW or more. Ethiopia has hydropower capacity of nearly 4 GW and more developments are planned, most notably the 6 GW Grand Ethiopian Renaissance Dam, which will be the largest in Africa when it comes into service in 2022. South Africa has installed hydropower capacity of close to 4 GW including the recent 1.3 GW Ingula plant.

Central Africa has very rich hydropower resources thanks mostly to the Congo River, the deepest river in the world and the second-longest in Africa after the Nile. There is a large mismatch between the significant hydropower potential in this region and the much more limited local electricity demand. This means that large-scale regional interconnections will be essential to promote its development. The DR Congo in particular has enormous hydropower potential that has been estimated at 100 GW, which could generate about 774 TWh of electricity per year. Plans in DR Congo to develop the Grand Inga Dam further have been beset with difficulties, but projects have been moving forward elsewhere.

While state-owned enterprises remain the largest developers of hydropower projects, many have been built by Chinese developers and backed by concessional financing. Chinese investors accounted for 60% of investment in sub-Saharan hydropower projects between 2010 and 2015.

Small-scale hydropower (1-10 MW) and mini-hydro power (0.1-1 MW) could provide power for rural electrification in some areas of sub-Saharan Africa, and there is particular potential in the central and south-eastern parts of the continent. A recent study estimated around 21 800 MW of small-scale hydropower technical potential (Korkovelos et al., 2018), with the central corridor of the sub-continent and especially South Africa, DR Congo and Sudan having the most potential. The same study also estimated that total mini-hydropower technical potential in sub-Saharan Africa was around 3 400 MW.

Wind

With close to 5.5 GW of installed wind power capacity in 2018, there is plenty of room for expansion given its theoretical potential to produce as much as 460 000 TWh of electricity a year (IRENA, 2014). Most wind resources are found close to coastal locations, mountain ranges and other natural channels in the eastern and northern regions of the continent. Algeria, Egypt, Somalia, South Africa and Sudan are among the countries with the highest wind energy potentials (IRENA, 2014). The best offshore wind energy potential is found off the coasts of Madagascar, Mozambique, Tanzania, Angola and South Africa.

Wind can be cost competitive with other technologies where the resources are good, but other factors could limit its deployment. For example, in East and North Africa, where the best resource potential is estimated, domestic markets are small and power grids are not well developed, meaning that significant variable generation from wind could be challenging to manage without additional grid investment.

Geothermal

Geothermal resources can be found throughout Africa but the bulk of the potential is concentrated in the East Africa Rift System, where total potential could be as much as 15 GW (BGR, 2016). This potential is largely untapped at present. Only Kenya has tapped its geothermal potential and installed capacity of almost 700 MW. Other countries in East Africa are now taking steps to make use of geothermal energy: Ethiopia is operating a 7 MW pilot plant and new developments totalling more than 1 GW are planned in Djibouti, Eritrea, Tanzania and Uganda. The expansion of geothermal power in the East Africa region faces a number of barriers, but technical and financial support is available (notably from Japan) to help countries formulate geothermal master plans and to promote private sector funding and local capabilities.

Bioenergy

Bioenergy continues to dominate the sub-Saharan energy mix and made up almost 60% of primary energy use in 2018. Almost three-quarters of bioenergy demand are accounted for by the traditional use of solid biomass in the residential sector, although there is also some use of solid biomass and biogas for modern power generation and heat.

Bioenergy can generate around 800 MW of electricity from current installed capacity, mainly in East and South Africa. However, large-scale deployment will be challenging, as the levelised costs of power generation from bioenergy are often higher than gas-fired generation and hydropower, due in part to the cost of collecting the biomass. Biogas has emerged as a substitute for firewood for cooking purposes in some areas, primarily in rural East Africa. Recently bio-slurry obtained from biogas production has started to be collected and utilised as fertiliser to increase agricultural production. Although at present there are technical and financial barriers limiting its application, biogas has a potentially important role to play in reducing indoor air pollution and related premature deaths (especially of women and children), limiting deforestation, and improving sanitation and the quality of life (especially for women) in rural and agricultural areas.

Advanced biofuels for transport have significant potential in many African countries. West Africa alone is estimated to have the potential to produce over 100 Mt per year of agriculture residues that could be converted into electricity or advanced biofuels such as ethanol and bio-butanol.

1.3.5 Environment

Water

Africa has less than 9% of the world's renewable freshwater water resources, and more than 50% of it is held in just six countries in Central and West Africa (UNESCO, 2019). The continent is home to roughly 80 transboundary lakes and rivers with most large river basins shared by five or more countries (UNECA, 2018b). Today, sub-Saharan Africa is in the midst of its worst drought in 35 years. In 2018, Cape Town almost ran out of water. In 2019, several cities in Mozambique, Zimbabwe, Ghana and Côte d'Ivoire experienced water shortages. Alongside changing and uncertain precipitation patterns brought on by climate change, Africa's water scarcity is compounded by a lack of water storage, supply and management infrastructure. By 2025, it is estimated that over 450 million people, mostly in West Africa, could be at risk of water stress (UNECA, 2018b).

Agriculture is the largest water user in sub-Saharan Africa today, despite the fact that just 3% of its total cultivated land is irrigated. Groundwater is estimated to be plentiful — the region withdraws less than 5% of its renewable groundwater whereas India, for example, withdraws almost 60% — but there is increasing evidence that some aquifers are being depleted (WWAP, 2019). Water use by the energy sector is low today, with coal and oil accounting for most of it. However, water availability could increasingly become a critical issue for energy sources, in particular for hydropower (see Spotlight in Chapter 3).

Household water use is also low and the World Health Organization (WHO) estimates that on average a person in Africa uses just 20 litres of water per day, well below the recommended minimum of 50 litres. Sub-Saharan Africa is also home to 745 million people that have no access to safely managed drinking water (over 70% of which reside in rural areas) and almost 840 million people that lack access to safely managed sanitation (roughly 60% of which are in rural areas) (UNICEF and WHO, 2019). Low rates of wastewater collection and treatment mean that a significant amount of untreated wastewater is released into the open. Contaminated drinking water has a significant health impact: diarrhoea is a major cause of mortality for children under five in sub-Saharan Africa.

Significant progress will be required to reach the targets set under the Sustainable Development Goal 6 (clean water and sanitation) by 2030 (Box 1.7). Water demand is projected to increase more in Africa than in any other part of the world rising by almost 300% from 2005 to 2030, and a large share of it is projected to occur in municipalities reflecting rapid urbanisation and more people gaining access to clean water (Wijnen et al., 2018). This will also result in larger amounts of wastewater to be collected and treated (which can increase energy demand depending on the level of treatment).

Box 1.7 ⊳ How does energy provision look different if viewed alongside water and food?

Millions of people in sub-Saharan Africa do not have adequate access to the basic building blocks of economic and societal development: energy, water and food. While providing electricity access at a household level is critical, it is not enough on its own to ensure economic development. Approaching development from an integrated water-energy-food perspective allows for a broader and more durable view of local economic development, and could also change the scale and type of the energy technologies deployed. The value of this perspective for sub-Saharan Africa is visible at both a household and a broad economic level. At a household level, it is clear that the technologies being deployed to provide access to electricity can also be used to provide access to clean drinking water (IEA, 2019c). At an economic level, viewing energy development though this prism can advance the prospects for sustainable productive uses, such as agriculture. Moreover, such an approach can help address the central role of women in providing these resources.

The potential for such an approach is highlighted by a recent micro and macroeconomic modelling exercise that looked at the Ikondo-Matembwe project in rural Tanzania (RES4Africa Foundation, 2019). This project, which serves eight villages, consists of two community-scale hydro-powered mini-grids that power an anchor client, an agribusiness focused on producing animal feed, hatching poultry, and providing electricity and water to the surrounding households. The preliminary results of this study, which used a cost-benefit analysis based on the project's investment data to assess the benefits of single versus multi-service scenarios, indicate that over its 20-year lifespan a renewable energy-based integrated project has more than twice as much economic impact[16] on a local community as a project geared to the provision of energy alone. Investing in an integrated approach also had a multiplier effect, significantly increasing local purchasing power which translated into improvements in other areas. Some of the biggest benefits came in the form of increased access to better education, improved agricultural productivity and time saved from having water and energy access on site.

More research and examples are needed of these kinds of projects to understand the scope for replicating them at scale, but it is evident that looking at energy, food and water together in an integrated way has clear potential to trigger captive energy demand, increase economic productive capacity, and set African communities and economies on a path that looks beyond the immediate imperatives to meet the 2030 sustainable development goals.

[16] Measured in net-present value.

GHG emissions

In 2018, Africa accounted for around 4% of the world's energy-related carbon dioxide (CO_2) emissions despite being home to around 17% of the population. The power sector was the largest emitting sector (480 Mt CO_2) followed by transport (355 Mt CO_2) and industry (150 Mt CO_2).

Total energy related CO_2 emissions in North African countries in 2018 were around 490 Mt or 40% of Africa's energy-related CO_2 emissions (1 215 Mt CO_2). South Africa's energy sector emitted 420 Mt CO_2 with its coal-fired power fleet responsible for more than half of the country's energy-related CO_2 emissions and more than three-quarters of the sub-Saharan region's power sector emissions.

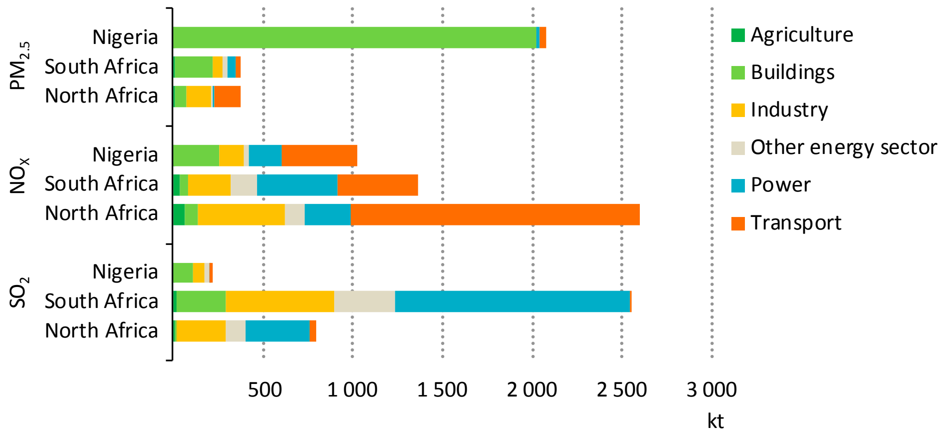
While the sub-Saharan African energy sector makes a very small contribution to global CO_2 emissions, the region is among those most exposed to the effects of climate change. For sub-Saharan Africa, which has experienced more frequent and more intense climate extremes over the past decades, the consequences of the world's warming by more than 1.5 degrees Celsius (°C) would be severe. Temperature increases in the region are projected to be higher than average global temperature increase; regions in Africa within 15 degrees latitude of the equator are projected to experience an increase in warmer nights and longer and more frequent heat waves (UN, 2019b). A recent report published by the Intergovernmental Panel on Climate Change found that the potential impacts of global warming levels on key sectors at local to regional scales, such as agriculture, energy and health, remain uncertain in most regions and countries of Africa (IPCC, 2018).

Local air pollution

Around 6.8 Mt of fine particulate matter ($PM_{2.5}$) were emitted in Africa in 2018, of which almost 85% was from the burning of biomass indoors. Damage to air quality from these sources disproportionately affects the poorest in Africa. Nigeria, with its large population and low levels of access to modern energy services, accounted for around a third of Africa's $PM_{2.5}$ emissions, emitting 2.1 Mt in 2018. This compares to around $PM_{2.5}$ emissions of 0.4 Mt in South Africa, 0.3 Mt in Tanzania and 0.2 Mt in Kenya in 2018. Efforts have been made across the continent to reduce $PM_{2.5}$ emissions mainly through incentivising the use of modern cooking fuels, such as LPG and natural gas. South Africa's National Environmental Management Air Quality Act of 2004 is one example of an African country regulating air quality and setting emissions standards, imposing limits on new and existing power plants and industrial installations.

Nitrogen oxides (NO_X) emissions in Africa were around 7.5 Mt in 2018, of which nearly 50% came from vehicle tailpipe emissions, a further 18% from industry, 16% from the power sector and 11% from buildings. In North Africa, vehicle tailpipe emissions made up almost two-thirds of NO_X emissions, reflecting the relatively high number of cars on the road. In South Africa, which has sub-Saharan Africa's largest car fleet, vehicle tailpipe emissions accounted for about a third of NO_X emissions: a further third came from the power sector (33%), largely as a result of the large share of coal in South Africa's power mix.

Figure 1.33 ▷ Emissions of $PM_{2.5}$, NO_X and SO_2 by sector in Nigeria, South Africa and North Africa, 2018



Nigeria accounts for a very large share of Africa's $PM_{2.5}$ emissions, North Africa for a large share of NO_X emissions and South Africa for its SO_2 emissions

Note: kt = kilotonnes.

Source: International Institute for Applied Systems Analysis.

Sulfur dioxide (SO_2) emissions were almost 5 Mt in 2018, almost 40% of which came from power generation, largely as a result of coal combustion in South Africa, and nearly 40% from the industry and transportation sectors (Figure 1.33).

In Africa, almost 500 000 premature deaths each year can be attributed to household air pollution, a health problem which is closely related to the lack of access to modern forms of energy. Fewer deaths in Africa are attributable to outdoor pollution than to household air pollution, but the number still stands at more than 300 000 per year, with most occurring in sub-Saharan Africa (excluding South Africa).

Urbanisation, industrialisation and clean cooking

How fast will Africa grow?

SUMMARY

- Africa has the world's fastest growing population: one-in-two people added to the world population in the period to 2040 are African. With over 40% of the continent's population under the age of 15, it also has the world's youngest population. This young, expanding population is rapidly becoming more urban. The last two decades have seen the number of people living in cities increase by 90%, and this trend is set to accelerate over the next two decades. By 2040, an additional 580 million Africans are living in cities – a pace of urbanisation that is unprecedented.

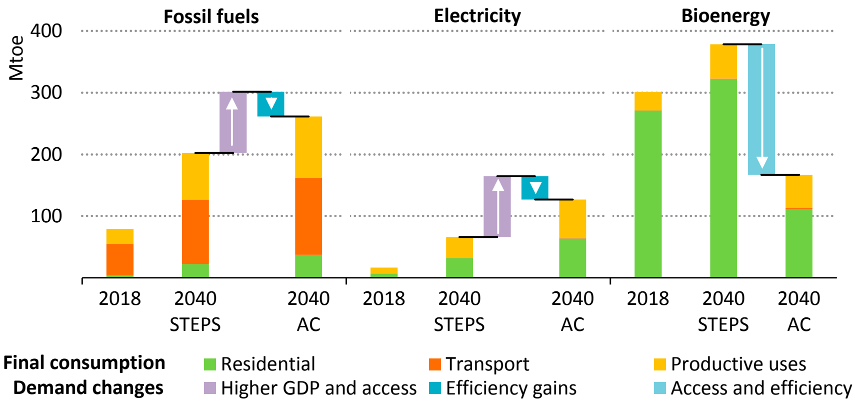
- The energy sector has a vital role to play in Africa's future. Growing urban populations imply rapid growth in material demand to build infrastructure, expansion of industrial and agricultural production, and increased mobility of people and goods, boosting energy demand. In the Stated Policies Scenario, the continent's economy grows to two-and-a-half times its current size by 2040.

- Our Africa Case outlines the implications for the energy sector of countries across the continent realising their ambitions for accelerated economic growth and universal access to energy. If the energy needs of the future set out in the Africa Case are to be met in a sustainable way, a strong emphasis on improvements in energy efficiency will be vital. Focus areas include fuel economy standards for cars and two/three-wheelers (largely absent today), highly efficient industrial processes, building codes and efficiency standards for appliances and cooling systems.

- The growth in population in areas with high average temperatures means that by 2040, if the global average temperature increase is kept to the limits of the Paris Agreement, over 1 billion people in sub-Saharan Africa will be living in areas that need space cooling (a number that increases to 1.2 billion if the world continues on its current trajectory of warming). This means that cooling is set to be one of the most important factors in determining the extent of future energy demand.

- Bioenergy is the largest source of energy in sub-Saharan Africa today and accounts for two-thirds of final energy consumption. Around 850 million people in sub-Saharan Africa rely on the traditional use of biomass, cooking with inefficient stoves, while another 60 million rely on kerosene or coal to meet their daily energy needs. Cooking with polluting fuels and stoves has major health and environmental consequences, and was linked to almost 500 000 premature deaths in 2018. Less than 200 million people in sub-Saharan Africa currently have access to cleaner options such as liquefied petroleum gas (LPG), natural gas, electricity or improved biomass stoves.

Figure 2.1 ⊳ Final consumption by fuel, sector and scenario in sub-Saharan Africa (excluding South Africa)



In the Africa Case, efficiency gains reduce potential demand growth to 2040 by one-third, while achieving SDG 7 reduces bioenergy use for cooking

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

- Some progress is made in the Stated Policies Scenario in reducing reliance on the inefficient use of bioenergy for cooking, but the number of people gaining access to clean cooking barely exceeds population growth. Switching from the traditional use of biomass to cleaner options faces both economic and non-economic barriers, but the Africa Case sees all households across the continent gain access to clean cooking by 2030, with benefits in particular for women and children. In the Stated Policies Scenario, the number of premature deaths linked to indoor air pollution continues to increase to 500 000 by 2030; in the Africa Case, clean cooking for all by 2030 reduces that number by more than two-thirds.
- Although nearly 600 million people in sub-Saharan Africa still use solid biomass in improved cookstoves in the Africa Case in 2040, improved efficiency is enough to cut bioenergy demand in half from today's level. Charcoal use for cooking is increasing, especially in urban areas, it remains an important source of energy in both cases in 2040. This makes improving efficiency along the charcoal value chain an important priority.
- Biogas has the potential to provide 50 million tonnes of oil equivalent (Mtoe) of locally produced low-carbon energy in Africa, largely via household-scale biodigesters; this potential doubles to almost 100 Mtoe by 2040, at an average cost of around $10 per million British thermal units (MBtu). The main economic barrier to increased uptake is the upfront cost of installing a biodigester. Other barriers such as maintenance requirements and feedstock availability can be overcome with well-targeted policies and programmes.

2.1 Introduction

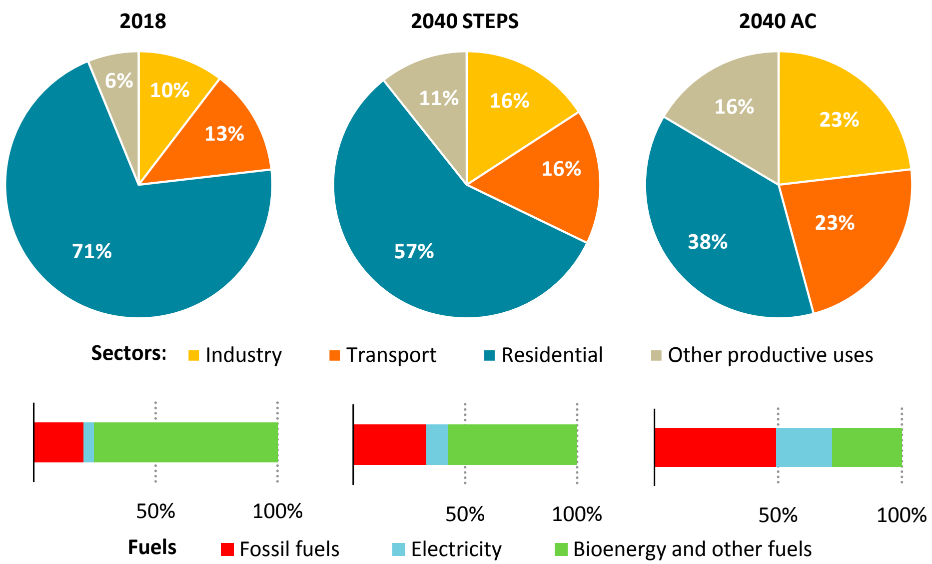
Africa's population has grown by 470 million since 2000, making it the fastest growing region in the world. It is also by some distance the youngest, with a median age of 20 years, compared to a global average of 30 years (United Nations, 2019). Changing demographics are at the heart of any discussion of economic development. Beyond the increase in the number of people in the region, the unprecedented magnitude of the shift from rural to urban living and the extent to which industrial development contributes a greater share of economic output will have a profound impact on energy demand growth in the future. Africa's projected population growth could act as a catalyst for economic growth. However, this will only be the case if there are enough job opportunities in productive enterprises to fully capture the potential dividends of the demographic change.

As an ever-higher proportion of the African population moves to cities in the period to 2040, demand for energy services will inevitably grow. The average household in a city consumes three-times more oil and electricity than the average rural household in sub-Saharan Africa (excluding South Africa), although there are large disparities within cities. A large part of the migration to cities is comprised of low or unskilled labourers — often moving to peri-urban areas which are home to 55% of the urban population in sub-Saharan Africa today (Odamo, 2019). In these areas, electricity access rates are lower than in the heart of the city, although still much higher than in rural regions. Charcoal and firewood remain the predominant cooking fuels in many peri-urban households, as traditional practices tend to endure even when cleaner options are available.

Most energy in sub-Saharan Africa (excluding South Africa) is used for cooking, which accounts for around 70% of total final consumption, compared to less than 10% globally. Low rates of access to electricity, low levels of appliance and vehicle ownership, limited transport infrastructure and low levels of industrial production explain why this is so. Bioenergy is the major source of energy used to meet cooking energy needs in sub-Saharan Africa (excluding South Africa). This cheap or free resource accounts for three-quarters of total final consumption. Traditional use of biomass, often in poorly ventilated spaces, has severe impacts on health and the environment. Efforts to improve access to clean cooking lag far behind efforts to secure access to electricity. Globally, nearly 2.4 billion people continue to use inefficient open fires or simple cook stoves today, around 840 million of whom live in sub-Saharan Africa (excluding South Africa). To date, cleaner processed forms of bioenergy like biogas and biofuels have made limited progress in the region.

In both the Stated Policies Scenario and the Africa Case, higher economic outputs and higher household incomes lead to increased energy service demand in every sector. Total final consumption in sub-Saharan Africa (excluding South Africa) grows by around 65% from today to 2040 in the Stated Policies Scenario, with the share of all productive uses within total final consumption rising as the scaling up of production leads to industry sector energy demand more than doubling by 2040 (Figure 2.2). In the Africa Case, industry energy demand more than triples on the assumption of accelerated industrial and economic growth. Increased economic prosperity is reflected in terms of higher household appliance ownership and expanding vehicle stocks. In the Africa Case, electricity demand within households for cooling and appliances in sub-Saharan Africa (excluding South Africa) rises 14% per year to reach more than 500 terawatt-hours (TWh) by 2040 (compared to 30 TWh today), with cities being responsible for more than 60% of this growth. Similar trends are observed for passenger vehicles, with car stocks more than tripling to reach 27 million within two decades in the Stated Policies Scenario and more than 35 million in the Africa Case. In 2040, over 80% of this passenger car fleet is operating in cities.

Figure 2.2 ▷ Final consumption by sector and fuel in sub-Saharan Africa (excluding South Africa) **in the Stated Policies Scenario and Africa Case, 2018 and 2040**



Economic growth spurs increases in energy demand in industry and transport. Bioenergy's share declines as households increasingly switch to cleaner fuels

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

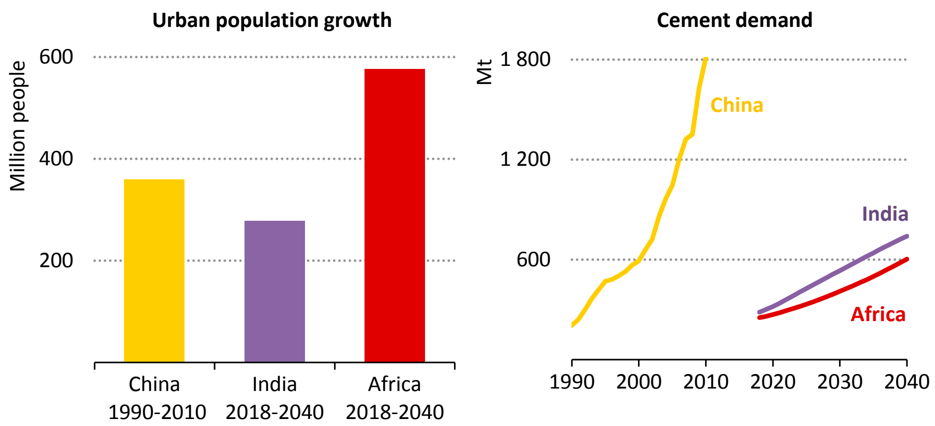
The share of fuels in the energy mix of every sector sees some significant changes in both scenarios. In the Stated Policies Scenario, bioenergy remains the largest source of energy, with a share of just under 60% in 2040 in sub-Saharan Africa (excluding South Africa), and total bioenergy consumption increases from 300 million tonnes of oil equivalent (Mtoe) today to 380 Mtoe in 2040. In the Africa Case, extending energy access to the entire population by 2030 (UN Sustainable Development Goal [SDG] 7) is achieved via a combination of improved cook stoves, liquefied petroleum gas (LPG), electrification, ethanol and other solutions. Bioenergy demand is cut in half, as the number of people relying on the traditional use of biomass drops to zero and kilns to produce charcoal become more efficient.

We analyse how the electricity sector can be expanded to supply the increased demand caused by urbanisation and electrification in Chapter 3, and carry out the corresponding analysis for fuel supply in Chapter 4. In this chapter, we assess the role of demand-side policies and aim to answer three crucial questions. What are the implications of rapid urbanisation and industrialisation for energy use in Africa? What role could a more efficient use of energy play in accelerating Africa's economic development? What is needed to reach full access to clean cooking?

2.2 Urbanisation and industrialisation, drivers of growth

The urban population in sub-Saharan Africa is growing rapidly, more than doubling since 2000 to reach 440 million today. The share of the population living in cities is now 40%, up from 32% in 2000. There are 520 million more people in cities in sub-Saharan Africa in 2040 than there are today (along with an extra 60 million in North Africa). Urbanisation of this scale and at this speed has never been seen before, and is expected to be twice as large as the projected growth of urban population in India over the next two decades.

Figure 2.3 ▷ Urban population growth and cement demand in China (historical), **India** (Stated Policies Scenario) **and Africa** (Africa Case)



Africa experiences unprecedented growth in its urban population, but follows its own trajectory for cement demand

Note: Urban population in Africa is assumed to be the same in both the Africa Case and Stated Policies Scenario.

Africa's rapidly increasing population and growing urbanisation bolsters demand for materials. This could underpin industries that in turn stimulate further growth and income generation on the continent. As a point of comparison, China's economic boom between 1990 and 2010 saw the population of cities increase by 360 million: cement production grew ninefold during this period, while iron and steel production increased ten-fold. Africa's future infrastructure is however unlikely to follow the same path as China's. Traditional materials and designs look set to play an important role in Africa, and so do local innovations.[1] Therefore, Africa is likely to follow its own growth trajectory (Figure 2.3). As well as mitigating the growth of cement and steel demand, an approach tailored to African conditions would help promote a housing stock suited to the climate, which in turn would act to offset some of the growth in demand for cooling. New initiatives could bring about urbanisation with reduced resource needs. Adobe houses, and bamboo- or wood-based low-storey buildings are examples of what may be possible in this context

Per capita energy consumption across sub-Saharan Africa is extremely low, at less than a third of the global average. This is, in part, a reflection of the fact that a higher percentage of people live in rural areas in sub-Saharan Africa than in any other region in the world, which makes it more difficult to achieve access to electricity and clean cooking for all (see Chapter 1). But it also reflects lower than average consumption across end-use sectors. There are, of course, large disparities both between and within countries, but the level of car ownership illustrates the size of the gap in energy services: at 115 cars per 1 000 people, South Africa's ownership rate is eight-times the sub-Saharan African average, but stands at one-quarter the average for advanced economies globally, while in Ethiopia the ownership of vehicles is less than 2 cars per 1 000 people. The potential for growth in energy consumption in the transport sector is very large, and an increase in the number of two/three-wheelers is already taking place in a number of sub-Saharan African countries.

There are other examples as well of low levels of energy consumption and potential for strong future growth. About 680 million people are located in hot areas in sub-Saharan Africa (where the average perceived daily temperature[2] exceeds 25 degrees Celsius (°C) over the whole year) which would typically require the use of cooling devices such a fan or air conditioner. However, only around 10 million households own an air conditioner across sub-Saharan Africa, while 100 million own an electric fan. The inevitable increase in future demand for cooling (spurred by population and income growth, the move to cities and climate change), requires a fundamental rethink not only of the way energy is produced and consumed across the continent, but the way the urban environment is constructed (Box 2.1).

Large infrastructure projects, from maritime port expansions to railway modernisation, are one of the main drivers of growth in materials demand (Table 2.1). The choice of whether industrial products will be imported (as they mostly are now, with the exception of cement), or produced domestically (underpinning a potentially transformative industrial growth story), will have major implications for Africa's energy and economic sectors.

[1] For example, a Colombian company has exported its manufacturing experience of producing bricks from used plastics to Côte d'Ivoire, where the aim is to build 500 classrooms using this technology by 2020.

[2] The combined effects of air temperature, relative humidity and wind speed.

Table 2.1 ▷ Selected large infrastructure projects in Africa

Project	Countries involved	Proposed construction start	Cost estimate ($ million)
Abidjan - Ouagadougou transport corridor	Burkina Faso and Côte d'Ivoire	Unknown	600
Batoka Gorge Hydropower Project	Zambia and Zimbabwe	2020	4 500
Brazzaville - Kinshasa Road/Rail Bridge	DR Congo and Republic of Congo	2020	550
Dar es Salaam Port Expansion	Tanzania and neighbouring countries	2020	420
Grand Ethiopian Renaissance Dam	Ethiopia	In progress	5 000
Inga 3 Hydropower Plant	DR Congo and regional partners	2024-25	12 000-14 000
Juba - Torit - Kapoeta - Nadapal - Eldoret Road Project	Kenya and South Sudan	Unknown	420
Lamu Port	Kenya	2020	3 100
Modernisation of Dakar-Bamako Rail Line	Senegal and Mali	Unknown	3 000
New Administrative Capital (Egypt)	Egypt	Unknown	20 000
Ruzizi III Hydropower Project	Burundi, DR Congo and Rwanda	2020	600
Sambangalou Hydropower Project	Guinea, Senegal and other West African Power Pool member countries	Unknown	455
Serenje - Nakonde Road Project	Zambia and regional partners	In progress	674
Trans-Saharan Gas Pipeline	Nigeria, Niger and Algeria	Unknown	10 000-13 700
Zambia Tanzania Kenya Transmission Line	Kenya, Tanzania, Zambia	Unknown	1 200

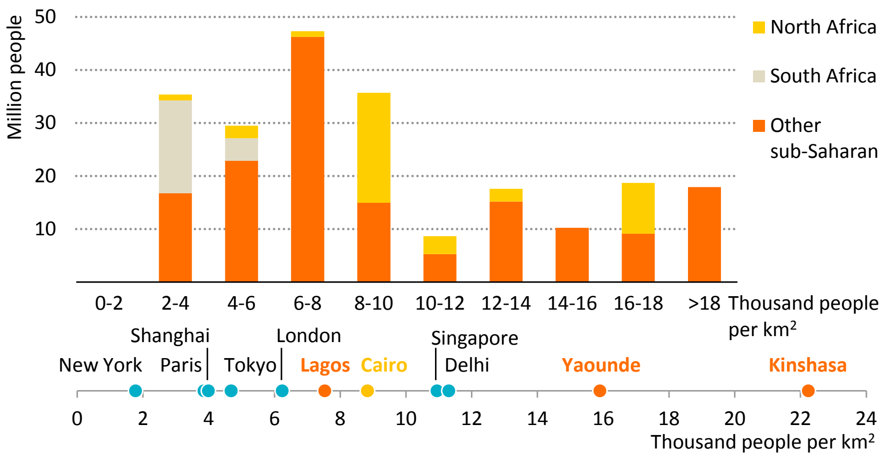
Box 2.1 ▷ Design, build and strengthen sustainability for African cities

Among the 534 cities of more than one million inhabitants across the world today, 66 are in Africa (Demographia, 2019). Uncontrolled urban development is making living conditions more precarious: some cities in Africa already suffer from population displacement and serious congestion.

About 85% of the inhabitants of today's African cities live in areas denser than metropolitan Paris (Figure 2.4). Although densely populated cities can ease the provision of services, they can exacerbate air and noise pollution and increase demand for space cooling. Temperatures in densely populated cities can be 3-5 degrees higher than in low-density neighbourhoods due to human activity, heat radiation from concrete, asphalt and other materials as well as an increasing number of air conditioners that move heat from inside to outside of buildings (Tremeac et al., 2012).

In 2040, there are twice as many people in cities in Africa as there are today. Strong policy ambitions, long-term investment and sound urban planning are needed to harness the opportunities and overcome the challenges of urbanisation and the rise of medium-size cities. Training, capacity building and engagement at the national, regional and community levels are critical to ensure that solutions are tailored to local needs. In order to balance economic and environmental aspirations, policy makers and urban planners need to plan for growth in energy demand related to the manufacturing, transport and use of building construction materials. From now to 2040, the equivalent of all built surfaces in Ethiopia are added every year to Africa's built environment. Material efficiency strategies including building design, lifetime extension and waste reduction are an essential part of this planning.

Figure 2.4 ▷ Urban population by density in cities of more than one million inhabitants in Africa and density of selected cities, 2018



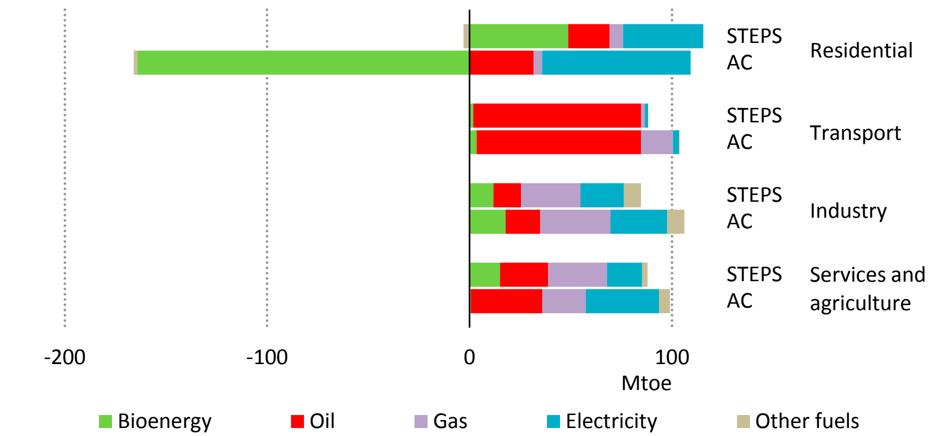
Growth and increasing density in African cities create both opportunities and challenges for policy makers and urban planners

High-density urban areas could provide opportunities to scale up the high energy performance construction market. Passive design allowing for natural ventilation and solar heat gain reductions could slash air conditioning demand by 65-70% in climates similar to coastal Senegal (Harkouss et al., 2018). They also fit well with other energy-efficient design strategies such as increasing natural daylight intake.

Providing infrastructure and promoting rules that encourage public or non-motorised transit could reduce the impact of urban growth on energy demand for transport in Africa. Bus rapid transit systems generally require low shares of public subsidies since moderate capital investment can sustain a large passenger throughput. Urban planning and city structure also matter. Planning should ideally lead to a mix of land uses – residential, commercial and industrial – while promoting walking, cycling and mass transit. Urban planners equally need to address current practices leading to sub-optimal choices such as importing old second-hand vehicles that pollute, the provision of free/cheap parking and the remuneration of public transport operators on the basis of number of passengers transported per day.

A number of countries, including Nigeria, Mozambique and Angola, have included steel and chemicals in their industrial development strategies. The Action Plan for the Accelerated Industrial Development of Africa (AIDA) initiative counts among its ambitions the development and implementation of industrial policy that promotes local production and upgrading of existing industrial technologies. At regional level, the initiative encompasses programmes such as the development of regional industrial strategies, the creation of industrial development funds for infrastructure and heavy industry, and support for incubators. At continental level, the AIDA initiative aims to harmonise industrial policies and promote development partnerships. The realisation of these ambitions is closely bound up with the evolution of the energy sector. Industrial expansion requires more energy than is produced today. It is also likely to accelerate urbanisation, leading to increased energy demand in households and for transport. At the same time it could generate higher incomes, further increasing energy demand. The upside for industrial output is explored in detail in the Africa Case.

Figure 2.5 ⊳ Change in total final consumption by sector and energy type in sub-Saharan Africa (excluding South Africa) **in the Stated Policies Scenario and Africa Case, 2018-2040**



Higher economic growth in the Africa Case sees increasing demand for all fuels, except bioenergy, with access to clean cooking for all and efficiency gains driving its reduction

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

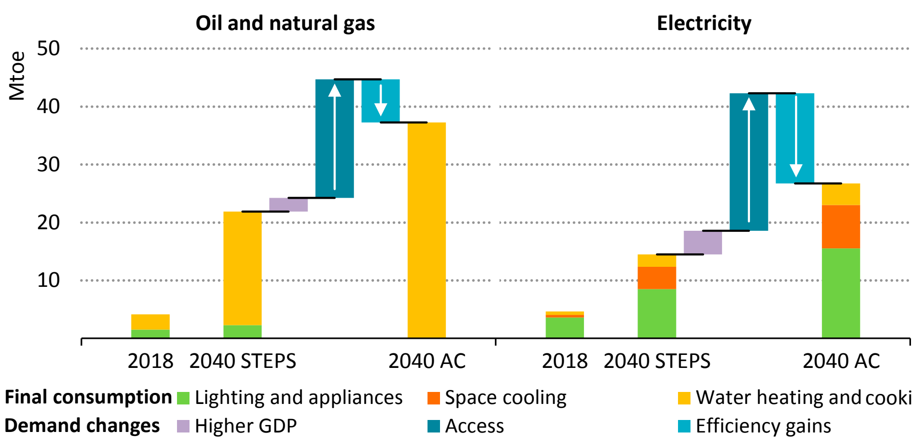
Greater economic output, higher household incomes and improved living standards also mean that car, appliances and cooling systems ownership rates in sub-Saharan Africa are higher in the Africa Case than the Stated Policies Scenario. The impact on energy consumption is mitigated to some extent by the implementation of more stringent vehicle efficiency policies and regulations, notably on the second-hand market. In the residential sector, building energy efficiency codes and higher minimum energy performance standards (MEPS) for appliances and cooling systems help to slow electricity demand growth in the Africa Case. Building codes also play an important role in the construction industry (only 30% of the building stock anticipated for 2040 currently exists). These codes require countries to establish regulatory frameworks to set performance standards and ensure compliance with them.

Overall, the reduction in bioenergy use in the residential sector in the Africa Case and the increased focus on energy efficiency, mean that total final consumption in 2040 in sub-Saharan Africa (excluding South Africa) is lower in the Africa Case than in the Stated Policies Scenario, despite an economy that is 60% larger (Figure 2.5).

2.2.1 Residential sector

The residential sector accounts for around 65% of total final consumption of energy in sub-Saharan Africa (compared to 22% globally and less than 20% in advanced economies), making it the largest end-use sector across sub-Saharan Africa. In the Stated Policies Scenario, increasing incomes and living standards, as well as improved access to affordable and reliable electricity, leads to a steady increase in energy consumption in the residential sector. However, its share in overall consumption diminishes to around half in 2040 as energy demand in industry grows at a rate that is nearly triple that of the residential sector. In the Africa Case, overall demand in residential buildings actually decreases by around one-quarter as a result of efficiency improvements and the rapid displacement of biomass in cooking (see section 2.3). Together with the accelerated industrialisation included in the Africa Case, this fall in demand reduces the share of the residential sector to around one-third of overall consumption by 2040.

Figure 2.6 ▹ Final consumption of selected fuels in the residential sector in sub-Saharan Africa (excluding South Africa) **in the Stated Policies Scenario and Africa Case, 2018 and 2040**



More efficient cookstoves, air conditioners and appliances temper energy demand growth from households

In the residential sector, oil and electricity are increasingly used for cooking and water heating in both scenarios, with LPG making big inroads (Figure 2.6). There is a major shift away from the traditional use of biomass, and universal access to clean cooking is achieved by 2030 in the Africa Case, fulfilling SDG target 7.1. Use of natural gas expands in cities that are able to make use of nearby gas resources.

2

In the Africa Case, rising incomes and access to basic energy services mean that demand for electricity grows more than for any other energy source (see Chapter 3). Demand for lighting and other appliances grows sixfold to 2040, while demand for cooling increases by more than 13% per year to 2040 in the Africa Case, making the issue of cooling one of the most consequential in determining the extent of future residential energy demand (see Spotlight). The consequences for energy demand of meeting this challenge can be mitigated by ensuring that sustainability is central to the choices made when designing Africa's future built environment (Box 2.1). Rigorous efficiency standards for new cooling systems (fans and air conditioners) and better design of new buildings are both central to the Africa Case and help to avoid 110 TWh of additional electricity demand (around 15% of residential electricity demand in 2040). Efficiency standards for major appliances avoid an additional 180 TWh.

S P O T L I G H T

Is cooling comfort achievable for Africa in a warming world?

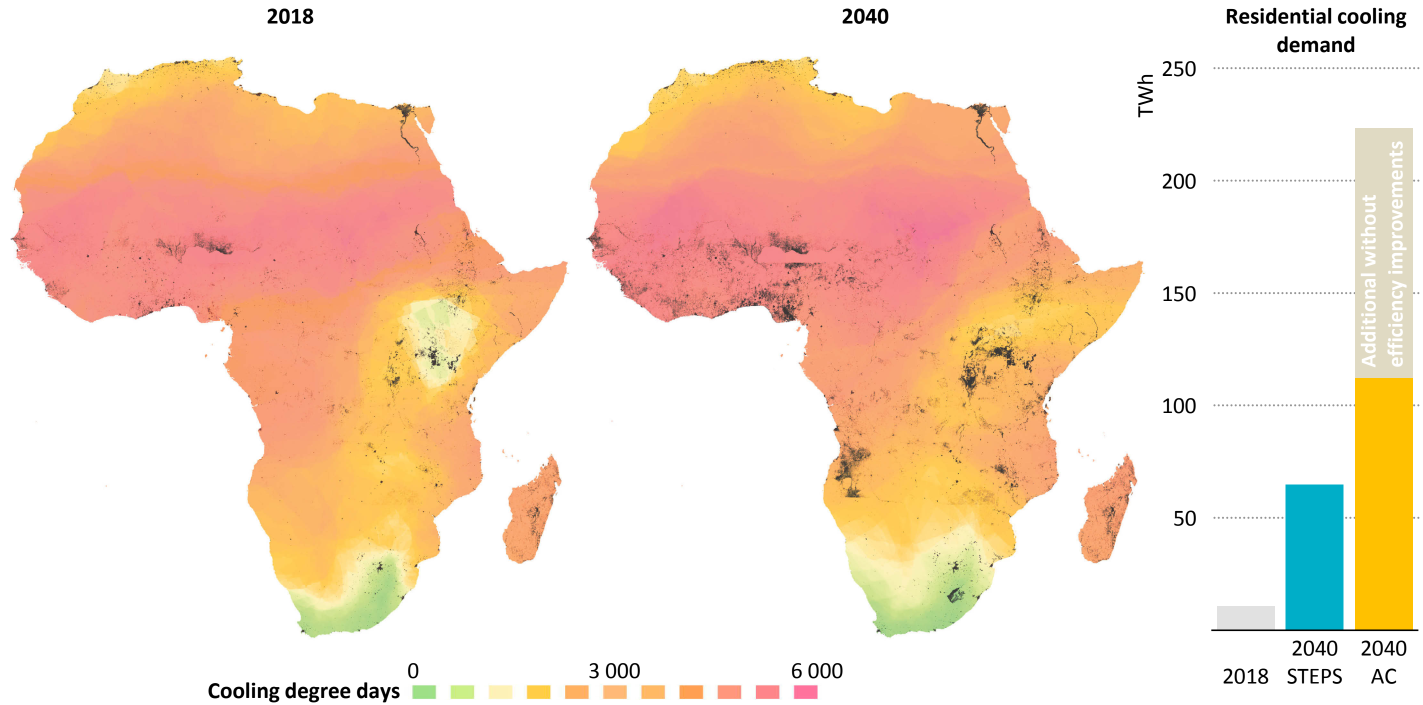
Roughly 680 million people in Africa (more than half of the population) currently live in areas that may need cooling systems.[3] This share varies by country: in Egypt and Tanzania, less than 40% of the population live in places that have daily average temperatures above 25 °C, while in countries such as Niger, Senegal and Sudan, nearly the entire population does.

Overall, around one-quarter of the global population that needs cooling today lives in Africa. Yet ownership of cooling devices is rare; air conditioner ownership across Africa averages only 0.06 units per household, while fans are somewhat more common averaging 0.6 units per household. Ownership rates reflect differences in income levels and climate. Wealthier countries such as Morocco, Algeria and Tunisia have air conditioner ownership rates that are three-times the African average, despite a lower than average number of cooling degree days (Figure 2.7).[4] In contrast, less affluent

[3] Cooling needs exist across multiple sectors, *inter alia,* providing health services, air conditioning in commercial buildings, cold storage for agricultural products, transport cold chains; this Spotlight highlights the biggest growth projected which is for residential buildings.

[4] Thermal comfort is measured in cooling degree days (CDDs), a universally recognised metric that allows comparison of cooling needs between regions. A CDD measures how warm a given location is by comparing actual temperatures with a standard base temperature (usually 18 °C). Calculating annual CDDs for a location gives an indication of cooling needs. CDDs can also include a heat index correction to account for the influence of humidity on perceptions of temperature and cooling needs. Many locations across Africa experience 4 000 – 5 000 CDDs annually, an order of magnitude higher than in countries such as France (230) and Italy (630). The number of CDDs in Africa dwarfs the major cooling demand centres of the United States (3 150) and China (1 100).

Figure 2.7 ⊳ Cooling degree days in the Stated Policies Scenario and cooling electricity demand, 2018 and 2040



Urban migration alongside a big increase in the number of hot days in Africa's cities will drive major growth in demand for cooling needs

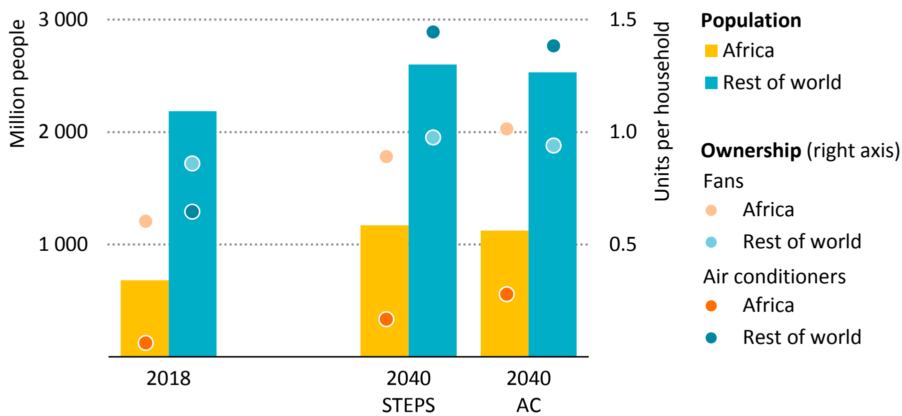
Notes: Every dot represents a dense area in terms of population (> 4 000 person/km^2) or more than 25 000 people. The thickness of the dot is proportional to population densities. Sources: Derived using NOAA (2018) and NCAR (2012) assuming the Representative Concentration Pathway (RCP) 2.6 Scenario (IPCC, 2014) and using a base temperature of 18 °C, taking humidity into account. Population data are derived from KTH-dESA (GitHub), Khavari et al. (2019) and from Africapolis.org.

countries with much higher cooling needs, such as Togo, Senegal and Niger have ownership levels that are half the African average or less.

The costs associated with operating an air conditioner are a big barrier for many households, an issue that is compounded by comparatively inefficient equipment. The average seasonal energy efficiency ratio (SEER), the level of cooling for any given unit of energy consumed, is on average almost 30% lower for a typical air conditioner in Africa than the world average. The average air conditioner sold in Africa is also typically less than half as efficient as the best available units on the market, reflecting Africa's currently weak air conditioner energy performance standards: most countries in Africa lack any mandatory standards for air conditioners, while standards are also weak for fans. Recent policy progress and proposed minimum energy performance standards in countries such as Kenya, Rwanda and Morocco point the way forward.

Population growth, urbanisation and climate change significantly increase the need for cooling in Africa. By 2040 more than one billion people need access to cooling in the Africa Case (Figure 2.8), a scenario that matches the ambitions of the Paris Agreement (this number increases to 1.2 billion if the world continues on its current trajectory). The anticipated increase in temperatures across the continent is higher than the global average, with Somalia, Ethiopia and Gabon being the countries most exposed.

Figure 2.8 ▷ Population with cooling needs and ownership in the Stated Policies Scenario and Africa Case, 2018 and 2040



Growth in the global population with cooling needs by 2040 is concentrated in Africa, but ownership of cooling devices remains lower than the global average

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

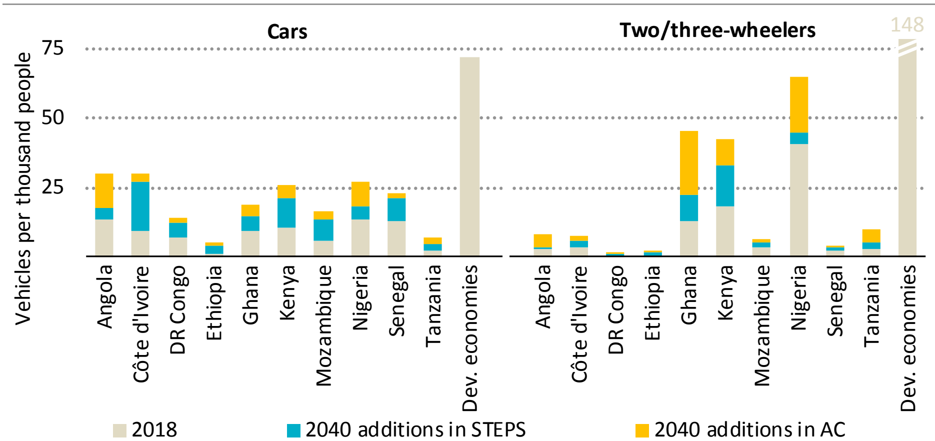
While the African continent experiences the largest increase in cooling needs by 2040, the Stated Policies Scenario points to air conditioner ownership in Africa growing to an average of just over 0.15 units per household (compared to a world average of 1.15 in 2040), ownership of fans increases to almost 0.8 units per household. While this means tens of millions of air conditioners and fans are sold in Africa in the coming decades, it still falls short of providing access to thermal comfort to millions of Africans.

In the Africa Case, cooling is more widely available: universal electricity access and higher levels of household income lead to demand for cooling increasing to over 110 TWh in 2040 in Africa, almost double the level of demand seen in the Stated Policies Scenario. More stringent policies for cooling equipment efficiency, and passive cooling through better design of buildings and use of vegetation in the Africa Case mean that around 110 TWh of additional demand are avoided.

2.2.2 Transport sector

Sub-Saharan Africa (excluding South Africa) has the world's lowest per capita car ownership level. It has a smaller passenger car stock than Australia, whose population is 95% smaller. In all scenarios and cases presented in this *World Energy Outlook*, there is a large expansion of the passenger car stock in the period to 2040 (Figure 2.9). In the Stated Policies Scenario, the car fleet in 2040 in sub-Saharan Africa (excluding South Africa) triples to reach 27 million, but this still means average ownership levels of only 15 cars per 1 000 people, equivalent to 60% of the rate in India today. Factoring in an accelerated rate of economic growth, as in the Africa Case, the car fleet reaches more than 35 million.

Figure 2.9 ⊳ Vehicle ownership by country in the Stated Policies Scenario and Africa Case, 2018 and 2040



Vehicle ownership doubles in sub-Saharan Africa (excluding South Africa) in the Stated Policies Scenario; the Africa Case provides a further boost, yet rates remain low

Note: Dev. economies = developing economies; DR Congo = Democratic Republic of the Congo; STEPS = Stated Policies Scenario; AC = Africa Case.

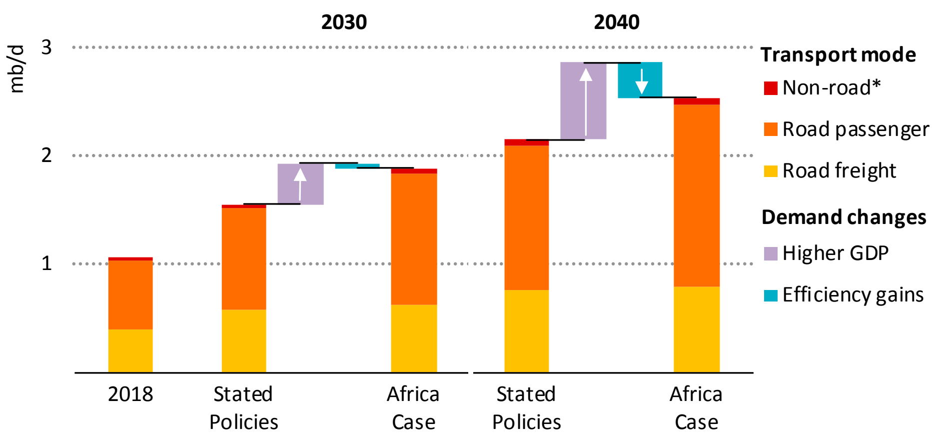
The increase in road transport demand fuels a significant rise in oil use in Africa. Under the assumptions of the Stated Policies Scenario, oil demand for transport grows from just over 1 million barrels per day (mb/d) today to reach 2.2 mb/d by 2040. Demand is slightly higher in the Africa Case, at 2.5 mb/d, but this assumes 8 million additional cars, with the increased efficiency of the fleet avoiding the consumption of nearly 320 thousand barrels per day (kb/d) in 2040 (Figure 2.10).

As is the case with residential energy demand, there is a large discrepancy between demand in cities and rural areas. The 6.6 million passenger cars in cities in sub-Saharan Africa (excluding South Africa), represent almost 80% of the total car stock of the region today. This number rises by almost 6% per year in the Stated Policies Scenario, raising the total to close to 23 million cars in cities by 2040 and bringing the share of cars in urban areas to 85% of the total stock. In the Africa Case, the number of cars grows by more than 7% a year increasing the urban car stock to nearly 30 million by 2040. Rural areas account for over half of the current stock of 16 million two/three-wheelers in the region: in both the Stated Policies Scenario and the Africa Case, they continue to account for a sizeable 40% share of the stock of two/three-wheelers through to 2040.

Future demand for energy in the transport sector is determined not just by the number of vehicles on the road but also by their condition. Up to 80% of cars for personal transport are used cars imported from Japan and Europe which no longer meet emissions standards in those countries. The situation is not much better for new cars: only Nigeria (Euro 3) and South Africa (below Euro 3) have any emissions standards in place for new car sales (UNEP, 2017), and the Euro 3 standard was superseded in Europe almost two decades ago. Members of the East African Community recently agreed to adopt Euro IV/4 equivalent standards for new vehicles (UN Environment, 2019). The average fuel economy of cars on the road in sub-Saharan Africa is 8.4 litres per 100 kilometres (L/100 km), less efficient than the average 7.4 L/100 km in North African countries. Among several possible solutions, the most practical would be to ensure a uniform age limit on imported cars across all African countries and to ban the import of cars that do not meet minimum emissions standards. Currently more than half of African countries do not impose any restrictions on second-hand vehicle imports, while for those that have set restrictions, half of them apply age limits of between 8-15 years (UN Environment, 2019). Lower age limits on imported vehicles would significantly improve average fleet efficiency. Angola was a first mover among sub-Saharan countries, with an age limit of three years. Fuel quality specifications could also bring significant benefits, not least in reducing pollution. Here the East African Community is leading the way: it harmonised fuel quality standards in 2016, setting sulfur limits for gasoline of 150 parts per million (ppm) and for diesel of 50 ppm.

Africa is one of the world's fastest growing markets for two/three-wheelers, with momentum partially driven by the increasing number of cheap second-hand motorcycles imported from Asia. Market growth means that the number of motorcycles in Africa is set to surpass the number of private cars by 2040. However, the market for two/three-wheelers in Africa is largely informal and unregulated, and market growth has not been accompanied by a shift to electric options as part of a transition to low-carbon transport and emissions reductions. Electric two/three-wheelers have a lot of potential value given the expected increases in demand for mobility and the current low levels of mobility in most parts of rural and urban areas in Africa, especially since travel in rural areas often involves long distances and fuel quality is less reliable. The higher upfront costs of an electric two/three-wheeler as compared with a conventional one would be offset by lower maintenance and operating costs, depending on the distances travelled and fossil fuel prices; the payback period could be two to three years. The lack of reliable access to electricity however is a major barrier to electrification of these vehicles, especially in rural areas where two/three-wheelers play a prominent role. Even when full access is achieved, decisions will be required on the extent to which transport should be a priority for electrification over other end-use sectors.

Figure 2.10 ▷ Oil demand for transport in sub-Saharan Africa (excluding South Africa) **in the Stated Policies Scenario and Africa Case**



Introduction of fuel economy standards could avoid 0.32 mb/d of oil demand growth driven by the fleet expansion

* Non-road includes aviation, shipping, rail and other transport.

Increased industrialisation means more transport of raw and finished goods, leading to higher demand for freight vehicles, rail, navigation and aviation. The new African Continental Free Trade Agreement should also stimulate improved connectivity between countries to facilitate goods transport from regions of production to major commercial centres and ports. A transcontinental railway financed by China is already in the works: it plans to connect shipping ports in West and East Africa and it is possible that it may link more than ten countries including Angola, DR Congo, Zambia, Tanzania and Kenya. Such projects should help to support the economic development of landlocked African nations and enhance trading and mining activities in the region significantly.

Box 2.2 ▷ Gender and mobility in Africa

Improving transportation is a big challenge for sub-Saharan Africa countries, and discussions on how best to deliver improvements must take account of the needs of women in both urban and rural communities. In cities, factors such as financial constraints, cultural norms prioritising asset allocation to men, and security concerns limit access to transport for women. In rural areas, women and children are more vulnerable than men to the negative impacts of a lack of transport options. Long distance walks to fetch water or wood for fuel, and to reach healthcare facilities and schools are a major obstacle in the daily lives of women. The effects range in severity from loss of productive time to reduced literacy rates and risks to personal safety. Proper transport planning needs to consider the different mobility needs of women and men throughout the day and to seek to ensure that women remain safe when travelling.

In sub-Saharan Africa, maternal mortality and morbidity rates continue to be high (Hofman et al., 2008; AMANHI, 2018). Although there are many factors in addition to obstetric causes that contribute to high mortality in sub-Saharan Africa, one is the delay in reaching emergency care. Emergency and routine medical check-ups for the elderly, children and women are critical to achieving most of the sustainable development goals, specifically SDG 3 on healthy lives and wellbeing, but rural populations in sub-Saharan Africa often still find it difficult to access healthcare and other essential services due to lack of mobility. Light two/three-wheelers could make a big difference to rural mobility in Africa. They are extremely popular in large, developing countries such as China and India and have great potential to improve women's lives in Africa. Electric two/three-wheelers would avoid air pollution issues and, provided that electricity is available, may be cheaper than fossil fuel powered alternatives.

Is there a role for biofuels for transport?

Biofuels account for less than 0.1% of transport energy use in Africa today, but there is strong potential for growth. The market grew 5% in 2018, mainly led by South Africa and Nigeria.

The potential for production of advanced biofuels in many African countries is enormous, thanks to the size of the continent's agricultural sector. Increasing biofuel production from the transformation of agricultural waste can be sustainable if based on the intensification of crop production and livestock grazing on existing agricultural lands, rather than the extension of crop and grazing lands (IRENA, 2017). Relying on intensification rather than extension reduces negative environmental impacts such as deforestation, land-use change and associated greenhouse-gas emissions. East Africa alone is estimated to have the potential to produce over 100 million tonnes (Mt) of agricultural residues per year, which could be converted into advanced biofuels like ethanol and bio-butanol (Bentsen et al., 2014). Realisation of this potential will depend on whether using this resource for biofuels production can compete in terms of cost-effectiveness with other potential uses of these residues such as direct combustion and electricity generation.

Many countries have announced mandates for boosting the use of biofuels in the transport sector, with the most popular mandates being ethanol blending rates of 5% or 10% (E5 and E10). Table 2.2 lists the intended biofuel blending targets and mandates of major African economies. In both the Stated Policies Scenario and the Africa Case, biofuels represent only a small share of total fuel consumption for the road transport sector, accounting for 1.5% and 2.5% respectively of the overall fuel consumption in road transport. The evolution of the biofuels market in the Africa Case takes into account the potential supply of agricultural residues in key African countries.

Table 2.2 ▷ Biofuel blending mandates for transport for selected countries in sub-Saharan Africa

Country	Mandate	Target	Potential from agricultural residues
Angola	Ethanol 10		11%
Ethiopia	Ethanol 5	Ethanol 10	n.a.
Ghana		Replace 10% of fossil fuels by 2020 and 20% by 2030	n.a.
Kenya	Ethanol 10	Ethanol 5, Ethanol 10	5%
Malawi	Ethanol 10		n.a.
Mozambique	Ethanol 10		1%
Nigeria	Biodiesel/Ethanol 2	Ethanol 10	n.a.
South Africa	Ethanol 2, Ethanol 10		n.a.
Sudan	Ethanol 5		n.a.
Uganda		Ethanol 20	n.a.
Zimbabwe	Ethanol 10	Ethanol 15, Ethanol 20	n.a.
Zambia		Ethanol 10	n.a.

Notes: n.a. = not available. Mandate or target numbers refer to the blending ratios of each type of biofuel. The distinction between mandate and target is related to the policy framework strictness and the mechanisms in place to enforce these shares. Enforcement of these mandates and targets vary by country: with some having announced them but not yet enforced or are not strict. For example, in Zimbabwe, when ethanol production is low, the E10 mandate is suspended. Potential from agricultural residues refers to the maximum share of oil use in transport that could be replaced with biofuels from agricultural residues.

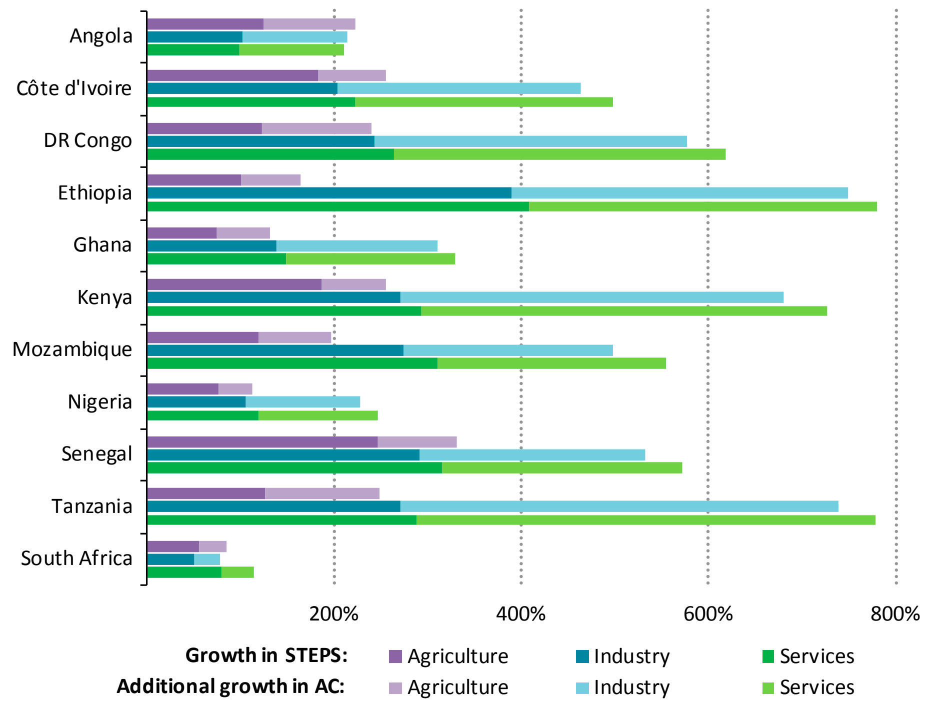
Sources: REN21 (2017); BiofuturePlatform (2018); Lane (2019); Sekoai and Yoro (2016); Ministry of Energy and Petroleum (Kenya) (2014); National Environment Management Authority (Uganda) (2010); Fundira and Henley (2017) ; UNCTAD (2014).

2.2.3 Productive uses

Much of the industrial production that does exist in Africa relies on the extraction and sale of natural resources without further transformation into higher value products. This is reflected in energy use in industry, which is low by international standards. Other productive activities, in the services and agriculture sectors, contribute higher shares to GDP in many African economies, with an average of 54% and 19% respectively across sub-Saharan Africa.

Future GDP growth is largely driven by the industry and services sectors, especially in the Africa Case. Industry and services value-added in some countries (Ethiopia, Kenya and Tanzania) in the Africa Case increase almost by an eightfold (Figure 2.11). In global average terms, generating $1 of value added within the industry sector consumes twice as much energy as $1 of value added from the agriculture sector, and up to eight-times the amount consumed to produce $1 of value added from the services sector. In sub-Saharan Africa the situation is different because the agriculture sector is less motorised than anywhere else, and the services sector includes many small-scale activities with limited contribution to GDP. This leads to the industry sector in sub-Saharan Africa consuming six-times more energy to generate $1 of value added than in either the agriculture or services sectors.

Figure 2.11 ▷ Increase in value added by sector in selected countries in the Stated Policies Scenario and Africa Case, 2018 to 2040

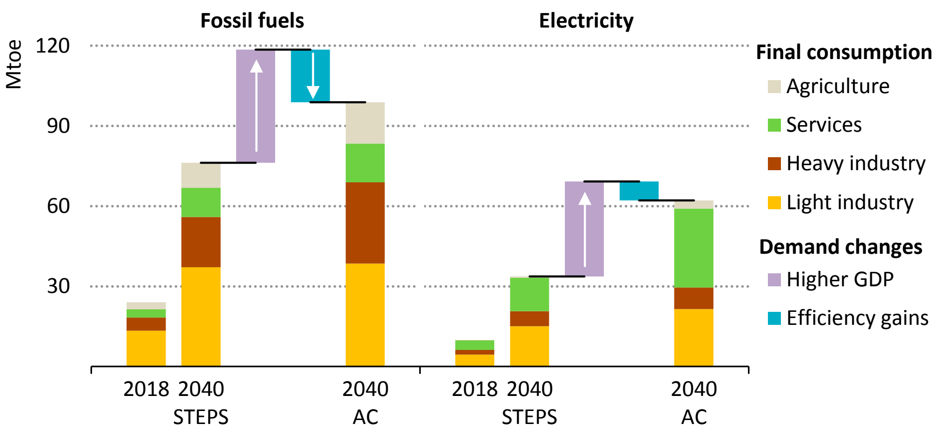


Industry and services sectors are major drivers of GDP growth in sub-Saharan Africa in both projections, while the share of agriculture in GDP drops to 13% in the Africa Case

Note: DR Congo = Democratic Republic of the Congo; STEPS = Stated Policies Scenario; AC = Africa Case.

The agriculture, industry and services sectors are all set to increase their energy demand in sub-Saharan Africa, with most of the demand growth being driven by light industry and services. Energy demand across these productive uses increases by 110% in the period to 2040 in the Stated Policies Scenario. In the Africa Case, GDP is more than 50% larger by 2040 than in the Stated Policies Scenario, but energy consumption for productive sectors is only 20% larger as a result of efficiency gains. The Africa Case also projects a different energy consumption mix by 2040 as electricity is increasingly used in the services sector and for motors in industry, causing electricity consumption to grow 50% faster than demand for oil and gas together. The share of consumption by sector also varies over time and by case. By 2040, as more industrial products are produced domestically (cement, steel, aluminium and in some countries, chemicals), the energy consumed by heavy industry doubles in the Stated Policies Scenario and triples in the Africa Case.

Figure 2.12 ▷ Final consumption in productive uses in sub-Saharan Africa (excluding South Africa) **by scenario**



Energy efficiency standards and material efficiency temper oil and gas demand growth by around 25% and electricity by 15% for productive uses

In the Africa Case, around 35 Mtoe of energy consumed by productive uses in sub-Saharan Africa (excluding South Africa) is avoided thanks to energy efficiency (Figure 2.12). There is an important opportunity to put in place robust efficiency policies today in anticipation of expected energy demand growth. In many countries around the world there are now standards for electric motors used within industry and the use of variable speed drives and other measures to increase the efficiency of motor systems is becoming increasingly common. In Africa, some countries have recognised the potential efficiency benefits from the implementation of MEPS for electric motors, but no countries have yet enforced them.[5]

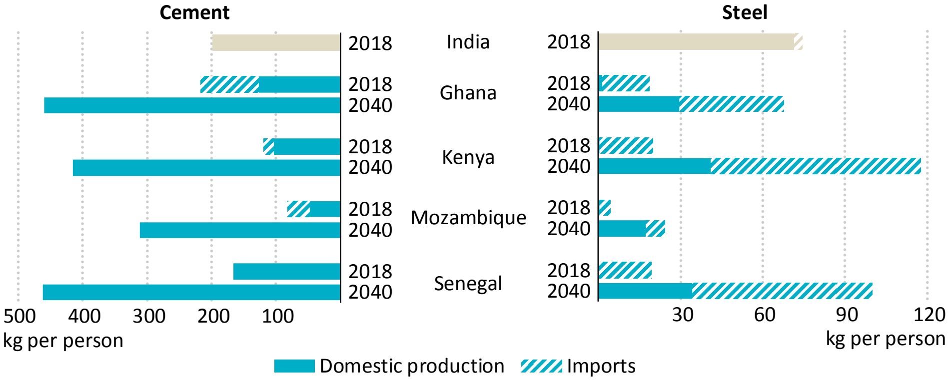
[5] In Uganda, standards have been developed, but are not yet mandatory. In South Africa, it has been listed as a planned policy in its post-2015 National Energy Efficiency Strategy. In Egypt, market assessments are seeking to pave the way for development of standards. In Ghana, planned implementation was announced in its National Energy Efficiency Action Plan, but not yet implemented.

Efficiency improvements in the Africa Case are not confined to industrial activities: efficient pumps for irrigation, and efficient appliances and cooling devices also help to reduce the energy intensity of other sectors compared to the Stated Policies Scenario.

Heavy industry

Currently, Africa's per capita use of construction material is a small fraction of the global average, and most of what is consumed is imported (Figure 2.13). However, Africa's rapid urbanisation presents considerable potential for industrial growth across the continent: domestic industries have an opportunity to compete effectively to provide the materials needed to build new cities and expand current ones, and in so doing to underpin wider industrial development.

Figure 2.13 ▷ Steel and cement demand per capita in selected sub-Saharan countries in the Africa Case compared with 2018 levels in India



Industrialisation projects could reduce import shares for cement and steel products in many African countries

Note: kg = kilogrammes.

Cement production is, by a large margin, the most significant energy-intensive industry in sub-Saharan Africa. It currently accounts for around 2% of global cement production, and the growth of cities and infrastructure across the continent provides a significant opportunity for production to expand. Current production ranges from traditional small-scale facilities to large-scale projects, notably in West Africa. There are ambitious plans in Nigeria to further expand cement production facilities such as Unicem. Cement is an energy-intensive industry, and relies heavily on coal for the clinker/limestone calcination process, particularly in South Africa, but the share of gas is projected to grow. A cement-based industrialisation pathway implies a significant increase in energy consumption. In the Africa Case, energy demand for cement almost quadruples by 2040 and cement production increases to around 430 Mt per year in sub-Saharan Africa (excluding South Africa).

Box 2.3 ⊳ Potential for hydrogen in Africa

Hydrogen could play a number of important roles in a sustainable energy future, including clean energy trade and displacing fossil fuel use in industry. Technologies for the production and use of low-carbon hydrogen are developing and projects around the world are scaling up. This promises to reduce costs, including the costs for electrolysis, the process by which water and electricity, including from renewables, can be converted to hydrogen fuel.

Globally, Africa has some of the highest potential for producing hydrogen from low-cost renewable electricity, especially from solar power. Production costs in North Africa are expected to be two-to-three times lower than in most of Europe or Japan. Energy storage for off-grid and back-up power could be an attractive application for hydrogen fuel cells; the telecommunications industry is already deploying fuels cells running on methanol to replace some diesel engines in South Africa, Namibia and other countries.

Today, hydrogen is produced and used at industrial scale in Africa to make ammonia-based fertilisers and to refine oil. Among the larger suppliers, Algeria, Egypt and Nigeria use natural gas to produce the vast majority of Africa's hydrogen for ammonia, while South Africa produces ammonia from coal at a smaller scale (all with accompanying greenhouse gas emissions). African countries also import considerable amounts of ammonia and ammonia-based fertilisers produced from fossil fuels without carbon capture, utilisation and storage. As technology for ammonia production from water electrolysis gets cheaper and smaller, hydrogen from solar power could help to avoid greenhouse gas emissions while meeting latent fertiliser demand.

Hydrogen also presents a potential export opportunity, whether as hydrogen itself or in the form of ammonia or other synthetic fuels. African countries endowed with natural gas resources and CO_2 storage options could also export low-carbon hydrogen produced using CCUS. A similar logic could apply to goods produced with low-carbon hydrogen, such as low CO_2 intensity steel. The first commercial plants using hydrogen as an alternative to fossil fuels for steel production are planned for the 2030s, a period when Africa's steel capacity is expected to grow. By looking at synergies with local steel capacity expansions in this timeframe, African countries could be good places to test this new technology, if governments and financers are supportive.

At present, more than half of steel demand in sub-Saharan Africa is met through imports but projections indicate expanding domestic steel production to meet local demand with the share of imports reducing gradually over time. Only a handful of sub-Saharan African countries currently produce steel, with South Africa accounting for the vast majority of the regions production. In the Africa Case, primary steel production in sub-Saharan Africa, excluding South Africa, increases from less than 1 Mt today to almost 20 Mt in 2040, pushing up energy demand by 12 Mtoe. This increase in production is not sufficient to meet all growth in domestic demand, and the share of imports remains high. New developments in the steel sector in Africa include investment in electric steel-making furnaces which enable scrap reuse. Another possibility, given Africa's endowment of low-cost renewable power resources, is the use of hydrogen through renewables-based electrolytic hydrogen production (Box 2.3). This, however, would require levels of capital investment that do not appear to be on the horizon for the moment. Overall, less than 1% of global steel is produced in sub-Saharan Africa and its global market share remains low in both scenarios.

Africa is home to one-third of the world's proven reserves of bauxite, but only a handful of countries, including South Africa, Mozambique, Cameroon, Ghana and Kenya, process it to produce aluminium. Together, sub-Saharan Africa (excluding South Africa) countries produce less than 1% of global aluminium, less than the region's demand. Aluminium production is electricity-intensive and plants are often located close to hydropower dams where cheap and reliable power can be delivered. The Inga Dam projects in DR Congo raises the prospect of attracting investment in new plants to produce aluminium, but this would require concurrent efforts to build local expertise. Aluminium production in the Africa Case increases at a rate that keeps pace with strong domestic demand growth, and energy consumption for aluminium production nearly quadruples by 2040 as a result.

The chemicals industry in Africa is heavily concentrated in South Africa and Nigeria, and demand for chemicals and energy inputs into the sub-sector is set to grow through to 2040. Chemical industries are often linked to the availability of oil and gas infrastructure, due to the need for petrochemical feedstock. Nigeria and Tanzania are examples of countries where the emergence and development of upstream resource extraction is attracting chemical industries, especially for methanol, with production expected to begin in coming years. By 2040, Gabon, South Africa and Nigeria use hydrocarbons in the fertiliser industry for large-scale ammonia production in all scenarios. As agriculture continues to account for an important share of African GDP in 2040, the case for local fertiliser industries is strong, and production is projected to increase. Clean hydrogen-based ammonia production, as tested in Morocco, could offer a sustainable way to boost ammonia production.

Light industry, agriculture and services

Light industries such as food processing and manufacturing are often located close to urban areas with existing electric grid infrastructure. They provide significant employment and are less energy intensive than heavy industries. The sub-sector is characterised by a strong degree of electrification and need for low-temperature heat. Security of energy supply is of paramount importance. If reliable energy supply can be guaranteed, the development of light industries including manufacturing is an attractive option for many sub-Saharan African countries. The Africa Case sees the sub-sector growing strongly throughout the projection horizon, and energy demand follows suit.

The agricultural sector accounts for more than half of employment in sub-Saharan Africa today. Agricultural productivity per hectare in sub-Saharan Africa is well below that of other regions, largely due to the limited use of irrigation to raise crop yields and lack of mechanisation (IEA, 2017). As a result, food production per person has not changed significantly since 2010. In the Africa Case, energy consumption in agriculture in sub-Saharan Africa increases threefold: most of the additional demand is for oil and electricity as the sector becomes increasingly mechanised. Agricultural value added represents around $830 billion today (18% of total GDP in sub-Saharan Africa). In the Stated Policies Scenario, it more than doubles, while in the Africa Case it almost triples.

The services sector consumes only a quarter of energy consumed by productive uses in sub-Saharan Africa today, but generates 55% of GDP. It depends principally on bioenergy and electricity; planned increases in electricity generation would support growth. Alongside increased demand for office space and associated cooling demand, new data centres and information technology infrastructure also propel growth in electricity demand. However, a shift from relatively informal services activities to high-tech services largely delivered in offices lowers the use of bioenergy and, as a result, leads to a reduction of the sector's energy intensity (measured in terms of energy consumed per unit of value added).

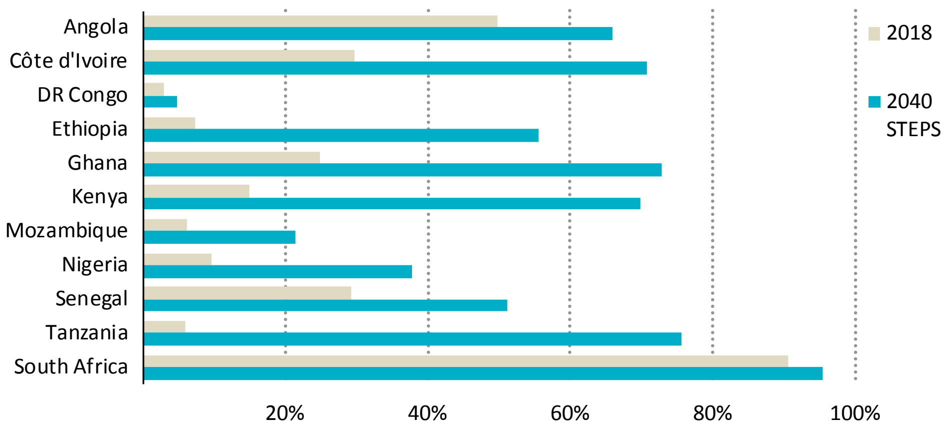
2.3 Clean cooking: the role of cities and higher incomes

While the world has seen considerable progress towards achieving universal access to electricity in recent years, increasing access to clean cooking facilities remains challenging. In sub-Saharan Africa, around 900 million people lack access to clean cooking (five-out-of-six people), accounting for a third of the global total. Almost 95% of them use solid biomass in the form of fuelwood, charcoal or dung in open fires, while the remainder use kerosene (especially in Nigeria) or coal (mostly in Southern Africa). At the global level, 80% of those without access to clean cooking are located in rural areas, and they make up 60% of the world's rural population. Less than 15% of the urban population globally lacks access to clean cooking, thanks to wider access to clean options, such as LPG, and higher average incomes. In sub-Saharan Africa, the lack of access to clean cooking in cities remains much higher than in other regions, with just one-third of the urban population having access to clean cooking solutions, but the problem is much worse in rural areas, where only 6% do. While fuelwood remains the dominant fuel in rural areas, for many urban households, charcoal has become the fuel of choice, as distances to sources of fuelwood increase.

The household air pollution resulting from reliance on inefficient and polluting cookstoves is directly linked to nearly 500 000 premature deaths in sub-Saharan Africa in 2018, and 2.5 million globally – a figure that equals the combined death toll of malaria, tuberculosis and HIV/AIDS. Despite the size of the gap between the current level of access to clean cooking and the goal of providing clean, reliable and affordable energy for all by 2030, the issue is often not given importance commensurate with its impacts. In addition to severe health effects, the reliance on traditional use of solid biomass for cooking contributes to forest depletion through unsustainable harvesting of fuelwood, as well as climate change (see Chapter 5). Moreover, cooking with solid biomass incurs a considerable cost in terms of time and income: on average, households dedicate 1.4 hours a day to collecting fuel, a burden borne primarily by women and children (IEA, 2017). The time spent gathering fuelwood exposes people to various dangers and reduces the time available for educational or productive ventures. Progress in switching to cleaner cooking fuels has so far been slow, despite growing awareness of the associated health, environmental and socioeconomic impacts, as well as decades of programmes targeting access to modern cooking.

In the Stated Policies Scenario, the population lacking access to clean cooking in sub-Saharan Africa slowly increases from around 900 million to 970 million in 2030 before declining to 870 million in 2040. The share of the population with access to clean cooking increases from one-third today to 65% in 2040 in urban areas, and from 6% today to around 40% in 2040 in rural areas. But progress across the continent differs by country depending on the existence, ambition and implementation of relevant policy frameworks (Figure 2.14). In this scenario, 80 million people in Nigeria and 70 million people in Ethiopia are expected to gain access by 2040. On the other hand, in several countries population growth outpaces the number of additional people gaining access. In DR Congo, the number of people without access to clean cooking facilities almost doubles to 150 million by 2040.

Figure 2.14 ▷ Access to clean cooking in selected sub-Saharan Africa countries in the Stated Policies Scenario, 2018 and 2040



Progress towards universal clean cooking access is slow, with just under half of the sub-Saharan African population remaining without access in 2040

Note: STEPS = Stated Policies Scenario.

Sources: IEA analysis; WHO Household Energy Database.

In the Africa Case, full access to clean cooking by 2030, in line with SDG 7, means that more than 1.1 billion people in sub-Saharan Africa move away from the traditional use of solid biomass by 2030. Improvements in both scenarios have important impacts on household air pollution. In the Stated Policies Scenario, premature deaths related to household air pollution increase in the short term before declining to 2% below today's level by 2040, while in the Africa Case, the number of premature deaths linked to household air pollution falls by two-thirds.

2.3.1 Increasing access to clean cooking options

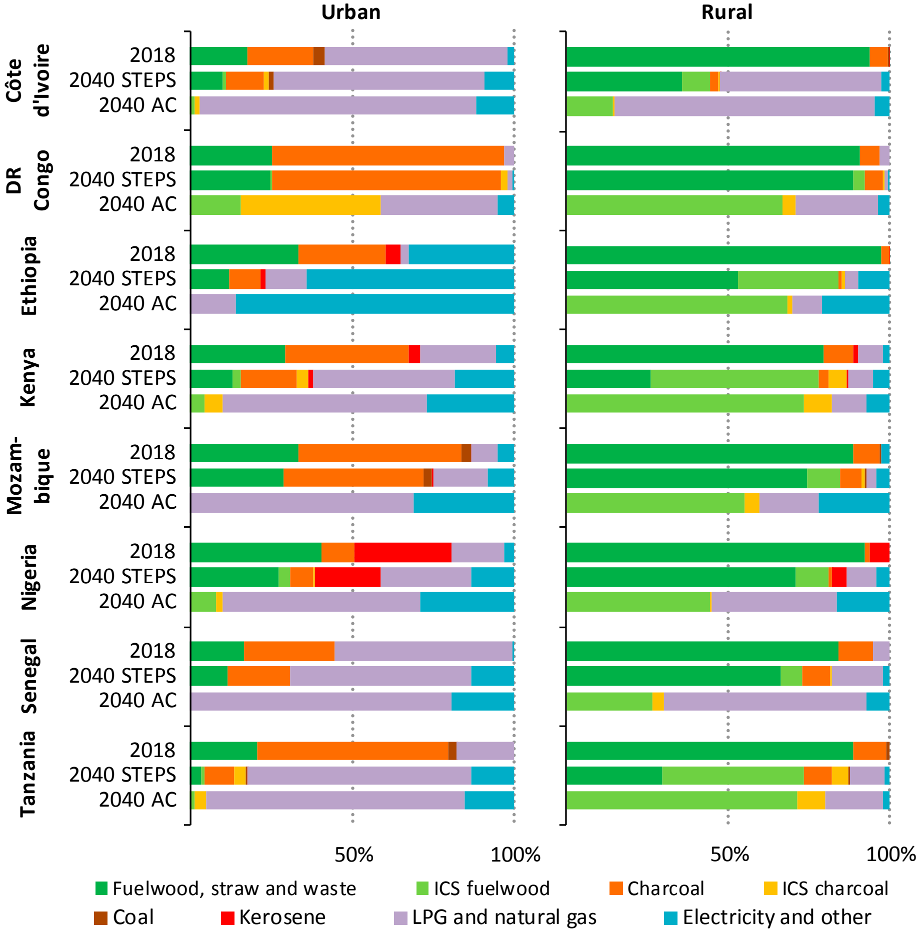
Future trajectories among the many countries in sub-Saharan Africa are very diverse and largely dependent upon policy choices and domestic circumstances. For example, 30% of urban households in Nigeria today rely on kerosene as a cooking fuel, but this is reduced through the increased uptake of LPG and gas in the Stated Policies Scenario, and completely replaced in the Africa Case by 2030 (Figure 2.15). Progress in Nigeria is facilitated by the National Cookstove Programme which provides funding for the distribution of clean cookstoves and encourages state and non-state actors to build on the national scheme via a market-based approach. In Côte d'Ivoire, the national plan seeks to increase efficiency of charcoal production and promote LPG use. In Ethiopia, recent gains in electricity access are expected to continue and result in 50% of urban households cooking with electricity in the Stated Policies Scenario (and 80% in the Africa Case in 2040), compared with 32% today. Examples of regional level frameworks to expand clean cooking access include the West Africa Clean Cooking Alliance which aims to disseminate clean, efficient and affordable cooking fuels and devices to all Economic Community of West African States citizens by 2030.

Households seeking to switch to cleaner cooking solutions, such as LPG, ethanol, natural gas, electricity and improved cookstoves, face economic and non-economic barriers. Evidence has shown that fuel and technology choices do not follow an energy ladder; higher incomes do not necessarily result in households switching from the traditional use of solid biomass to clean cooking options. Instead, a phenomenon called "fuel stacking" is increasingly prevalent in Africa, with many households using a number of different cooking solutions depending on needs and economic circumstances. The relatively high price of the technologies (and the lack of adequate and accessible financing) is an important impediment to the dissemination of clean cooking options. Even with declining prices for clean cooking technologies, and financing through loans and microcredit, millions of poor rural and urban households may not be able to afford the cost of these technologies. The variability of the fuel price is another barrier that impedes households considering switching to other options or prevents them from fully relying on cleaner cooking options.

Cultural habits, traditional cooking practices, low levels of empowerment of women and lack of awareness of the health, social, economic and environmental benefits of using cleaner options also remain persistent obstacles to widespread diffusion of clean cooking technologies to poor households. For example, wood smoke can be regarded as beneficial for avoiding bad odours, for the taste of food, or for repelling insects, exemplifying the importance of cultural habits. Health education has an important part to play in this context.

In terms of accessing clean cooking technologies, women may be disadvantaged by the fact that men often make purchasing decisions within the household. This can result in decisions to purchase or finance technologies such as solar lighting systems that are perceived as beneficial for the entire family rather than technologies such as clean cookstoves that can be perceived as having more limited benefits. Understanding how intra-household gender hierarchies influence technology acquisition is crucial for designing responses to address them. Simple design adaptations such as adding cell phone chargers to cook stoves rather than solar lanterns can sometimes give a competitive advantage to technologies that women tend to use more often than men.

Figure 2.15 ▷ Primary fuels used for cooking in selected sub-Saharan countries in the Stated Policies Scenario and Africa Case, 2018 and 2040



Displacing the traditional use of fuelwood and charcoal involves multiple solutions, depending on the availability and affordability of cleaner options

Note: STEPS = Stated Policies Scenario; AC = Africa Case; DR Congo = Democratic Republic of the Congo; ICS = improved cookstoves; LPG = liquid petroleum gas.

Sources: IEA analysis; WHO Household Energy Database.

In urban areas in particular, the large-scale uptake of LPG, electricity, ethanol and gas in the Stated Policies Scenario enables a switch away from the use of inefficient and polluting stoves, and fuels such as lignite and kerosene. Charcoal continues to play a key role in urban areas due to its light weight, low price and high energy content compared to fuelwood (30 megajoules per kilogramme [MJ/kg] for charcoal compared to around 16 MJ/kg for fuelwood). In rural areas, reliance on fuelwood, straw and waste is set to remain relatively high, although they are increasingly burned in more efficient and improved cookstoves. Continued reliance on bioenergy in rural areas is often compounded by lack of infrastructure to supply clean cooking fuels like LPG, and by fragile supply chains.

Cooking practices are very context-specific. There is no one-size-fits-all option and each clean cooking solution comes with its disadvantages. Cooking with LPG on easy to connect burners offers clean indoor air as well as a very comfortable user experience. Meals can be cooked or reheated quickly with no difficulty in igniting or maintaining the burning flame. However, LPG can raise problems of affordability, given the high upfront cost for the burners and hoses, initial deposit for a cylinder, plus the gas content of the cylinder (users might also need to save money to be able to pay upfront to refill their cylinder). Although LPG is relatively safe compared to kerosene or biomass, illegal and unsafe refilling of the pressurised cylinders does carry dangers. Some innovative pay-as-you-go enterprises aim to tackle these challenges by supplying LPG bottles to customers that are equipped with smart meters and release small quantities of gas instantaneously when payment is received via mobile money services. Other innovative service models are also gaining traction: for example some companies are piloting the distribution of biomass pellets or briquettes, with sale costs designed to cover the cost of a subsidised or loaned gasifier stove (see Chapter 1, section 1.2.1 for more on innovative bioethanol solutions). Several biogas programmes offer support at a bigger scale, for example by providing village-scale biodigester installations including training and assistance to the community.

The economic and social barriers to the use of charcoal are much lower than for most other fuels. Using charcoal for cooking and heating comes at a lower upfront cost than using electricity, biogas or natural gas, all of which require the development of capital-intensive, durable infrastructure for fuel supply. The limited capacity for a typical solar panel to produce enough electricity for cooking may also weigh in favour of using solid biomass, as may the ability to continue traditional cooking practices with charcoal. All of the above are factors in the attractiveness of charcoal relative to alternative fuels, driving growth in its demand. Burning charcoal in improved cookstoves however can significantly reduce air pollutant emissions and fuel requirements. In the Stated Policies Scenario more than 10% of households still cook with charcoal by 2040 in sub-Saharan Africa (excluding South Africa), but 15% of them do so with improved cookstoves: this increases to 100% in the Africa Case.

Over recent years, several international organisations and initiatives have promoted access to clean cooking, including Sustainable Energy for All and the Clean Cooking Alliance, both of which have been instrumental in researching, building evidence and raising the profile of issues linked to lack of access to clean cooking. Acknowledging that progress has been slow, despite all efforts, the international community is seeking to create a renewed and stronger momentum for tackling the lack of access to clean cooking. To accelerate progress towards universal access, several international development organisations are calling for joint efforts from the energy and the health communities, on the basis that addressing the lack of clean cooking solutions and its consequent indoor air pollution should be a key priority for both. Combining strategies and actions to reach the SDG 7 on energy and SDG 3 on health will require more policy attention as well as more funding to support technology and business model innovation.

In 2017 only $2 million of equity were invested in companies in the clean cooking sector, a mere 0.1% of what is estimated to be necessary to bring clean cooking solutions to scale (ACUMEN, 2018). Private sector involvement in clean cooking remains highly fragmented, not least because a majority of clean cooking companies are small scale and face difficulties in accessing adequate funding (Clean Cooking Alliance, 2019). The recently launched Clean Cooking Fund, backed by the World Bank, aims to help address these problems by providing result-based finance, grants and technical assistance to organisations that offer innovative solutions to accelerating deployment of clean cooking solutions.

2.3.2 Rapid urbanisation requires better use of charcoal

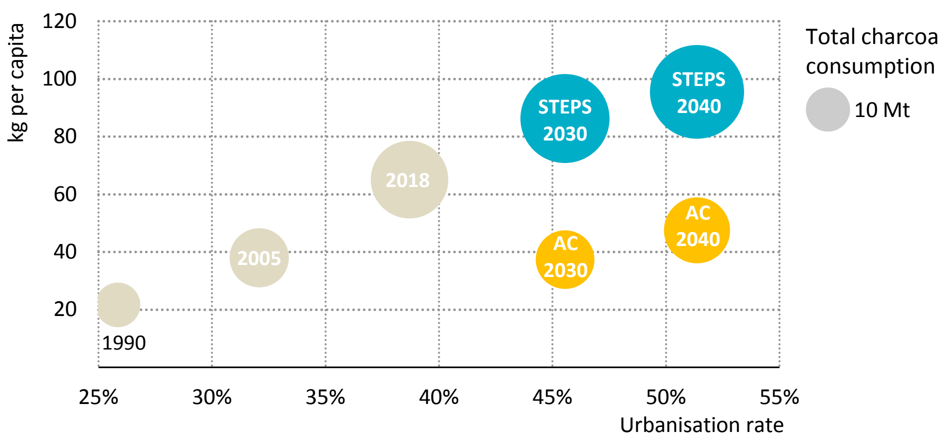
More than 750 million cubic metres of wood was harvested on the African continent in 2017, accounting for roughly 20% of the global total. The share of harvested wood used for energy is around 90% in Africa, considerably higher than the global average of around 50% (FAO, 2017). With Africa producing over 60% of the world's charcoal, much of this wood is converted to charcoal to enhance its calorific value and make it easier to transport to urban areas (FAO, 2017). Charcoal use across sub-Saharan Africa (excluding South Africa) is thriving, with demand growing at an annual average rate of around 4% since the year 2000. The use of charcoal is rising most rapidly in urban areas where population growth and the often unsustainable use of forest resources limits the availability of fuelwood (Figure 2.16). As a source of income and employment creation along the value chain (for production, transportation, sales and distribution), charcoal manufacturing and trade have shaped patterns of economic development in many areas.

As urbanisation increases across Africa, the growing demand for both land and charcoal is likely to put additional pressure on traditional forest management and extraction practices. While sustainable land and biomass use is part of the climate mitigation strategy of most African countries, few countries include commitments on charcoal production or use in their Nationally Determined Contributions pledged under the Paris Agreement. Some countries, for example Kenya, however have decided to ban the use of charcoal to reduce stress on forests. Given the importance of charcoal use for cooking in sub-Saharan Africa (excluding South Africa), and the implications of its use, improving the sustainability of the charcoal value chain could bring significant benefits.

In the Stated Policies Scenario, charcoal consumption per capita continues to increase over time, with overall charcoal consumption in sub-Saharan Africa (excluding South Africa) increasing by 50% by 2040 compared to today's level. By contrast, the increasing number of improved cookstoves in the Africa Case along with other clean cooking options allows for a reduction in charcoal consumption in sub-Saharan Africa by over 25%. With urbanisation rates increasing to 51% in 2040, reducing total charcoal use requires dramatic changes in consumption patterns to decouple urban migration and increased charcoal use.

Addressing the inefficiencies of charcoal stoves is a first step towards reducing demand for charcoal, and would also reduce indoor air pollution. Twenty-three countries in sub-Saharan Africa have already committed to promote efficient or improved cookstoves as part of their updated Nationally Determined Contributions. Further opportunities exist to improve the upstream efficiency of charcoal production and reduce related greenhouse gas emissions (Box 2.4).

Figure 2.16 ▷ Charcoal consumption per capita and urbanisation rates in sub-Saharan Africa (excluding South Africa) **in the Stated Policies Scenario and Africa Case**



Close ties between urbanisation and charcoal use are loosened in the Africa Case, reducing total charcoal consumption and subsequent pressure on forest resources

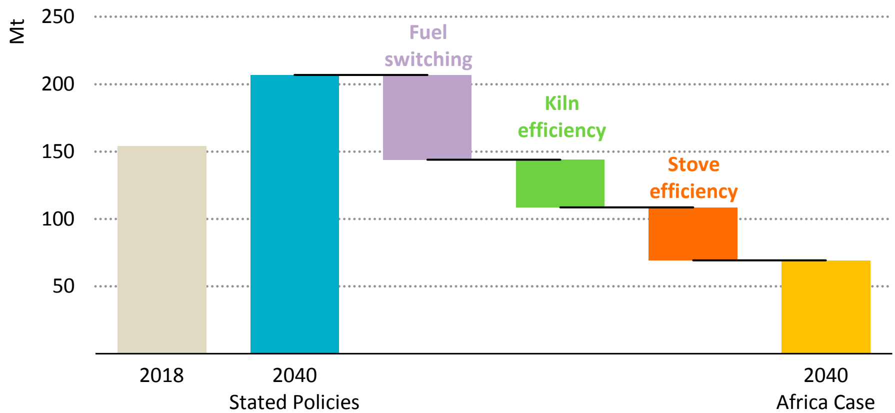
Notes: STEPS = Stated Policies Scenario; AC = Africa Case.

It is unlikely to be possible to achieve a sustainable charcoal value chain and access to affordable, efficient cook stoves for end-users without changes in policies and regulations. A comprehensive policy framework could lead to a number of benefits including improved efficiency of charcoal production, reduced stress on forest resources and improved health outcomes. The costs involved in promoting efficient stoves and kilns, and improving forest management would need to be set against wider financial and societal benefits, not least in advancing progress towards multiple sustainable development goals.

Box 2.4 ▷ Can charcoal production be made more efficient?

Charcoal manufacturing, transportation and distribution are responsible for two-thirds of the efficiency losses in the overall charcoal value chain: the other third comes from the energy performance of stoves. There is sizeable potential to reduce upstream efficiency losses: conventional production practices rely on earth-mound kilns that operate at 8-20% efficiency, but more efficient kilns can reach efficiency levels of at 35-40%. There is similarly sizeable potential to improve the efficiency of stoves: energy-efficient charcoal equipment for cooking can achieve a thermal efficiency of 30-40%, compared with 10-20% for most traditional cookstoves. Shifting to efficient stoves for both fuelwood and charcoal burning in the Africa Case would cut biomass consumption for cooking in sub-Saharan Africa (excluding South Africa) by 60% by 2040, and would reduce charcoal consumption for cooking by 35%. These types of gains are instrumental in achieving the reductions in wood demand for charcoal production in the Africa Case (Figure 2.17).

Figure 2.17 ▷ Wood demand for charcoal production in the Stated Policies Scenario and Africa Case



Wood use for charcoal production is cut by two-thirds in 2040 in the Africa Case with more efficient kilns and stoves accounting for one-third of the gains

Putting a price on wood resources and reinvesting revenues (for example from wood cutting taxation, licensing fees, certifications) to help ensure sustainable forest management and wider use of efficient stoves is a key step in improving the sustainability of the charcoal value chain (FAO, 2017). The diversification of bio-based fuels (using agricultural waste and wood residues) would also reduce the need for wood extraction from forests, and consequently the time spent by women and children in gathering wood and cooking.

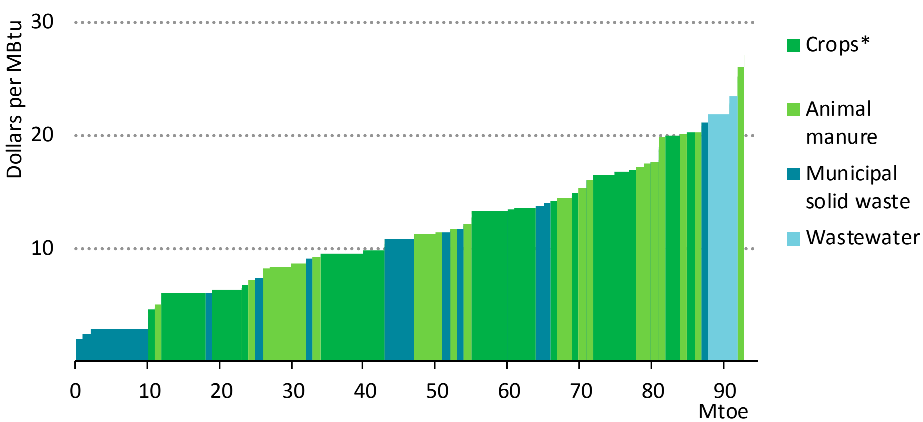
2.3.3 Rural areas – how to unleash the potential of biogas?

Rural areas face a unique array of challenges in transitioning towards clean cooking, with the lack of availability of modern fuels being one of the principal barriers to change. LPG is not always available due to long distances and poor transport links between distribution centres and households, and to demand competition from urban areas. A move to electric cooking is impeded by very low rates of electricity access in rural areas in Africa, the unreliability of electricity supply in many places where it does exist, and the prioritisation of electricity for uses such as lighting and appliances. Other modern fuels such as ethanol and processed biomass pellets or briquettes often face similar barriers to access.

Biogas provides an alternative clean cooking solution that is ideally suited to many rural areas and can also be used as a local source of clean energy for heating. A mixture of methane and carbon dioxide (CO_2), biogas can be produced from organic by-products and waste otherwise thrown away or abandoned. Biogas is ideally suited to communities where agricultural residues and animal manure are available as a feedstock. In addition to providing a source of clean energy, anaerobic digestion produces as a by-product a valuable fertiliser that can enhance agricultural production.

Based on our new bottom-up assessment, we estimate that today in Africa there is sustainable technical potential available to produce around 50 Mtoe of biogas. The potential doubles by 2040 to almost 100 Mtoe at an average cost of just over $10 per million British thermal units (MBtu), which would represent around one-third of the projected natural gas demand in the region in the Stated Policies Scenario. About 80% of this potential is in sub-Saharan Africa (Figure 2.18).

Figure 2.18 ⊳ Cost curve of potential biogas supply by feedstock in Africa, 2040



By 2040, over 90 Mtoe of biogas could be produced in Africa, around half of which would cost less than $10/MBtu

* Includes crop residues only, energy crops are excluded given concerns about their sustainability.

Note: MBtu = million British thermal units.

The biggest contribution to the potential comes from rural areas with strong agricultural sectors. Crop residues, especially cereals, account for almost 60% of the total potential, animal manure for close to 25%, and municipal solid waste (MSW) for most of the remainder. At the end of the outlook period, the picture changes slightly as further urbanisation increases the availability of MSW and as anticipated changes in diet bring an increase of livestock and therefore of animal manure.

The main route to biogas production (over 80% of our estimated 2040 potential) is via a biodigester, an airtight system where anaerobic digestion occurs and biogas is produced. These can be either decentralised (household-scale) or centralised. A decentralised biodigester has a basic design and is built to provide enough biogas to fulfil the energy needs for cooking and water heating of a single family. It produces biogas at an average cost of $6/MBtu, with variations depending on the capital cost of the biodigester installed. Centralised biodigesters can be of small, medium or large scale and the feedstock is usually provided from a single farm or a group of farmers with the involvement of local entrepreneurs. In this case costs are higher – in the range of $12-20/MBtu – with limited economies of scale and additional labour and feedstock costs.

A clear picture of today's consumption of biogas in Africa is not available due to lack of data. We estimate that current biogas use is around 5 000 tonnes of oil equivalent (toe) (6 million cubic metres of natural gas equivalent), and its use is concentrated in countries with specific support programmes for this fuel. Some governments, such as Benin, Burkina Faso and Ethiopia, provide subsidies that can cover from half to all of the investment, while numerous projects promoted by non-governmental organisations provide practical know-how and subsidies to lower the net investment cost. In addition to these subsidies, credit facilities have made progress in a few countries. A new lease-to-own[6] (LtO) arrangement has recently been developed by a limited number of companies in Kenya, and around 45% of the households in Kenya that installed a digester in 2018 financed their unit through an LtO arrangement (ter Heegde, 2019).

Research in East Africa shows that families with access to biogas see benefits in terms of ease of cooking and a reduction in the time spent collecting fuelwood, as well as a lower incidence of health and respiratory problems. There are also co-benefits in terms of agricultural productivity (as a result of using the bio-slurry as fertiliser) and reducing deforestation (Clemens et al., 2018).

In the Stated Policies Scenario, consumption rises to over 3 Mtoe of biogas in Africa by 2040. However, there is much larger uptake of biogas in the Africa Case, spurred by the drive in this scenario to provide universal access to clean cooking by 2030. Biogas demand rises to 9 Mtoe in 2040, over half of which is used for providing access to clean cooking in sub-Saharan Africa, the remainder is used for power generation. An additional 2 Mtoe is used for biomethane production in South Africa. In this scenario, over 135 million people in Africa use biogas to move away from reliance on traditional use of solid biomass.

[6] Lease-to-own credit mechanism allows the user to purchase the biodigester when the lease period expires.

The main economic challenge is the relatively high upfront cost of the biodigester. In Africa, upfront costs for an average sized household biodigester with a technical lifetime of over 20 years can range between $500-800 (ter Heegde, 2019). A part of the capital cost can be reduced by using traditional and locally available construction materials such as sand and gravel, and by relying on local labour. For the remainder, financing help is often needed.

There are also significant non-economic barriers, notably biodigester maintenance and availability of gathered feedstock. These barriers can be even more pronounced for a biodigester at the community scale or larger. In a survey in East Africa, more than a quarter of biodigesters installed between 2009 and 2013 were out of operation by 2016 because of a lack of readily available maintenance expertise (Clemens et al., 2018). Feeding a household biodigester regularly with animal manure requires at least two mature cattle, so any deterioration in household circumstances quickly affects biogas production, while local communities need to develop and maintain a system to collect waste and residues for centralised biodigesters. Local entrepreneurs and government partnerships with the private sector have a crucial role to play in overcoming these barriers, with governments promoting biogas utilisation through a range of programmes and facilities while the private sector ensures a proper and sustainable development of the sector along all the supply chain.

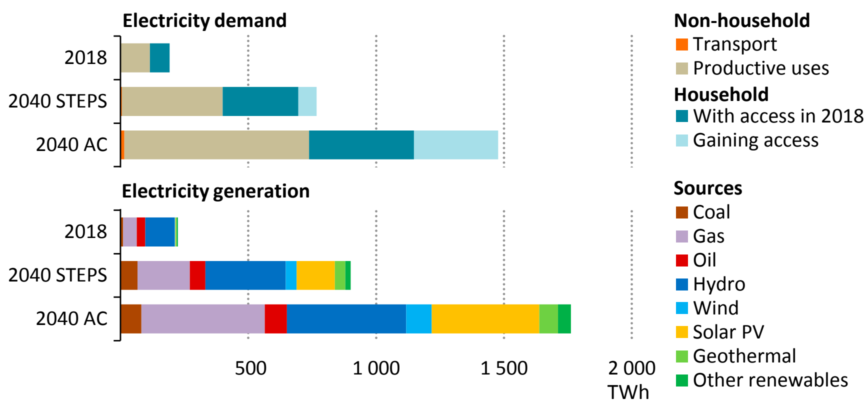
Access to electricity and reliable power

Generating a brighter future for Africa

S U M M A R Y

- Today, 600 million people in sub-Saharan Africa (one-out-of-two people) do not have access to electricity, according to our latest country-by-country assessment. A number of countries make important headway in the Stated Policies Scenario, with South Africa, Ethiopia, Ghana, Kenya, Rwanda and Senegal reaching full access by 2030. This allows around 20 million people to gain access every year. Yet progress is uneven: 530 million people (one-out-of-three people) remain without electricity in 2030. Annual gains in access would need to triple to reach universal access by 2030.
- South Africa differs from its sub-Saharan African peers with its mature economy, successful access programmes and integrated policy making. Competitive auctions for renewables are stimulating private investment. The financial health of the state-owned utility remains vulnerable, strengthening its commercial and operational performance is essential to the future well-being of the power sector.

Figure 3.1 ▷ Electricity demand and generation in sub-Saharan Africa (excluding South Africa) **by scenario, 2018 and 2040**



Demand quadruples by 2040 in the Stated Policies Scenario and increases almost eightfold in the Africa Case, renewables and gas rise to meet demand growth

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

- Electricity demand in the rest of sub-Saharan Africa is set to quadruple by 2040, driven by rising incomes and industrialisation. However, per capita demand remains low, at less than 15% of today's global average. Accelerated economic development and universal access to electricity in the Africa Case push demand to almost 1 500 terawatt-hours (TWh) by 2040, with households in urban areas approaching the ownership and consumption levels of middle-income countries.

- Keeping pace with soaring needs, electricity supply in the rest of sub-Saharan Africa increases fourfold in the Stated Policies Scenario. Generation capacity triples to 270 gigawatts (GW) by 2040, but this is far short of the 600 GW reached in the Africa Case. The expansion is achieved through a combination of renewables and natural gas. Solar photovoltaics (PV) plays a key role in delivering access and becomes the largest source in terms of installed capacity in the mid-2030s in the Stated Policies Scenario, and in the mid-2020's in the Africa Case, overtaking hydropower.
- While hydropower generation grows in both scenarios, new detailed analysis on its vulnerability to climate change shows increased variability of outputs and the need to plan for long-term resilience with a diverse power mix and regional co-operation.
- The expansion of generation capacity is not sufficient to provide reliable and affordable electricity. Around 80% of sub-Saharan African businesses recently suffered from electricity disruptions, leading to average annual losses of around 8% of sales. Sustaining economic growth of 7.3% per year in the Africa Case requires continuous focus on transmission and distribution assets to reduce the incidence of power outages by over three-quarters and take network losses to below 10% (from 18% today) improving economic outcomes for companies, including power utilities.
- Focus on improved network management, densification and extensions see the grid provide about 70% of the 230 million new connections expected by 2030 in the Stated Policies Scenario. In the Africa Case, mini-grids and stand-alone systems, mostly based on renewables, are essential to bridge the gap to achieve universal access; they are the least-cost solutions for over two-thirds of the additional people that attain access, connecting almost 450 million people by 2030 in the Africa Case.
- Investment in the power sector in sub-Saharan Africa averages more than $45 billion per year over the outlook period in the Stated Policies Scenario (compared to $21 billion today). The Africa Case requires a fivefold increase to ensure reliable and affordable power for all (over $100 billion per year). In both scenarios, half of the total investment goes to expansion, reinforcement and maintenance of grids, increasingly for mini-grids and cross-border infrastructure. Investment in low-carbon generation accelerates, driven by a rise in spending on solar PV projects, which reaches almost $25 billion per year on average in the Africa Case.
- Most power sector investment in Africa today is underpinned by public funds, with heavy reliance on international development finance. Given the financial constraints of utilities and limited fiscal capacity of governments, private sources of finance will be essential to bridge investment gaps. Policy and regulatory improvements are needed to address investment risks, facilitate a more effective use of public funds and help reduce the cost of capital. Four areas are crucial to foster a more self-sustaining environment for investment: better financial performance of utilities; improvements in procurement frameworks; more sustainable business models for the decentralised sector; and strengthened provision of long-term finance.

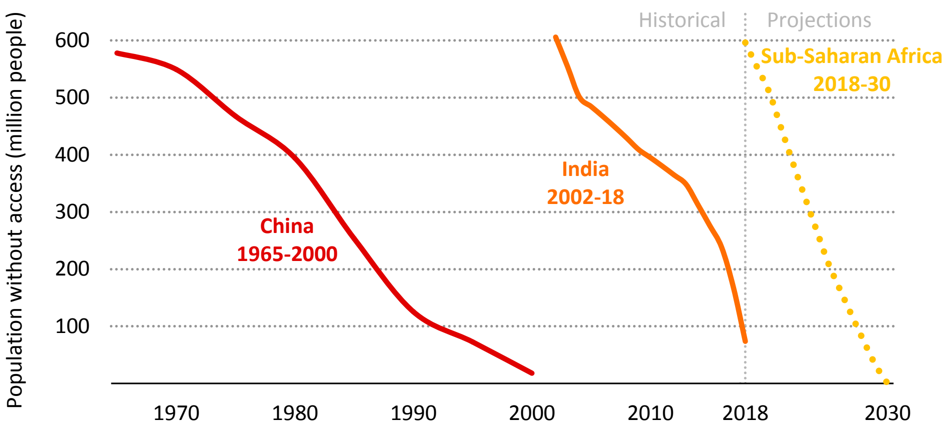
3.1 Introduction

The achievement of universal access to reliable electricity is vital if Africa is to thrive, and that means providing access for the first time to the 600 million people currently deprived of electricity, electrifying schools and hospitals, and ensuring that electricity is available for companies and entrepreneurs. China and India faced similar challenges and it took them 35 and 16 years respectively to reach a 95% access level and to connect as many people as now need to be connected in sub-Saharan Africa (Figure 3.2). More decentralised and modular technologies are now available and they are reducing the length of time it takes to provide access and the costs of doing so.

3

The regional and country-by-country projections for the Stated Policies Scenario and the Africa Case are described in this chapter. We analyse the electricity demand and supply outlook and their drivers, the changing electricity generation mix by technology and access solution, and the implications for affordability, reliability and investment needs.

Figure 3.2 ⊳ Reaching universal access to electricity in sub-Saharan Africa compared with achievements in China and India



Achieving access for all in sub-Saharan Africa in only twelve years will require an unprecedented effort

An increasing number of countries are implementing policies with a view to meet the United Nations Sustainable Development Goal 7[1] by 2030, resulting in substantial progress in the Stated Policies Scenario. New technologies and business models are attracting investment from donors, development banks and increasingly the private sector. Nonetheless, without a significant step up in efforts, the population without access to electricity will remain as high as 530 million in 2030 in sub-Saharan Africa.

[1] Sustainable Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all.

In the Africa Case, we examine by country, and for sub-Saharan Africa as a whole, the range of technologies, policies and investment frameworks needed to achieve the universal electricity access target. Our least-cost analysis points to the best way forward as being comprehensive policies that make use of all solutions, centralised and decentralised, with mini-grids and stand-alone systems providing power to more than half of the population gaining access by 2030.

We go beyond looking at the achievement of universal access and also examine what it would take to develop a reliable, affordable and sustainable power system capable of making the African Union's Agenda 2063 a reality (see Part B introduction, Box B.2). Reliable electricity is an essential element of a thriving economy, and Africa has the opportunity to be the first continent to industrialise and build resilient and reliable power systems based on cleaner sources, with a combination of readily available renewables and natural gas now looking like the most competitive way to provide electricity.

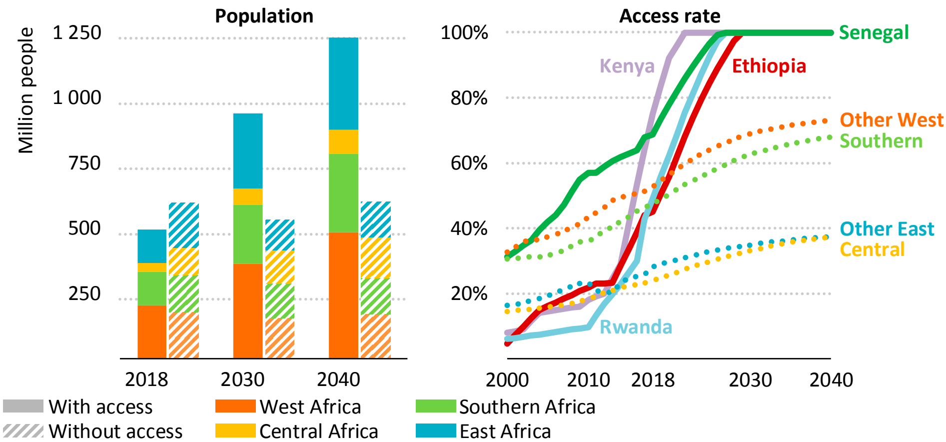
3.2 Outlook for electricity access

While more than 99% of the population in North Africa has access to electricity, the situation is very different in the rest of the continent. In the Stated Policies Scenario, the number of people without access to electricity across sub-Saharan Africa declines slightly to 530 million by 2030, but increases after that to 600 million as rapid population growth outruns efforts to increase access (Figure 3.3). Many countries on the continent are putting in place policies which, if effectively implemented, will allow around 20 million people to gain access to electricity each year by 2030, a rate similar to what the region has witnessed since 2013 (see Chapter 1).[2] However, the rate is less than a third of what would be needed to reach full access by 2030. The share of the population with access to electricity in sub-Saharan Africa rises from 45% today to nearly 65% in 2030 in the Stated Policies Scenario, with over 230 million people gaining access.

Projected progress in the Stated Policies Scenario is most rapid in East Africa, as it moves from a regional access rate of 43% today to more than 70% by 2030. Kenya, Ethiopia and Rwanda are all set to achieve universal access before 2030 (Table 3.1). Ethiopia brings access to the highest number of people in the region by 2030 (more than 70 million). Tanzania also sees rapid progress, with its electrification rate climbing to around 70% in 2030 from less than 40% in 2018. Progress is also made in West Africa and Southern Africa, where the regional access rates reach over 60% by 2030. South Africa and Ghana, which achieved two of the highest access rates on the continent in 2018 after two decades of effective government leadership, are expected to reach full electrification by 2030. Senegal is expected to achieve universal access in 2025. Strong efforts in Nigeria and Côte d'Ivoire result in their rates of access increasing to 80% and more than 90% respectively by 2030. Countries across Central Africa see limited progress under the Stated Policies Scenario, but there are some bright spots: Gabon and Cameroon both reach more than 90% by 2030.

[2] The investment and financing implications are discussed in sections 3.7 to 3.8.

Figure 3.3 ⊳ Electricity access progress in sub-Saharan Africa in the Stated Policies Scenario



Strong policy support is instrumental to drive the rapid increase in access rates observed in several countries, but many struggle to provide access to increasing populations

Table 3.1 ⊳ Electricity access policies and targets in selected countries

Country	Target	Implementation measures
Kenya	Full access by 2022	Kenya National Electrification Strategy (2018): investment of $2.8 billion from 2018-22. Kenya Off-grid Solar Access Project: distribute 250 000 solar home systems to power households, schools, health facilities and agriculture by 2030.
Ethiopia	Full access by 2025	Electrification Program (2017): geospatial least-cost roll-out plans, fast-paced extension of the grid to reach 65% of the population with the grid and 35% with decentralised systems by 2025; public-private off-grid programme for 6 million households.
Rwanda	Full access by 2024	Energy Sector Strategic Plan and Rural Electrification Strategy: connect 52% households to the grid and 48% to decentralised systems by 2024; connect all productive users; cut by half the duration and number of interruptions; introduction of appliance efficiency standards.
Senegal	Full access by 2025	National Rural Electrification Program (PNER), aiming to electrify 95% of rural clients through grid extension, 4% through solar only or solar-diesel hybrid mini-grids, and the rest through solar home systems.
Côte d'Ivoire	Connect all areas by 2025	Programme Electricité pour Tous: electrify 1 million households. Programme National d'Electrification Rurale: connect all towns above 500 inhabitants by 2020, and all areas by 2025. Tariff reductions for poor households.

Despite this impressive projected progress in a number of countries, around 20 countries, accounting for 30% of the population of sub-Saharan Africa in 2030, still have less than half of their population with access to electricity in 2030 on the basis of current and stated policies. Across sub-Saharan Africa, 36% of the population have no access to electricity in 2030, of which three-quarters, or more than 400 million people, live in rural areas.

Achieving full access by 2030 would require tripling the current rate of annual connections to reach over 60 million people on average each year. This would mean finding ways to connect people living "under the grid" but lacking access (see Spotlight in Chapter 1, section 1.2.2). It would also mean accelerating the deployment of mini-grids and stand-alone systems, which are the least-cost way to provide power to more than half of the population gaining access by 2030 (see section 3.4.2). In 2030, around 50% of the population without access in the Stated Policies Scenario live in the Democratic Republic of the Congo (DR Congo), Nigeria, Uganda, Niger, and Sudan: scaling up efforts in these countries is particularly important.

Delivering access to electricity in an integrated way would support economic growth and overall development. Access could bring new sources of productive employment to remote populations, in particular for women. Less time to complete domestic chores provides more time for paid jobs. Access to electricity also benefits women-owned businesses, helping women to move from extreme poverty to near middle-class status, as shown within areas connected by a mini-grid company in Ghana (Power Africa, 2019). A recent study shows that the decentralised renewables sector is beginning to support employment at a similar scale to the traditional utility sector, with strong potential for future growth (Power for All, 2019).

3.3 Outlook for electricity demand

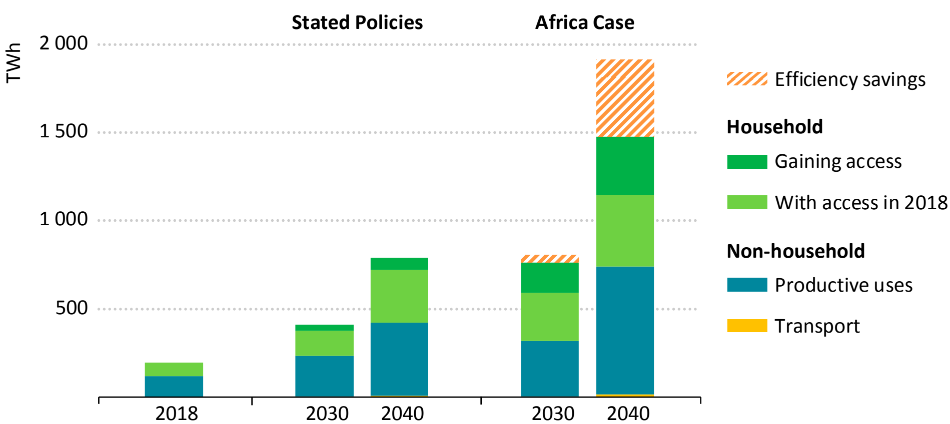
Electricity demand[3] in Africa today is 700 terawatt-hours (TWh), with South Africa and the North African countries accounting for over 500 TWh of this total. Yet it is the sub-Saharan Africa countries (excluding South Africa) that see the fastest growth in electricity demand in the Stated Policies Scenario, with demand increasing at an average annual rate of 6.5%, the highest rate of any region worldwide. By 2040, electricity demand in sub-Saharan Africa, excluding South Africa, reaches 770 TWh under current and stated policies, four-times today's level. Electricity demand per capita increases from an average of 185 kilowatt-hours (kWh) today to over 430 kWh in 2040, but still represents less than 15% of today's global average of over 3 000 kWh.

Low per capita electricity demand masks large inequalities that seem likely to persist. About 440 million people across sub-Saharan Africa (excluding South Africa) live in households that have access to electricity today, predominantly in urban areas. In the Stated Policies Scenario, households with access today and new ones in areas with existing

[3] Electricity demand is defined as total gross electricity generated less own use generation, plus net trade (imports less exports), less transmission and distribution losses.

access to electricity consume an additional 220 TWh by 2040. This compares to an increase of only 70 TWh in order to provide access to electricity for the first time to 320 million people in this scenario. Growth in electricity demand from an emerging middle-class and newly connected households goes hand-in-hand with growth in demand from the productive sectors of the economies (Figure 3.4). Demand from industry and the services sectors more than triples to 390 TWh by 2040 in the Stated Policies Scenario, fuelled by domestic consumption and economic growth. Electricity demand from agriculture increases by 150%, but still accounts for only 6 TWh in 2040.

Figure 3.4 ▷ Electricity demand by scenario in sub-Saharan Africa (excluding South Africa)



Demand quadruples by 2040 in the Stated Policies Scenario and increases almost eightfold in the Africa Case. Demand would be even higher without efficiency savings.

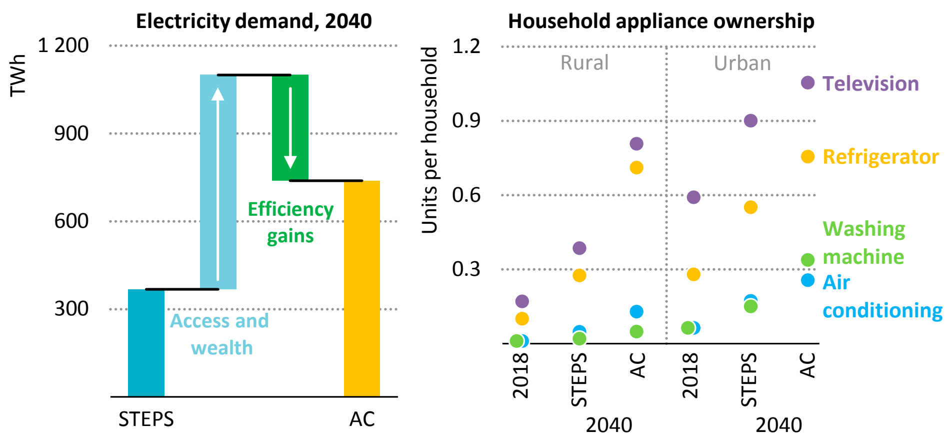
The Africa Case sees national strategic plans and the Agenda 2063 ambitions realised in full, with important implications for electricity demand. A virtuous cycle emerges in which electricity demand growth is fuelled by the development of local industries and services, increasing employment and incomes, and this in turn increases the consumption of locally produced goods and services. Electricity demand in the Africa Case grows at close to 10% per year to reach almost 1 500 TWh in 2040. Extension of electricity access to all households in the Africa Case adds 260 TWh of demand relative to the Stated Policies Scenario by 2040. Nonetheless, achieving universal electricity access still accounts for only a quarter of demand growth to 2040.

The electricity demand growth rate in sub-Saharan Africa (excluding South Africa) would reach 11% per year in the Africa Case without efficiency improvements in appliances and equipment. Energy efficiency measures are essential to achieve the vision of the Africa Case, helping to improve the competitiveness of local industries and reduce the impact of increases in energy services on electricity bills (see section 3.6). A handful of countries in sub-Saharan Africa are already leaders in energy efficiency when it comes to the residential appliances that accompany decentralised models of electricity access. Extending innovations of this kind to the wider appliance market is central to the savings achieved in the Africa Case.

3.3.1 Electricity demand growth by sector

The residential sector is the largest contributor to electricity demand growth, accounting for some 50% of the growth to 2040 in sub-Saharan Africa (excluding South Africa) in both the Stated Policies Scenario and Africa Case (Figure 3.5). As income levels increase across Africa, households increasingly own appliances such as refrigerators, washing machines and phones: the wealthier ones also own cooling devices. Domestic appliances are the biggest contributor to growth in residential electricity demand in the Stated Policies Scenario, adding 175 TWh to demand by 2040. Space cooling adds another 40 TWh, with the number of air conditioners across the region expected to increase almost sixfold to about 45 million by 2040. In the Africa Case, universal access to electricity is achieved by 2030 and household incomes rise more rapidly. As a result, residential electricity demand is 370 TWh higher in 2040 relative to the Stated Policies Scenario, with the increase equally split between rural and urban areas.

Figure 3.5 ▷ Residential electricity demand and household appliance ownership by scenario in sub-Saharan Africa (excluding South Africa)



In the Africa Case, an increase in residential demand stemming from better access to electricity and increased ownership of appliances is partially offset by efficiency gains

Notes: STEPS = Stated Policies Scenario; AC = Africa Case. Access and wealth refers to the increase in demand associated with higher electricity access and higher average household incomes in the Africa Case relative to the Stated Policies Scenario. Efficiency gains refers to the reduction in electricity demand due to efficiency gains in the Africa Case relative to the Stated Policies Scenario.

By 2040, the urban population in sub-Saharan Africa (excluding South Africa) more than doubles to over 900 million, and average incomes in urban households increase by close to 40%, driving up appliance ownership rates. In the Stated Policies Scenario, on average 90% of urban households own a television and 55% a refrigerator by 2040. Ownership of air conditioners triples by 2040, but even in urban areas air conditioner ownership rates remain among the lowest in the world, despite the hot climate in many areas (see Chapter 2). Average urban household incomes are more than twice as high in the Africa Case relative to the Stated Policies Scenario, which leads to urban households purchasing more appliances, and electricity demand in urban areas increases at 10% per year, compared with 7.4% in the Stated Policies Scenario. More people own air conditioners in the Africa Case, but two-thirds of urban households remain without in 2040.

In the Africa Case, universal access to electricity in rural areas of sub-Saharan Africa (excluding South Africa) results in an additional 210 TWh of electricity demand by 2040. Rural households also benefit from higher levels of appliance ownership, roughly doubling the average number of televisions, refrigerators and washing machines in the Africa Case relative to the Stated Policies Scenario. Rural ownership of air conditioners remains uncommon. The impact of universal access and higher incomes is enough to see average per capita consumption in rural areas increase ten-fold to 320 kWh in the Africa Case, compared to only 100 kWh in the Stated Policies Scenario.

The services sector benefits from increasing electrification which contributes to economic growth. Electrification of the services sector is often a by-product of household electrification efforts, but it can also be an objective in itself: in Rwanda, the Energy Sector Strategic Plan announced in 2018 aims to bring electricity access by 2024 to all public infrastructure, schools, health facilities, small businesses and administrative offices, in addition to households. In the Stated Policies Scenario, electricity demand from the services sector reaches 170 TWh in sub-Saharan Africa (excluding South Africa) by 2040, with the majority of growth stemming from demand for cooling and appliances. Achievement of the electrification and economic growth targets in the Africa Case sees demand from the sector increase by a further 170 TWh.

Industry contributes to around 30% of the growth in electricity demand to 2040 in the Stated Policies Scenario. Electricity demand from industry increases at an annual average of 6%, which is a third faster than the rate of growth of total industry sector energy demand. Much of the growth comes from the use of electric motors in processing, manufacturing and other light industries. The Africa Case sees a step up in the rate of electricity demand growth in industry to 7.5%, driven by the modernisation of industry and increasing domestic demand for locally produced goods as well as expanding exports. Improvements in industrial energy efficiency in the Africa Case temper demand growth as well as helping to improve the competitiveness of industry. By 2040, electricity demand from industry exceeds 340 TWh, 100 TWh higher than the Stated Policies Scenario.

The agricultural sector sees increasing electricity demand for irrigation (some of it met through the use of stand-alone solar photovoltaic [PV] powered pumping systems) and for cooling (to support refrigerated storage of produce). The expansion of irrigation and cooling leads to important productivity gains,[4] and these bring further increases in electricity demand. Electricity demand for agriculture increases from about 3 TWh today to over 6 TWh in the Stated Policies Scenario, while in the Africa Case it rises to 36 TWh as a result of a larger increase in value added in the sector and a bigger shift from other sources of energy to electricity.

The electrification of transport struggles to get started in the Stated Policies Scenario: there are very few policies that support electric vehicles (EVs) (cars, buses, trucks and two/three-wheelers) and electricity accounts for only 0.5% of transport energy demand by 2040. Progress is faster in the Africa Case, but electricity still powers less than 1% of cars by 2040, together with around 18% of two/three-wheelers. By 2040, electricity demand for transport reaches 15 TWh in the Africa Case: this is almost triple the level in the Stated Policies Scenario.

The limited electrification of transport even in the Africa Case is a result of the size of the power requirements for EV charging, relative to other uses. Designing the extension of electricity access with the electrification of transport in mind would significantly increase the costs of achieving universal access. Concerns over the reliability of electricity supply and the costs of EVs also hinder their uptake. Conditions for the electrification of transport are more favourable in urban areas with existing grid connections: as a result, the majority of EV uptake in Africa is concentrated in cities, with almost 30% of the urban two/three-wheeler fleet electrified by 2040.

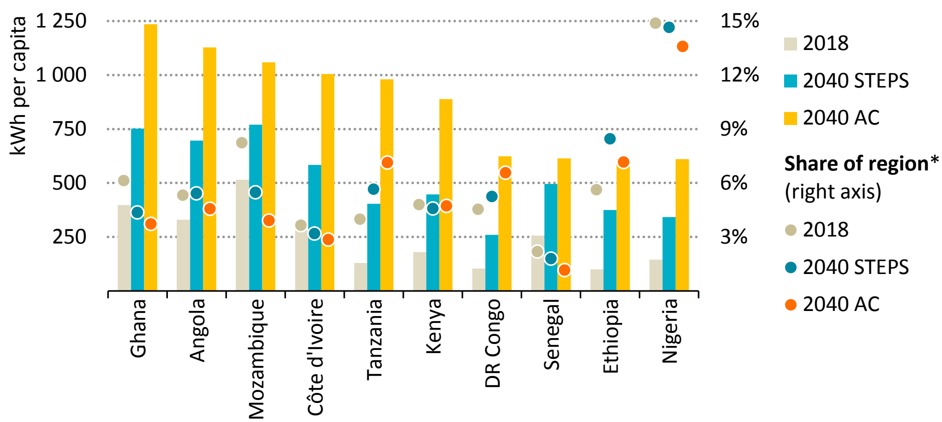
3.3.2 Electricity demand growth by region

The evolution of electricity demand is far from homogenous across African countries; it ranges from 4.5% to 8.5% per year through to 2040 in the Stated Policies Scenario, reflecting disparities in economic developments and the rate of progress in improving electricity access. Kenya, Ghana and Ethiopia all reach universal access to electricity before 2030, raising average per capita electricity demand to 450 kWh, 750 kWh and 375 kWh respectively in 2040. Per capita electricity demand growth is more limited in countries with lower average incomes today, and in those that experience the fastest population growth or make slower progress on electricity access, such as DR Congo and Nigeria (Figure 3.6).

While higher than average incomes contribute to higher per capita electricity demand by 2040 in Angola, Ghana and Côte d'Ivoire relative to the regional average, it is the larger economies that lead total electricity demand growth. About 15% of the increase in total electricity demand in the Stated Policies Scenario across sub-Saharan Africa (excluding South Africa) comes from Nigeria. Ethiopia accounts for a further 9%, with Tanzania, DR Congo and Angola not far behind. Overall, just seven sub-Saharan African countries account for over half of demand growth over the outlook period in the Stated Policies Scenario.

[4] Chapter 4 of *Energy Access Outlook 2017: From Poverty to Prosperity* takes an in-depth look at how energy can improve agricultural productivity in Africa (IEA, 2017).

Figure 3.6 ▷ Electricity demand per capita and share of regional electricity demand by scenario, 2018 and 2040



Electricity demand per capita rises fastest in the Africa Case, but in 2040 it is still only around a third of today's average in other developing countries

* Region = sub-Saharan Africa excluding South Africa.

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

In the Africa Case, even those countries that have lower average incomes and currently are making slow progress on access to electricity see a jump in per capita electricity demand, thanks to the combined impacts of universal access to electricity and accelerated economic growth across all sectors of the economy. In DR Congo, for example, electricity demand is 625 kWh per capita in 2040 in the Africa Case, more than double the level in the Stated Policies Scenario as a result of a near 9% gross domestic product (GDP) growth rate and the electrification of an additional 120 million people. In absolute terms, this translates to an additional 55 TWh of electricity demand in 2040, enough to see DR Congo's share of total electricity demand in sub-Saharan Africa (excluding South Africa) increase from 5% in the Stated Policies Scenario to 7% in the Africa Case.

Box 3.1 ▷ Electricity in South Africa – deep transformation ahead?

South Africa's energy landscape looks different from that of other sub-Saharan countries. The country has a more mature economy than its neighbours and a history of relatively low energy prices, in particular for coal and electricity. The competitiveness of electricity relative to other fuels results in a share of electricity in final energy consumption of 25% today, which is high by international standards. This has favoured the development of energy-intensive industries and the extensive electrification of energy use in buildings. South Africa currently accounts for over half of all electricity consumed in sub-Saharan Africa.

Competitive electricity prices and the coupling of clean cooking efforts with electrification mean that around 85% of South African households cook with electricity today. Electrifying cooking increased residential electricity demand, but the largest consumer of electricity in South Africa remains the industry sector, which accounts for 60% of demand.

In the Stated Policies Scenario, South Africa sees further electrification of the economy with electricity demand growing at nearly 2% per year to reach 320 TWh by 2040, equivalent to demand in the United Kingdom today. Average residential electricity consumption reaches nearly 1 400 kWh per capita in 2040, the same level as Korea today and seven-times higher than the average for the rest of sub-Saharan Africa in 2040. Thanks to very proactive government programmes, only 5% of the population does not have access to electricity today, mainly in remote areas. South Africa is on track to achieve universal access well before 2030.

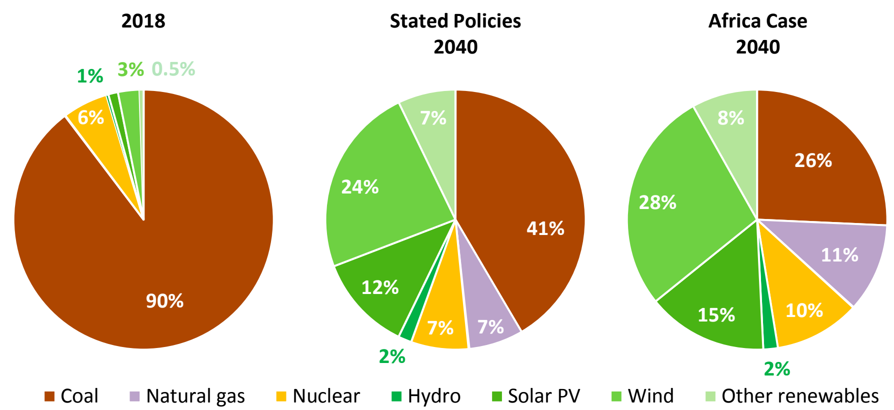
In the Africa Case, the impact of increased electrification across the economy (and more rapid economic growth) is offset by significant improvements in efficiency. The scope for further energy efficiency improvements remains large for motors in industry, heating in buildings and air conditioning. Maximising this potential moderates demand growth. By 2040, electricity demand in the Africa Case is 6% (20 TWh) lower than in the Stated Policies Scenario. Pulling the efficiency lever is central to ensuring reliable, secure and affordable electricity supply.

Although access to electricity has improved, the reliability of electricity supply has deteriorated over recent years with severe power disruptions. A shortage of generating capacity, mainly caused by disruptions and maintenance needs of old coal-fired power plants and delays in the construction of new thermal plants, has caused the vertically integrated state-owned utility, Eskom, to regularly resort to rotational load shedding.

South Africa's latest draft Integrated Resource Plan (IRP 2018) points to a new direction for the power sector, and opens the door for alternatives to coal-fired generation based on a market-based model. The government seeks to procure over 30 GW from independent power producers, half of which will come from the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Falling costs are indeed making these solutions more competitive. The average levelised cost of electricity (LCOE) of renewable energy technologies in South Africa has declined substantially over the last five years – by an estimated 55% for utility-scale solar PV (about $90 per megawatt-hour [MWh] on average in 2018) and by more than 20% for onshore wind ($70/MWh). To date, the REIPPPP has attracted about $15 billion in investment in the power sector (20% foreign) and it is one of the most advanced private procurement programme for the power sector in Africa (see sections 3.7 and 3.8). Despite its early success, however, many projects found it difficult to get to the stage of triggering the release of funding, in part because of political uncertainty and the deteriorating performance of Eskom.

This shift away from coal reflects South Africa's goal of lowering carbon dioxide (CO_2) emissions and its commitment to the "peak, plateau and decline" emissions trajectory that led to the adoption of a Carbon Tax Act in 2019. This strategy implies a significant decline in the use of coal for electricity generation: its contribution shrinks in the Stated Policies Scenario from 90% today to just over 40% of in 2040 (Figure 3.7).

Figure 3.7 ▷ Electricity generation mix by scenario in South Africa



An extensive transformation of South Africa's electricity mix gives much more weight to renewables, but coal retains a significant share

About 85 GW of additional capacity is required by 2040 to meet growing demand and compensate for ageing coal plant retirements in the Stated Policies Scenario. Most additions are renewables units, led by wind and solar (about 25% each), making up close to 45% of electricity supply by 2040. South Africa is building two coal-fired power plants (Medupi expected to be completed by 2020 and Kusile by 2024) and despite the retirement of 30 GW of existing capacity over the period to 2040, coal remains the dominant fuel in terms of both capacity and generation.

In the Africa Case, the power sector in South Africa proceeds further and faster with diversification of the generation mix, driven by improved maintenance and management of the power system as well as the increased effectiveness of the procurement programme. The contribution of renewables to electricity supply grows at a much faster rate to provide over half of generation. By 2040, wind and solar PV become some of the most attractive options while generation costs from fossil fuel plants increase and wind overtakes coal as the primary source of electricity generation. Deeper regional co-operation and integration also sees South Africa benefit from competitive electricity imports, as large hydro projects such as Grand Inga in DR Congo move ahead more quickly.

Achieving the Stated Policies Scenario would require multiplying current investment levels by almost three (from $3.7 billion in 2018 to an average of almost $10 billion per year over the period to 2040). The Africa Case would require 8% less ($9 billion per year), aided by the impact of additional energy efficiency pushing down electricity demand. In both the Stated Policies Scenario and the Africa Case investment would need to shift away from coal (around 35% of total power sector investment in 2018) and focus more on low-carbon generation and on-grid extension and strengthening.

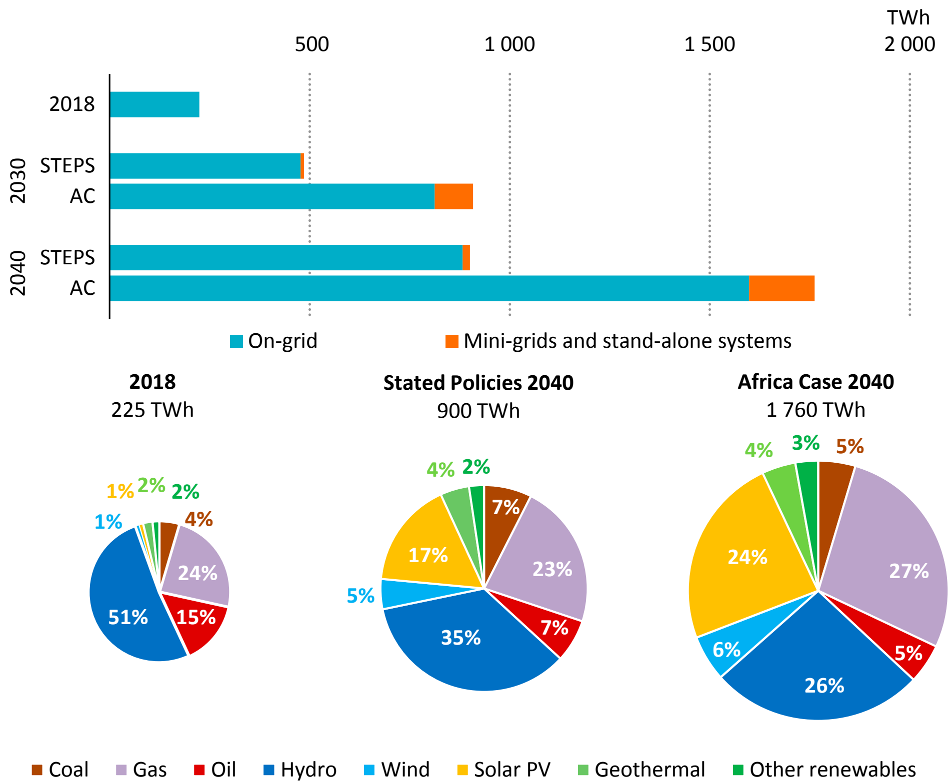
3.4 Outlook for electricity supply

Efforts to meet rapidly growing electricity demand lead to a significant expansion of the power system over the period to 2040 in the Stated Policies Scenario. Total power generation capacity in Africa (which includes on-grid, mini-grid, stand-alone systems and back-up generation capacity) more than doubles to reach 615 gigawatts (GW) in 2040. Natural gas remains the primary source of electricity generation, in particular in North Africa, while the contribution of coal gradually decreases as new projects are offset by ageing plants retirements in South Africa (Box 3.1). Many countries are actively developing their considerable renewable energy resource and over two-thirds of the additional power needs are met by renewables.

Excluding South Africa, the sub-Saharan Africa power sector is already relatively low-carbon and it remains so in the future in both scenarios (Figure 3.8). In the Stated Policies Scenario, electricity output increases fourfold, from around 225 TWh in 2018 to just over 900 TWh in 2040. On-grid supply continues to serve as the primary means of delivering electricity, but decentralised solutions for access play a larger role than anywhere else in the world, especially in the Africa Case. Although on-grid solutions have traditionally served as the most cost-effective option to supply electricity in areas close to an existing grid, the falling costs of stand-alone solar PV and battery storage technologies as well as new business models using digital and appliance innovations are making these solutions more competitive. In the Africa Case, mini-grids and stand-alone systems offer the least-cost solution to deliver over 160 TWh, or nearly 10% of electricity supply, enabling access to new or improved energy services to more than half of people gaining access by 2040.

In the **Stated Policies Scenario**, hydropower output almost triples over the period to 2040 and remains the largest source of electricity, although its share of supply declines from a half today to 35%. Natural gas provides more than a fifth of the additional generation to 2040, and retain a market share above 20%. Falling cost drives fast deployment of utility-scale and distributed solar PV, and also geothermal and wind: the combined contribution of these non-hydro renewable resources increases to over a quarter of overall supply. Coal-fired generation increases from a low base, providing cheap baseload power to meet fast-growing demand. Generation from oil increases in absolute terms, but its share in generation declines markedly to 7% in 2040, half its share in 2018.

Figure 3.8 ▷ Electricity supply by type, source and scenario in sub-Saharan Africa (excluding South Africa), **2018 and 2040**



Most of the soaring electricity needs are met through new grid connections; renewable sources make the largest contribution, followed by gas

In the **Africa Case**, electricity output in sub-Saharan Africa (excluding South Africa) soars to 1 760 TWh by 2040, nearly twice the level in the Stated Policies Scenario and about eight-times 2018 levels. Renewables-based generation accounts for the largest share of the additional 860 TWh needed, bringing the total share of renewable-based generation to over 60%. On-grid hydropower and solar PV account for over 40% of the overall generation mix by 2040, but decentralised renewable solutions also play a much bigger role in delivering power, providing electricity access to 400 million people across sub-Saharan Africa (excluding South Africa) by 2040. The substantial increase in electricity demand also requires major new contributions from gas-fired generation, which account for over a third of the extra needs relative to the Stated Policies Scenario. With these additions, the share of gas in the electricity mix increases to nearly 30% in 2040 and it becomes the largest source of generation in the region. The share of coal declines compared to the Stated Policies Scenario, as does that of oil. Other renewable power sources such as geothermal and wind expand to significant levels in several countries benefiting from high quality sites.

Box 3.2 ▷ Geospatial estimation of the least-cost pathway to universal access to electricity

Over the years, our World Energy Model (WEM) has been expanded and coupled with other tools to provide a detailed outlook for electricity access in the next decades.[5] As part of this work, the IEA has been working closely with several leading universities, including the KTH Royal Institute of Technology (KTH), to analyse the least-cost route to achieve full access to electricity, using the most recent tools available. Analysis was done for a few individual countries in 2014 for our first focus report on Africa (Nigeria and Ethiopia) (IEA, 2014), and for all sub-Saharan African countries in *Energy Access Outlook 2017* (IEA, 2017).

For this *Special Focus*, the IEA refined its analysis using up-to-date datasets and the latest version of the Open Source Spatial Electrification Tool (OnSSET)[6], developed by KTH. The results provide detailed coverage of 44 countries in sub-Saharan Africa. Regional results are presented in section 3.4.2 and national results for 11 focus countries are shown in the country profiles (Chapter 6).

Overall electricity access objectives and demand projections are determined by country and region in the WEM based on population dynamics and economic growth for the Stated Policies Scenario and the Africa Case. They integrate the latest policy frameworks and national targets as well as technology and energy prices. Demand related to access is initially assumed at 250 kWh a year for rural and at 500 kWh for urban households, before growing over time to reach the national average.

Demand and other key drivers (e.g. technology and fuel costs) retrieved from WEM are then used in OnSSET in combination with several open access geospatial datasets. These include demographic indicators (e.g. population density and distribution), infrastructure (e.g. existing and planned transmission and distribution networks, roads), resources availability (e.g. solar, wind, hydro) and derivative layers (e.g. distance to the grid, to the closest road or city, diesel transportation cost) among others. The geospatial model runs a least-cost analysis mainly taking into account techno-economic factors and yields electrification investment outlooks. While grid densification (connecting areas close to the existing network) is prioritised, the geospatial model does not necessarily mirror the detail of government electrification plans (where they exist) or account for the financial and technical capacities of utilities.

3.4.1 On-grid supply

On-grid electricity supply dominates in urban areas and rural communities close to transmission lines and accounts for a majority of electricity consumption in sub-Saharan

[5] For the full WEM methodology, see www.iea.org/weo/weomodel/.

[6] For more details on the Open Source Spatial Electrification Tool, see www.onsset.org; for the latest OnSSET methodology update refer to Korkovelos, A. et al. (2019).

Africa (excluding South Africa) over the outlook period. The evolution and growth of grid supply by energy source varies across countries in sub-Saharan Africa, reflecting the differences in resources, costs and policies of each (Figure 3.9).

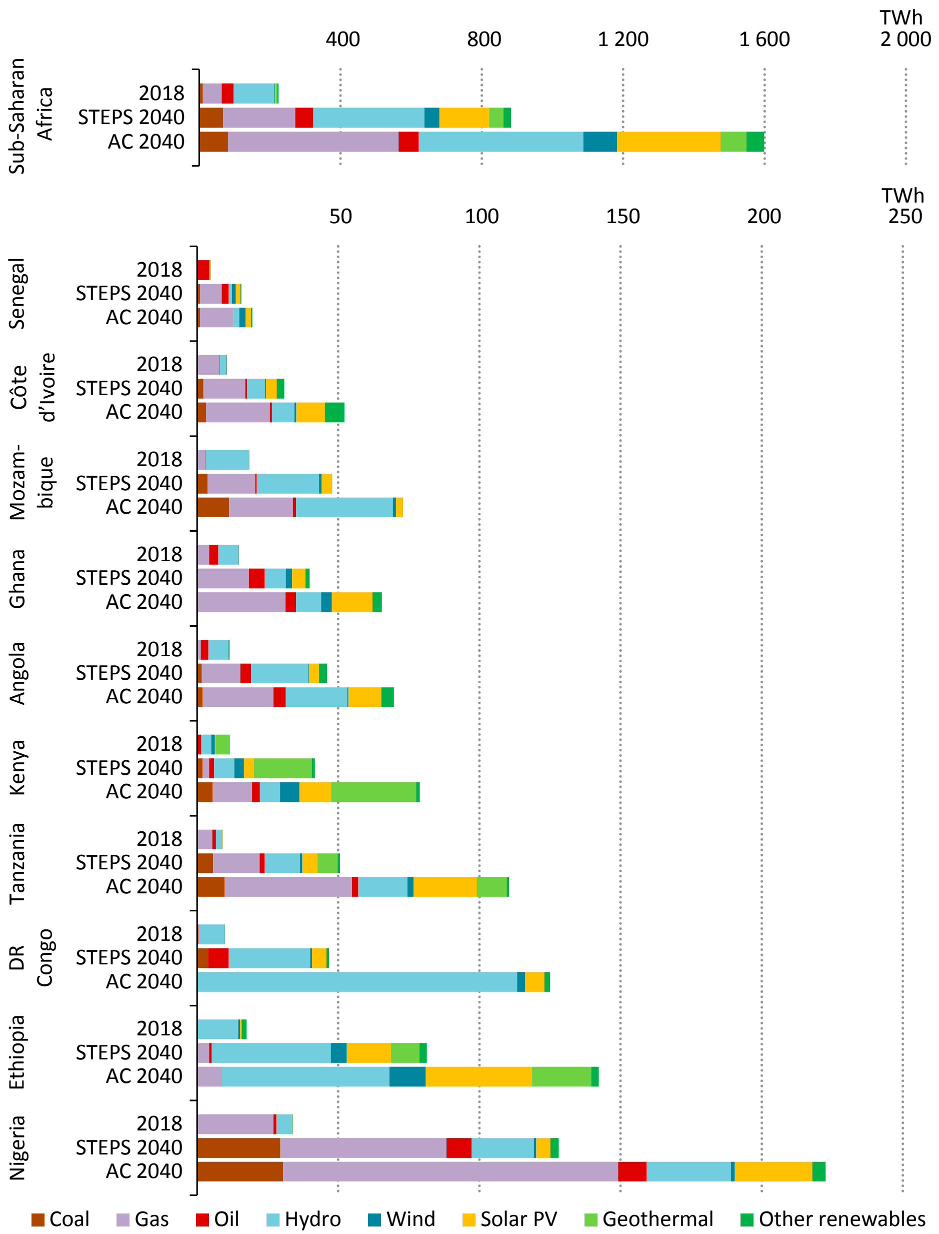
In the Stated Policies Scenario, total on-grid installed capacity in sub-Saharan Africa (excluding South Africa) increases to 270 GW by 2040, a threefold increase from the 80 GW of installed capacity in 2018. The power fleet steadily diversifies away from traditional sources of power and over half of the 190 GW of new plants commissioned over the period are non-hydro renewables (75% when hydropower is included). Gas-fired capacity expands, while the contribution of oil decreases.

In the Africa Case, the power sector proceeds further and faster with ensuring more reliable and affordable electricity for all (sections 3.5 and 3.6). The design of policies and the effectiveness of their implementation play a critical role in incentivising timely and adequate expansion of the physical infrastructure and in ensuring a better performing power sector. Deeper regional co-operation becomes more important. This all requires a steep increase in investment and a major reallocation of capital (sections 3.7 to 3.9). The generation fleet in sub-Saharan Africa (excluding South Africa) nearly doubles compared to the Stated Policies Scenario, reaching about 490 GW by 2040, driven by the substantial increase in electricity demand. The capacity mix diversifies further, with renewables accounting for over three-quarters of the additional installed capacity relative to the Stated Policies Scenario. Gas-fired generation takes on an increasingly important role in all areas and rises in tandem with renewables.

Hydropower remains a cornerstone of sub-Saharan Africa's power system (excluding South Africa) but its share declines as other renewable technologies and natural gas expand. Hydropower currently provides more than half of on-grid generation in sub-Saharan Africa (excluding South Africa) and over 80% of electricity supply in DR Congo, Ethiopia and Mozambique. In the Stated Policies Scenario, generation from hydropower almost triples by 2040. Over two-thirds of the 17 GW under construction today are scheduled to come online by 2025 including the Grand Renaissance Dam (6 GW) in Ethiopia. The Mambilla Dam (3 GW) in Nigeria helps alleviate local demand for fossil fuel resources and provide more reliable access to power. In Angola, the Laúca Dam (1 GW) is expected to be fully operational in early 2020 and the Caculo-Cabaca Dam (2.2 GW) in 2024. Construction of a major hydropower project (2.1 GW) was launched in Tanzania's Rufiji Basin in mid-2019.

In the Africa Case, better regional co-operation and integration of power networks is instrumental in unlocking a larger share of hydropower's huge potential. Larger markets absorb the power output from resources heavily concentrated in the Nile Basin and Congo River, making these resources more economical to develop. Generation from hydropower quadruples by 2040, led by DR Congo with (115 TWh) by 2040, with the completion of Stage V of Grand Inga and by Ethiopia with a quadrupling of output (60 TWh). Large hydropower projects are also developed in Mozambique (including the Mphanda Nkuwa Dam). These three countries become sizeable exporters to neighbouring countries and regions.

Figure 3.9 ⊳ On-grid electricity generation by scenario in sub-Saharan Africa (excluding South Africa) **and selected countries, 2018 and 2040**



The fuel mix of on-grid electricity supply diversifies in all countries, with hydropower being increasingly complemented by gas, solar PV and geothermal

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

In the Stated Policies Scenario and the Africa Case, the share of hydropower in total electricity generation declines by 15 and 20 percentage points, respectively, as alternatives become available. While hydropower remains an essential element of electricity supply, diversifying the electricity mix helps to reduce the risk of power disruptions during droughts and in the long term to strengthen resilience to changing climate conditions.

Natural gas use continues to increase: the size of the gas-fired power generation fleet in sub-Saharan Africa (excluding South Africa) more than doubles to 50 GW by 2040 as an additional 1.6 GW of capacity is added each year on average in the Stated Policies Scenario. A third of this expansion occurs among traditional gas producers, such as Nigeria, through increasing efforts to capture and make use of associated gas from oil production. Angola also expands gas-fired generation with the newly commissioned Soyo combined-cycle gas turbine plant.

In the Africa Case, gas-fired power generation overtakes hydropower in the 2030s to become the largest source of on-grid electricity generation in the region and accounts for nearly a third of the electricity mix. This expansion is also driven by additional growth in countries such as Senegal, Mozambique and Tanzania, which capitalise on newly developed domestic supplies of natural gas. These countries become pivotal actors in gas-fired generation as power sector governance improves and enhanced regional co-operation leads to the development of wider and deeper markets (see Chapter 4). Gas also plays an increasingly important role in providing back-up power during dry spells in countries that continue to depend on hydropower.

The deployment of **non-hydro renewables** accelerates to nearly 5 GW of new capacity per year between 2019 and 2040 in the Stated Policies Scenario. Solar PV represents 40% of all new capacity additions over the period. Geothermal resources play a central role in East African countries and particularly in Kenya where geothermal becomes the largest source of electricity in terms of both installed capacity and electricity production. The share of electricity from wind also increases in the Stated Policies Scenario although some of the best resources remain far from major load centres.

The uptake of these new alternative renewable sources is projected to keep pace with the higher electricity demand growth in the Africa Case and deployment accelerates to 10 GW of additional capacity each year over the period. The majority – over 70% – comes from solar PV. Installed solar PV capacity increases across the entire region to reach about 160 GW in 2040, overtaking hydropower and gas to become the largest source in terms of installed capacity (and the third-largest in terms of generation output).

Coal-fired power capacity also increases over the outlook, from around 3 GW today to 12 GW in 2040 in the Stated Policies Scenario and 17 GW in the Africa Case, as projects gradually come online in Zimbabwe, Senegal, Nigeria and Mozambique.

New **oil units** contribute to only 1% of total additions across the region in the Stated Policies Scenario, but almost 5% in Nigeria. This reflects the fact that only a few small projects are currently planned. In the Africa Case, the oil share shrinks further as programmes to convert oil-fired units to burn domestic gas accelerate, notably in Angola and Senegal.

S P O T L I G H T

Hydropower in Africa: strengthening resilience to a changing climate

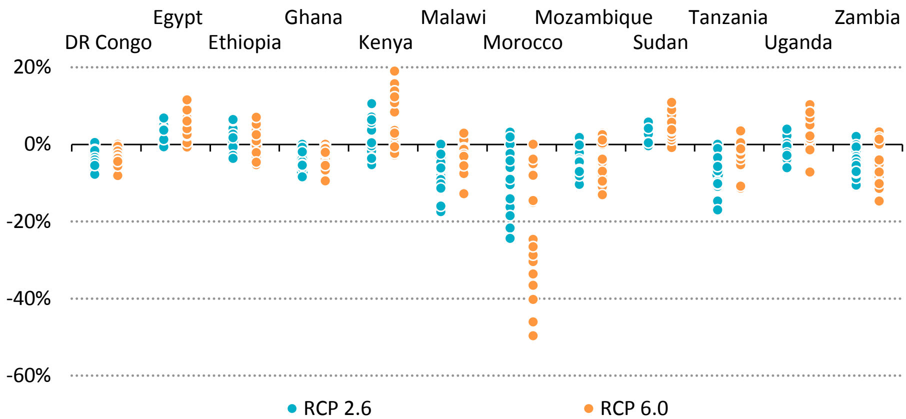
Hydropower is the most important source of low-carbon electricity globally, accounting for 16% of total electricity generation. In Africa, hydropower plays an even bigger role, accounting for 22% of electricity generation on average (excluding South Africa). The full technical potential for African hydropower is far greater – new analysis points to a total potential of around 1 120 TWh in just 12 countries (taking into account environmental constraints), which is over eight-times today's level of hydropower generation in all of Africa.

Increasing reliance on hydropower may pose risks for the power sector due to impacts of a changing climate. Changes in rainfall patterns and temperature may lead to changes in river flows, and in evaporation and transpiration, altering the resource potential for hydropower. More frequent and intense extreme weather events such as droughts and floods may also lead to more variability in generation output. While impacts are likely to vary by region and even locally, climate-related events have already had noticeable effects on power systems, for example in Zambia where a severe drought in 2015-16 led to a drop in usable capacity of the largest hydropower plant and to power blackouts.

New analysis carried out for this *World Energy Outlook* assessed future climate change impacts on hydropower outputs and potential in 12 African countries under various climate change scenarios to 2099. The analysis linked global circulation models with hydrological models to examine changes of hydropower availability at precise locations using high-resolution discharge and elevation data (Gernaat et al, 2017). Two Intergovernmental Panel on Climate Change (IPCC) climate scenarios were compared: one leading to a global temperature rise likely to be below 2 degrees Celsius (°C) by 2100 (Representative Concentration Pathway [RCP] 2.6), implying a peak in emissions in 2020 and subsequent decline; and the second leading to a global temperature rise of around 3 °C by 2100 (RCP 6.0), implying a continuing gradual rise in emissions before they peak well into the second-half of the century (IPCC, 2014).

The annual availability of hydropower (measured by capacity factors) becomes more uncertain in both scenarios, but year-to-year variability is higher in RCP 6.0, the scenario with more climate impacts (Figure 3.10). Average annual capacity factors decline by some 2 percentage points by 2099 in both scenarios. However, hydropower capacity factors show stronger fluctuation in RCP 6.0 than in RCP 2.6 for most of the plants analysed (55 out of 64). Several Nile Basin countries (notably Sudan, Uganda, Egypt and Kenya) experience more than 50% relative increase of annual variability in RCP 6.0 compared to RCP 2.6, as do Zambia, Mozambique and Morocco. Without planning to improve resilience, this increased variability could have critical impacts on the reliability of power systems that are heavily and increasingly reliant on hydropower.

Figure 3.10 ▷ Variability of annual hydropower capacity factors for selected African countries by climate scenario, 2020-2099



Increased greenhouse gas concentrations are associated with an intensification of year-to-year variability in hydropower generation

Note: RCP = Representative Concentration Pathway (IPCC, 2014).

Regional differences in hydropower availability also become more marked under the scenario with the higher global temperature rise (RCP 6.0). For example, hydropower in Morocco is projected to see a 9% decrease in capacity factors under RCP 2.6, while capacity factors in Nile Basin countries (Egypt, Kenya, Sudan and Uganda) would increase by 0-2%. In RCP 6.0, these differences are accentuated, with drier conditions leading to Morocco's outputs declining by 24% relative to today, compared to 4-8% increases in the Nile Basin. These striking regional differences underline the importance of developing enhanced interconnections and power pools that link countries and sub-regions together.

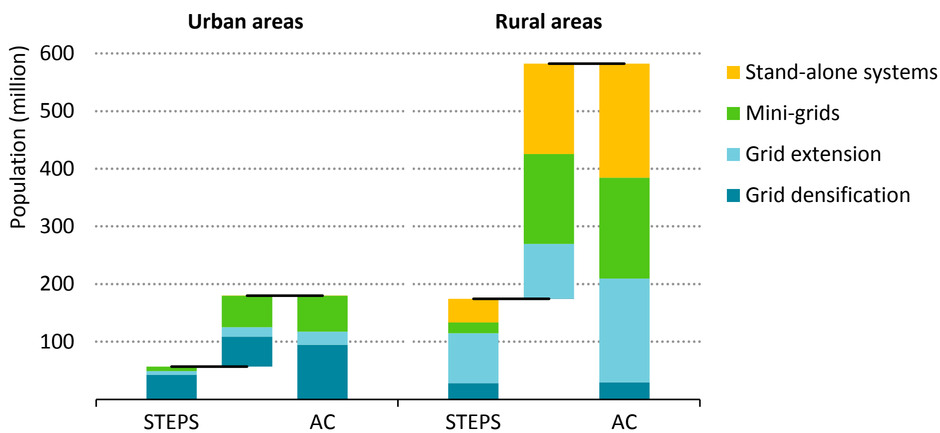
The sensitivity of African hydropower to rises in global temperature points to the importance of integrating climate resilience – the capacity to absorb, accommodate, adapt to and recover from climate change impacts – into planning for the construction and operation of future hydropower plants. For example, most planned hydropower projects do not currently take into account projected hydrological changes, relying instead on historical conditions (CDKN, 2015). This could lead to suboptimal operation of plants, at a time when many African countries are increasingly expecting hydropower to satisfy rapidly increasing power demand and to be a source of flexibility to support the integration of variable renewables such as wind and solar PV.

3.4.2 Role of decentralised systems to reach universal access to electricity

Geospatial analysis indicates that the least-cost way to reach full access by 2030 and to meet demand from newly connected households is to deploy mini-grids and stand-alone systems while also extending the main grid (Box 3.2). Providing electricity for all in sub-Saharan Africa would require an additional investment of around $25 billion per year above the level mobilised in the Stated Policies Scenario over the period to 2030.

In the Stated Policies Scenario, grid connections constitute the least-cost option for around 70% of the 230 million new connections that are expected to be achieved by 2030, mainly in areas that are close to a grid. A high proportion of the population lives close to a network (see Chapter 1), and grid densification connects around 70 million people, mainly in urban areas, while grid extension reaches more than 90 million, almost all living in rural areas. The number of people who gain access from decentralised solutions increases to almost 70 million over the period as technology costs continue to decline.

Figure 3.11 ▷ Solutions to provide electricity access by area and scenario in sub-Saharan Africa, 2019-2030



Access in urban areas will largely be via grid connections, while decentralised solutions are the least-cost option for about 370 million people in rural areas to reach full access

Sources: IEA analysis; KTH-dESA.

Decentralised systems are even more important to bring electricity to the 530 million additional people who need to be reached in the Africa Case in order to provide access to electricity for all. They represent the least-cost solution for more than two-thirds of these additional connections. Mini-grids play a major role in closing the gap in urban areas that cannot be reached by the grid before 2030, accounting for almost half of the additional urban connections. In rural areas, decentralised solutions provide more than three-quarters of additional connections, with mini-grids and stand-alone systems both having a role to play depending on population density (Figure 3.11). As a result, decentralised systems connect in total almost 450 million in the Africa Case by 2030. They can be installed quickly, providing valuable basic energy services to households who would otherwise need to rely on polluting and inefficient fuels. If deployed carefully, such systems can complement the grid, providing services immediately and preparing the way for later grid extension.

The best way to determine the optimal mix of solutions to provide access to all is to prepare integrated plans based on geospatial mapping. Such plans allow governments to develop a precise strategy, assess the investment needed, design adapted policies to reach all populations, and clarify the roles of different actors (government stakeholders, donors, private sector and non-governmental organisations). Turning such plans into actual investment flows and concrete progress on the ground raises some challenges (section 3.9), but they remain the best way to develop an integrated approach and to facilitate private sector participation.

Several countries, including Ghana, Senegal, Ethiopia, Nigeria and Rwanda, have developed long-term comprehensive strategies. As an example, the Ethiopian government announced plans in its 2019 National Electrification Plan to connect 100% of households by 2025 by connecting to the grid those 65% of households located less than 2.5 kilometres (km) from the existing network and putting in place decentralised solutions for the remaining 35%. By 2030, the government plans to extend the grid to reach households located between 2.5 km and 25 km from the existing grid. The 5% of households living farther than 25 km from the grid would have decentralised solutions over the long term.

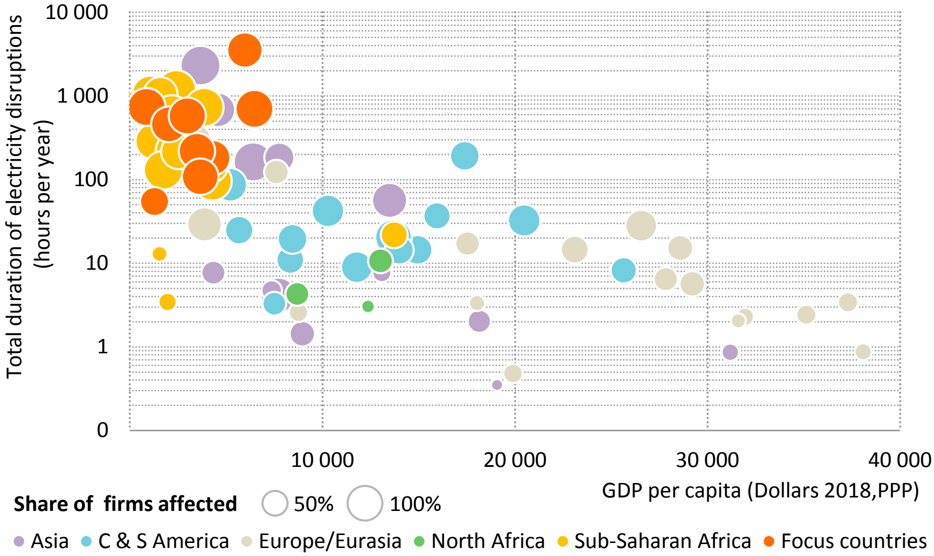
3.5 Reliability

The provision of high quality electricity services is essential to economic growth. An electricity supply that is unreliable acts as a brake on overall economic activity and welfare, and inhibits the output of individual firms. The provision of low quality or unreliable electricity supplies forces firms to manage gaps in supply or to turn to more polluting and expensive alternatives such as diesel generators. Both choices have detrimental effects on firm efficiency and undermine competitiveness.

Poor electricity infrastructure in low-income countries is a major cause of unreliability (Figure 3.12). Under-investment in existing transmission and distribution assets and the inability to meet peak load due to installed capacity deficit result in frequent service disruptions (unscheduled outages or regular load shedding), ranging from a few hours to a few days. Between 2006 and 2018, around 80% of sub-Saharan African firms suffered frequent electricity disruptions, typically six hours in length, imposing losses of around 8% of annual sales on average (World Bank, 2018). Outages tend to be most frequent and prolonged in Nigeria (see Chapter 1). By contrast, firms in Organisation for Economic Co-operation and Development (OECD) countries experience interruptions of around one hour per month on average.

Investment in power systems, combined with improvements in the performance of utilities, results in a decline in the number of outages in sub-Saharan Africa by the end of the projection period. In the Stated Policies Scenario, the number of hours lost as a result of

Figure 3.12 ▹ Electricity outages and GDP per capita in selected regions, 2017

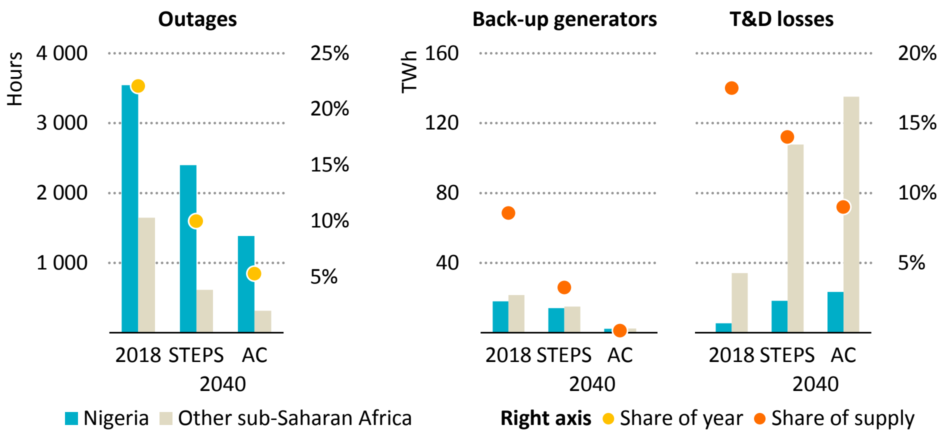


Frequent outages tend to be concentrated in low-income sub-Saharan countries

Notes: C & S = Central and South America. PPP = purchasing power parity. Focus countries are Angola, Côte d'Ivoire, DR Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal and Tanzania.

Source: IEA analysis based on World Bank (2019a).

Figure 3.13 ▹ Reliability indicators by scenario in sub-Saharan Africa (excluding South Africa), **2018 and 2040**



Major improvements in reliability in the Africa Case reduce the incidence of power outages by 60% in Nigeria and over three-quarters elsewhere; network losses shrink to below 10%

Note: T&D = transmission and distribution; STEPS = Stated Policies Scenario; AC = Africa Case.

outages declines to around 900 hours a year on average across the region; this ranges from below 1% of the year in Mozambique, Senegal, Kenya and Côte d'Ivoire up to nearly 30% in Nigeria, despite significant progress there. The number of outages declines even further in the Africa Case, falling to less than 500 hours a year on average and to about 15% of the year in Nigeria (Figure 3.13). As a result, the output of back-up generation declines in the Stated Policies Scenario from 40 TWh a year to around 30 TWh a year and to less than 5 TWh a year the Africa Case, reducing fuel and maintenance costs, noise and air pollution.

Inefficiencies arising from network losses can be very costly for utilities. Network losses are very high in sub-Saharan Africa (excluding South Africa) and at 18% are higher than in other developing regions (see Chapter 1). Investments in power systems result in losses falling to around 14% in the Stated Policies Scenario and to as low as 9% in the Africa Case.

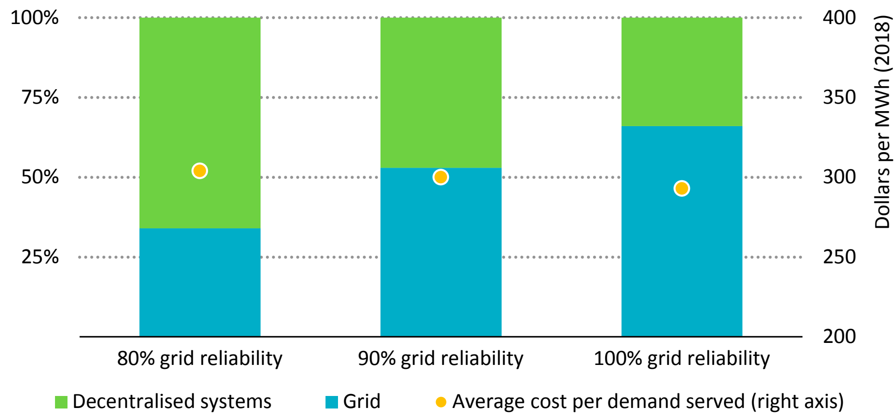
Box 3.3 ▷ Improving grid reliability: a pathway for lower cost electrification

Providing access to electricity is essential, but access has to bring with it a reliable supply of electricity if households, businesses and public services are to reap the full benefits. A lack of reliable electricity supply from the grid disrupts daily lives and activities, lowers trust and use of the grid, and increases costs for consumers and utilities. Grid reliability also influences the best mix of solutions to provide universal access to electricity, by improving the cost-effectiveness of extending the grid to connect more potential consumers. This in the end affects the overall cost of electrification.

To shed light on the relations between the least-cost pathway to universal access and grid reliability, we developed a new analysis in collaboration with the MIT-Comillas Universal Energy Access Lab. Using the Reference Electrification Model (REM), building level geospatial analysis informs network and mini-grid deployment and design to optimise electrification planning (MIT-IIT, 2019). Taking an excerpt from the National Electrification Plan of Rwanda as a test case, we considered a rural and peri-urban area of 30×60 km in the Nyagatare region, with some 48 000 buildings that represent about 22 different consumer profiles (from 100 Watts [W] to 300 kW peak demand). Through the REM, we examined the least-cost electrification solutions for these consumers at various levels of grid reliability, defined as the percentage of demand served. The results highlight the complementarity of on-grid and decentralised solutions at all grid reliability levels in the area analysed (Figure 3.14). Poor grid performance, similar to the situation currently observed in many countries, contributes to the attractiveness of decentralised solutions to connect up to two-thirds of those gaining electricity access. These solutions remain attractive even with reliability improvements, a trend accentuated by expected declines in costs of decentralised systems. Nonetheless, improving the reliability of the grid could facilitate optimising the infrastructure by connecting more consumers and increasing average consumption of electricity, in addition to removing a major obstacle to development of businesses and community services. The additional investments to improve reliability by installing sufficient generation capacity to cover peaks would be offset by a decline in the cost per unit of demand served.

Investing in better grid reliability to optimise grid utilisation, while deploying decentralised systems to reach populations distant from networks, appears to be the best way to provide improve access to electricity at the lowest cost.

Figure 3.14 ▷ Connections by type to reach universal access to electricity with different grid reliability levels in a region of Rwanda



Even with high grid reliability, decentralised systems would be cost effective for many people; improving grid reliability can reduce the cost per demand served

Power sector regional integration

Increased power sector integration in sub-Saharan Africa can help with the goal of providing more affordable and reliable power. Affordability can be improved by reducing the need for investment: access to other markets allows countries to reduce the amount of installed capacity needed to meet peak demand, and sharing reserves between balancing areas means each can maintain less reserve capacity. Closer integration also enhances reliability by allowing the system to respond better to seasonal imbalances and unexpected shocks. Sub-Saharan African countries enjoy a diverse range of natural resources and have scope to benefit from the complementary nature of those resources.

Economies of scale achieved at a regional level may also enable countries to proceed with large projects that would not be justified based only on domestic power demand levels. Completion of Stage V of Grand Inga and associated interconnection projects in Southern African countries, for example, would allow the export of hydropower from DR Congo in the Africa Case and would significantly reduce average electricity generation costs in the region.

To realise these gains, governments and utilities across the region need to step up co-ordination in order to increase investment in transmission infrastructure, establish regional markets and improve regulation for cross-border trading (for example by defining and implementing regional transmission tariffs).

3.6 Affordability

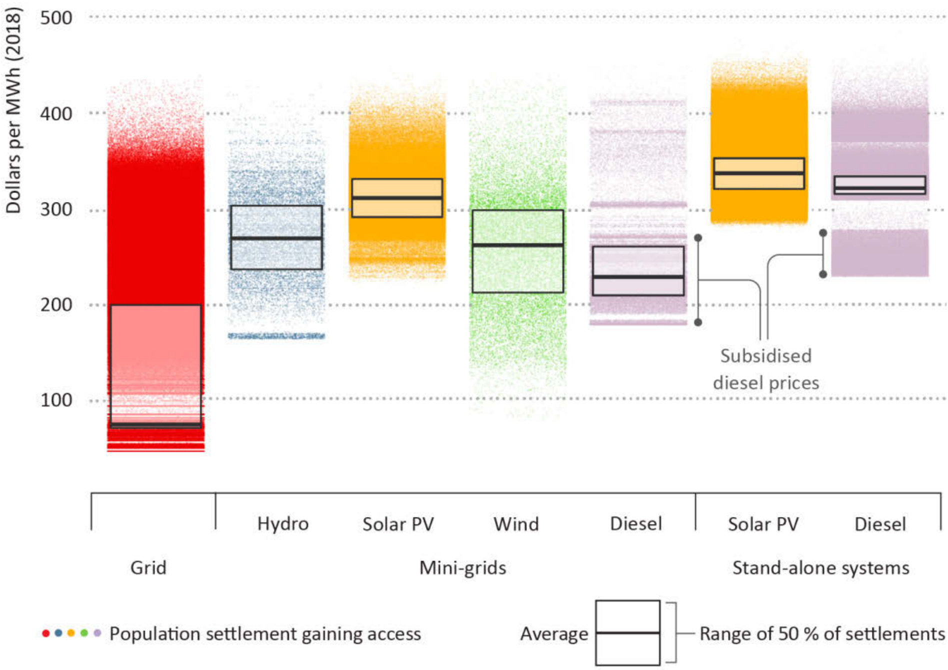
3

The affordability of energy is a primary concern for policy makers, businesses and consumers. As discussed in Chapter 1, many households cannot afford the often very high upfront costs of grid connection, and current electricity tariffs make even basic energy services unaffordable for a large share of the population connected. However, the tariffs that constrain affordability for consumers are often set too low for utilities to be able to recoup their costs of supply. The risk is that this locks the power sector into a cycle of low revenue, high debt, inadequate maintenance, under-investment and poor quality of service. One of the biggest challenges of achieving universal access to electricity relates to the cost of providing power, which increases dramatically to supply sparsely populated and remote areas compared with households close to an existing grid. Our geospatial analysis shows that the least-cost option to provide access increases by a factor of four from easily accessible areas to the most remote ones (Figure 3.15). It is therefore inevitable that ensuring access to all requires government policies, subsidies and tax exemptions in one way or another. Much is already being done. In Togo, for example, the government recently announced its CIZO Plan to electrify 555 000 households with solar kits; the "CIZO solar cheque" will subsidise the hardware costs for households with a monthly payment, in partnership with a few licenced companies.

Supporting energy efficiency and productive uses can also help to improve affordability. Energy efficient appliances can enable consumers to access higher levels of energy services at lower costs, and so reduce the size (and the cost) of the system needed to support these services (IEA, 2017). Broadening the scope of electricity access plans to include the provision of energy for productive uses, such as agriculture or industry, can support the ability of end-users to pay while at the same time bringing down the cost of supply by increasing the load factor. Providing support for the acquisition of efficient equipment along with access to electricity can bring multiple benefits. A recent study from the World Bank (ESMAP, 2019) indicates that many productive tools and equipment appear to have a pay-back period of less than 12 months. Private companies including providers of mini-grid and solar home systems are starting to consider how best to support the development of commercial activities among electrified communities to ensure the sustainability of their projects. Success on this front will require cross-sectoral planning and co-ordination (for example between energy, water and agriculture ministries) as well as financial support.

Fossil fuel consumption subsidies have been used by a number of countries as a way of making electricity more affordable for citizens and companies (potentially helping them become more competitive). Some sub-Saharan countries, for example Ghana, subsidise certain fossil fuels as part of a strategy to promote switching from the use of traditional biomass. While fossil fuel subsidies – relatively more prevalent in North Africa – can help to support the use of energy services by the poorest households, they also create a substantial fiscal burden on what are often overstretched government budgets. We estimate the value of fossil fuel consumption subsidies in 2018 to have been $2.9 billion in Nigeria, $5 billion in Libya, $17 billion in Algeria and $27 billion in Egypt.

Figure 3.15 ▷ Levelised cost of electricity (LCOE) to achieve universal access to electricity by 2030 in sub-Saharan Africa, in the Africa Case



The cost of supplying electricity varies dramatically depending on household location; decentralised solutions are often the cheapest option for remote households

Notes: Each point represents an individual settlement in sub-Saharan Africa. It shows the LCOE of the least-cost solution determined for each settlement through our geospatial analysis (see Box 3.2).

Source: IEA analysis; KTH-dESA.

Amending current fossil fuel subsidy schemes is desirable for a number of reasons. These include: the need to reflect the true cost of electricity and remove distorted incentives (with implications for investment decisions); the need to reduce consumption of electricity from emissions-intense sources and encourage the use of more efficient and low-carbon sources; and the need to reduce the resultant fiscal burden that such subsidies cause.

Successful reform programmes broadly share the same key design and implementation features. They tend to focus in particular on being clear about the amount of the subsidy and the different categories of consumers who benefit from it. Obtaining wide understanding of, and support for, proposed reforms is essential: gradual implementation and assistance to the poorest households may be needed. There is plenty of experience in other countries to draw on and learn from. International development finance institutions can provide technical and financing assistance to help with fossil fuel subsidy reform.

3.7 Investment needs for reliable, sustainable and affordable power

The amount of investment needed for the provision of electricity in sub-Saharan Africa is substantial and well above the level of the current flows of capital into the region's power sector. Achieving the outcomes projected in the Stated Policies Scenario would require annual power sector investment in sub-Saharan Africa to more than double to around $46 billion per year, and would mean a cumulative total of more than $1 trillion in investment between 2019 and 2040 (1.6% of the regional GDP over the period). The Stated Policies Scenario would see the electricity access rate rise to 64% in 2030.

Reaching full access by 2030 and maintaining it to 2040, as in the Africa Case, would require multiplying current investment levels by five. The cumulative investment in this case would reach more than $2 trillion between 2019 and 2040 (2.7% of the regional GDP in the Africa Case over the period), or over $100 billion per year, more than doubling the capital needed under the Stated Policies Scenario (Table 3.2). Half of the investment needs would be spent on grid expansion, reinforcement and maintenance. Most of the rest would be for low-carbon power capacity, where solar PV takes an important role, reaching almost $25 billion per year on average. Cumulative investments in solar PV by 2040 in the Africa Case reach $535 billion. Decentralised solutions (mini-grids and stand-alone systems) would take an even more central role in this scenario, capturing a fourth of all investment in new capacity over the period to 2040.

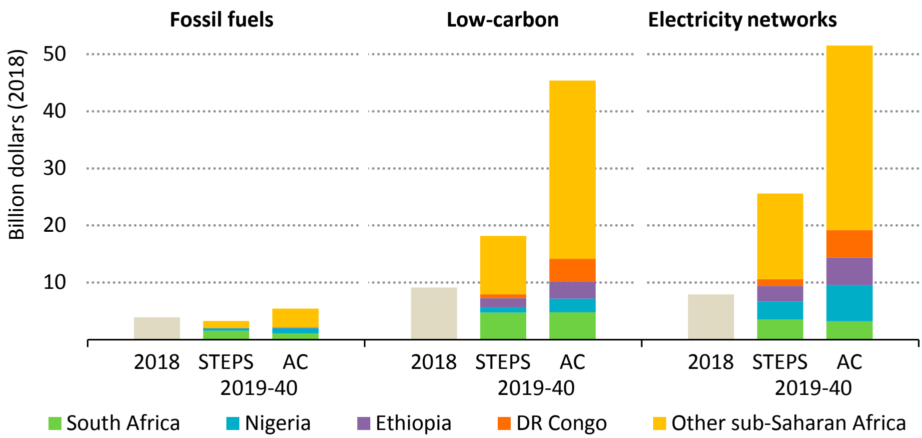
Table 3.2 ▷ Average annual power sector investment in sub-Saharan Africa by scenario, 2019-2040 (Billion dollars, 2018)

	Stated Policies Scenario			Africa Case		
	On-grid	Mini-grid and stand-alone	Total	On-grid	Mini-grid and stand-alone	Total
Total power plants	**19.3**	**1.7**	**21.0**	**34.1**	**16.8**	**50.8**
Coal	2.0	0.0	2.0	1.7	0.0	1.7
Natural gas	1.3	0.0	1.3	2.9	0.0	2.9
Oil	0.0	0.1	0.2	0.4	0.5	0.8
Hydro	4.4	0.0	4.4	7.7	0.0	7.7
Solar PV, wind, other low-carbon	11.6	1.6	13.2	21.4	16.3	37.7
T&D	25.3	0.2	25.5	49.0	2.5	51.5
Total	**44.6**	**1.9**	**46.5**	**83.1**	**19.3**	**102.3**

Note: T&D = transmission and distribution; Other low-carbon = bioenergy, nuclear and other renewables.

In addition to higher investment levels, a reallocation of capital would be needed across countries and technologies in both scenarios. In South Africa, a major reallocation of capital away from coal-fired power (currently around 35% of the investment) towards electricity networks and low-carbon generation would need to happen (Figure 3.16). Nigeria, Ethiopia and DR Congo are the other countries with the highest annual investment needs. Together, these four economies account for around 40% of the investment needs in both outlooks. In addition, investment in natural gas generation would also need to pick up and maintain the current investment pace. Average annual investment in natural gas in the 2019-40 period in the Africa Case is more than twice that of the Stated Policies Scenario and four-times the 2018 investment level. With more renewable plants and higher access levels, gas helps maintain security of supply at lower emission levels than other fossil fuels.

Figure 3.16 ▷ Annual average power sector investment by scenario in sub-Saharan Africa



The investment gap is particularly large for renewables and electricity networks in both outlooks, and needs to accommodate more capital for natural gas in the Africa Case

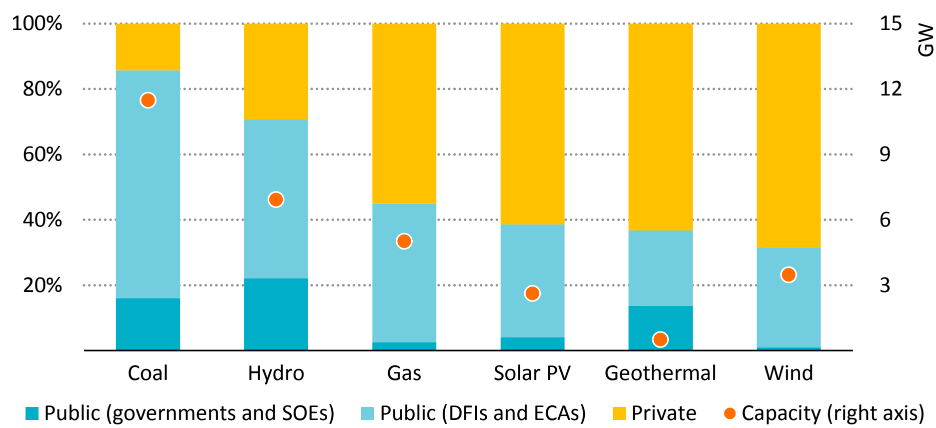
Notes: STEPS = Stated Policies Scenario; AC = Africa Case. Low-carbon generation includes renewables and nuclear (nuclear only projected in South Africa).

Who will supply the capital needed to enable this investment? While investments will inevitably be funded from a variety of sources and types of funds – international and local; private and public; equity and debt – the choice of capital provider and financing vehicle makes a big difference to the pace and affordability of Africa's shift towards more reliable, sustainable and affordable power. The approach taken needs to be informed by an analysis of the ways in which power sector investments have been financed in sub-Saharan Africa, the drivers for investment decisions, and the priority areas necessary to tackle investment risks. Such an analysis can help with the design or the re-evaluation of policies and regulations to ensure their ability to reduce the cost of capital, especially for renewables where financing costs account for around half of the LCOE. The first part of this section addresses this by presenting an overall picture of the financing of the power sector in sub-Saharan Africa and describes the role of private financing in particular. The second part identifies four priority areas that require further policy and regulatory interventions to reduce investment risks and scale up the funds needed to finance investments.

3.8 Sources of finance for power investment in sub-Saharan Africa

The majority of the power sector investment in sub-Saharan Africa has been financed by public funds, mainly from domestic governments or state-owned utilities, development finance institutions (DFIs) and export credit agencies (ECAs). Of the new projects with final investment decisions in the period 2014-18, two-thirds of the new generation capacity was publicly funded. The level of reliance on public funds was highest for large, conventional generation projects and lowest for renewable projects, in part because in South Africa all new renewable capacity since 2011 has been procured via a competitive tender programme (Figure 3.17). The role of DFIs and ECAs as financiers has been important across the board, but particularly so for large coal-fired generation and hydropower projects where they accounted for around 60% of funds raised. Chinese DFIs have played an especially visible role: between 2013 and 2017 over $10 billion of Chinese funds financed 80% of the total investment for ten hydropower projects (over 6 GW) and over $6 billion for five coal-fired plants.

Figure 3.17 ⊳ Financing sources for power generation investment by share, type and capacity in sub-Saharan Africa, 2014-2018



Large-scale generation projects have been more reliant on public sources of finance, while renewables were financed more with private finances

Notes: DFIs = development finance institutions; ECAs = export credit agencies; SOEs = state-owned enterprises. Based on utility-scale projects that reached financial close between 2014 and 2018.

Sources: IEA analysis based on World Bank (2019) and IJ Global (2019).

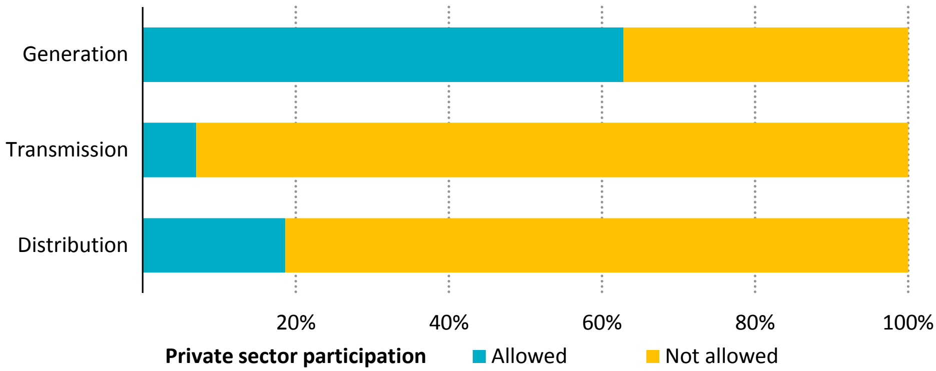
3.8.1 Investment framework and market structure

Private sector financing has been focused on generation (Figure 3.18), mainly through projects developed by independent power producers (IPPs).[7] In contrast, most of the

[7] IPPs are generation projects owned and operated by entities other than utilities, e.g. private developers.

investment in electricity networks has come from the public sector. To date, 16 of 43 sub-Saharan African countries do not allow for private sector participation in electricity generation or networks, and 18 others only allow it in power generation.

Figure 3.18 ▷ Private sector participation in electricity supply in sub-Saharan Africa by activity



In many countries there is no private sector participation allowed. Where it is allowed, it is mainly in the generation activity.

Notes: In the distribution category, decentralised solutions are not included. Based on 43 countries in sub-Saharan Africa.

Unlike power generation, transmission and distribution grids have monopolistic characteristics and are generally subject to strong regulation. In sub-Saharan Africa, private sector participation in transmission has come about mainly through "whole-of-grid concessions"[8], but these did not result in much investment and two-out-of-three were cancelled (World Bank, 2017). Private participation in distribution networks is more common, also under concessions, but it is still far from usual: fewer than ten countries in Africa allow it (Eberhard et al., 2016).

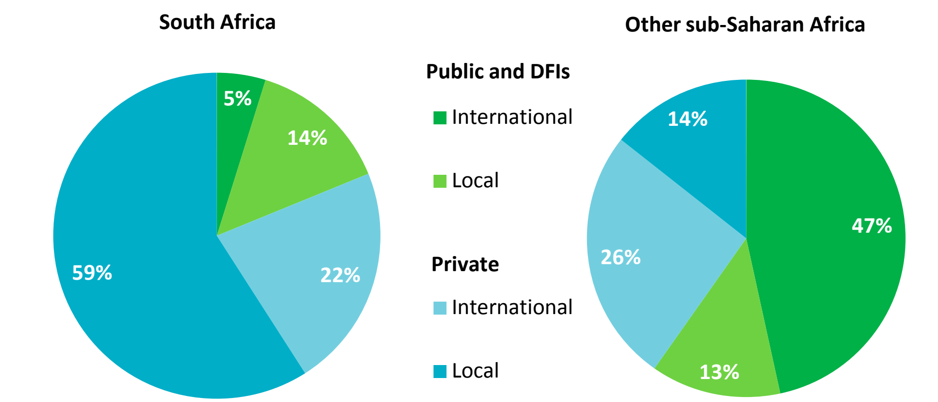
Supportive policies and regulations as well as maturing markets have helped attract private sector investment into mini-grids and stand-alone systems. The World Bank estimates that there has been almost $4 billion of cumulative investment in Africa to date in almost 1 500 mini-grids (ESMAP, 2019). Although the majority of mini-grids were financed and are operated by state-owned utilities (some installed long ago), the privately-financed market has been growing – there are about 480 mini-grid developers in the African market today. Estimates based on another study of the global solar market of stand-alone systems show that 75% of the total funds raised by top developers between 2012 and 2017 (almost $700 million) went to developers operating in East and West Africa (IFC, 2018).

[8] Whole-of-grid concessions are long-term contracts where a private company is responsible to operate and maintain the existing grid, as well as investing in new lines and ensuring quality of supply. The company's annual revenues are set by a regulatory authority and subject to periodic revisions.

3.8.2 Private financing is concentrated in IPPs, mostly in South Africa

For almost 90 utility-scale IPP projects that obtained financing between 2014 and 2018 in sub-Saharan African countries, more than 60% of the funds were from private sources (World Bank, 2019a). Improved policy frameworks helped reduce perceptions about risks and increase project bankability. Lenders were willing to lend more money and the average share of costs that they were willing to cover rose from an average of 67% in 2014 to 79% in 2018.

Figure 3.19 ⊳ Sources of financing for independent power producers in sub-Saharan Africa financed between 2014 and 2018



Policy frameworks to underpin IPP projects are less developed in sub-Saharan Africa, other than South Africa, which limits the ability of public and development finance to catalyse private investment

Note: DFIs = development finance institutions; IPP = independent power producers.

Sources: IEA analysis based on World Bank (2019a) and IJ Global (2019).

South Africa alone attracted two-thirds of the private finance for IPPs, or almost $7 billion over the 2014-18 period. In South Africa, IPPs were less reliant on public funds and required lower shares of equity than in other countries, with the private sector providing more than 80% of funds for IPPs (Figure 3.19). A good enabling environment, combined with a well-developed financial sectoral and clear sector policies were critical factors. A notable example is the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), a competitive programme to tender all new renewable capacity introduced in 2011, which was instrumental in enhancing the bankability of renewable projects. However, delays in the recent rounds of the programme – driven by political uncertainty as well as the deteriorating financial performance of state-owned utility Eskom – have raised questions over the positioning of the REIPPPP in South Africa's overall power sector development.

The financing picture is very different in other parts of sub-Saharan Africa. In most other countries there has been a high degree of reliance on public funds to finance IPP projects, and public and development finance has not been as effective in catalysing private financing, though this has varied between countries. Between 2014 and 2018, every dollar funded by public and development finance was matched by one or more dollars of private funds in Namibia, Nigeria, Mozambique and Ghana, but slightly above half a dollar in Zambia, and less than that in other countries. On average, every dollar funded by public and development finance was matched by half a dollar of private funds, whereas in the case of South Africa each dollar was matched by almost four dollars of private finance.

Table 3.3 ▷ Selected large development finance initiatives supporting sub-Saharan Africa's power sector

Initiative	Main financiers	Committed funds (billion $)	Type of support by project phase		
			Preparation	Financing	Implemen-tation
Green Climate Fund	Mainly developed countries	5.2	●	●	●
Africa Renewable Energy Initiative	France, Germany and European Commission	10.0	●	●	●
Clean Infrastructure Funds	Developed countries	8.1		●	●
New Deal on Energy for Africa	African Development Bank	12.0	●	●	●

The World Bank Group, the African Development Bank (AfDB), European governments and institutions, and the United States and Japanese governments provided most of the public funds used in the sub-Saharan African power sector between 2008 and 2017. The majority of this went to transmission and distribution projects, then to renewable-based generation and last to non-renewable power. The three main recipient countries were Kenya, Tanzania and Ethiopia (OECD, 2019). Separately, DFI funding from China has been growing rapidly (Horn, Reinhard and Trebesch, 2019). Funding has come from other sources too: a diverse array of organisations have established initiatives and committed funds to support power infrastructure development or help with project preparation, financing and implementation support (Table 3.3). Some initiatives, like US-led Power Africa or the AfDB's New Deal on Energy for Africa, expect their commitments to bring in significant additional funds. For example, the AfDB's New Deal on Energy for Africa expects to leverage $45-50 billion in co-financing by 2020. Similarly, the Power Africa programme has supported power sector investments in Africa that, if fully realised, would total more than $50 billion.

Development finance support has been substantial across sub-Saharan Africa and, to various degrees, has helped to catalyse private funds. In many cases, the presence of DFIs, providing financing and risk mitigation measures, has been critical to obtain financing. Further commitments are expected in the coming years.

However, while public financing looks set to continue to play an important role, closing the very large investment gap requires a much bigger role for private financing: there are limits to what governments can do, given their fiscal constraints, and state-owned utilities are mostly in a weak financial position. Attracting larger amounts of private funds requires policy and regulatory improvements in the region, as well as project-specific measures to reduce investment risks. Such improvements could increase the catalytic effect and allow for a more effective use of public funds.

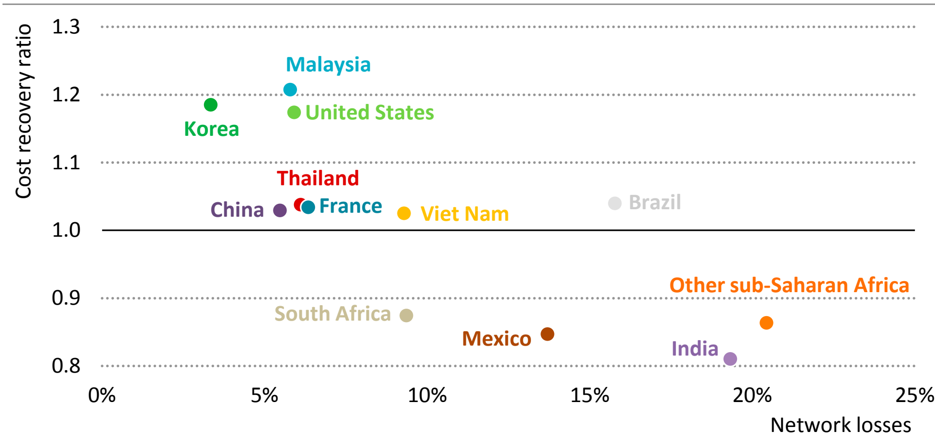
3.9 Closing the investment and financing gap

This section highlights four priority areas that will be vital to address to reduce risk perceptions, to obtain more and cheaper financing, and to bring new actors to the power sector.

3.9.1 Improve the financial and operational performance of utilities

Utilities in sub-Saharan Africa have high transmission and distribution losses (Figure 3.20). This, combined with tariffs below costs and low collection rates, results in utilities being generally short of cash and hampers their ability to raise funds. It is estimated that only 19 out of 39 utilities in sub-Saharan Africa earned enough revenues to cover operational expenses, and only four of these covered at least half of their capital expenses (Kojima, 2016). As utilities are the main counterpart to private investors in generation, this situation can raise concerns on the part of those investors about future payment and makes it more difficult to secure financing at low cost.

Figure 3.20 ▷ Electricity network losses versus cost recovery ratio for major utilities in selected markets



The weak financial and operational performance of utilities in sub-Saharan Africa hampers affordable financing in the power sector

Note: IEA analysis with calculations for cost recovery based on financial statements of reference utilities in each market.

Strengthening the governance framework of utilities is critical to improve operational and financial efficiencies. The World Bank study estimated that 11 utilities in the region could become financially viable if network losses dropped to 10%, cash collection rates increased to 100% and staff ratios matched those of efficient utilities in other regions (Kojima, 2016). Reducing network losses requires setting feasible targets, robust planning and a clear action plan to invest in infrastructure. Getting this done may come with challenges but there are positive examples in the region (Box 3.4). Moving towards cost recovery, which may require subsidies or cross-subsidisation, is also necessary to increase the pace of investment by easing perceived counterparty risks and allowing for increased financing at lower cost.

Box 3.4 ▹ Improving performance of a distribution utility: lessons from Uganda

The Government of Uganda initiated reforms in 1999 to unbundle the state-owned utility, Uganda Electricity Board. IPPs were introduced and the government awarded a concession to operate and maintain the generation assets. A state-owned transmission company was created and made responsible for planning, procurement and operation. Umeme, a private consortium, won a 20-year concession to operate and maintain the network.

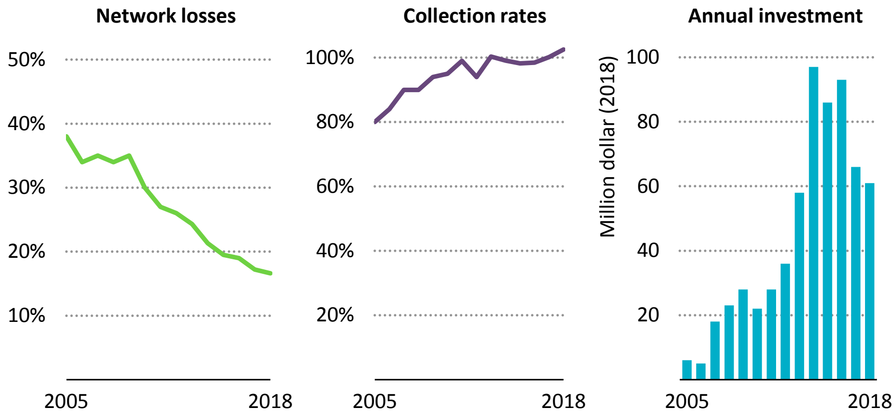
Improvements in operations were slow during the first few years of the concession, but Umeme was able to reverse the situation. Network losses halved from 38% in 2005 to 17% in 2018, driven by an increase in annual investment from an average of $16 million in the 2005-09 period to $81 million in the 2014-18 period, and an improvement in the power supply. In addition, the number of customers multiplied by four while collection rates increased by 20 percentage points (Figure 3.21).

Key factors included:

- Contract-based performance indicators. Indicators included loss reduction targets and investment obligations ($65 million by the end of the fifth year).
- Regulatory independence. The government agreed that the regulator would set annual tariff adjustments based on a methodology defined in the concession contract.
- Commercial efficiencies. Increased channels to pay bills (including mobile payments) and the roll-out of prepayment metering made a difference (which in 2018 represented 24% of revenues).
- Technical support from international donors.
- Various risk mitigation mechanisms established with DFI support. The security package included a payment guarantee and insurance to cover termination and other political risks.

The process was not always smooth. In 2006, the government and Umeme renegotiated the contract after a power crisis (one of the two original investors left the concession at this point). Improvements in electricity access were slow and, although access has increased recently, the percentage of those with access remains low (around 11% in rural areas). Quality of electricity supply also remains an issue for customers despite the reduction in losses.

Figure 3.21 ▷ Transmission and distribution network losses, collection rates and annual investments in Uganda, 2005-2018



After a period of slow progress, the private distribution company reduced network losses and increased collection rates, which supported increased investment

Note: Collection rates surpass 100% due to pre-paid metering.

Sources: IEA analysis based on World Bank (2014) and Umeme (2018).

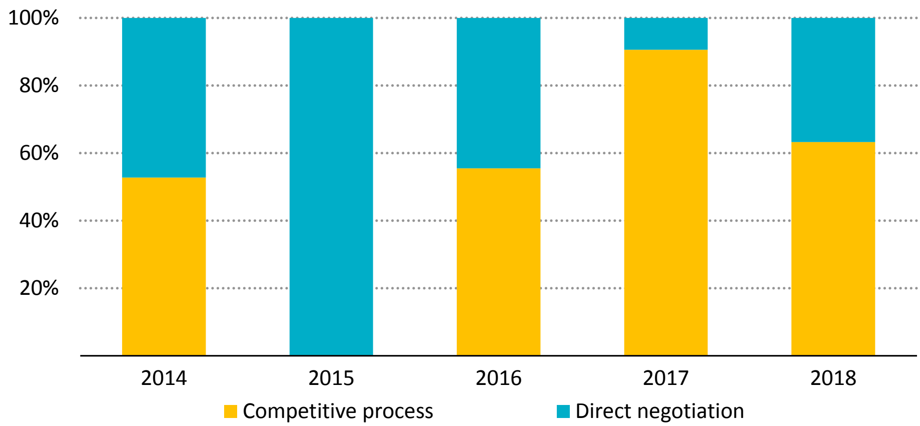
3.9.2 Enhance policy and regulatory frameworks to improve bankability

Robust procurement frameworks and well-designed contracts are crucial for project bankability. Competitive procurement is picking up in sub-Saharan Africa and is attracting strong interest from investors. Excluding South Africa, which largely acquires independent power projects through competitive tenders, half of the privately-financed IPP projects that reached financing in 2014-18 were competitively awarded (Figure 3.22).

Designing and conducting competitive tenders and auctions requires technical expertise and can take longer than direct negotiations. However, well-designed auctions bring a high degree of transparency and predictability, enhance market confidence and facilitate price discovery. Bid prices for solar PV under the REIPPP decreased by 80% between 2014 and 2018, while a programme to procure utility-scale solar PV in Zambia and Senegal together attracted almost 100 applicants and brought record low prices for the region of $48/MWh in 2017 and $43/MWh in 2018.

A key feature to ensure that procurement programmes translate into investments at scale is the bankability of the underlying contracts. Successful procurement programmes are accompanied by power purchase agreements that clearly define risks and responsibilities, e.g. clauses on dispute resolution, force majeure and termination. Credit enhancement mechanisms such as escrow accounts or public guarantees may also be necessary to mitigate payment risks and increase utilities creditworthiness. For example, the tenders in Zambia and Senegal had both sovereign and DFI-backed guarantees. Maintaining predictable, clear policies throughout the process is also important to preserve interest from private investors and lenders.

Figure 3.22 ▷ IPP capacity awarded by type in sub-Saharan Africa (excluding South Africa), **2014-2018**



Competitive procurement is increasing in sub-Saharan African countries, though almost half of privately-financed capacity was awarded by direct negotiation

Sources: IEA analysis based on World Bank (2019a).

3.9.3 Create supportive enabling environments for rural electricity access

As discussed in section 3.4, reaching access targets requires a combination of on-grid and decentralised solutions. Scaling up investments in decentralised solutions may come with a variety of challenges, many of which evolve around revenue and regulatory uncertainty.

Supportive policies, as well as low-cost financing from DFIs, foundations and impact investors i.e. those that invest in projects that have development benefits, have fostered private-led projects, but revenue uncertainty still presents a major challenge, especially as much of future electrification will take place in more rural and generally poorer areas (Table 3.4). Mini-grid developers cannot recover the high upfront investments if customers consume little, while retailers of solar home systems may need to anticipate longer repayment periods and higher default rates from the customers they provide loans. Consumers may be restricted by their ability to pay for electricity.

Table 3.4 ▷ Main risks and their underlying causes in deploying mini-grids and solar home systems

	Mini-grids	Solar home systems
Revenue risk		
Low demand	Inability/delay to recover high upfront investment due to electricity demand lower than expected (over-sized mini-grid).	Low sales due to limited ability to pay, restricting demand to low-end solar home systems.
Low affordability	Customers with low and unpredictable income.	
Tariff level and subsidies	Dependence and uncertainty regarding subsidies (especially if tariffs required to be set at national uniform levels); difficulty to maintain support for and collect cost recovery tariffs (high compared to the grid), if allowed tariffs not capped.	Prices of solar home systems are generally unregulated, but developers may face uncertainty regarding regulation of subsidies (when applied), dependence on mobile services and regulation of interest rates of loans.
Regulatory risk		
Registration and licensing	Unclear rules on licensing and registration of assets and delays to obtain such permits.	Generally none.
Tariff setting	Incomplete/unpredictable tariff setting methodology. Delays to obtain tariff approvals.	N/A
Interaction with central grid	Weak/incomplete specifications of what happens when the central grid arrives to an area where a mini-grid operates (e.g. mini-grid becomes SPP or SPD; financial conditions in case of asset buy-out by utility).	N/A

Note: N/A = risk does not arise given technological and commercial characteristics; SPP = small power producer; SPD = small power distributor.

A study in rural Rwanda shows that households that received a free small PV kit used it intensively and reduced their kerosene and energy consumption: it also found that children studied longer (Grimm et al., 2016). Other studies also support the hypothesis that consumers are cash and credit constrained, and that social benefits, when fully internalised, exceed the investment costs. This points to the need for some sort of government or public support to realise these benefits.

Electricity subsidies, or similar financing mechanisms, could help rural households overcome the affordability constraint. They could also increase the sustainability of the decentralised electricity sector and encourage private companies to expand to more rural areas. Subsidies could be provided to households in the form of lower tariffs or help with connection costs or they could go to developers in the form of grants for capital expenses or concessional financing. Whatever option is chosen, subsidies need to be clear, predictable and well targeted.

Even if subsidies are expanded successfully, increased consumption will still be critical. Annual electricity demand per person in sub-Saharan Africa currently stands at around 190 kWh (excluding South Africa). This is one of the lowest levels of demand in the world. In some countries, increasing electricity access has led to increasing consumption as well, but at lower rates. For example, while access grew at an annual rate of 3.5% in Ghana between 2000 and 2018, per capita consumption grew by 1.5% per year. In Kenya, the growth in the access rate was four-times the growth in per capita consumption. Policies to increase productive uses and higher industrialisation could help reverse this trend.

Those countries where private mini-grid developers are most active, such as Tanzania, Nigeria, Kenya and Rwanda, are also those that have the best-developed regulatory frameworks. A strong and well-articulated regulatory framework that is clear about the most important issues will help to attract private investors. The issues that need to be covered include tariffs levels, subsidies and tariff setting; regulation of entry; and what happens when the central grid arrives. Tanzania's mini-grid regulation provides four alternatives on this last point: mini-grids can become small power producers (SPPs) selling electricity to the grid; they can become small power distributors (SPDs) buying electricity from the grid; they can combine the two (SPP+SPD); or they can sell the mini-grid assets to the utility. Lack of clarity over compensation issues, and concerns about enforcement of the regulation still appear to be causing concern to developers.

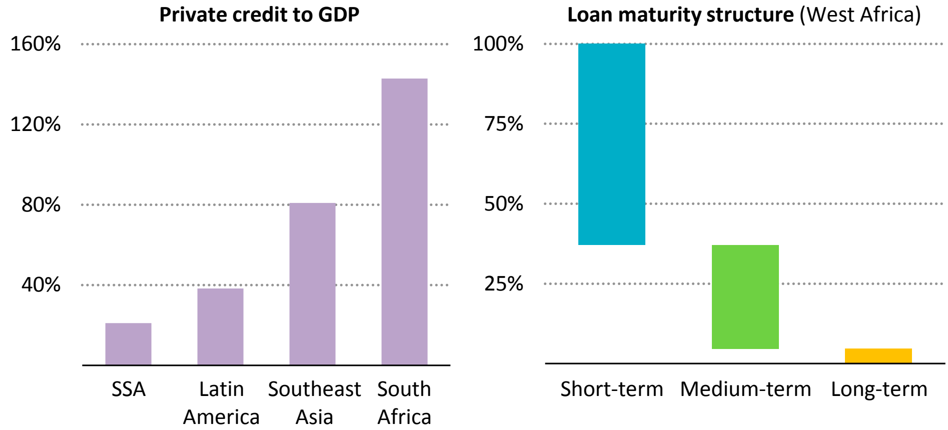
3.9.4 Strengthen provision of long-term finance

Given the long-lived and capital-intensive nature of power projects, the availability of long-term finance is crucial for power sector investment. In most of sub-Saharan Africa, however, access to long-term finance is severely constrained. It relies heavily on international development finance. Given the substantial risks associated with currency fluctuations, the local financial sector has a central part to play in ensuring a steady flow of long-term financing to power projects: a mismatch between revenues in local currency and costs in foreign currency (for equipment, borrowing, prices for power purchase agreements) can weigh heavily on the finances of state-owned utilities. While access to local banks in sub-Saharan Africa expanded over the past decade, it still compares unfavourably with access in other developing economies, with the exception of South Africa; and the majority of loans are still for short-term investments (Figure 3.23).

Developing the local financial sector and its ability to extend long-term finance has the potential to make a big difference to secure private investment in the power sector. DFIs can help by acting as a catalyst, for example by providing guarantees, refinancing or on-lending mechanisms. The refinancing of the Kenya Power and Lighting Company, the company that owns and operates the majority of the electricity network in Kenya, is a good example of how DFIs can strengthen the role of local banks and help utilities access cheaper and longer term finance ($500 million of commercial debt was restructured for longer term and lower cost commercial debt). Domestic pension and sovereign wealth funds could also play a more important role in financing power investments. Senegal's

Sovereign Fund for Strategic Investments, FONSIS, which has provided equity for solar PV plants in Senegal, is leading the way.

Figure 3.23 ▷ Level of private credit and loan maturity of the local banking sector in sub-Saharan Africa, 2016-2017



The local financial sector is playing a limited role in power sector financing other than in South Africa; the provision of long-term finance is particularly constrained

Notes: SSA = sub-Saharan Africa (excluding South Africa). Long-term loan has a maturity more than five years; medium-term loan between one and five years; and short-term loan less than one year.

Sources: IEA analysis based on World Bank (2019b) and BCEAO (2018).

Domestic policies outside the power sector also matter. Policies on issues such as the repatriation of funds, tax incentives and the regulation of public-private partnerships all affect the overall enabling environment and the regulatory framework for financiers. Clear economic policies that are conducive to private sector participation have an important role to help scale up power sector investment in Africa.

Natural gas and resource management

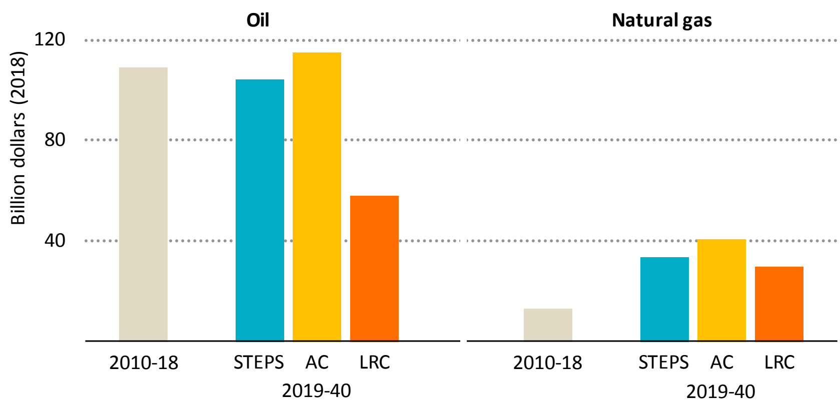
New horizons for Africa's resources?

SUMMARY

- Africa is endowed with abundant oil, gas and mineral resources and these have provided an important source of income for the continent's economic growth. But changing energy market dynamics offer different prospects for each fuel. Oil production reaches 8.2 million barrels per day (mb/d) by 2040 in the Stated Policies Scenario, just shy of today's level (after a dip in the 2020s); gas production doubles between 2018 and 2040; and coal production remains at today's level.
- Africa also has many of the metals and minerals that are critical for clean energy technologies. It accounts for two-thirds of global cobalt production, 80% of platinum and half of manganese production. Responsible development of these resources is crucial to support the continent's economic prosperity and global energy transitions.
- Natural gas is facing a potential turning point in Africa. Outside North Africa, natural gas has not so far played a major role in energy development – at 5%, the share of gas in the energy mix in sub-Saharan Africa is one of the lowest in the world. The future looks likely to be different: recent discoveries across the continent could fit well with Africa's push for industrial growth and its need for reliable electricity supply. Developing gas infrastructure however will be a major challenge given generally small market sizes and concerns about affordability.
- Four case studies are presented to illustrate the differing dynamics for gas across the continent. Nigeria is an incumbent producer that has struggled to develop domestic gas consumption. Egypt is a resurgent producer with extensive domestic infrastructure that has successfully managed to revive upstream activity. Mozambique and Tanzania are emerging producers, thanks to recent major discoveries, but face the challenge of getting domestic value from gas. Ghana is short of gas and seeking access to liquefied natural gas (LNG) imports.
- In the Stated Policies Scenario, gas demand in sub-Saharan Africa triples to over 100 billion cubic metres (bcm) by 2040. Production across the region grows even more rapidly as sub-Saharan Africa becomes a major supplier of gas to international markets. In our Africa Case, both production and demand rise further.
- Developing domestic markets is likely to see traditional pipelines complemented by small-scale and distributed approaches in some areas. Oil use equivalent to some 10 bcm (30% of today's gas demand in sub-Saharan Africa) can already be displaced by small-scale LNG with today's costs and prices. Bringing gas into the energy system is a challenging task, and getting these new value chains up and running would require a concerted effort from Africa's decision makers.

- Many resource-holders in Africa have not yet capitalised on their resource endowments in a way that supports economic and social growth. Changing global energy dynamics are likely to put further pressure on production and on development models that rely on hydrocarbon revenues. This underscores the need for transparent resource management as well as efforts to reform and diversify the economies. Given the importance of resources to Africa's development plans, we highlight three strategic responses that could help mitigate the risks and support responsible development.
- The first is to ensure competitive investment frameworks. Recently there has been a global shift towards upstream investment with shorter lead times and a more rapid return of capital. Although there are some examples of investments of this kind in Africa, in many cases the conditions for investors are out of step with this trend, and this could weigh against decisions to put capital into projects in Africa. This makes it all the more important that clear regulatory frameworks are in place and that the role of national oil companies is clearly defined.

Figure 4.1 ▷ Annual average net income from oil and natural gas production by scenario in sub-Saharan Africa



Africa faces significant challenges in sustaining net income from oil production, while natural gas offers more stable sources of revenue

Note: STEPS = Stated Policies Scenario, AC = Africa Case, LRC = Lower Revenue Case.

- The second is to develop the infrastructure required to bring resources to African consumers. This requires strategic choices on refining capacity and distribution networks. The third is to ensure that the revenue garnered from oil and gas is managed wisely. Average annual net income from oil and gas in sub-Saharan Africa amounts to $140 billion over the outlook period, but reduces sharply by 36% in a Lower Revenue Case in which global oil demand and prices are substantially lower as a result of faster energy transitions. In all cases there is a major shift towards less lucrative (per unit of energy) but potentially more stable revenues from gas.

4.1 Introduction

Africa has abundant oil, gas and mineral resources, and the revenue that these resources have generated has been an important source of income and economic growth. Oil and gas exports brought around $1.7 trillion of net income to African producers during the commodity boom in the 2000s, and the resource industry contributed around a quarter of Africa's economic growth between 2000 and 2008 (McKinsey, 2010). However, this income has also been a source of corruption and in many cases it has hindered broad-based development. Africa's resource producers remain among the least diversified economies in the world, and their economic prospects remain tied to the volatile movement of global commodity prices. The plunge in oil prices in 2014 brought these structural weaknesses into sharp relief. Many producers experienced a significant drop in export revenue (and fiscal capacity) and investment into Africa's upstream sector was severely curtailed. Oil prices have started to rise again in recent years, but changing energy dynamics make it risky to assume that ample resources will translate into reliable future revenues.

The challenges are particularly formidable for oil. Producers face both rising competition in global markets and growing uncertainty over long-term demand, and issues such as weak regulatory environments, political and social instability and the lack of local supply chain and technical expertise tend to undermine the competitiveness of African resources. Producers need to make considerable efforts to resume output growth and position themselves competitively in global export markets. There is also an imperative for both incumbent and emerging producers to take a hard look at how best to use the revenue from resource development to support the broader development of their economies. In the Stated Policies Scenario, the reduction in upstream investment since the oil price downturn puts the continent's oil production on a downward trajectory until the mid-2020s. Production resumes afterwards, but remains below today's levels through to 2040. In the Africa Case, higher domestic demand and improved resource governance lead to higher production, but net exports of oil remain well below today's levels (Table 4.1).

The story is different for natural gas. Gas takes a growing share in the global energy system in all of the IEA scenarios. Helped by a series of major discoveries in recent years, gas has a potentially important role to play in Africa's energy mix as a source of reliable baseload energy and as a companion for the rapid growth of renewables. It is however likely to be challenging to build infrastructure that makes the gas available and affordable in domestic markets. In the Stated Policies Scenario, Africa's gas production increases twofold in the period to 2040 and it rises further in the Africa Case where the potential for using gas in power and industry is exploited. Gas production is relatively more resilient in a Lower Revenue Case than oil production, offering a more stable source of income over the period.

Table 4.1 ⊳ Fossil fuels demand, production and net trade in Africa by scenario

			Stated Policies				Africa Case	
	2000	2018	2025	2030	2035	2040	2030	2040
Oil (mb/d)								
Demand	2.2	3.9	4.9	5.5	6.2	7.0	6.4	7.8
Production	7.8	8.4	7.9	8.0	8.1	8.2	8.4	8.8
Nigeria	2.2	2.1	2.1	2.1	2.2	2.3	2.3	2.6
Libya	1.5	1.0	1.0	1.1	1.3	1.5	1.2	1.6
Angola	0.7	1.5	1.3	1.3	1.2	1.2	1.3	1.4
Algeria	1.4	1.5	1.3	1.3	1.3	1.3	1.3	1.2
Net exports	5.4	4.2	2.8	2.2	1.5	0.8	1.8	0.6
Natural gas (bcm)								
Demand	58	158	185	221	265	317	238	349
Production	124	240	287	372	435	508	407	561
Algeria	82	96	96	104	112	125	103	111
Mozambique and Tanzania	0	5	21	61	82	105	70	130
Egypt	18	59	81	92	95	98	93	101
Nigeria	12	44	41	45	56	65	56	84
Net exports	67	81	102	151	169	190	169	212
Coal (Mtce)								
Demand	129	160	166	161	160	161	153	148
Production	187	225	217	199	210	221	196	198
South Africa	181	209	198	174	176	173	171	148
Mozambique	0	11	13	18	24	32	18	34
Net exports	59	66	52	39	50	60	43	51

Notes: mb/d = million barrels per day; bcm = billion cubic metres; Mtce = million tonnes of coal equivalent. Net exports = domestic production + refinery processing gains – demand including international bunkers.

Against this backdrop, this chapter explores two key issues that are critical to shaping the future of African resources:

- **The role of natural gas in Africa's energy mix:** We look at the strategically important role of natural gas on the continent with the help of four case studies featuring Nigeria, Egypt, East Africa (Mozambique and Tanzania) and Ghana. The section also explores how recent discoveries could affect the position of gas in Africa's energy mix.
- **Maximising the value of Africa's resources**: We examine the outlook for resource development and related revenues in Africa under different scenarios. Despite their vast resource endowment, many African governments have been unable to capitalise on opportunities to support growth. This section discusses the strategies available to resource-holders to mitigate risks and ensure that resources are used to support broad economic and social goals.

4.2 The role of natural gas in Africa's energy mix

The position of natural gas in Africa's energy mix today varies widely across the continent. In North Africa, gas is a mainstream fuel that meets around half of the region's energy needs. In 2017, with strong growth in Algeria and Egypt, gas consumption in North Africa overtook oil use for the first time in history. However, the picture is very different in much of sub-Saharan Africa, where gas has been a niche fuel. The share of gas in sub-Saharan Africa's energy mix is around 5% – the lowest regional share in the world.

There are a number of reasons for the low penetration of gas in sub-Saharan Africa. In many cases, there is a considerable distance between production and consumption centres, necessitating large-scale, capital-intensive infrastructure. Except in Nigeria and Angola, there has been relatively little domestic production, and the commercial case for importing gas has generally been weak. Even in countries with significant gas resources, like Nigeria, it has proved difficult to align interests, build infrastructure and maintain reliable supply along the value chain from producer to end-user: existing gas-fired plants have been underutilised, and there have been periodic power outages.

There are nevertheless reasons to believe that the future of natural gas in Africa may be different from the past:

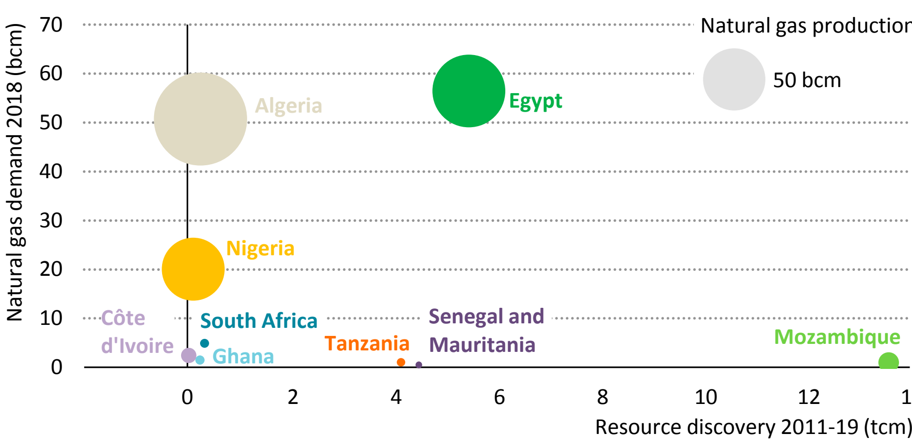
- **Africa's evolving energy needs**: Gas could be a good fit for Africa's push for industrial growth as well as a suitable partner for a rapid expansion in the role of solar photovoltaics (PV) in electricity generation.
- **Scope to displace costly oil products**: In 2018, some 15% of electricity in sub-Saharan Africa (excluding South Africa) was generated using oil products such as diesel or heavy fuel oil.[1] These are mostly back-up generators used in industry to avoid the risk of unreliable power supply. At current prices there is scope in many cases for gas to offer a cheaper alternative.
- **Major gas discoveries in every part of the continent in recent years** (Figure 4.2): The immense finds in East Africa (Mozambique and Tanzania) in recent years have been followed by further discoveries in Egypt and off the coast of West Africa on the maritime border of Mauritania and Senegal, and by the discovery of gas condensate resources in South Africa in 2019. These discoveries could have a significant influence on the outlook, especially since – with the exception of southern Africa – the continent does not have large resources of coal.
- **Favourable outlook for gas importers**: A wave of new liquefied natural gas (LNG) export capacity is coming online and exporters are keen to find a new market for their gas. Gas prices in the key importing regions have plummeted, while growing liquidity and flexibility in LNG markets are helping ease concerns over security of supply.

[1] In 2017, the share of oil in power generation was around 35% in Angola and almost 90% in Senegal.

- **Innovation in LNG technology**: The development of new technologies such as floating storage regasification units (FSRU) and small-scale technologies offers more flexibility for current and potential future gas users, and this could boost demand for gas. FSRUs can reduce the need for more costly onshore gas infrastructure and there is scope for them to be redeployed when no longer needed. Small-scale LNG technologies can help to provide new sources of demand and thus make gas less dependent on the realisation of complex onshore infrastructure projects.

In addition to helping to provide energy in producing countries, natural gas can contribute to economic growth by providing a sizeable source of fiscal revenue, although the extent to which it contributes to growth depends on the revenues being used effectively and transparently (see section 4.3).

Figure 4.2 ▷ Natural gas resource discoveries, demand and production in selected countries in Africa



With the exception of Egypt, recent gas discoveries in Africa have been in countries with very small gas markets

Notes: bcm = billion cubic metres; tcm = trillion cubic metres. Bubble size represents production volume in 2018.

The outlook for natural gas to 2040 in the Stated Policies Scenario varies widely according to resources, market conditions and policy preferences in different countries. In this analysis, we consider four sets of circumstances:

Incumbent producers: This designation applies to Nigeria and Algeria, both of which are exporting around half of their gas production to global markets. The policy priority for these countries is to sustain production levels and stay competitive in export markets. Unlike Algeria, where gas plays a significant role in the energy mix, the penetration of gas in Nigeria is low compared to its population and resources. Nigeria therefore faces the longstanding question of whether it can develop domestic gas demand.

Resurgent producers: Egypt is a good example of a country that has well-developed gas infrastructure, but where gas production is recovering from a prolonged downturn. The policy priority in this case is to accelerate production growth to serve domestic demand and develop strategies to maximise the value of its resources.

Emerging producers: This applies to countries where there is significant resource potential but where both production and demand are small today. Following their recent major gas discoveries, Mozambique and Tanzania are at the forefront of this group, but it also includes Senegal and Mauritania. For these countries the first task is to turn discoveries into viable and successful commercial projects. Given the strong export orientation of the planned projects, they need to be competitive against other sources in global LNG markets if they are to succeed. A second task is to develop domestic gas markets where it makes sense for them to do so.

Gas importers: There are many countries with limited resources and so – if gas is to play a role in their energy future – they need to rely on imports either in the form of gas or gas-based electricity. While many African countries belong to this group, Côte d'Ivoire and Ghana are the ones that are most actively exploring import options (although Ghana has some domestic production notably from the Jubilee, Sankofa and TEN fields). South Africa has traditionally belonged to this group and imports gas from Mozambique, but this might change if recent offshore discoveries prove to be sufficiently promising. For these countries the key task is to obtain the gas they need at competitive prices while ensuring security of supply.

In this section, we look at the prospects for gas in each of these segments.

4.2.1 Prospects for gas in key regions

Incumbent producer: the case of Nigeria

Nigeria has an estimated 15 trillion cubic metres (tcm) of natural gas resources, which is more than any other African country except for Algeria. Gas accounts for around 10% of total primary energy demand today, mostly for power generation and own use in the oil and gas industry. However, the current outlook for Nigeria's gas industry is far from bright. Rapid production growth after 2000 tailed off due in part to regulatory uncertainties and the country is now struggling to arrest a decline in output. A shortage of domestic gas supply has severely affected the reliability of power supply, leading to load shedding and growing reliance on private (diesel-based) generators. Exports via the West African Gas Pipeline have been subject to frequent interruptions, and that has caused difficulties for neighbouring countries such as Ghana, Benin and Togo. Meanwhile, almost 15% of gross production is wasted through flaring, incurring both economic and environmental costs.

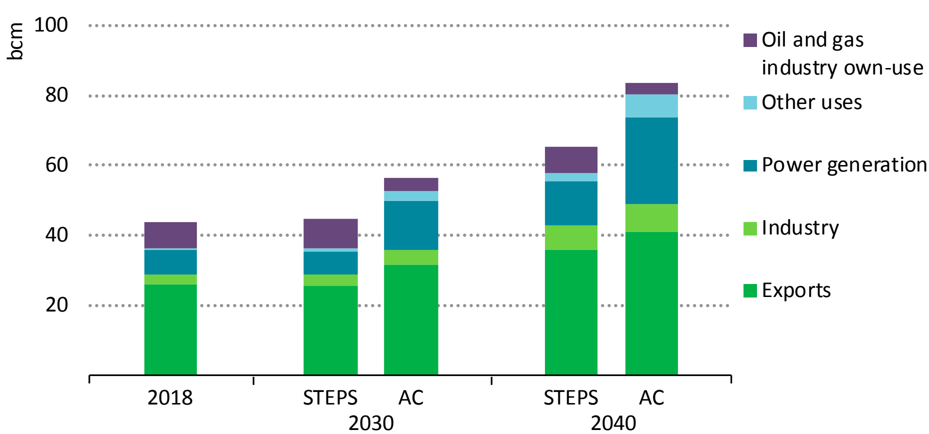
Upstream activity is far below a level commensurate with the country's resource base. The slump in investment, related in part to lower oil prices since 2014, is damaging for the medium-term outlook – gas production stalls through to the mid-2020s in the Stated Policies Scenario. One of the key issues is uncertainty over the fiscal conditions, exemplified by nearly two decades of uncertainty around the key provisions of the Petroleum Industry

Bill, which is designed to overhaul the legislation governing the operation of the oil and gas industries in Nigeria. Without clarity on governance and regulation, many companies will continue to rein in spending on new projects, with implications not only for Nigeria but also for adjacent countries that depend on exports from Nigeria for their gas supplies.

Reducing gas flaring would help to increase production. Nigeria has made notable progress in reducing flaring – the amount of gas flared has fallen by 70% since 2000 – but the country remains the seventh-largest gas flaring country in the world, and the value of the gas flared is estimated to be some $1.8 billion in 2018. Flaring is also a significant source of carbon dioxide (CO_2) emissions and incomplete flaring releases methane to the atmosphere as well. Despite the government's goal of eliminating flaring by 2020, the progress has stalled since 2016. Strengthened regulations and adequate gathering, processing and transportation infrastructure to bring associated gas to markets are essential to realise the government's target. In the Stated Policies Scenario, it is assumed that the envisaged reforms are gradually implemented, that output starts growing again from the late-2020s, and that Nigeria's annual gas production in 2040 rises 50% above today's level to 65 bcm.

The outlook for gas production also depends on reform of the electricity sector. Producers in Nigeria have domestic supply obligations that require them to supply a certain volume of gas to domestic markets. These obligations have typically not been met in full. Below-cost power tariffs and the precarious financial situation of electricity generation and distribution companies have led to frequent non-payment. The poor condition of the gas transmission and distribution system is also a major constraint. Without reforms to the power sector as well as the upstream, there is no guarantee that higher production would lead to improved supply of gas (and power) to the country.

Figure 4.3 ▷ Natural gas production and use by sector and by scenario in Nigeria



Accelerated upstream reforms and industrial growth mean that in 2040 gas use and production are 40% and 30% higher in the Africa Case than in the Stated Policies Scenario

Notes: STEPS = Stated Policies Scenario, AC = Africa Case.

While the challenges are formidable, realising the potential of gas could bring significant benefits. In the Stated Policies Scenario, electricity demand in Nigeria grows at rates in excess of 6% per year in the period to 2040, necessitating a significant increase in generation. Given the high share of gas in both existing and planned power generation capacity, using additional gas looks to be a cost–effective way of providing much-needed electricity, alongside the anticipated ramp-up of investments in renewables (from a very low base). Attracting more private capital to the sector will be essential if this is to happen: the recent 460 megawatt (MW) Azura-Edo project, Nigeria's first project-financed independent power producer project, could be an important signal in this context. Nigeria is also aiming to foster gas-based industries (for example fertiliser, methanol) to substitute domestic production for imports and to position the country as a regional hub for manufacturing, a key element in our projections for gas demand in both the Stated Policies Scenario and the Africa Case. Gas demand in Nigeria rises rapidly in the latter part of the projection period, reaching 30 billion cubic metres (bcm) in 2040 in the Stated Policies Scenario and over 40 bcm in the Africa Case (Figure 4.3).

Resurgent producer: the case of Egypt

Gas production in Egypt has undergone dramatic changes since the early 2000s. Domestic output grew by 17% per year on average between 2000 and 2008 (when production reached a peak of 62 bcm) and Egypt became an exporter of gas. However, a significant reduction in investment resulted in a 40% drop in production between 2008 and 2015. The country became a net importer of gas again in 2015, chartering two FSRUs in order to be able to bring in LNG imports. The Egyptian economy is heavily dependent on gas: more than 80% of the country's power generation capacity is gas-fired. Declining domestic output therefore caused repeated power outages and weighed heavily on industrial competitiveness. LNG export facilities were idled, and more polluting oil products started to take market share.

The discovery of the large Zohr offshore gas field in 2015 – one of the biggest finds worldwide over the last decade – changed the situation. With favourable upstream policies to expedite development, production from the Zohr field started in late 2017 and is set to reach around 30 bcm in 2019. This growth is now being supplemented by production from several other fields, notably Nooros, Atoll and the first and second phases of the West Nile Delta complex, leading to a major turnaround in the country's production. Gas production in 2018 returned to the level of the previous peak in 2008 and Egypt achieved self-sufficiency later in the year.

With sustained upstream reforms and efforts to reduce arrears to international operators, gas production in Egypt grows to around 100 bcm by 2040 in the Stated Policies Scenario. The upbeat production outlook, coupled with the country's underutilised LNG export infrastructure, opens the possibility of Egypt going well beyond self-sufficiency and acting as a regional export hub, although this would require the resolution of various political and commercial issues. However, question marks remain as to Egypt's net export position in the longer term. On the supply side, there would be need for continued upstream investment as the outputs from the Zohr and adjacent fields reach a plateau.[2] But the bigger issue is that gas demand in Egypt may rise very rapidly. Egypt is already the largest gas consumer in Africa and there is strong potential for further growth, especially in the power sector where gas is the dominant fuel.

Gas pricing is a key variable in determining the outlook for consumption. Although the government made a notable upward revision to domestic gas prices in 2014 in response to tightening supply, prices paid by power generators (around $3 per million British thermal units [MBtu]) remain below the levels to incentivise new supply investment, estimated to lie in a range between $4-6/MBtu (MEES, 2018). Prices for the petrochemical industry are within that range ($4.5/MBtu) (OIES, 2018). In contrast, prices for steel and cement producers are set at $7- 8/MBtu, and this has triggered fuel switching away from gas to coal. Earlier this year the government announced a plan to implement automatic price indexation for oil products, but gas prices for power generation are still being subsidised. A further reform of gas pricing is needed to maximise the value of the country's resources. To be effective this should cover both the upstream and the end-user, and it would be worth giving consideration as part of any reform package to the case for transparent end-user pricing schemes including clear rules of price discrimination by sector.

Emerging producers: Mozambique and Tanzania cases

East Africa's gas resources are impressive, with up to 5 tcm in Mozambique and nearly 2 tcm in Tanzania. Commercialising this significant resource base is a priority for both countries but this would require unprecedented capital investment (in Mozambique it would far exceed the country's annual gross domestic product [GDP]). This points to the need for a regulatory framework that serves domestic development priorities while remaining attractive for foreign investors.

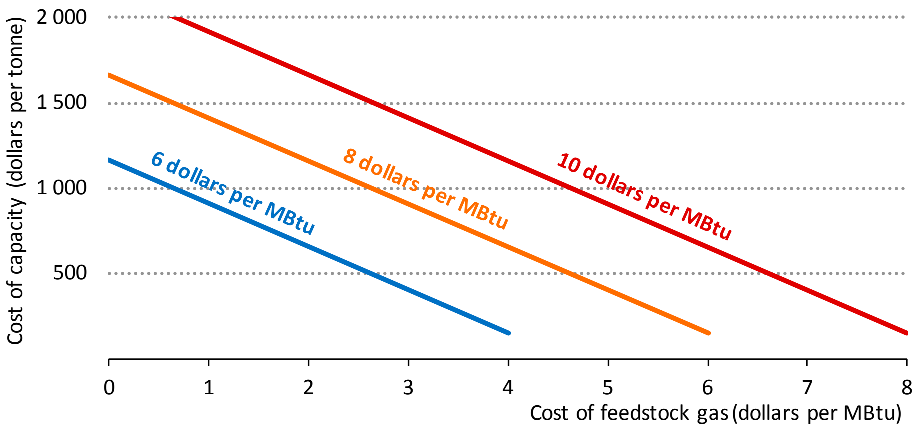
Mozambique is taking the lead in East African natural gas development. Several projects are moving forward with a strong export orientation given the importance of economies of scale. Coral LNG, the first floating LNG project in Africa, is being built with an aim of starting operations in 2022: BP has committed to take all of the LNG that it produces into its export portfolio. The Anadarko-led Mozambique LNG, the country's first proposed onshore LNG terminal, would involve larger volumes of gas: a final investment decision (FID) was reached on this project in 2019, with a number of offtake agreements oriented toward Asian markets.[3] Another project, Rovuma LNG led by Eni and ExxonMobil, has secured sufficient offtake commitments from affiliated buyers to move ahead. Its development plan has received government approval and it is approaching a FID. The LNG project in Tanzania, however, has been held up by regulatory delays: the government now expects the project to start construction in 2022 and come into operation from the late-2020s.

[2] Trade with other East Mediterranean countries (e.g. imports from Israel, exports to Jordan) can also impact the trade balance.

[3] Total will replace Anadarko as a leader for the Mozambique LNG project following the merger.

In spite of the gas resources being offshore, development costs for the relevant fields and export facilities are potentially modest. Proximity to India and other fast growing Asian markets is another plus. However, the projects are expected to start operation at a time when global gas markets are very competitive, with many new and established exporters looking to gain or strengthen a foothold in the market. The delivered costs of gas to Asia for these projects are estimated to be broadly similar to those of projects in other emerging gas exporters (e.g. Canada, Australia). However the remote location, lack of established infrastructure and unfavourable security conditions create a risk of cost overruns which could significantly undermine the competitiveness of the projects. Strict control of costs and schedules is therefore very important (Figure 4.4). In the Stated Policies Scenario, gas exports from Mozambique reach nearly 75 bcm by 2040 (including exports to South Africa via pipeline) while those from Tanzania reach around 20 bcm.

Figure 4.4 ⊳ Required levels of liquefaction capital cost and feedstock gas costs in East Africa by delivered prices to Asia



Strict cost and schedule control is indispensable for East African LNG to secure its place in global LNG markets

Notes: MBtu = million British thermal units. Delivered prices to Asia are the sum of the costs of developing gas resources, building liquefaction terminals and shipping the LNG volumes to Asia. Assumed asset lifetime is 30-years with a cost of capital in the range of 8%.

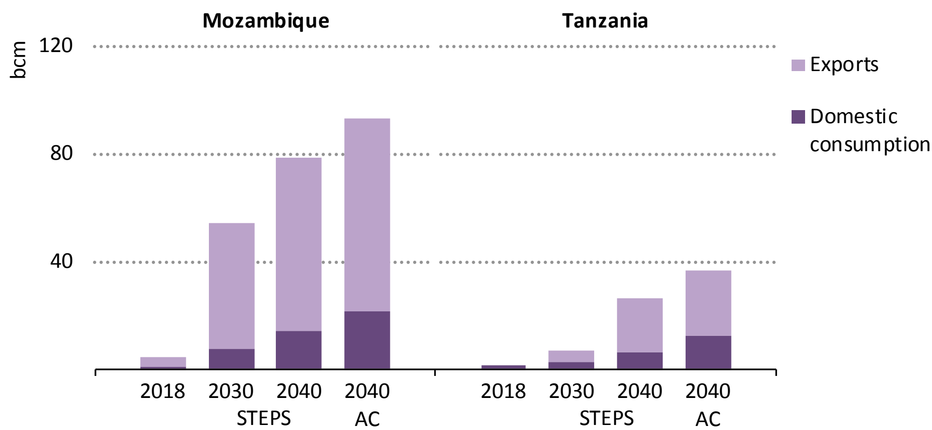
Although Mozambique and Tanzania's gas resources are primarily earmarked for export, governments in both countries are keen on developing a domestic gas industry. Domestic market obligations have been an element of discussion between the gas industry and the government with the design of the policy (how much and at which price) being a critical factor for both sides. The biggest hurdles for domestic gas consumption growth are lack of infrastructure and relatively low purchasing power of end-users.

Mozambique's gas resources are in the remote and sparsely populated north, and bringing the gas to the cities in the south would require costly pipeline infrastructure. This is under consideration (as are short-haul LNG shipments), but there is a major question mark on the economics. The development of local gas demand hubs served via FSRUs would require less capital expenditure and may prove more flexible. "Gas-by-wire" options[4] could also lower the costs of infrastructure investment, while large gas consuming "anchor" industries could play an important role in underpinning the economics of infrastructure projects. Many projects (including projects to build fertiliser, methanol and gas-to-liquids plants) have already been proposed as candidates to support an initial commercial case for developing the infrastructure.

Tanzania is in a slightly more favourable position in terms of getting gas into its domestic market: some of its gas fields are onshore and relatively close to Dar es Salaam, and there is already a pipeline which could potentially be expanded. There is a strong economic case for using gas to displace oil-fired generation: Tanzania's Gas Master Plan sets out a strategy to promote the use of gas to displace traditional uses of biomass, spur industrial growth and nurture gas-based industries. A plan to export Tanzanian gas to Kenya is also being explored. There is however more uncertainty on the upstream side about whether and when projects might move to a FID (and construction).

In the Stated Policies Scenario, domestic gas consumption reaches around 15 bcm in Mozambique and 6 bcm in Tanzania in 2040, roughly 20% of each's country's total output. In the Africa Case, gas makes further inroads into the energy system, with the combined gas demand in the two countries reaching almost 35 bcm by 2040 (Figure 4.5).

Figure 4.5 ▹ Natural gas consumption and export by scenario in Mozambique and Tanzania



Gas production in East Africa grows substantially in the period to 2040: the vast majority is exported as LNG

Note: STEPS = Stated Policies Scenario; AC = Africa Case.

[4] Gas plants are built near coastal areas that have good access to LNG and electricity networks are extended to wider areas.

East Africa's gas industry, if successfully developed, has the potential to be a major contributor to long-term economic growth: increased exports would yield cumulative net fiscal incomes amounting to over $200 billion for Mozambique and nearly $50 billion for Tanzania in the period to 2040. This would help governments to address growing debt accumulation and ensure macroeconomic stability. However, it is vital that there should be transparency about the use of these revenues and that they should be used to bring tangible economic benefits for the country. History suggests that, after major discoveries, some countries have quickly scaled up public investment and accumulated excessive debts based on unrealised future revenues, damaging their economic performance in the process. Avoiding this so-called "pre-source curse" is essential if income from gas exports is to provide maximum benefit to Mozambique and Tanzania.

Senegal and Mauritania are also potential producers. Major offshore discoveries were quickly followed by a FID on the Tortue LNG project. The bulk of the gas produced is destined for export, but there is a plan to build a pipeline to the shore to serve domestic markets. As both countries currently rely heavily on oil for power supply, there is significant scope for gas to displace oil and meet growing electricity demand. In Senegal, the share of gas in power generation increases from less than 2% today to nearly half in 2040 in the Stated Policies Scenario, rising to 60% in the Africa Case.

Gas importers: the case of Ghana

Despite major gas discoveries in several parts of the continent, a large number of African countries still do not have direct access to large resources, and so need to rely on imports via LNG, pipeline or gas-by-wire. Ghana is one example, and it has been meeting its gas needs through a combination of domestic production and pipeline imports from Nigeria via the West Africa Gas Pipeline (WAGP). Domestic gas is mainly delivered to the Takoradi area in the west: imports from Nigeria serve the Tema area in the east. However, near-term domestic production prospects are uncertain and gas supply from Nigeria through the WAGP has been erratic.[5] These have led the country to explore the prospects for LNG imports. Tema LNG, the first FSRU, has been much delayed but now aims to start supplying imported gas from the early-2020s. At a delivered price of around $8/MBtu, imported gas is likely to displace the prevalent use of oil in the power and industry sectors (OIES, 2019).[6] Ghana has also recently put in place an interconnector between its two separate gas transmission systems to take surplus gas from the Takoradi system to the Tema system.

Further increases in LNG imports will depend on how demand for gas evolves. In the Stated Policies Scenario, gas demand in Ghana continues to be concentrated in the power sector. With generation from hydropower remaining stable, the growth in electricity demand is mostly met by gas and solar PV in the period to 2040, pushing up total gas demand to 4 bcm in 2040. In the Africa Case, gas plays a larger role in meeting higher electricity

[5] Physical attacks on the pipeline, diverting gas towards Nigeria's domestic market and the payment dispute by the Volta River Authority – Ghana's off-taker – all contributed to unstable supply of gas via the WAGP.

[6] With oil prices around $50 per barrel.

demand growth and is also used in the industry sector. Gas demand in 2040 is over 70% higher in this scenario, reaching 7 bcm, which points to a need for additional LNG imports. The requirements for LNG could be higher if Ghana pursues an option to export gas-based electricity to neighbouring countries via the West Africa Power Pool, for example to Benin, Burkina Faso, Côte d'Ivoire and Togo.

A number of other countries including Benin, Côte d'Ivoire, Kenya, Mauritius and Namibia are also reviewing options for LNG imports, but little progress has been made to date. Côte d'Ivoire was considering a plan to build an import terminal, but the project has been delayed following lower-than-expected demand growth and disputes over pricing. One of the challenges in developing smaller LNG projects focused on one country's gas demand is that small changes in either domestic demand or production outlook can easily reduce economies of scale and therefore affect the viability of the project. Concerns over the creditworthiness of off-takers and the reliability of payments can also constrain financing options for LNG projects.

For countries with little domestic production and limited access to LNG, gas has difficulty making inroads into the energy mix as small market size often does not justify investments in pipeline infrastructure. Some countries in this position are exploring a gas-by-wire option which would involve importing gas-generated electricity from countries within the same regional power pool. This option also offers an opportunity for exporting countries to increase economies of scale. It does however depend on a well-functioning power pool system (see Chapter 3).

4.2.2 Outlook for natural gas demand, production and infrastructure developments in Africa

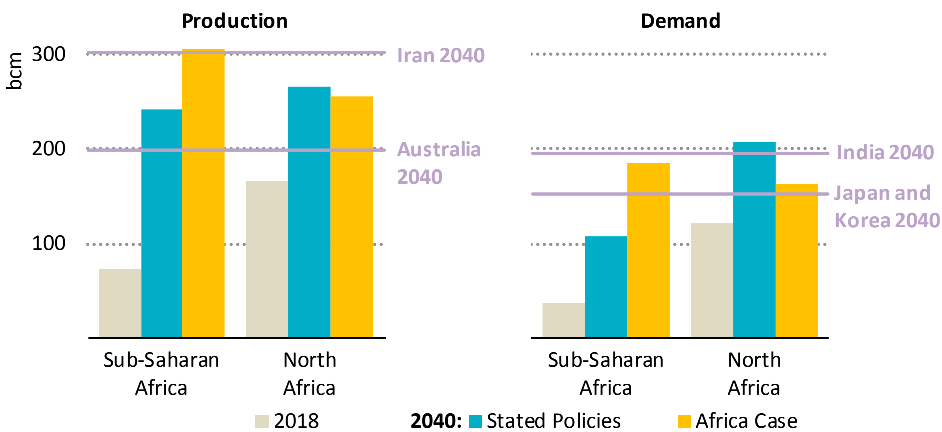
Gas production in Africa is set to rise significantly in both the Stated Policies Scenario and the Africa Case as the development of recent new discoveries moves sub-Saharan Africa into the higher ranks of global gas producing regions.

Gas production increases in all North African countries in the Stated Policies Scenario. In Algeria, the largest gas producer in Africa today, production edges down to the early-2020s due to the lack of new developments to compensate for the decline in existing fields, but rebounds over time as additional output from legacy fields is joined by new projects. The country remains the largest gas producer in Africa through to 2040. Production in Egypt rises to some 100 bcm in 2040, reflecting developments in the Zohr and Nooros fields and plans to evaluate the Nour prospect. Libya also sees a significant increase in gas production, and it accounts for around 30% of the overall increase in North Africa.

Projected production in sub-Saharan Africa more than triples, reaching over 240 bcm by 2040. Recent discoveries mean that a range of new countries, notably Mozambique, Tanzania and Senegal, join the club of major producers. These three countries account for almost two-thirds of the increase in gas production in sub-Saharan Africa over the next two decades. Mozambique becomes the largest gas producer in sub-Saharan Africa by 2030. In the Stated Policies Scenario, production in sub-Saharan Africa in 2040 approaches the level in North Africa. In the Africa Case, where higher demand coexists with reduced regulatory risks, production rises by an additional 60 bcm, pushing it above 300 bcm by 2040.

The upbeat outlook for gas production in the Stated Policies Scenario underpins a threefold increase in demand in sub-Saharan Africa over the period to 2040. The share of gas in the energy mix rises from 5% today to just under 10% in 2040. In the Africa Case, with greater efforts to expand gas (and electricity) infrastructure, the share of gas in the energy mix rises to nearly 20% in 2040 (close to the average share of developing economies today). In this scenario, gas demand in sub-Saharan Africa climbs to around 180 bcm in 2040 (Figure 4.6). Exports from North Africa rise at a rate of 1% per year in the Stated Policies Scenario, while those of sub-Saharan Africa grow at a much faster pace. Today, Africa as a whole exports a similar volume of gas as Australia. By 2040, growing LNG exports from East Africa mean that sub-Saharan Africa is a major force in global gas markets.

Figure 4.6 ▷ Natural gas production and demand in Africa by scenario

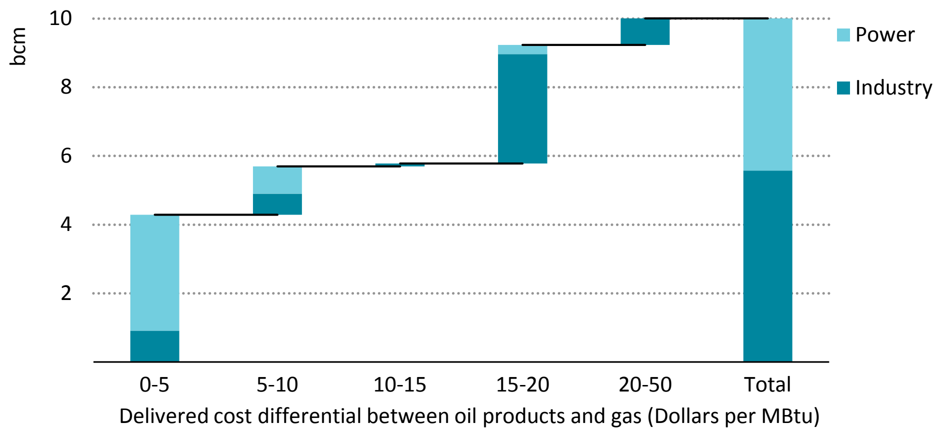


Africa strengthens its position in global gas markets in terms of both production and demand; gas makes strong inroads into the energy mix in the Africa Case

While the prospects and constraints vary by country, gas (or electricity) infrastructure is an essential prerequisite if gas is to thrive. Recent signs indicate that approaches to gas infrastructure development are likely to become more diverse. In addition to major long-distance pipelines to supply large-scale power plants, companies are increasingly looking at reaching industrial and commercial customers via small-scale LNG delivery or through distribution networks around industrial hubs. For example, Greenville LNG is operating 300 LNG trucks to deliver gas to a range of industrial customers, small-scale power plants and logistics companies in Nigeria and could potentially extend this to large mines and power plants in Burkina Faso (Africa Energy, 2019). Shell is developing distribution pipeline networks in the areas around major industrial hubs in Nigeria. Companies are also seeking better use of existing fuel distributors to distribute gas.

These small-scale, distributed approaches (akin to the value chain of liquefied petroleum gas) are likely to complement the traditional distribution channels (large pipelines) and help unlock new markets for gas. For example, many industrial and commercial customers today are paying higher costs for oil products, especially diesel, to operate their facilities: we estimate that some 10 bcm of this oil demand (30% of today's gas demand in sub-Saharan Africa) could be displaced economically given today's prices (Figure 4.7). However, given the relative ease with which oil products can be transported, this switch would happen only if policies and infrastructure allow gas suppliers to reach potential customers.

Figure 4.7 ▷ Potential for oil displacement by small-scale LNG in power and industry in sub-Saharan Africa, 2018



Small-scale LNG has potential to displace 10 bcm of oil use in power and industry at today's prices

4.2.3 Conclusions

Recent major discoveries present a renewed opportunity for gas to have a larger role in supporting Africa's energy and industrial development, but it is difficult to say "this time will be different" given that the challenges posed by small market size, infrastructure constraints and affordability remain considerable. Nonetheless, successful industrialisation hinges upon the stable provision of energy, and gas is well suited to providing this, whether directly where medium- and high-temperature heat is needed or indirectly where a source of relatively clean electricity is needed.

The idea of Africa leapfrogging directly from an energy system dominated by bioenergy to a fully decarbonised system is attractive, and it makes sense to develop renewables as rapidly as possible. However, it is hard to see how a fully decarbonised system can be achieved cost effectively in the coming decades while also meeting the continent's stated goals for industrialisation and economic development. Reliable electricity supply is an important element of the solution and this is set to be accompanied and supported by rapid deployment of renewables. However, in this sector there is also scope for gas to play an important role by providing a flexible and dispatchable source of electricity, helping to constrain the expansion of oil-based generators or coal-fired plants. In addition, there are other energy uses that cannot easily be electrified, including many industrial processes. The choice for these uses is occasionally between gas and renewables, but much more often between gas and more polluting fuels. The challenges for gas relate to infrastructure, affordability and business models: bringing gas into the energy system is inherently a challenging task, and cannot be taken for granted. Getting these new value chains up and running would require a concerted effort from Africa's decision makers.

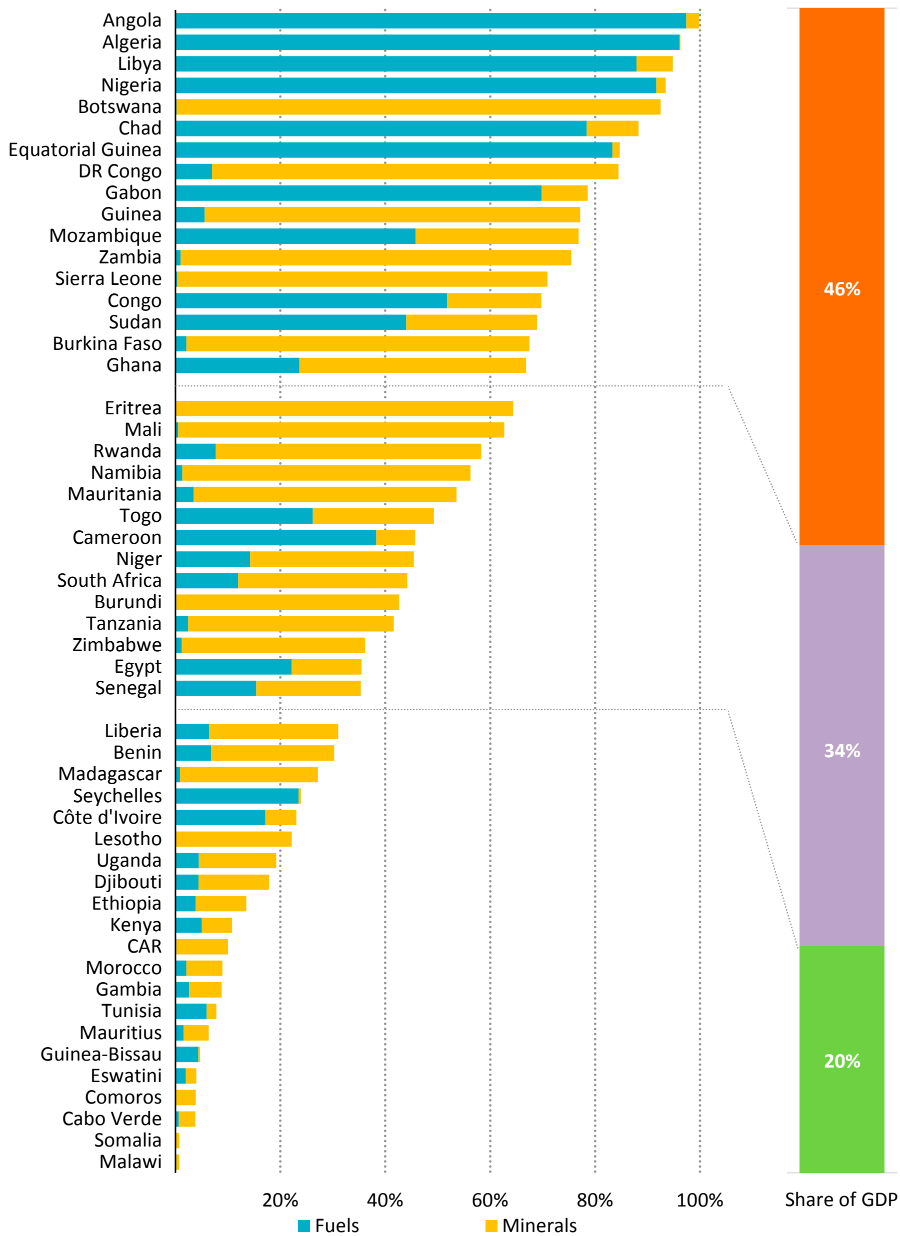
4.3 Maximising the value of Africa's resources

Africa is endowed with abundant oil, gas and mineral resources. However, in many cases resource-rich African countries have not been able to capitalise on these resources in a way that supports their economic and industrial growth. A World Bank study suggests that, following a major resource discovery, countries on average not only failed to meet high expectations for economic growth, but actually registered lower growth rates in the short-run than before a discovery, mostly as a result of weak governance (Cust and Mihalyi, 2017).

Fossil fuels and minerals account for over a third of exports in roughly 60% of African countries, which together account for 80% of the region's GDP. Countries in which these commodities make up more than two-thirds of their exports account for almost half of the region's GDP (Figure 4.8). Since demand and prices for commodities tend to be highly variable depending on market circumstances, this means that the export revenues of many African countries are subject to large swings, with knock-on effects on their economies. There are many examples of the dangers of over-dependence on this narrow and volatile source of revenue. Recent market developments – and uncertainties over the future – underline the risks of a high reliance on resource revenues. The rollercoaster ride in oil prices since 2014 has exerted severe fiscal and economic strains on many producers in Africa, while the near-term impact of buoyant US tight oil production on global supply and the longer term impact of energy transitions on demand make a compelling case for improved resource and revenue management and for economic diversification and reform.

African producers are responding to these challenges. After a major slump in activity post-2014, there are signs that interest and activity in parts of Africa's upstream are picking up again. Against this backdrop, how can Africa make the most of its vast resources to spur inclusive development and growth? To answer this question, we take a look at the outlook for fossil fuel production and resource revenue under different scenarios, examine what strategies are open to African resource-owners to mitigate risks, and assess what the potential impact of abating these risks might be on production and revenue.

Figure 4.8 ⊳ Share of commodities in total merchandise exports and GDP in African countries, 2017



African economies are highly exposed to commodity exports; those relying on commodities for more than a third of their exports account for 80% of the continent's GDP

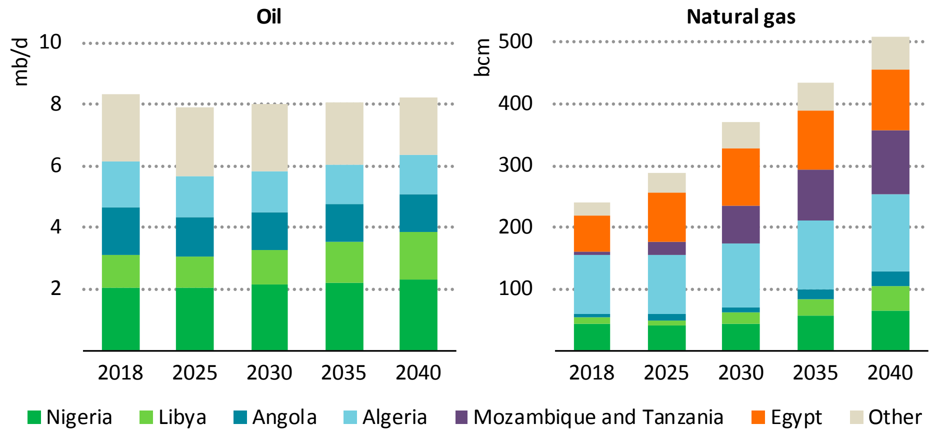
Notes: CAR = Central African Republic. Minerals include ores, metals, precious stones and gold.

Source: IEA analysis based on UNCTAD Stats.

4.3.1 *Outlook for fossil fuel production*

The oil price plunge in 2014 severely curtailed spending in Africa's upstream and this continues to weigh on the near-term production outlook. A combination of market conditions, lower revenues, ageing fields and regulatory uncertainties means that investment across Africa's upstream oil and gas sector has fallen by 40% since the high point reached in 2011, and the fall in sub-Saharan Africa has been particularly steep. More recently, there have been some signs of a pickup in activity with new licensing rounds, some major discoveries (primarily of gas) and FIDs. In the Stated Policies Scenario, after a dip in the 2020s, overall oil production almost returns to today's level by 2040.

Figure 4.9 ▷ Oil and natural gas production outlook in Africa in the Stated Policies Scenario



Oil production in Africa makes a moderate rebound from the mid-2020s, while gas production doubles as incumbent producers are joined by new players

The oil outlook is driven by a handful of major producers, all of whom face significant question marks and challenges. Libya has the largest oil reserves in Africa and remains the main source of production in North Africa. Its production continues to rebound and by 2040 almost reaches the level seen in 2010 (when the recent volatility in production levels started), although downside risks from political instability and civil unrest remain. Algeria's output continues to trend downwards due to the depletion of existing fields, dropping to 1.2 mb/d in 2040. The production outlook in sub-Saharan Africa depends heavily on two major producers, Nigeria and Angola, who have managed recent challenges in contrasting ways. In Nigeria, continued uncertainty over upstream regulation and governance mean that near-term output is projected to plateau until the mid-2020s, before improved market and (by then) domestic reforms allow for a modest resumption of production growth. In Angola, the government has accelerated reforms in an effort to stimulate investment. Assuming this effort is sustained, we project that Angola's output decline is slowed somewhat but that production nonetheless gradually falls to 1.2 mb/d in 2040 (Figure 4.9). A new group of producers also emerges in sub-Saharan Africa in our projections, including

Uganda, Kenya and Senegal: their contribution to growth is relatively minor although the associated revenue promises to make a significant difference to their fiscal balances.

The gas outlook is quite different. Gas production in Africa grows by 270 bcm between 2018 and 2040, a doubling of output that is comfortably ahead of the rate at which oil production grows (see section 4.2.2). Thanks to a number of new discoveries and also the growing role of gas in the global energy system, there is a clear shift towards gas in upstream activities. Since 2010, some 20% of upstream oil and gas investment in Africa has been directed towards gas, and this increases to 36% between 2018 and 2040 in this scenario.

Coal production in Africa declines through to 2030 before making a modest rebound to 220 million tonnes of coal equivalent (Mtce) in 2040 in the Stated Policies Scenario. South Africa remains the dominant coal producer in Africa. Despite the steady decline in output, it still accounts for three-quarters of Africa's coal production in 2040, down from over 90% today. Coal output in Mozambique, mainly coking coal for export, increases threefold to around 30 Mtce in 2040, offsetting some of the decline in South African output. While coal mining is not as significant for the continent as oil and gas, the production of other minerals and metals is a key component of Africa's economy and is expected to remain so; many of its minerals and metals play a critical role in helping the global energy transition.

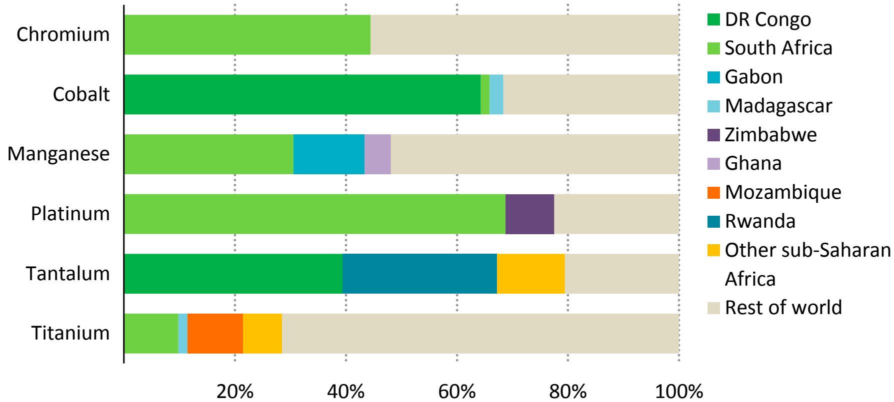
S P O T L I G H T

What does the clean energy boom mean for mineral production in Africa?

The rapid rise of clean energy technologies is not only changing the landscape for the power sector, but also for mineral and metal producers, including those in sub-Saharan Africa (Figure 4.10). For example, the greater need for batteries for energy storage and electric vehicles is set to supercharge demand for lithium, cobalt and manganese. What might this mean for sub-Saharan Africa's mineral production?

In 2017, net income from mineral production accounted for 2% of GDP in sub-Saharan Africa, with a majority of Africa's mineral reserves and production located in the south part of the continent. The Democratic Republic of Congo (DR Congo) is rich in cobalt; it accounts for almost two-thirds of the world's production and has half of the world's known reserves. South Africa produces 70% of the world's platinum (used both in internal combustion engines and fuel cells), 45% of the chromium (used in wind turbines) and a third of the world's manganese (a vital element for steel and advanced batteries). Rwanda and DR Congo both produce tantalum (some 30% and 40% of the global supply respectively) which is critical for electronics. Namibia and Niger were the world's fourth- and fifth-largest producers of uranium, critical for nuclear power plants (World Nuclear Association, 2019). It is also highly likely that Africa is home to rare earth elements, though no comprehensive survey has been undertaken to determine the potential (World Bank, 2017).

Figure 4.10 ▷ Share of sub-Saharan African countries in global production of key metals and minerals, 2018



Sub-Saharan Africa provides a significant share of the world's key metals and minerals critical to clean energy technologies

Source: USGS (2019).

As with oil and gas, sub-Saharan Africa has experienced boom-and-bust cycles of mineral exports and associated revenues. For example, a rapid recent rise in demand for cobalt caused prices to surge between 2016 and mid-2018, unleashing an opposite imbalance in the market that caused prices to fall by more than 60% from their peak. Demand for other minerals is also subject to volatility depending on the pace at which a cleaner energy future unfolds and on which technologies are in high demand, something strongly influenced by policy making. The projected growth of electric vehicles in the Stated Policies Scenario means that significant new sources of cobalt supply will need to come on line in a timely manner. Depending on the chemistry of the batteries produced, meeting the demand (230 kilotonnes per year in 2040) requires production to almost double in the Stated Policies Scenario.

There remains significant uncertainty regarding the nature and extent of sub-Saharan Africa's mineral resources. Further exploration and quantification is critical to a better understanding of the potential for extraction as well as recycling. There is also likely to be strong scrutiny of how these materials are sourced and what standards are in place all along the supply chain.[7] As with oil and gas, robust regulatory and oversight mechanisms are needed to ensure that impacts on local environments and communities are minimised and that revenues are used efficiently.

[7] Companies are paying increasing attention to responsible sourcing of African minerals. For example, BMW, BASF, Samsung SDI and Samsung Electronics recently launched a joint initiative to support sustainable and fair cobalt mining in the DR Congo. The initiative plans to explore ways to improve living and working conditions for the local small-scale mining operations over a three-year period.

4.3.2 Strategic responses for resource-holders in Africa

Africa's resources provide an opportunity for accelerated economic development, but the historical track record underlines the potential downside risks. Highly volatile income streams can upend economic stability and often do not benefit wider society, while changing global energy dynamics can undercut the size and reliability of this revenue. With this in mind, we explore three areas where policies can make a major difference to future outcomes: ensuring competitive frameworks for investment; investing strategically in associated infrastructure; and managing resource revenue wisely. Success in all these areas will need to be underpinned by improvements in governance to provide assurances of predictability and stability for those looking to invest in energy in Africa.

Ensure transparent and competitive frameworks for investment

In response to an uncertain and changing energy system over the last few years, company strategies and investment profiles have moved away from more capital-intensive projects towards shorter cycle projects that recoup investment more quickly. There have been shorter cycle projects in Africa as well. For example, the Zohr field in Egypt started production less than three years after its discovery in 2015, but it is the exception rather than the rule. On the other side of the ledger, there have been many incidences of project delays due to regulatory uncertainty, complex bureaucracy and politics, weak infrastructure and gaps in technical capabilities. Such project delays tend to count against African upstream investment opportunities when they are compared by potential investors with opportunities in other parts of the world. Analysis of the time lags between a FID and first production show that sub-Saharan Africa has not been following the global trend towards a shorter time-to-market for new projects (Box 4.1). In addition, many projects get stuck in planning and permitting processes before getting to a FID, as illustrated by the difficulty in proceeding with oil discoveries in Kenya and Uganda.

Box 4.1 ⊳ Time-to-market: the watchword for African oil and gas?

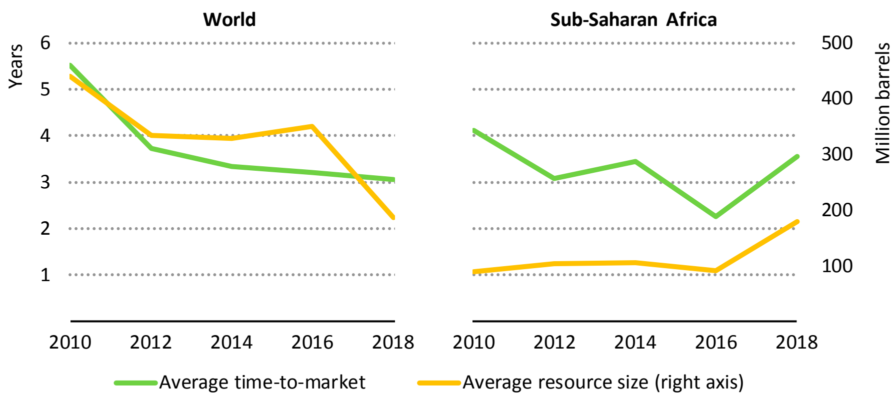
The average size and time-to-market for oil and gas development globally has steadily declined as energy companies respond to lower revenues and market uncertainties: in 2018 the average time required to bring a project to market was 20% lower than it was in 2010 (IEA, 2019). The time-to-market for projects in sub-Saharan Africa, which tend to be smaller than the global average, however, has not changed noticeably over this period (Figure 4.11). A myriad of above-ground challenges, especially for onshore projects, bring a risk of further delays between project planning and start-up.

In response, oil and gas producers in various countries have taken steps to ensure that licensing processes and fiscal terms, including taxes, royalties, production sharing and dividends from resource extraction, are fair and transparent. Angola is an example of how a revision to a contract scheme can unlock investment decisions: following reforms to its regulatory and fiscal regime for offshore projects in 2018, Total approved the Zina

II project after many years of delay. Mozambique, which revised its Petroleum Law in 2014, scores well compared to other countries in sub-Saharan Africa on the Natural Resource Governance Institute's Resource Governance Index in terms of transparency and accountability regarding licensing and taxation (Natural Resource Governance Institute, 2019). Ghana, which has recently updated a range of upstream regulations, also scores well though it is much stronger on taxation than licensing. However, uncertainty about regulatory frameworks and a lack of transparency remain a widespread problem, and there are sometimes long delays in enacting legislation designed to address problems. Prominent examples include Nigeria's longstanding struggle to pass new petroleum industry legislation, and the as-yet unratified 2014 Hydrocarbon Law in Gabon, which has delayed the licensing round for shallow water and deepwater blocks opened in 2018.

4

Figure 4.11 ⊳ Average time-to-market trends in the upstream oil and gas sector for sub-Saharan Africa and the world



Global trends of favouring shorter cycle projects are not visible in project selection in sub-Saharan Africa; time-to-market is further exacerbated by above-ground issues

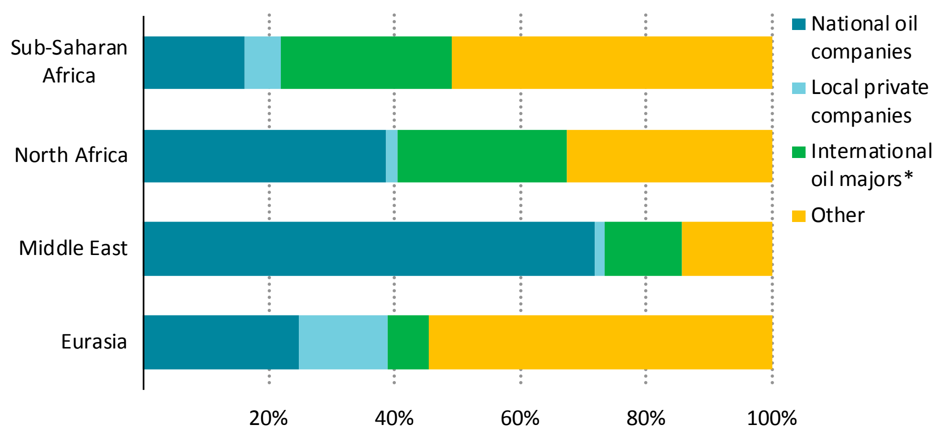
Notes: Number of years on Y-axis indicates time from FID to operation. Year on X-axis indicates FID year. Average size and time-to-market are for onshore, offshore and deepwater projects.

How a national oil company (NOC) performs can also have a significant impact on competitiveness and how the local hydrocarbon industry evolves. NOCs in Africa have grown in number, but there are questions about how effectively they are fulfilling their mandates. The role and governance of each NOC varies by country, but NOCs in sub-Saharan Africa tend to account for a smaller share of upstream investment than most of their counterparts elsewhere in the world (Figure 4.12). Many have been hampered in attracting investment by the lack of a clear mandate and by limited financing capabilities and technical expertise. Lack of oversight and accountability may also reduce the incentives for NOCs to operate efficiently.

Ensuring that the mandate of a NOC is aligned with the resource base and the needs of a changing energy sector is a crucial challenge for many African countries. While NOC models vary, some countries with modest reserves structure their NOCs to focus mostly on the downstream sector, taking on a role of product purchaser (for example, the National Oil Corporation of Kenya) or refiner (South Africa's PetroSA). For resource-rich countries the role of NOCs is more likely to focus on the development of resources and associated sectors (Ghana National Petroleum Corporation and Mozambique's National Hydrocarbon Company) and management of mature operations (Angola's Sonangol). Another model might see a focus on facilitating resource development, for example by conducting geological surveys and exploration activities where private companies are reluctant to step in.

No matter what the model is, clarity of purpose together with regulatory certainty, consistency and transparency are vital to attract investment, develop partnerships and allow a NOC to fulfil its obligations. Currently, sub-Saharan Africa ranks second to last among global regions in terms of transparent operation of its NOCs (Heller and Mihalyi, 2019). Ensuring prudent fiscal management and accountability of expenditures is another very important responsibility for NOCs, particularly given the scale of the resources involved (for example, Sonangol's debt has increased to more than 20% of Angola's GDP). NOCs also need to position themselves for broader changes in the energy sector, including national emissions reduction goals, by focusing on their environmental performance and minimising flaring and indirect emissions (especially methane leaks). In some cases, they may have the expertise and means to broaden their horizons by supporting the deployment of a range of low-emissions technologies.

Figure 4.12 ▷ Share of investment in upstream oil and gas by type of companies in selected regions, 2018



Share of upstream investment by NOCs in sub-Saharan Africa is smaller than in other regions

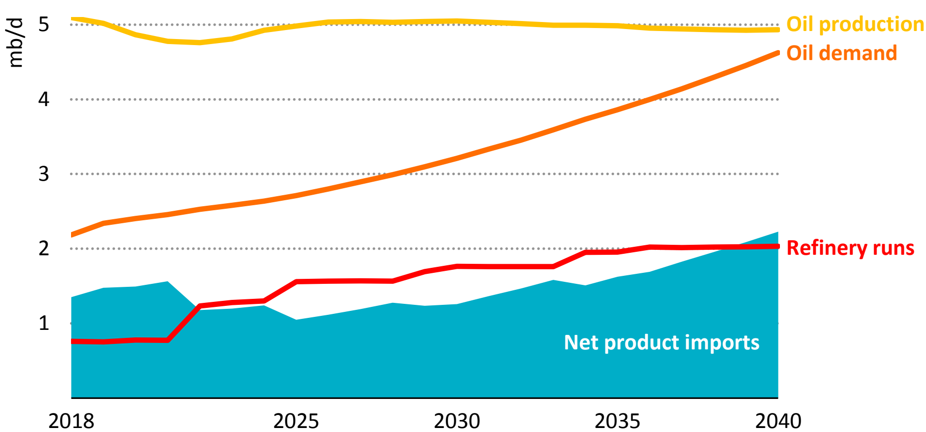
* Includes BP, Chevron, ConocoPhillips, ENI, ExxonMobil, Shell and Total.

Invest strategically in associated infrastructure

Once resources are extracted, two other crucial issues come into play: whether infrastructure exists to use these resources productively in Africa's domestic energy markets (discussed in this section), and whether the revenues are used prudently to promote a broader development agenda (discussed in the next section).

In the Stated Policies Scenario, oil demand in sub-Saharan Africa more than doubles between 2018 and 2040, driven by strong growth in transport and buildings. The annual rate of growth (at 3.5% per year) is one of the world's highest, and oil demand grows faster than in developing economies in Asia. An increasing number of (mostly energy inefficient) cars on the road pushes up demand for gasoline and diesel, and progress towards clean cooking raises demand for liquefied petroleum gas (LPG). Although sub-Saharan Africa produces around 5 mb/d of crude oil every year, its weak refining system means that it continues to rely on imports to meet its needs for oil products (Figure 4.13). The extent of the shortfall is even greater for low-sulfur products as many countries are moving to introduce more stringent regulations on fuel quality which local refineries struggle to meet. For example, Ghana reduced the allowed sulfur content in diesel from 3 000 parts per million (ppm) to 50 ppm in 2017 and many other countries plan to follow suit. In East Africa, where Kenya is the only country with a refinery, almost all oil products are imported.

Figure 4.13 ▷ Oil production and demand, refinery runs and net oil product imports in sub-Saharan Africa in the Stated Policies Scenario



Sub-Saharan Africa remains a net importer of oil products through to 2040

The persistent deficit in oil products indicates that there is a case for new refining investments to upgrade existing facilities or to build new ones. Many projects are on the drawing board, but only one small refinery in Cameroon has come into operation in recent years. The reasons why more capacity has not been built include the relatively small size of individual country markets, high upfront investment costs, lack of local crude oil supply (except in major producing countries in West Africa), subsidised fuel prices, widespread smuggling and regulatory hurdles. Some projects are, though, making progress, with Nigeria's 650 thousand barrels per day (kb/d) Dangote project and smaller projects in Angola, South Sudan and Uganda now looking likely to be commissioned. Nigeria is also pursuing an option for modular mini-refineries which can be built and transported relatively easily and which may be well suited to small and relatively remote markets. Both the Stated Policies Scenario and the Africa Case assume that a number of refineries are built in the latter part of the projection period, but the region still remains a net importer of products through to 2040.

A growing need for imports of oil products does not necessarily pose a problem given rising international competition in refining and the possible growth of gasoline (and diesel) volumes seeking an export outlet in the global refining system. This is especially the case in East Africa where there is ample modern and cost-efficient refining capacity in relatively near reach, notably in the Middle East and India. However, a different risk is created by the lack of distribution pipelines and storage capacity in much of Africa. The lack of distribution pipelines means that imported products often have to travel thousands of kilometres by trucks from port to consumers, adding costs and accompanying a considerable risk of accidents. Plus the lack of storage undermines the ability to respond to volatile market conditions.

There is a strong case for strengthened infrastructure to bring oil products to consumers. This would require countries to harmonise varying regulations on product pricing, fuel quality and eligibility of importers, and to put in place adequate safety regulations for distributors. Given relatively smaller upfront capital requirements compared to refining, investments are already being made in distribution, storage, import facilities and service stations in Ghana, Tanzania, Uganda and elsewhere.

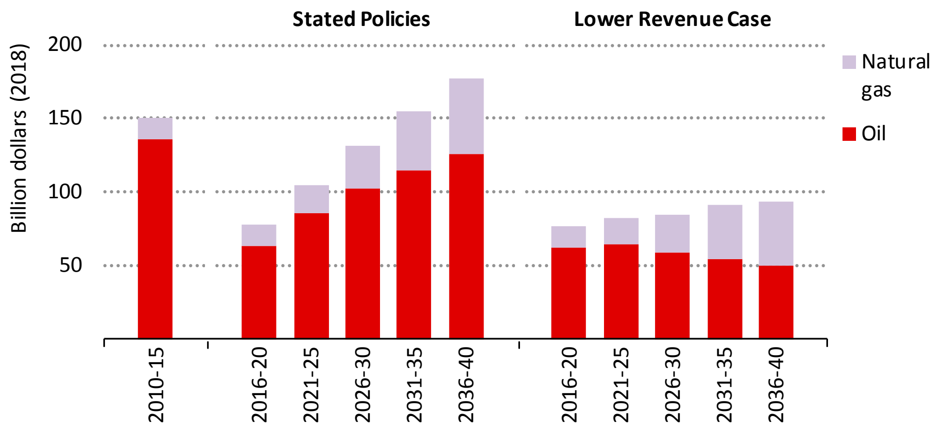
In the light of recent gas discoveries in Africa, midstream gas infrastructure – pipelines, gas processing and transportation – is also gaining importance (see previous section). Gas processing plants could provide an additional revenue stream for the planned gas projects and make LPG more readily available. While large-scale pipelines connecting prospective producing regions with major demand centres might well bring benefits large enough to justify their costs, such pipelines are expensive and it is likely to make sense to combine them with other options such as gas-by-wire or small-scale compressed natural gas or LNG solutions to reach small and more remote and widely dispersed markets that do not currently justify larger-scale pipeline developments.

Hydrocarbon investment can also catalyse the development of other infrastructure. For example, upstream oil and gas require electricity and could serve as an anchor load to increase the viability of new power infrastructure. Mining facilities also typically require new transport links, and could help spur new road or rail infrastructure. Major projects can also be an opportunity to develop new local supply chains and industries, an aim often pursued by local content clauses, with the potential to bring long-lasting value to local economies.

Manage hydrocarbon revenues to finance sustainable economic development

As discussed in Chapter 1, there are considerable risks for producers when national budgets are heavily dependent on hydrocarbon revenues. The extent of these risks depends on which pathway the energy sector follows, in particular with regard to future demand levels and prices (Figure 4.14).

Figure 4.14 ⊳ Average annual net income from oil and natural gas production by scenario in sub-Saharan Africa



Average net income rebounds in the Stated Policies Scenario, while it remains relatively flat in the Lower Revenue Case

Notes: Net income from oil and gas is defined as the difference between the costs of oil and gas production, including a normal return on capital, and the value realised from its sale on either domestic or international markets. This net income changes over time and between various scenario projections, depending on the cost and volume of production, as well as both the international and domestic price, including any applicable energy subsidies.

Looking at the trends for individual countries and regions, projected net oil and gas income for producers in sub-Saharan Africa is generally higher by the end of the outlook period in the Stated Policies Scenario, but the trend is not a linear one and net income projections for oil and gas ultimately follow different trajectories (Table 4.2). In the near term to 2025, oil producers in sub-Saharan Africa suffer for two main reasons. First, the oil market remains well-supplied due in large part to US shale, which exerts downward pressure on prices. Second, the slowdown in investment since 2014 and rapid declines in maturing fields begins to bite, resulting in lower production. As a result, Nigeria and Angola receive on average 20% and 30% less annual income from oil output to 2025 than they did on average from 2010 to 2018. Small producers are hit much harder – producers in Central Africa (e.g. Cameroon, Chad, Congo and Equatorial Guinea) receive 40% less revenue.

By the mid-2020s, net oil income for producers in sub-Saharan Africa starts to rebound in the Stated Policies Scenario, as the effects of an anticipated near-term pickup in investment come through, US oil production plateaus and the market once again has more room for conventional supply. However, production in Nigeria and Angola remains relatively low and this is only offset in part by the rise of emerging African producers, meaning that net oil income for sub-Saharan Africa as a whole is just below its 2010-18 levels over the *Outlook* period. In the Lower Revenue Case (where global oil demand and prices are substantially lower because of stronger action in support of climate goals, in line with the objectives of the Paris Agreement) oil production in sub-Saharan Africa declines by almost 40% over the projection period, and the average net income of oil producers in sub-Saharan Africa is 45% lower than in the Stated Policies Scenario.

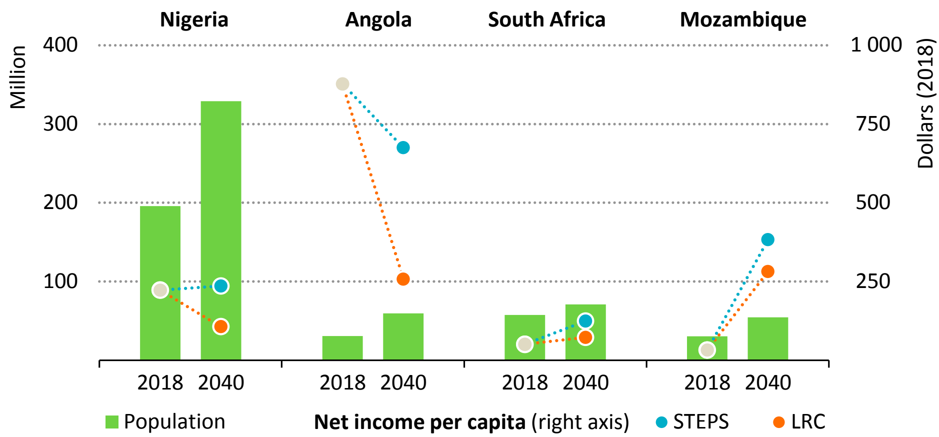
Table 4.2 ▷ Average annual net income from oil and natural gas by scenario and by country in Africa ($2018 billion)

	Oil & gas	Oil				Natural gas			
		Stated Policies Scenario		Lower Revenue Case		Stated Policies Scenario		Lower Revenue Case	
	2010-2018	2019-2025	2026-2040	2019-2025	2026-2040	2019-2025	2026-2040	2019-2025	2026-2040
Sub-Saharan Africa	123	83	114	67	54	19	40	18	35
Angola	36	25	31	20	14	2	3	2	3
Mozambique	1	0	2	0	1	3	13	3	11
Nigeria	54	37	52	29	24	10	13	10	11
Tanzania	0	0	1	0	1	0	3	0	3
South Africa	3	3	5	3	3	0	1	0	1
North Africa	61	33	57	28	30	16	21	19	37
Algeria	38	17	20	14	12	10	11	11	17
Libya	16	14	33	11	13	1	6	1	4
Africa	**184**	**116**	**171**	**95**	**85**	**35**	**61**	**37**	**72**

Natural gas is less lucrative than oil but our projections suggest that it may offer more stable revenues. Although pressure from US shale affects gas as well as oil, robust global demand for gas means that, overall net income in sub-Saharan Africa grows steadily over the projection period in the Stated Policies Scenario. The downside in the Lower Revenue Case is also less pronounced, offering some comfort to emerging producers such as Mozambique. In general, those with more gas in their portfolio fare better than those countries dependent on oil. For big oil producers such as Nigeria and Angola, cumulative net income declines by roughly 40% relative to the Stated Policies Scenario, among gas producers, in Mozambique cumulative net income declines by 20%, while it declines by 15% in Tanzania.

There are two other important points in the context of our projections for net income. The first is that there is a risk – especially for oil – of substantial volatility in market conditions and prices, which implies continued difficulties for fiscal management. The second is that producer economies in sub-Saharan Africa will need to contend with a growing population and the need to create more jobs (see Chapter 1). By 2040, there will be almost 750 million more people in sub-Saharan Africa than today. Nigeria alone accounts for almost 20% of the increase. Beyond considerations of employment, population growth also affects net income from oil and gas when calculated on a per-capita basis (Figure 4.15). This underlines the importance of ensuring that revenues from oil and gas are well managed if sub-Saharan Africa is to attain its development objectives.

Figure 4.15 ⊳ Population and oil and gas net income per capita by scenario for selected African countries, 2018 and 2040



Growing population dwarfs the increase in net income from oil and gas production; the impacts are amplified in the Lower Revenue Case

Note: STEPS = Stated Policies Scenario; LRC = Lower Revenue Case.

Deciding how and when to allocate revenues generated from oil and gas is a challenge: many countries have pressing and immediate investment needs alongside the need to diversify the economy. To manage vulnerabilities and avoid inefficient spending, each country will need to develop a revenue management plan tailored to its own situation. Such plans could include fiscal rules and a sovereign wealth fund (SWF) (Box 4.2), and should include arrangements to ensure oversight of and transparency about resource revenue flows and expenditure. Assessments of oil and gas revenue management among sub-Saharan African economies indicate that most remain very vulnerable to commodity market cycles, although the examples of Cameroon and Ghana highlight what can be done.[8]

[8] Scoring based on 2017 Resource Governance Index from Natural Resource Governance Institute.

Public debt remains a significant problem despite the fact that almost half of the countries in sub-Saharan Africa have fiscal rules in place to manage spending and borrowing, and balance the budgets (Natural Resource Governance Institute, 2019).

Box 4.2 ▷ Role of sovereign wealth funds in sub-Saharan Africa

One often-used tool for revenue management is a sovereign wealth fund which can help counter-balance volatile commodity prices and diversify revenue streams**.** In general, these funds are designed as saving accounts to put money aside for future use; as buffers to support public sector financing during times of reduced oil and gas income; and as vehicles to help support economic diversification by investing in domestic infrastructure and sectors. For example, Senegal's Fonds Souverain d'Investissements Strategiques (FONSIS) has played an important role in scaling up solar PV projects in the country

In Africa, the rise of SWFs is a relatively recent phenomenon; half of them have been established in the last six years (Hove and Ncube). Some countries set up a fund as soon as they discover resources to help manage expected but yet unrealised revenue (although there is also a tendency for some countries to run into difficulties by increasing expenditure well in advance of future revenue, a phenomenon which has been called the "pre-source curse").

But a SWF may not always be an optimal solution, and there is a risk of "premature funds" in countries with limited savings and high levels of debt. Some countries have funds that are small in comparison to public debts. For example, Ghana's public debt in 2014 was 40-times the size of its savings fund, with the rate of return on savings insufficient even to service the interest rate on its debt (Bauer and Mihalyi, 2018). Others, such as Kenya, Tanzania and Uganda have either set up funds or are considering it despite the fact that revenues are unlikely to provide a significant share of fiscal revenues in the future. This raises the question of whether the money would be better spent to reduce debts, invest in infrastructure or address economic and structural deficiencies. The effectiveness of any such spending will however depend on the administrative capacity to identify and implement the projects that can bring the best economic and social returns.

4.3.3 Conclusions

Africa's resource wealth represents both an opportunity and a risk. Faced with multiple social and economic challenges and a major infrastructure deficit, resource-rich African countries are unlikely to forego the chance to develop valuable domestic resources. But extracting value from Africa's resource wealth requires the establishment of sound, stable and transparent regulatory and fiscal regimes, and the right institutions and practices to implement them. This is all the more important in an environment where there are significant uncertainties over prices and future market conditions.

In the Africa Case, it is assumed that many of the above-ground challenges currently impeding production are eased. This, alongside higher domestic demand and economic growth, helps make projects in sub-Saharan Africa more competitive globally and encourages investment from prospective investors. As a result, oil and gas production in sub-Saharan Africa is over 10% and 25% higher in 2040 than in the Stated Policies Scenario. While a higher volume of produced hydrocarbons is directed towards domestic markets, the average annual net income for oil and natural gas from 2019-40 is still 10% higher than in the Stated Policies Scenario. Translating higher income into sustained economic growth requires continued efforts to ensure transparent revenue management, along with prudent investment in infrastructure aimed at increasing and diversifying economic growth.

Implications for Africa and the world

5.1 Introduction

How the African energy system evolves over the next two decades, and what it will look like in 2040, are vitally important questions not only for Africa but also the rest of the world. The future pathway is far from certain but, whatever the policy choices, the implications of those choices will resonate throughout Africa and beyond. We have outlined possible pathways for the continent's energy development to 2040 as described in detail in Chapters 2, 3 and 4. These pathways are based on an in-depth, sector-by-sector and country-specific analysis of Africa's energy sector opportunities: to the best of our knowledge, this is the most comprehensive such analysis undertaken to date.

The chapter consists of two sections:

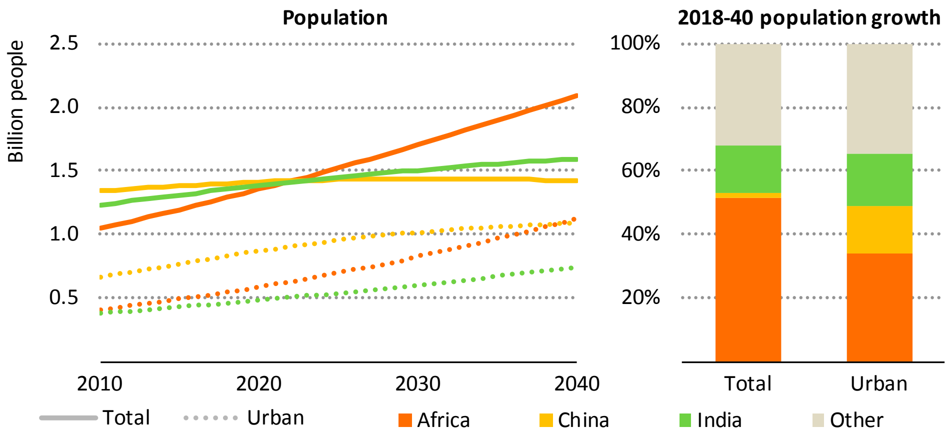
- **A discussion of the policy implications and outcomes of the analysis in the global context**: This section provides a brief summary of what the future might hold for Africa's energy sector, and what it might mean for global energy and emissions trends, looking in particular at two scenarios. The first is the Stated Policies Scenario, which takes account of existing plans and announced intentions, and the second is the Africa Case, which is based on the Agenda 2063 vision agreed by African leaders (see Box I.2 in the introduction).
- **Detailed regional and country energy profiles**: The second part presents the results of the Stated Policies Scenario and Africa Case for sub-Saharan Africa as a whole as well as for eleven countries in this region: Angola, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania. The countries covered represent three-quarters of sub-Saharan Africa's gross domestic product (GDP) and energy demand today, and two-thirds of population. The profiles aim to provide decision makers with a data-rich set of information on the potential energy pathways for each country, considering their unique energy demand and supply needs and stages of development.

5.2 Implications for the world

Africa's population is among the fastest growing and youngest in the world, and this trend is set to continue in the period to 2040. One-in-two people added to the world population by 2040 are African, and a third of global urban population growth occurs in Africa (Figure 5.1).

Over the next 20 years, total population growth in Africa is more than double the combined population growth of China, India and Southeast Asia. In the coming years, Africa overtakes both China and India in terms of total population. This large increase (mostly occurring in cities) will be a major force driving Africa's energy demand growth.

Figure 5.1 ▷ Total and urban population in Africa, China and India, and share in global growth, 2018-2040



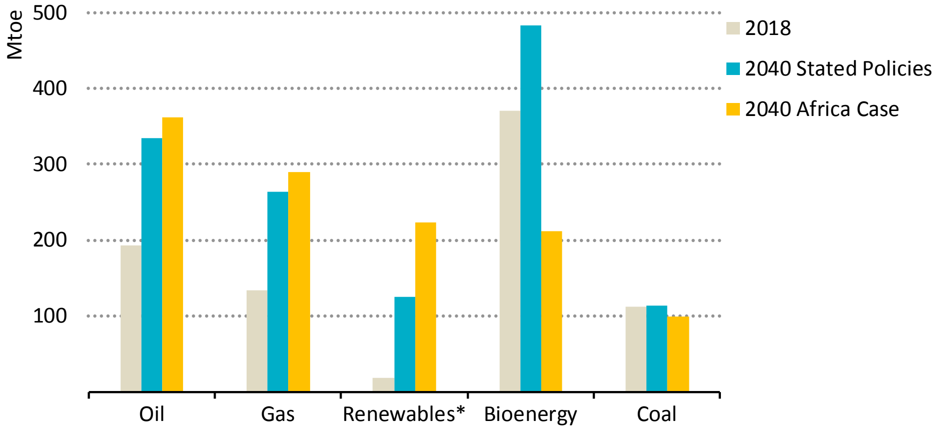
One-in-two people added to the world population and one-in-three people added to urban populations in the period to 2040 are African

5.2.1 Africa as a key driver for global energy demand growth

A rapidly rising population and growing pace of urbanisation make Africa a key driver of global energy demand growth. In the Stated Policies Scenario, total primary energy demand in Africa grows by 2% per year between 2018 and 2040, double the pace of global demand growth. At the same time, the composition of energy consumption in Africa increasingly moves away from the traditional use of biomass to modern and more efficient energy sources, notably electricity, natural gas and oil products.

Effective energy policy choices are essential not only to bring to fruition the continent's growth ambitions (including those contained in Agenda 2063), but also to support other economic and developmental goals. These goals include building a sustainable energy system, managing the rapid pace of urbanisation, scaling up industrial capacity and maximising the value of the continent's natural resources. As a tangible representation of the Agenda 2063 vision, the Africa Case incorporates policies to build the African energy sector in a way that allows higher economic growth to be sustainable and inclusive. It shows that achieving the goals of Agenda 2063 does not necessarily require more energy-intensive economies, compared with the Stated Policies Scenario. There is a considerable reduction of bioenergy use in the Africa Case, and growth in demand for other sources of energy is moderated by strong efficiency improvements. There is also a significant increase in electricity demand, but additional demand is mostly met by renewables. As a result, overall primary energy demand in 2040 in the Africa Case is 10% less than in the Stated Policies Scenario (Figure 5.2).

Figure 5.2 ▷ Total primary energy demand by fuel and scenario in Africa



Achieving the outcome of the Africa Case adds only marginal amounts to demand for oil and gas relative to the Stated Policies Scenario while reducing the use of bioenergy

* Excludes bioenergy.

Africa emerges as a key source of **global oil demand** growth in our projections. At present, car ownership levels in Africa – especially in sub-Saharan Africa – are very low (in Ethiopia, for example, less than 2-out-of-1 000 people own a car). Oil demand grows as the size of the car fleet expands, and as liquefied petroleum gas (LPG) is increasingly used for clean cooking.

In the Stated Policies Scenario, the size of the car fleet in Africa more than doubles by 2040. This contributes to an increase of oil demand by 3.1 million barrels per day (mb/d) over the period, higher than the projected growth in China and second only to that of India. However, average car ownership levels in sub-Saharan Africa (excluding South Africa) in 2040 are still equivalent only to 60% of the level in India today. The lack of policies both for new and second-hand vehicles means that most cars have low fuel efficiency and are not subject to emissions standards that are common in many parts of the world.

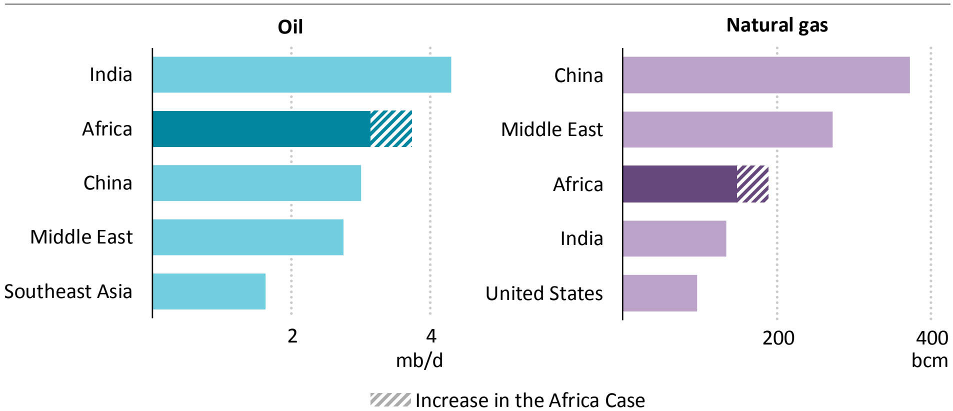
In the Africa Case, the number of cars increases further to nearly 80 million by 2040, but improved vehicle efficiency offsets the expansion of car stocks and the numbers of kilometres driven. An increase in oil demand in this scenario relative to the Stated Policies Scenario is rather driven by the residential sector, where progress towards clean cooking creates additional demand for LPG.

Africa's growing weight is also felt in **natural gas markets**. The combination of renewables and natural gas provides a good fit for the development vision that African leaders signed up to in Agenda 2063. In the power sector, natural gas can help satisfy the growing appetite for baseload electricity and complement the rapid expansion of renewables, especially in those countries with large gas resources. There are also many energy uses that are hard to electrify (for example, industrial processes such as steel making) that are likely to see demand growth as African industry supports the continent's growth in urbanisation and infrastructure. In many cases, the choice for these uses is between gas and other (more polluting) fossil fuels rather than between gas and renewables.

The challenges for natural gas development relate to infrastructure, affordability and business models. A number of major gas discoveries (representing over 40% of global gas discoveries between 2011 and 2018) have been made in recent years, but the extent to which they will provide fuel for African development, as well as revenue from export, is uncertain. Making the most of these resources would require new pipeline infrastructure, although small-scale liquefied natural gas (LNG) technologies are allowing a new approach to distribute gas to consumers. Much will depend on the strength of Africa's policy push to displace polluting fuels from its energy mix, or to prevent them gaining a stronger foothold, and on the availability of finance to support the expansion of gas infrastructure.

In the Stated Policies Scenario, the share of gas in sub-Saharan Africa's energy mix rises from 5% today (one of the world's lowest) to just under 10% in 2040. In the Africa Case, it reaches almost 20% in 2040. In both scenarios, Africa becomes the third-largest source of additional gas demand globally between today and 2040, following China and the Middle East (Figure 5.3). Thanks to the emergence of new producers, notably Mozambique, Tanzania, Senegal and Mauritania, Africa also strengthens its position in global export markets.

Figure 5.3 ▷ Growth in oil and natural gas demand by region in the Stated Policies Scenario and Africa Case, 2018-2040



Africa emerges as a key source of demand growth for oil and natural gas. The growth in oil demand is second only to India; the growth in gas demand is the third-largest in the world

Reliable electricity supply plays a central role in meeting rising energy demand in Africa. Electricity demand in Africa is set to increase strongly, more than doubling from 700 terawatt-hours (TWh) today to over 1 600 TWh in 2040 in the Stated Policies Scenario and to 2 300 TWh in the Africa Case. Renewables make a major contribution to the additional generation required. Falling costs drive the fast deployment of utility-scale and distributed solar photovoltaics (PV), and deployment of geothermal and wind also picks up sharply: in the Stated Policies Scenario, the combined contribution of these non-hydro renewable resources increases from less than 5% today to around 30% of Africa's total power generation in 2040. Hydropower also remains a cornerstone of sub-Saharan Africa's power system – notably in the Democratic Republic of the Congo (DR Congo), Ethiopia and Mozambique – and generation almost triples by 2040. Better regional co-operation and integration of power networks is instrumental in unlocking hydropower's huge potential.

The scale of deployment of non-hydro renewables is even more significant in the Africa Case. A large part of this comes from solar PV, which overtakes hydropower and natural gas to become the largest electricity source in Africa in terms of installed capacity (and the second-largest in terms of generation output). Solar PV deployment between today and 2040 amounts to almost 15 gigawatts (GW) a year, equivalent to the amount of solar PV capacity the United States adds every year over the same period. Wind also expands rapidly in several countries benefiting from high quality wind resources, notably Ethiopia, Senegal and South Africa, while Kenya is at the forefront of geothermal deployment. The growth in overall renewable-based electricity generation in African countries is higher than in the European Union (Figure 5.4).

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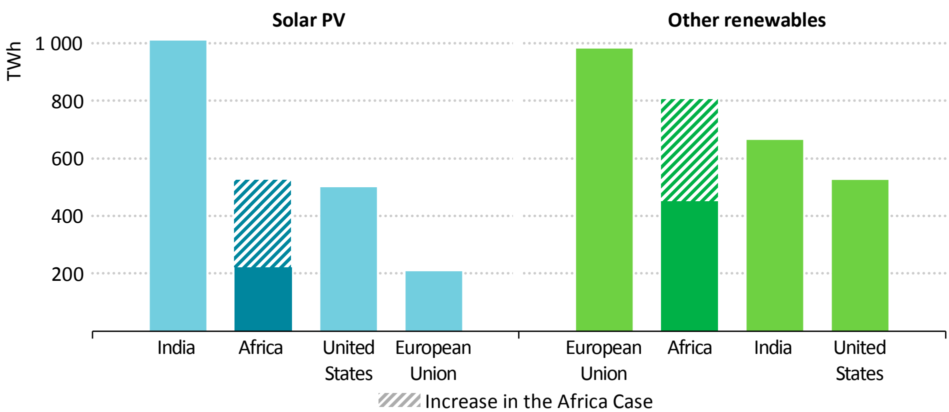
Figure 5.4 ▷ Growth in renewables-based electricity generation in selected regions, 2018-2040



Renewables account for three-quarters of additional electricity generation in the Africa Case, and bring Africa to centre stage in global renewables markets

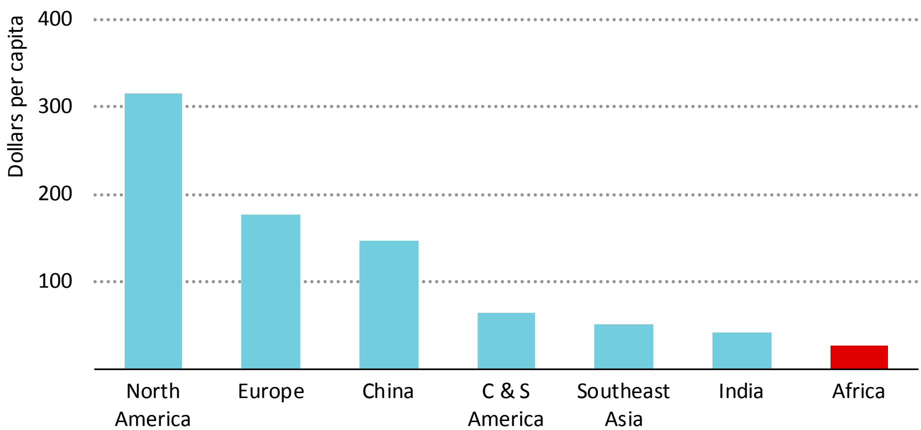
Note: Other renewables include hydro, wind, geothermal, concentrating solar power and biomass.

Achieving this level of deployment would require the development of efficient supply chains and the physical infrastructure necessary to facilitate smooth trade in goods and technologies between countries (as envisaged in the African Continental Free Trade Area). A favourable regulatory environment which reduces risks and the cost of finance would also be essential, as would the technical capacity to underpin a large-scale installation and maintenance sector.

5.2.2 Mobilising investment for reliable power: challenging but achievable

Africa needs to expand its energy infrastructure, especially in the power sector, to serve its growing population. Despite being home to 17% of the world's population, Africa currently accounts for just 4% of global power supply investment. On a per capita basis, power supply investment in Africa ranks among the lowest in the world (Figure 5.5). In sub-Saharan Africa, power generation capacity per capita has shown little or no growth since 1990 while that of India and Southeast Asia has grown fourfold.

Figure 5.5 ▷ Per capita power supply investment by region, 2018



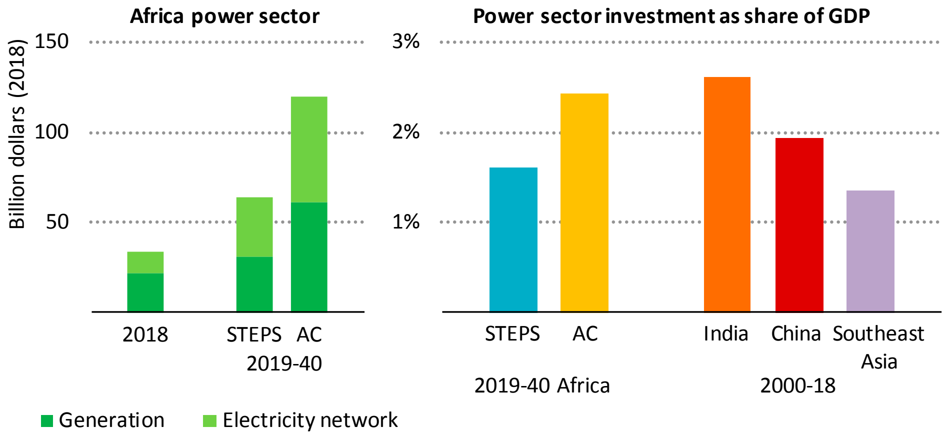
Africa's per capita investment in power supply ranks among the lowest in the world

Note: C & S America = Central and South America.

Addressing the deficit of power infrastructure in Africa will require a significant ramp-up in spending. Investments in power supply need to double through to 2040 in the Stated Policies Scenario to around $65 billion per year. The Africa Case requires a further doubling to around $120 billion per year to ensure reliable and affordable power for all and to serve an economy growing at over 6% a year. Nigeria, South Africa, DR Congo and Ethiopia are among the countries with the highest investment needs. Half of the investment is needed to expand and upgrade electricity networks – including mini-grids – and most of the rest is needed to increase low-carbon generation capacity where solar PV plays an important role. Investment needs in solar PV in sub-Saharan Africa amount to almost $25 billion per year on average in the Africa Case – almost double the level of investment in the European Union today.

The cumulative investment in Africa's power supply between 2019 and 2040 reaches $1.4 trillion in the Stated Policies Scenario (1.6% of the continent's GDP over the same period) and $2.6 trillion in the Africa Case (2.4% of GDP). Mobilising these levels of investment is a significant undertaking, but it is achievable if concerted efforts are made by African governments and the global community. There are some precedents. India, for example, has invested the equivalent of 2.6% of GDP in the power sector since 2000 and China has invested 1.9% of GDP over the same period (Figure 5.6).

Figure 5.6 ⊳ Average annual power supply investment in Africa by scenario and historical power sector investment in selected regions



Scaling up power supply investment is challenging but achievable if concerted efforts are made to establish a favourable investment climate and reduce investment risks

Notes: STEPS = Stated Policies Scenario; AC = Africa Case.

To date, investment in power supply in Africa has relied largely on state budgets with significant contributions from development finance institutions (DFIs). The prominent role of these public sources is likely to continue. Against a backdrop of growing fiscal deficits in many countries and tightening donor resources, however, it is critical that public spending is supplemented by private capital and that funding from DFIs is used to catalyse private financing.

Mobilising private capital requires concerted efforts from both African governments and international DFIs. A large number of countries in Africa limit private participation in the power sector: 16-out-of-43 sub-Saharan African countries do not allow private participation in both generation and electricity networks. Establishing a framework for private capital is clearly a necessary first step. Many of the utilities are loss-making and have low operational efficiency: 19-out-of-39 utilities in sub-Saharan Africa are not able to recover enough cash to cover operational expenses (Kojima, 2016). Together with below-cost tariffs and low collection rates, this raises investment risks and makes it difficult to secure financing at affordable costs. Improving the financial and operational performance of utilities and moving towards cost-recovery are therefore essential to attract financing. Robust procurement frameworks (using competitive auctions, for example) and well-designed contracts are also crucial to enhance project bankability.

There is scope for international DFIs to help scale up investment and catalyse more private capital. Between 2013 and the first half of 2018, power sector investments based on private participation in infrastructure models in sub-Saharan Africa amounted to around $4.5 billion per year on average (less than 10% of the annual power sector investment needs between today and 2040), with South Africa accounting for more than half. Outside South Africa, each dollar of public funding (from DFIs and state budgets) attracted $0.6 of private capital either directly (via equity and direct loan) or indirectly (via guarantee) – the figure is $0.4 for renewables. This compares unfavourably with $0.9 for Southeast Asia and more than $4 for South Africa. It is therefore important for international DFIs not only to scale up direct investments but also to encourage private sector investment through targeted interventions (such as risk sharing, liquidity support and take-out financing). There is also a need to nurture the local financial sector to provide a sustained flow of long-term financing to infrastructure projects.

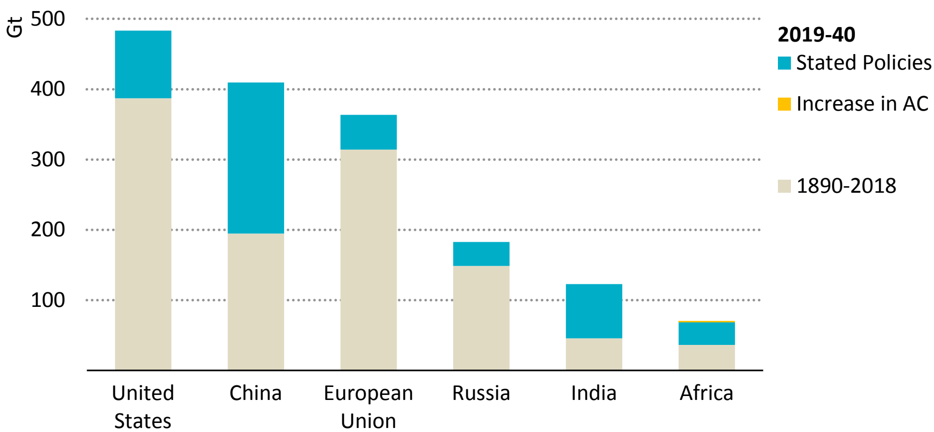
The prospects for Africa's power supply investment will be stronger if governments in African countries take account of what have worked well (and what have not) in other countries. India provides some instructive lessons. In the 2000s, the Indian government introduced a number of measures to establish a policy and regulatory framework to attract private capital, including model architecture for public-private partnerships (PPP) and financial instruments (such as an on-lending facility) to induce local financial institutions to invest in infrastructure. This contributed to a significant scale-up of private investment in power infrastructure and India was recognised as the highest recipient of PPP investments worldwide (World Bank, 2015). However, scrutiny of the commercial viability of projects was sometimes insufficiently rigorous, there were frequent construction delays, and the availability of fuel was often limited: this led to many projects performing less well than expected, and emphasises that there are potential pitfalls to manage even where the overall framework is a strong one.

5.2.3 Not a major emitter, but climate change matters greatly for Africa

Africa has not been a significant contributor to global greenhouse gas (GHG) emissions during the age of industrialisation. Energy-related carbon dioxide (CO_2) emissions in Africa accounted for only 2% of global cumulative emissions from 1890 to today (Figure 5.7). Although Africa experiences rapid economic growth in the Stated Policies Scenario (by two-and-a-half times from today to 2040), its contribution to global energy-related CO_2 emissions increases to just 4.3% over the period to 2040.

Realising the outcomes in the Africa Case would increase total CO_2 emissions over the period to 2040 by around 2 gigatonnes (Gt) (or 100 million tonnes (Mt) per year) relative to the Stated Policies Scenario, raising Africa's contribution to 4.5%. Although this is not a major increase globally, it is highly desirable – and in line with the vision in Agenda 2063 – that they are attained in a way which takes full account of the importance of sustainability, with a very strong role for clean energy sources. Looking beyond CO_2, the transition away from the inefficient combustion of biomass for cooking in the Africa Case leads to same levels of GHG emissions as in the Stated Policies Scenario as the increase in CO_2 emissions is offset by reductions in other GHGs (methane and nitrous oxide).

Figure 5.7 ▷ Cumulative energy-related CO_2 emissions by region and scenario



Africa has accounted for a very small share of global CO_2 emissions to date, and that does not change to 2040

Note: AC = Africa Case.

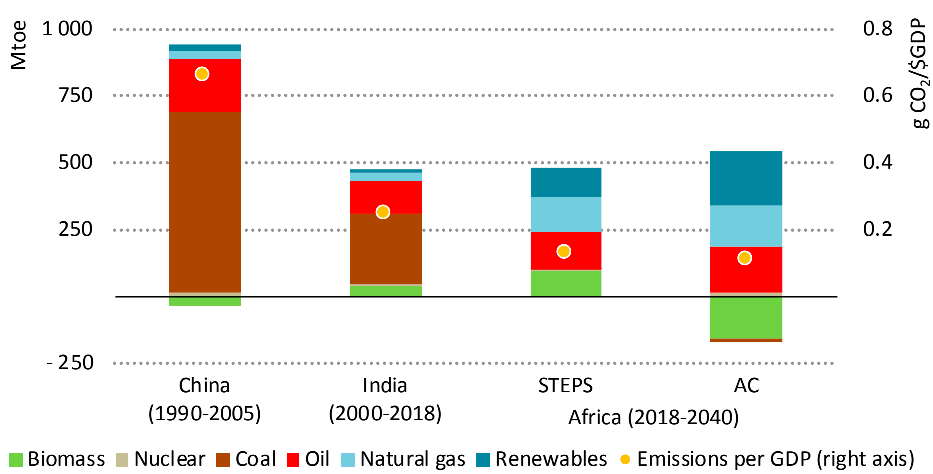
Thanks to technology improvements and resource endowments, Africa has the opportunity to pursue a much less carbon-intensive model of development than seen in many other parts of the world. For example, China relied heavily on coal (and oil to a lesser extent) to replace bioenergy and meet rapidly growing energy demand between 1990 and 2005 when its economy registered a fourfold growth. This resulted in cumulative emissions of around 50 Gt CO_2, meaning that China incurred around 660 grammes of carbon dioxide (g CO_2) emissions to generate one dollar of GDP over this period. India has similarly relied on coal, oil and (to a lesser extent) natural gas to serve its expanding economy over the two decades since 2000. This was accompanied by cumulative emissions of around 28 Gt CO_2 or 250 g CO_2 per dollar of GDP.

In our projections, however, Africa follows a different pathway, with much stronger shares of renewables and natural gas in the energy mix. In the Stated Policies Scenario, the share of renewables (excluding bioenergy) and natural gas grows significantly to 10% and 20% respectively by 2040, while the reliance on traditional uses of bioenergy and coal diminishes. As a result, only 130 g of CO_2 emissions are incurred to generate one dollar of GDP between today and 2040, while the economy grows at a rate of 4% per year.

In the Africa Case, the size of the economy almost quadruples in the period to 2040, but the continent consumes less energy overall with a higher share of cleaner energy sources. The shares of renewables and natural gas expand further to 20% and 25% by 2040, while the share of traditional uses of bioenergy declines. The emissions associated with economic growth are 15% lower in this case, at around 110 g CO_2 per dollar of GDP (Figure 5.8). These emissions relative to economic growth are lower than the figures observed in advanced economies between 2000 and 2018.

With the appropriate policies to support a strong expansion of clean energy and sufficient emphasis on energy efficiency improvements, Africa could be the first continent to achieve a significant level of industrialisation with cleaner energy sources playing a prominent role, requiring much less energy and emissions to deliver economic growth than other economies in the past.

Figure 5.8 ▷ Changes in primary energy demand by fuel and associated emissions per GDP in China, India and Africa



Africa could be the first continent where renewables and gas play a prominent role in supporting a shift away from bioenergy and underpinning economic and industrial growth

Notes: STEPS = Stated Policies Scenario, AC: Africa Case. Emissions per GDP = cumulative CO_2 emissions / cumulative GDP during the indicated period. Renewables exclude bioenergy.

While Africa is responsible for a relatively small portion of global CO_2 emissions, its ecosystems already suffer disproportionately from global climate change, and future impacts are expected to be substantial. The continent therefore not only needs to adapt to the warming already experienced but also to prepare for the intensification of climate change impacts (World Bank, 2018). Temperatures in Africa are likely to rise faster than the global average during the 21st century. Climate change and climate variability are likely to multiply existing threats and pose increased risks to food, health and economic security in Africa (IPCC, 2014).

This underlines the importance of ensuring that new infrastructure in Africa is climate-resilient. For example, only 30% of the buildings that are likely to exist in 2040 have already been built. If building codes are implemented for new buildings to optimise the use of natural light and ventilation for passive cooling, this could reduce the need for cooling systems (fans and air conditioners) and avoid the potential heat islanding effects that could occur in cities (see Spotlight in Chapter 2). Today, a quarter of the global population living in areas that are hot enough to require cooling systems live in Africa, and this share increases to 30% by 2040 in all scenarios. As new cities are built or existing cities grow larger, smart planning is essential to ensure that buildings are highly energy efficient and to facilitate sustainable modes of public transport.

Climate change is also likely to affect the availability of hydro resources. Detailed new analysis in this report shows the negative impacts of climate change on the availability and variability of hydropower outputs in a number of countries. While hydropower remains an essential element of sub-Saharan Africa's electricity supply, diversifying the electricity mix would help to mitigate the risk of power disruptions during droughts and strengthen resilience to changing climate conditions.

In contrast to many other regions, the energy sector is not the biggest contributor to total GHG emissions in Africa. It represents around a third of total GHG emissions (compared to more than two-thirds at the global level). In sub-Saharan Africa (excluding South Africa), land use and forestry[1] (LULUCF), agriculture and waste contribute most towards total GHG emissions. The reduction in the size of Africa's forests, which are natural carbon sinks, is the primary reason for the growth of GHG emissions in Africa: some countries have seen their forest area decrease by more than half over the last 25 years (Box 5.1), highlighting the importance of deforestation for climate policies.

While the ecological and environmental toll of reliance on fuelwood for cooking cannot be exactly quantified, the traditional use of solid biomass for cooking comes at a large cost to human health and wellbeing. Air pollution in Africa is one of the leading causes of premature deaths. Around 500 000 premature deaths are attributed to smoky indoor air arising from the use of solid biomass for cooking while 300 000 premature deaths are linked to outdoor pollution in cities.

In the Stated Policies Scenario, premature deaths owing to household air pollution decrease slightly over the outlook period as a consequence of efforts to bolster access to clean cooking through LPG stoves, improved biomass stoves or biodigesters. There is a much greater adoption of these cleaner technologies in the Africa Case: over 1.1 billion people move away from traditional use of solid biomass by 2030, and the number of premature deaths from household air pollution falls by two-thirds.

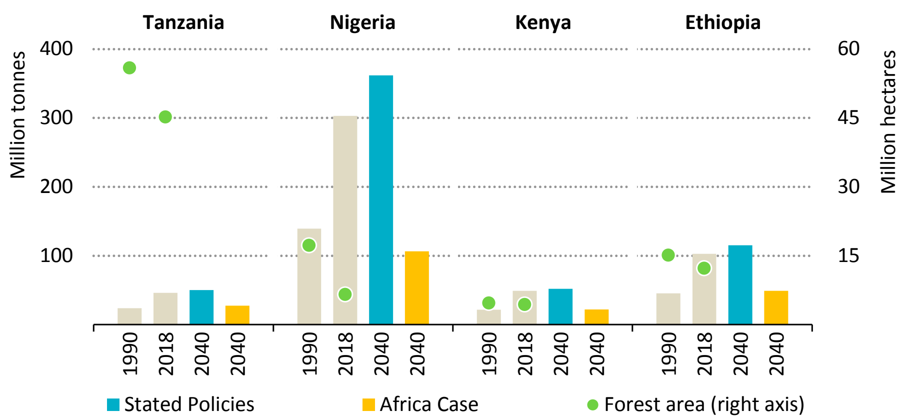
[1] LULUCF refers to land use, land-use change and forestry.

Box 5.1 ▷ Implications of unsustainable bioenergy use

Since 1990, the total forest area in Africa has fallen by 85 million hectares (ha), which is more than the total land area of Mozambique (Figure 5.9). Some countries have been more affected than others. For instance, Nigeria has lost 60% of its forest cover since 1990, while Tanzania and Ethiopia have lost almost 20% of their forest areas (FAO, 2019).

Conversely, fuelwood consumption (directly used by households for cooking or to produce charcoal) has doubled in sub-Saharan African countries (excluding South Africa) over the same period. While the relationship between deforestation and growing demand for fuelwood is difficult to quantify, efficiency improvements across the various bioenergy value chains could play a significant role in protecting forests, biodiversity and carbon sinks.

Figure 5.9 ▷ Fuelwood consumption in the Stated Policies Scenario and the Africa Case, and forest area in selected African countries



Making fuelwood consumption more sustainable is key to tackling deforestation in many sub-Saharan African countries

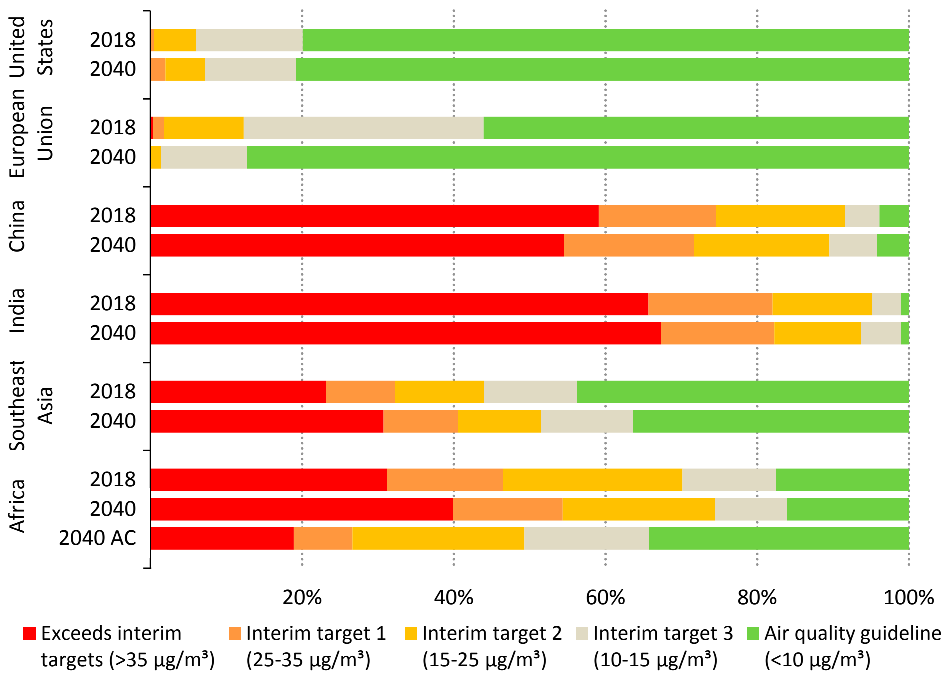
A number of countries have already made commitments to address deforestation in their updated Nationally Determined Contributions. Nigeria acknowledges the need to halt deforestation, conserve remaining natural forests and reverse forest degradation. Others, including DR Congo, have pledged to commit efforts to reforestation activities. Converting these ambitions into actions and extending them across the continent would make the African biomass industry more sustainable.

The increase in demand for energy services brought about by the fast-growing and rapidly urbanising population across the continent will have significant implications for air quality in cities. The increase in the overall level of air pollutant emissions in the Stated Policies

Scenario is not a surprise, given the exceptionally low baseline for current energy consumption. The mix of technologies and fuels chosen by consumers can however play an important part in mitigating the increase of pollutant emissions, which will ultimately have wide-ranging implications for the health and wellbeing for millions of people.

In the Stated Policies Scenario, sulfur dioxide (SO_2) emissions decrease by a quarter across Africa by 2040. There is an increase in industrial emissions but this is more than offset by a significant decrease in emissions from coal-fired power plants, mainly in South Africa. Emissions of nitrogen oxides (NO_X) increase by one-quarter, mainly from the incomplete combustion of fuels in cars, despite a significant fall in emissions in the power sector during the period to 2040. In the Africa Case, improved emissions standards for passenger vehicles result in emissions from this segment falling, despite the increased number of cars on the road.

Figure 5.10 ▷ Population exposed to fine particulate pollution ($PM_{2.5}$) **in selected regions in the Stated Policies Scenario and Africa Case**



Proportion of the population in Africa exposed to high levels of $PM_{2.5}$ pollution drops in the Africa Case and remains lower than in some Asian countries in the Stated Policies Scenario

Notes: AC = Africa Case; µg/m³ = micrograms per cubic metre. Interim targets and Air Quality Guideline refer to World Health Organization exposure thresholds.

Source: International Institute for Applied Systems Analysis

Higher emissions of NOx and $PM_{2.5}$ also take a considerable toll on health and wellbeing. In the Stated Policies Scenario, the increasing concentration of $PM_{2.5}$ by 2040 means that the number of premature deaths associated with outdoor air pollution increases by almost 60%, reaching 480 000 in 2040. In the Africa Case, emissions of the three major air pollutants decline sharply from the current levels. Reduced exposure to $PM_{2.5}$ is particularly important: despite a significant increase in energy services, the number of premature deaths associated with outdoor air pollution in 2040 is almost 30% lower than in the Stated Policies Scenario.

5.2.4 Achieving sustainable development goals requires Africa's success

In many areas, global energy transition goals are closely linked to successful growth and development in Africa. The continent's economic and social prosperity are in turn closely linked to successful global energy transitions. Two examples highlight the interlinkages between the world and Africa: first, access to modern energy services; and second, Africa's role as a major supplier of the minerals necessary to achieve the global energy transition.

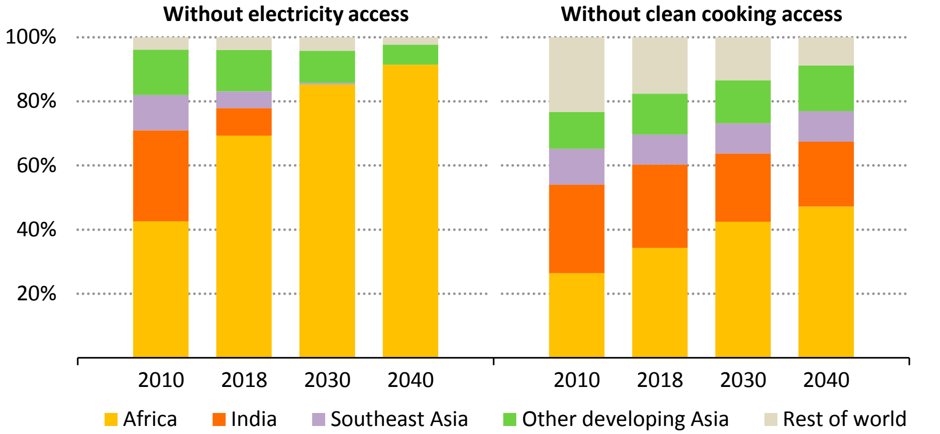
More than two-thirds of the world's population without access to electricity and around a third of the population without access to clean cooking live in Africa. By 2030 in the Stated Policies Scenario, most of the remaining population without access to electricity and clean cooking remain concentrated in Africa. Addressing energy access in Africa is therefore of paramount importance to solving this global concern.

Boosting energy access rates in Africa brings huge benefits in terms of reduced poverty, lower air pollution and increased economic prosperity. Access to electricity is crucial to the provision of essential services: in health centres, for instance, it is vital for the use of efficient modern equipment, the storage and preservation of vaccines and medicines, and the ability to conduct emergency medical procedures, for example during child birth. Access to clean cooking is essential to reduce the health impacts and the number of premature deaths related to household air pollution.

In the Stated Policies Scenario, around 20 million people are connected to the electricity network each year, which is less than a third of what would be needed to reach full access by 2030. By 2030, 85% of all people without access to electricity live in Africa (Figure 5.11). In DR Congo, for example, the projected number of people without access to electricity increases by 30% in this scenario, as policies fail to keep pace with population growth. Reaching full electricity access by 2030 as envisaged in the Africa Case requires a tripling of efforts to extend connection to over 60 million people each year. Reaching this level of access would need an additional push for decentralised renewables in the context of a comprehensive set of policies and investments that makes use of all available solutions, with mini-grids and stand-alone systems providing power to more than half of those gaining access by 2030. Energy efficiency also has an important part to play.

Delivering access to clean energy in an integrated way would also support economic growth and overall development. Research suggests that access could bring new avenues of productive employment to remote populations, particularly for women. In addition to freeing up time by speeding up domestic chores and giving women more time to engage in paid jobs, access to electricity can have a particular impact on female-owned businesses, helping them to transition from extreme poverty to near middle-class status, as shown recently in Ghana (Power Africa, 2019).

Figure 5.11 ▷ Share of population without access to electricity and clean cooking by region in the Stated Policies Scenario



Those without access to electricity and clean cooking are increasingly concentrated on the African continent

Moreover, electricity can also play an important role in improving agricultural productivity through advanced irrigation techniques, as several successful examples of stand-alone solar water pumps have demonstrated. Cold storage powered by renewable electricity could also reduce post-harvest losses of agricultural outputs, which are currently estimated at 20-50% of the food produced in sub-Saharan Africa (depending on the food type).

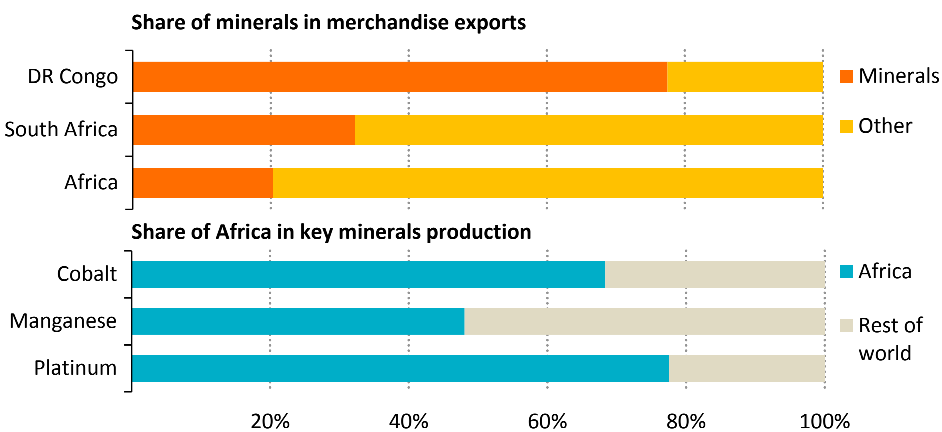
In the Stated Policies Scenario, Africa is one of the few regions where the number of people without access to clean cooking increases, as the expansion of clean cooking is unable to keep pace with rapid population growth, and around half of the global population without access to clean cooking in 2040 lives in Africa. There are exceptions: Ghana sees a visible improvement in this area, but many other countries are not set to emulate this example. While urbanisation increases the use of alternative options such as LPG and natural gas in many regions, solid biomass (in the form of charcoal) remains the preferred option for cooking in African cities. The Africa Case sees all households across the continent gain access to clean cooking by 2030. This reduces significantly the number of premature deaths linked to indoor air pollution.

Resource development, minerals in particular, is another area where Africa and the world share a common interest. From cobalt and manganese for batteries to chromium and neodymium for wind turbines, and to platinum for hydrogen fuel cells, minerals are a critical component in many clean energy technologies. As energy transitions accelerate, demand for minerals is set to grow significantly. For example, demand for cobalt from deployment of electric vehicles increases to around 170 kilotonnes per year (kt/year) in 2030 in the Stated Policies Scenario, higher than today's supply capacity, and to almost 360 kt/year in the case of higher electric vehicle uptake (IEA, 2019). Africa is a major producer of many of these minerals: DR Congo accounts for two-thirds of global cobalt production and South Africa produces 70% of the world's platinum.

In 2017, net income from mineral production was equivalent to around 2% of sub-Saharan Africa's GDP and minerals accounted for some 20% of total merchandise exports in Africa (77% in the case of DR Congo). Rising demand for minerals means that successful global energy transitions offer an opportunity for economic growth in mineral-rich countries in Africa. For example, if DR Congo were to maintain today's share in global production, growing global demand for cobalt would bring additional revenue of $4-8 billion to the country in 2030 (based on today's prices), equivalent to around 3-6% of the country's projected GDP in that year.

However, there are large question marks over whether African countries can keep up with rising global demand in a timely and sustainable manner. Current practices are often inefficient, polluting and subject to social protests. Given that African countries account for a large proportion of the global production of key minerals, failure to keep up with demand could not only hamper Africa's economic outcomes but also hold back the pace of global energy transitions (Figure 5.12).

Figure 5.12 ▷ Composition of Africa's merchandise exports, 2017, and key minerals production, 2018



Responsible and sustainable development of Africa's mineral resources is vital for Africa's economic prosperity and global energy transitions

Source: IEA analysis based on UNCTAD Stats (2019) and USGS (2019).

Putting in place structures and governance arrangements to ensure responsible minerals development would help guard against a range of potential problems. Robust regulatory and oversight mechanisms would be needed to ensure that impacts on local environments are minimised and that revenues are used in a transparent manner. There is also a need for careful scrutiny of how minerals are sourced and how supply chains are managed. Those who use minerals can play a helpful role, as can international financial institutions. For example, BMW, BASF and Samsung recently launched a pilot initiative to support sustainable and fair cobalt mining in DR Congo, which aims to improve working and living conditions for small-scale mining operations and surrounding communities. The World Bank has launched the Climate-Smart Mining Facility to help minimise the environmental and climate impacts of mining activities. As in so many other areas, the future of Africa's development and the prospects for global sustainable growth are closely interlinked.

Regional and country energy profiles

The following section presents the results of the Stated Policies Scenario and Africa Case for the sub-Saharan region as a whole as well as for the following eleven countries:

Together these eleven countries accounted for three-quarters of sub-Saharan Africa's gross domestic product (GDP), two-thirds of its population and three-quarters of its energy demand in 2018. The profiles presented in this section aim to provide decision makers with a data-rich set of information on potential energy pathways that reflect each country's unique energy demand and supply needs and regional characteristics. The policy, technology and economic assumptions that underpin both the Stated Policies Scenario and the Africa Case are described in the introduction to the *Special Focus* and discussed on a regional basis in Chapters 2, 3 and 4, with the implications presented in Chapter 5.

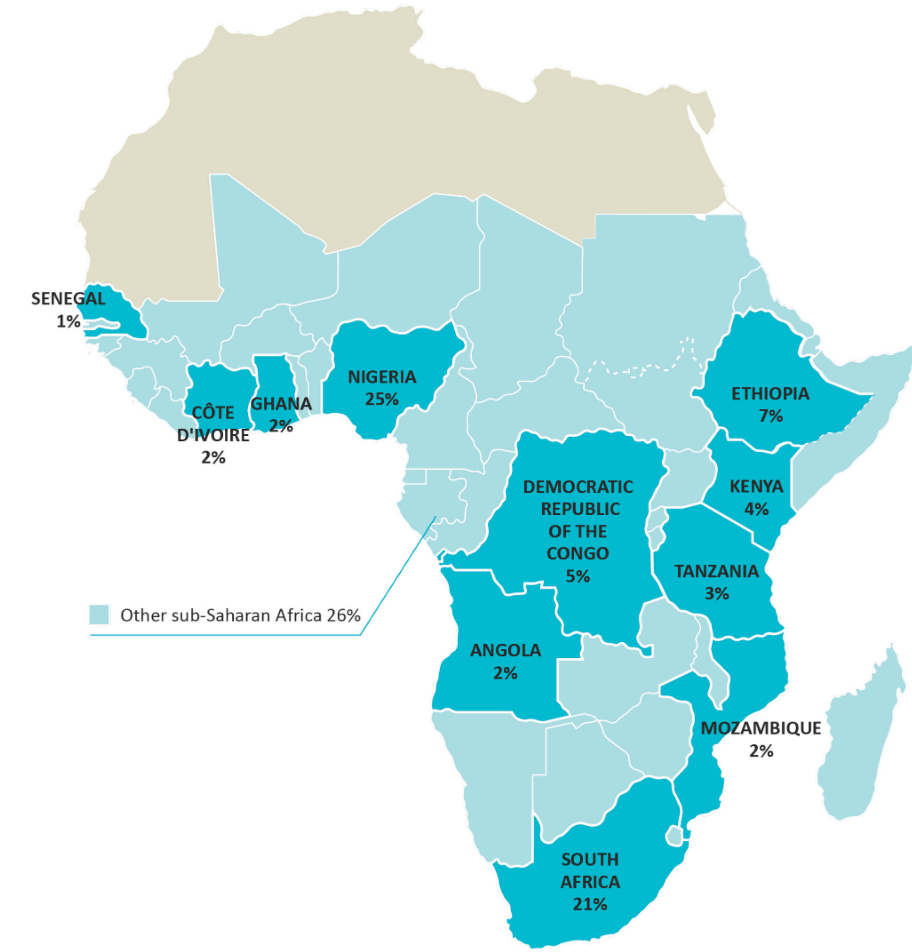
How to read the profiles:

We use a standard format to present the country and regional profiles. Each profile contains a set of figures and tables corresponding to the following categories:

- Key characteristics of the country's energy system.
- Major macroeconomic indicators, including GDP and population growth, carbon dioxide (CO_2) emissions and data for electricity access and clean cooking access by scenario.
- Description of energy-related policy initiatives, including specific performance targets.
- Outlook of how primary energy demand and GDP (based on GDP expressed in year-2018 dollars in purchasing power parity [PPP] terms) evolve to 2040 and the role of each fuel in delivering the alternative energy futures.
- View of how the electricity mix changes over time to meet growing electricity demand.
- Final energy consumption by scenario, showing the potential efficiency gains achieved by implementing more stringent fuel economy standards, building codes, equipment and appliance efficiency requirements.

- Fuel and technology mix[1] used in cooking in 2018 and in 2030 by scenario.[2]
- The trajectory for demand and production of major fossil fuels, highlighting trade balances.
- Cumulative investment by sector required to meet the growth in energy demand and supply in both the Stated Policies Scenario and the Africa Case.[3]

Figure 6.1 ▹ Focus countries for the Africa Energy Outlook by share of sub-Saharan African primary energy demand



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

[1] *Other clean* includes electricity, natural gas, biogas and biofuels. *Charcoal and other solid biomass* refer to the combustion of these fuels in inefficient stoves.

[2] More detailed information on the methodology can be found in Chapter 2.

[3] Investment in electricity networks and generation excludes investment in electricity access, which is counted separately in this figure.

Notes to profiles:

Scenarios: AC = Africa Case; **STEPS** = Stated Policies Scenario.

End-use sectors are industry (including manufacturing and mining), transport, buildings (including residential and services) and other (including agriculture and non-energy use).

Traditional use of solid biomass refers to the use of solid biomass with basic technologies, such as a three-stone fire, often with no or poorly operating chimneys.

Productive uses refers to energy used towards an economic purpose. This includes energy used in agriculture, industry, services and non-energy use. Some energy demand from the transport sector (e.g. freight-related) could be considered as productive, but is treated separately.

GIS maps for each country or region contained in these profiles were developed in collaboration with the Royal Institute of Technology (Sweden) – Division of Energy Systems Analysis (KTH-dESA). The maps detail the least-cost pathway to deliver universal electricity access by means of a combination of on-grid, mini-grid and stand-alone systems.[4]

Units and terms: GDP = gross domestic product; CAAGR = compound average annual growth rate; PPP = purchasing power parity; Mt CO_2 = million tonnes of carbon dioxide; Mtoe = million tonnes of oil equivalent; GW = gigawatt; TWh = terawatt-hour; kV = kilovolt; LPG = liquefied petroleum gas; mb/d = million barrels per day; Mtce = million tonnes of coal equivalent; bcm = billion cubic metres, PV = photovoltaics, GHG = greenhouse gas.

Investment data are presented in real terms in year-2018 US dollars.

[4] More detailed information on the methodology can be found in Chapter 3, Box 3.2.

6.1 Sub-Saharan Africa[1]

Fastest growing population **Strong** economic growth **Major** commodities exporter

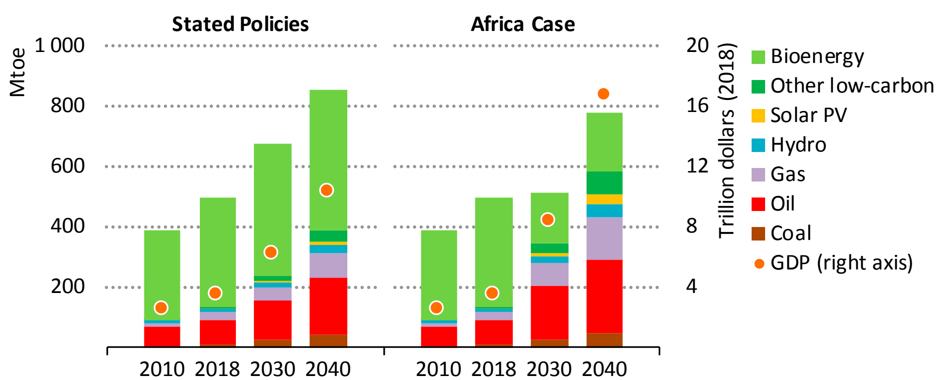
Table 6.1A ▷ Sub-Saharan Africa key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	1 375	3 536	6 161	10 346	8 381	16 683	5.0%	7.3%
Population (million)	626	1 034	1 404	1 761	1 404	1 761	2.5%	2.5%
with electricity access	20%	43%	62%	66%	100%	100%	2.0%	4.0%
with access to clean cooking	6%	13%	31%	51%	100%	100%	6.3%	9.6%
CO_2 emissions (Mt CO_2)	130	312	534	843	762	1 154	4.6%	6.1%

Policy	Key targets and measures
Regional Strategies	▪ Agenda 2063: A prosperous Africa based on inclusive growth and sustainable development. ▪ African Continental Free Trade Area: accelerating intra-African trade and boosting Africa's trading position in the global market by strengthening Africa's common voice and policy space in global trade negotiations.

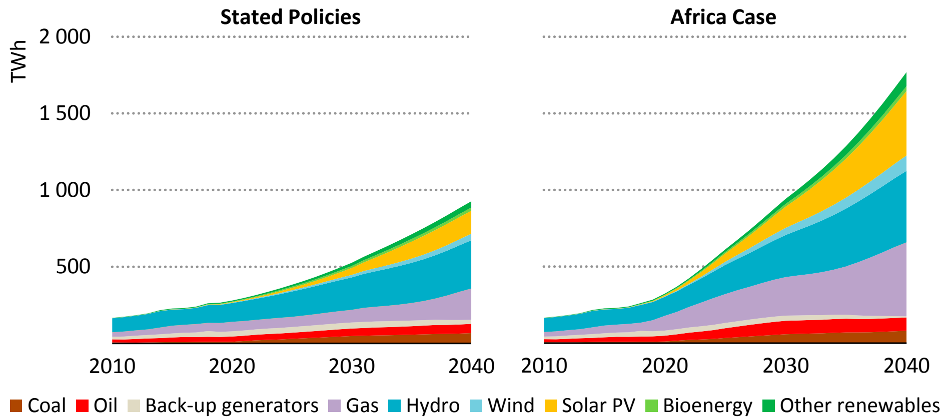
- Drastic efficiency improvements, in part due to the accelerated move away from solid biomass, result in primary energy demand being lower in the AC than in the STEPS even though GDP is 60% higher in the AC.
- Supply from natural gas and renewable sources expand in both scenarios to meet rising demand for energy as the sub-Saharan economy expands.
- Electricity access and clean cooking facilities for all are achieved by 2030 in the AC.

Figure 6.1A ▷ Sub-Saharan Africa primary energy demand and GDP



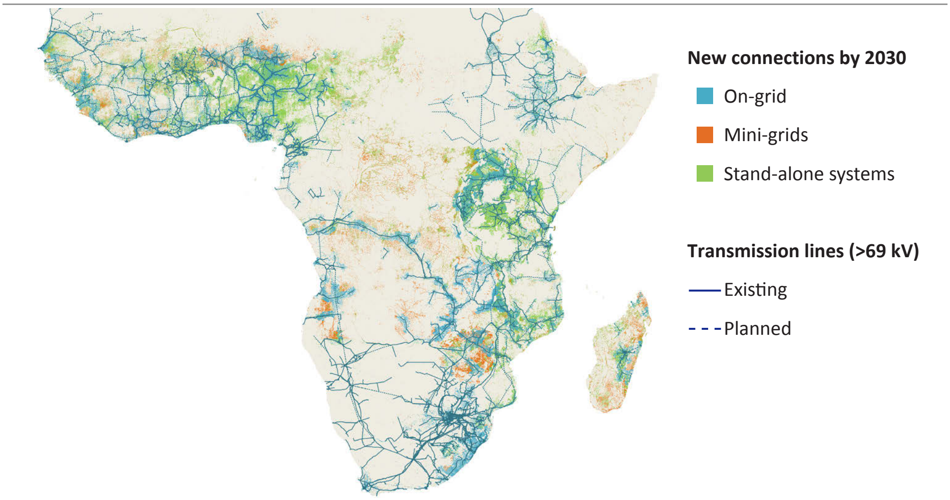
[1] Excluding South Africa.

Figure 6.1B ⊳ Sub-Saharan Africa electricity generation by technology



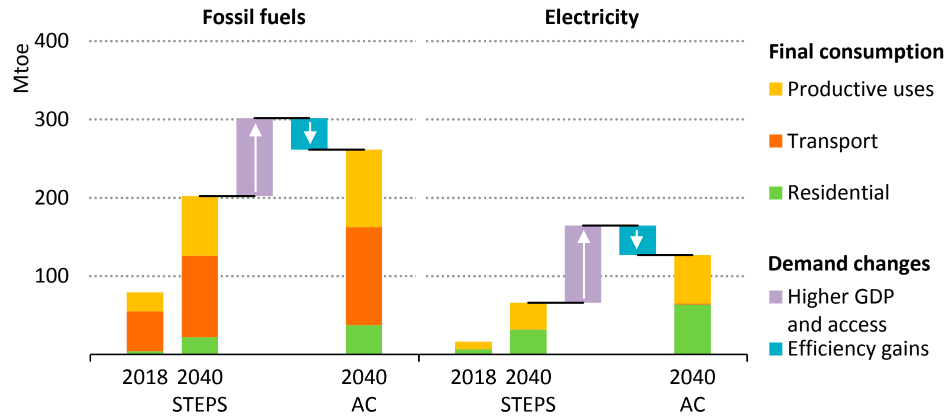
- Today's power mix, dominated by hydro, gradually diversifies as solar PV and natural gas increasingly make inroads into the power system. In the STEPS, the combined share of solar PV and natural gas reaches the level of hydro by 2040.
- In the AC, natural gas (27%) passes hydropower (26%) as the largest source of power supply by 2040 while the share of solar PV rises to 24%.

Figure 6.1C ⊳ Sub-Saharan Africa electricity access solutions by type in the Africa Case



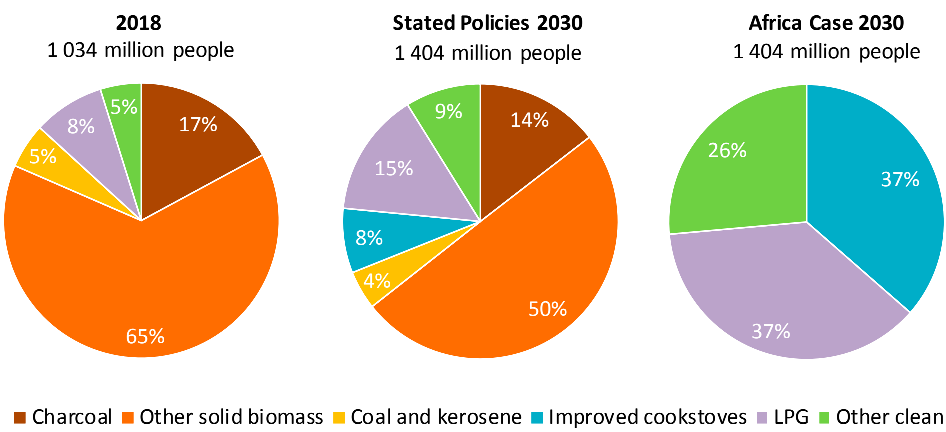
- In the STEPS, the main grid connects around 70% of the 230 million people gaining electricity access by 2030, alongside decentralised options for the remainder in more remote areas. In 2030, 530 million people remain without access.
- In the AC, decentralised solutions are the least-cost option for more than two-thirds of the 530 million additional people connected by 2030 to reach full access.

Figure 6.1D ⊳ Sub-Saharan Africa final energy consumption



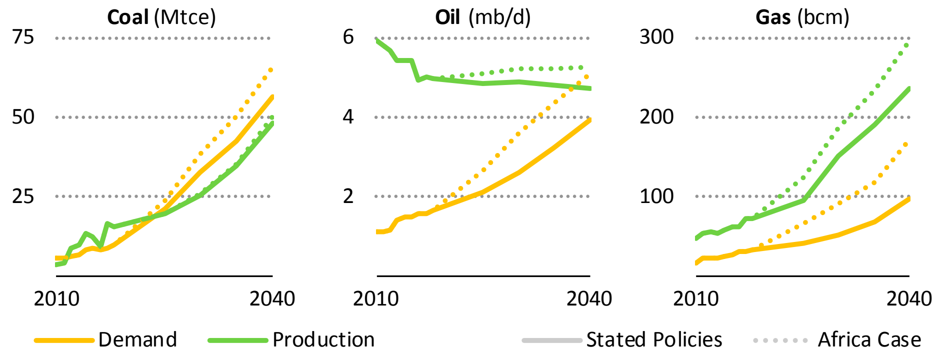
- Growing trends of urbanisation and industrialisation drive strong energy consumption growth for transport and productive uses in both the STEPS and the AC, increasing oil demand the most, especially in the AC, which sees faster economic growth.
- Electricity consumption is very low today, but quadruples through to 2040 in the STEPS, with demand growth led by light industry, appliances and cooling systems. Demand rises further in the AC.

Figure 6.1E ⊳ Sub-Saharan Africa fuels & technologies used for cooking



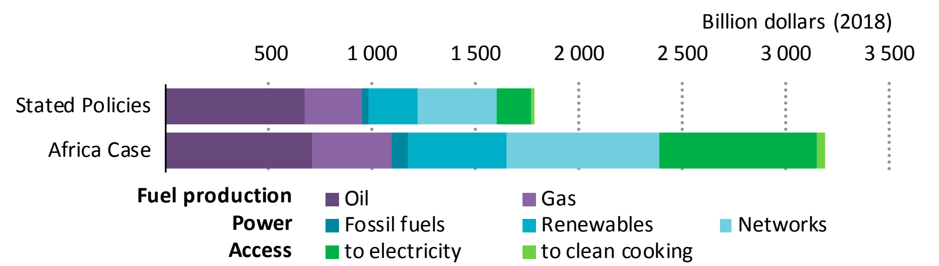
- In the STEPS, more people gain access to clean fuels and technologies for cooking by 2030, but 70% of the population still lack access.
- To bridge the gap and achieve full access to clean cooking for all in the AC, liquefied petroleum gas (LPG) is the most scalable solution for urban settlements, with improved biomass cookstoves doing most to provide access in rural areas.

Figure 6.1F ⊳ Sub-Saharan Africa fossil fuel demand and production



- Rapidly growing oil demand and stagnating domestic oil production reduce net oil exports in the STEPS; exports are further reduced by faster economic growth in the AC.
- Gas demand and production increase by 2040 in the STEPS, but both grow more rapidly in the AC and the region becomes a major supplier of gas to global markets.

Figure 6.1G ⊳ Sub-Saharan Africa cumulative investment needs, 2019-2040



- In the STEPS, $1.8 trillion of cumulative energy supply investment is needed, with upstream oil and gas and power each accounting for around half of this.
- The AC requires 80% more capital with a stronger emphasis on power sector investments, including a doubling of spending in renewables and electricity networks.

Sub-Saharan Africa policy opportunities

- Enhanced power sector integration in sub-Saharan Africa could help to deliver more affordable and reliable power and reduce average electricity generation costs.
- Challenges relating to infrastructure, affordability and business models must be overcome if the region is to capitalise on the potential of natural gas.
- More efficient use of energy across end-use sectors such as fuel economy standards for cars and two/three-wheelers, building codes for new buildings, and more efficient industrial processes and efficiency standards for appliances and cooling systems would support wider economic development and offset growth in energy demand.

6.2 Angola

Second-largest oil producer **Oil** accounts for 90% of exports **Luanda:** future megacity

Table 6.2A ⊳ Angola key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	72	199	287	404	349	625	3.3%	5.3%
Population (million)	16	31	45	60	45	60	3.1%	3.1%
with electricity access	12%	44%	57%	65%	100%	100%	1.7%	3.8%
with access to clean cooking	37%	50%	58%	66%	100%	100%	1.3%	3.2%
CO_2 emissions (Mt CO_2)	5	17	20	33	27	48	3.1%	4.8%

Policy	Key targets and measures
Performance targets	▪ Establish targets for renewable energy sources to 2025: 100 MW of solar PV; 370 MW of small and medium hydro; 500 MW of biomass; 100 MW of wind. ▪ Up to 35% (unconditional) to 50% (conditional) reduction in GHG emissions by 2030 as compared to the business-as-usual scenario.
Industrial development targets	▪ National Development Plan of Angola 2018-2022: Lessen economic dependence on oil and natural gas revenues, strengthen the business environment, increase energy efficiency and achieve middle-income status by 2022.

- Angola could supply an economy three-times larger than today's in the AC with only twice the amount of energy.
- Oil remains an important energy source, but end-use tariffs that are more reflective of costs reduce its share of the overall energy mix and help diversification towards natural gas and renewables in the AC.

Figure 6.2A ⊳ Angola primary energy demand and GDP

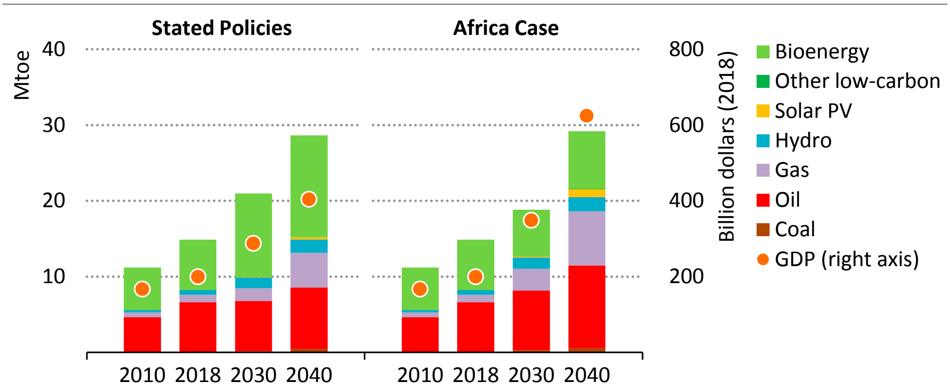
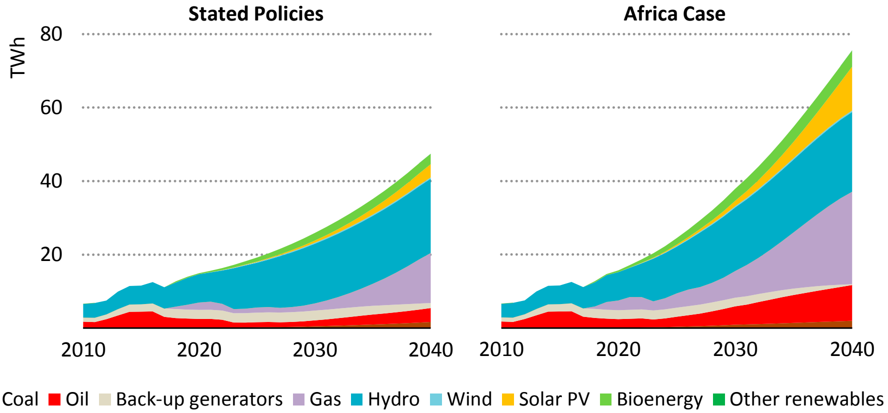
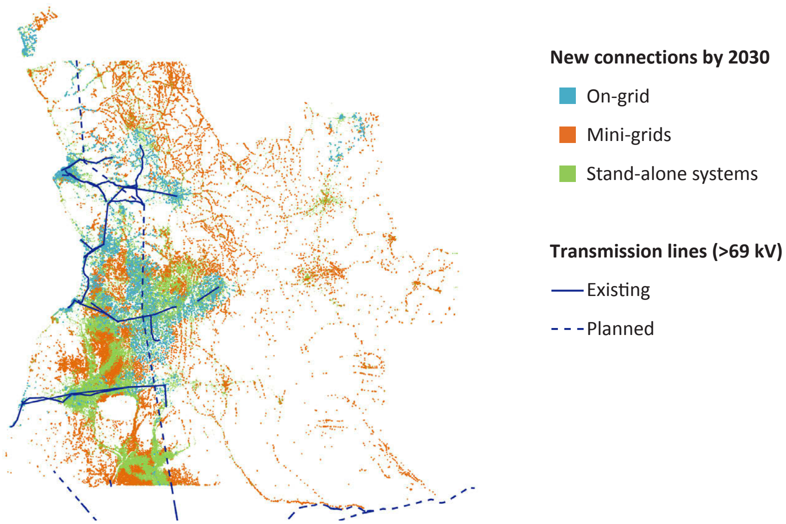


Figure 6.2B ⊳ Angola electricity generation by technology



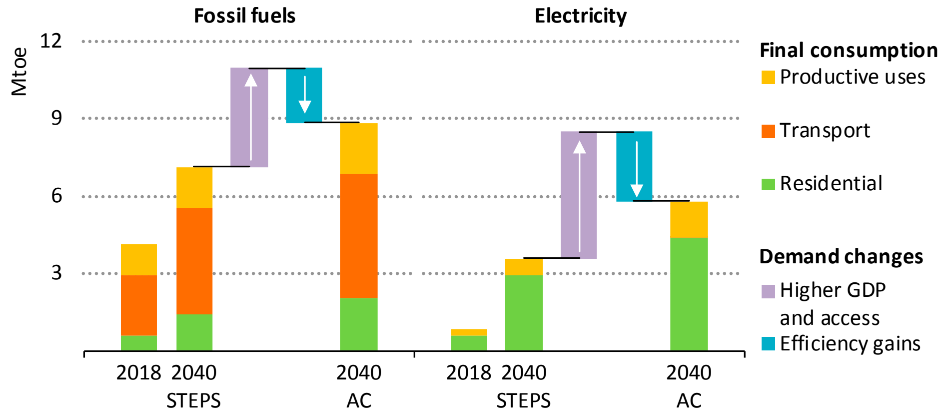
- Angola currently relies mostly on hydropower and oil (including diesel) for power generation.
- Providing access to all increases electricity demand sevenfold in the AC. Gas and comparatively cheap hydropower play key roles in meeting this growth along with solar PV.

Figure 6.2C ⊳ Angola electricity access solutions by type in the Africa Case



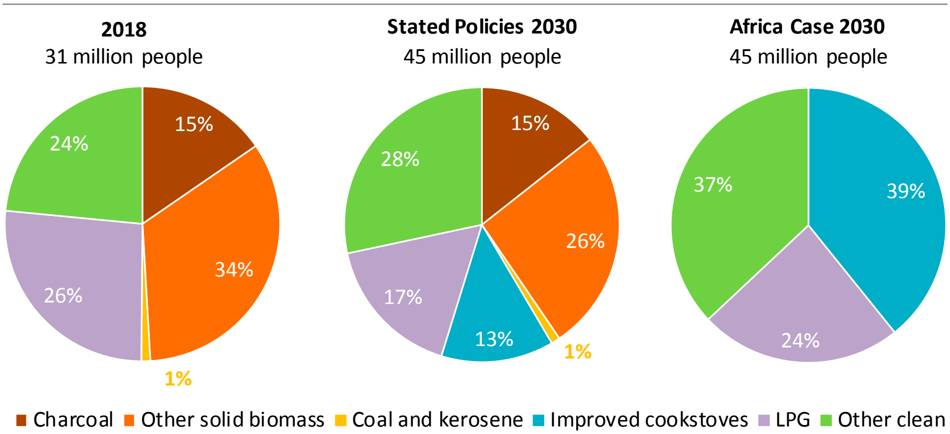
- The electricity access rate in Angola is 44% today, with most of the population currently without access located in the west of the country.
- The least-cost path to full access to electricity in the AC is mini-grids (46%), alongside grid connections for a large part of the population (38%) living near the existing and planned grids; stand-alone systems help to reach the most remote areas.

Figure 6.2D ⊳ Angola final energy consumption



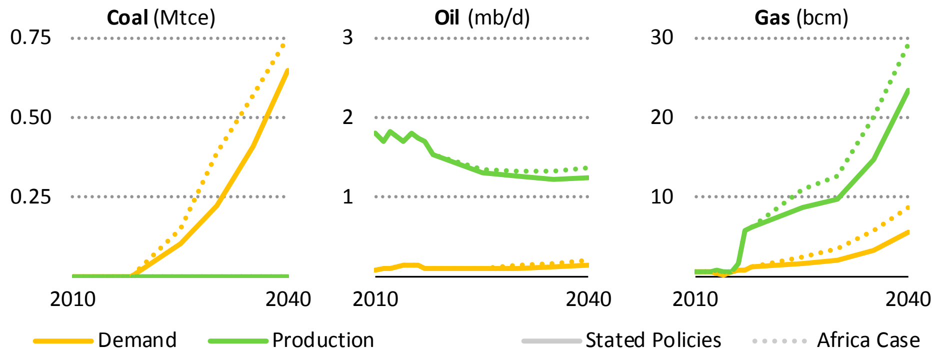
- The number of cars expands from 0.4 million in 2018 to 1.1 million in 2040 in the STEPS, and rises further in the AC. The associated increase in oil demand can be mitigated to an extent by improving fuel economy standards.
- Angola could meet nearly all of its cement demand domestically before 2040 in both scenarios provided a reliable supply of gas and electricity is available.

Figure 6.2E ⊳ Angola fuels and technologies used for cooking



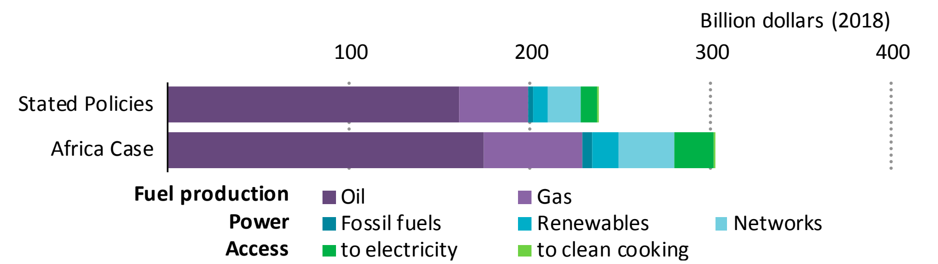
- Angola has one of the highest shares of access to clean cooking in sub-Saharan Africa, thanks to government policies supporting LPG and natural gas.
- A further push on access policies adapted to rural conditions could help provide clean cooking to 90% of people in rural areas through improved biomass cookstoves in the AC.

Figure 6.2F ▷ Angola fossil fuel demand and production



- Recent policy reforms in the oil and gas sector help stabilise the outlook for oil production in both scenarios.
- Growing population and stagnant oil production reduce per capita net income from oil and gas production in both scenarios, increasing the need for economic diversification.

Figure 6.2G ▷ Angola cumulative investment needs, 2019-2040



- Around $240 billion of cumulative energy supply investment is needed in the STEPS, of which over 80% goes to upstream oil and gas.
- The AC requires around 25% more capital than the STEPS, with a strong emphasis on investments in upstream gas, electricity access and networks.

Angola policy opportunities

- Angola's natural gas resources could underpin a domestic industrial base that would have the added benefit of diversifying the economy away from oil exports.
- Angola would benefit from sustaining and strengthening recent reforms in the oil and gas sector, including efforts to streamline investment procedures and restructure the role of the national oil company.
- The availability of domestic natural gas presents a significant opportunity for efficient and dependable electricity generation.

6.3 Côte d'Ivoire

Largest cocoa exporter **Rapidly** expanding economy **Diversity** of resources

Table 6.3A ▷ Côte d'Ivoire key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	56	107	221	330	264	569	5.3%	7.9%
Population (million)	17	25	34	42	34	42	2.4%	2.4%
with electricity access	50%	63%	94%	100%	100%	100%	1.1%	1.1%
with access to clean cooking	18%	30%	59%	71%	100%	100%	4.0%	5.7%
CO_2 emissions (Mt CO_2)	6	11	19	24	21	33	3.7%	5.1%

Policy	Key targets and measures
Performance targets	▪ Increase electricity generation to 4 000 MW by 2020 and 6 000 MW by 2030. ▪ *Programme National d'Électrification Rurale*: connect all localities with more than 500 inhabitants by 2021 and all areas by 2025.
Industrial development targets	▪ Achieve emerging economy status by end of 2020 while ensuring that industry accounts for 40% of the economy. ▪ Accelerate the structural transformation of the economy through industrialisation, develop infrastructure throughout the country and protect the environment. ▪ Rise in investment rate from 19.3% in 2015 of GDP to 24.5% in 2020 with significant contribution from private sector.

- Rapid industrialisation in the AC could yield an economy that is five-times larger than today but with energy efficiency the country consumes only twice as much energy.
- Natural gas has a key role to play in electricity generation in the AC. Promoting its use could see its share of the energy mix rising by eleven percentage points more than STEPS.

Figure 6.3A ▷ Côte d'Ivoire primary energy demand and GDP

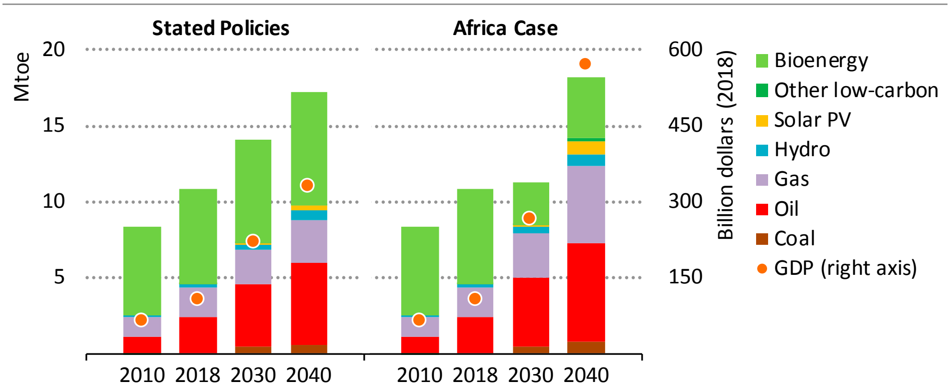
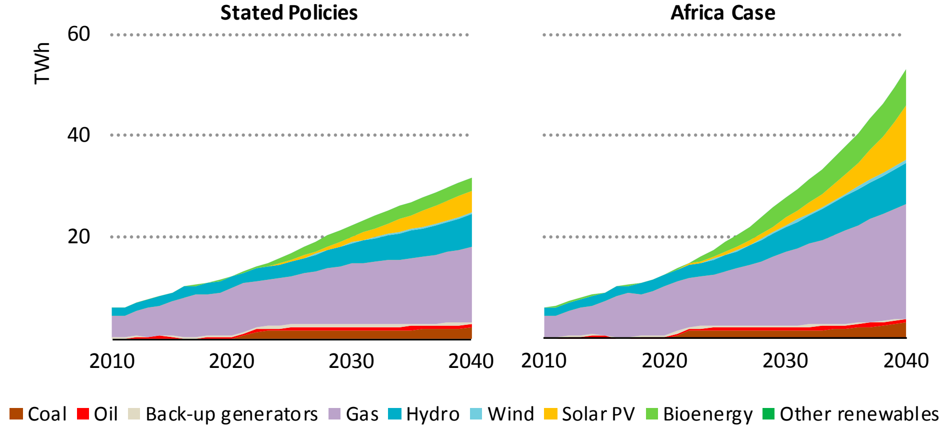
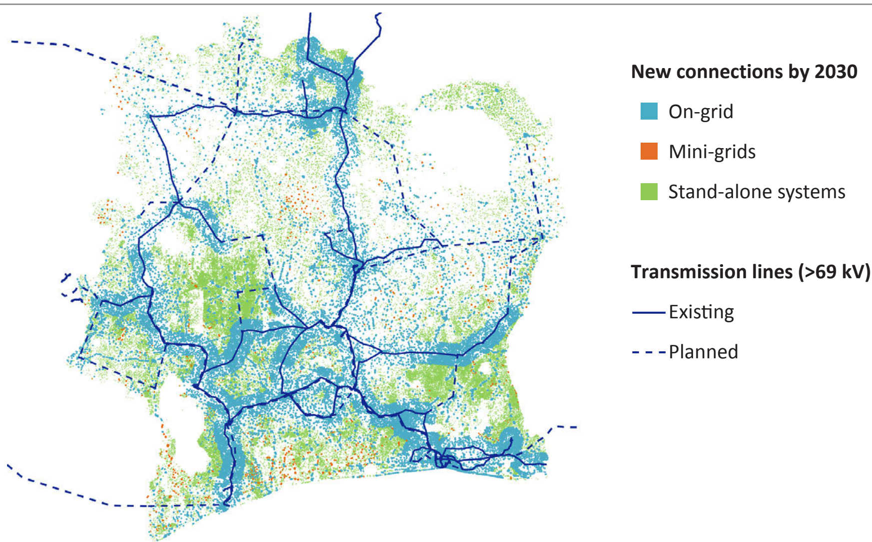


Figure 6.3B ▷ Côte d'Ivoire electricity generation by technology



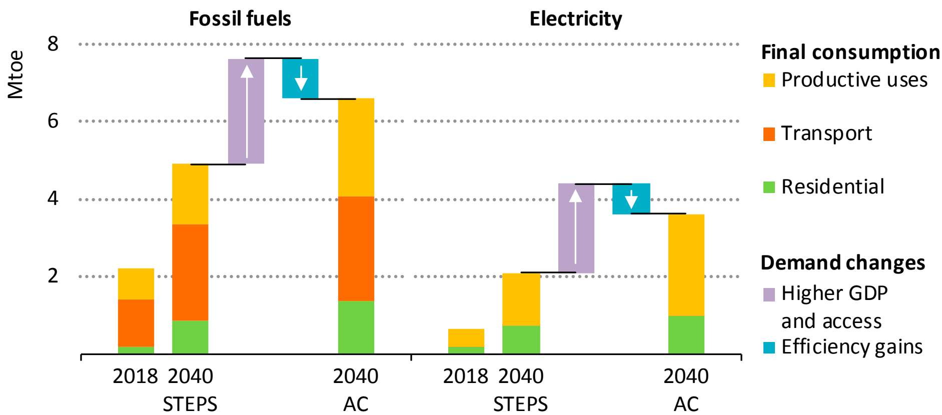
- Providing access to all and increasing industrialisation in the AC raises electricity demand sixfold compared to today.
- Gas continues to play a large role in power generation, but its share is reduced from three-quarters today to around 45% as solar and bioenergy increase in both scenarios.

Figure 6.3C ▷ Côte d'Ivoire electricity access solutions by type in the Africa Case



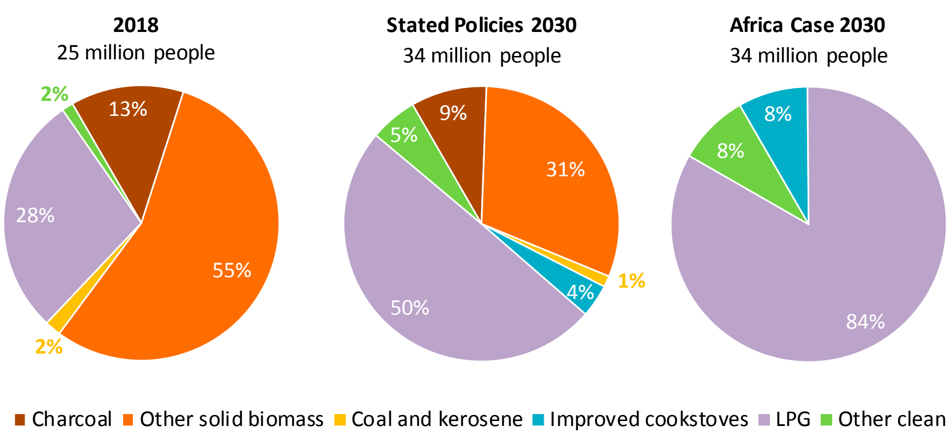
- Effective programmes supporting electrification of villages and households connect more than 90% of the population by 2030 in the STEPS.
- Given the current coverage of the grid network, grid densification and grid extension are the least-cost solution for around 40% of the population in the AC.

Figure 6.3D ▷ Côte d'Ivoire final energy consumption



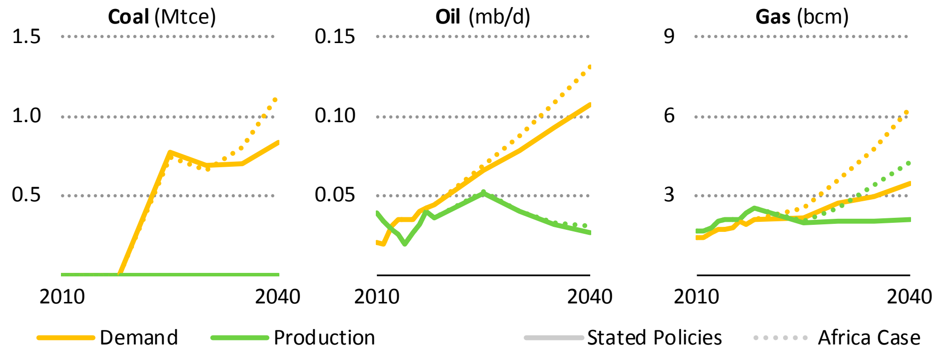
- The number of cars grows fivefold and related oil consumption fourfold in the AC, but the growth could be almost 20% larger without fuel economy standards.
- Côte d'Ivoire electrifies much of industry, with electricity displacing oil to become the major fuel. Electricity demand for residential cooling increases by almost 2 TWh in the AC.

Figure 6.3E ▷ Côte d'Ivoire fuels and technologies used for cooking



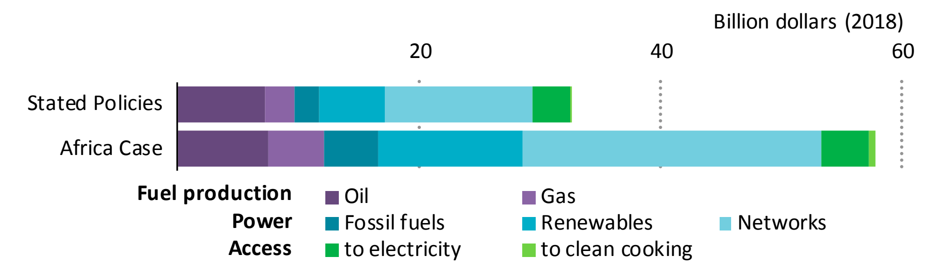
- With strong policy support, LPG is the preferred solution to improve access to clean cooking, reducing the use of traditional stoves with charcoal and other solid biomass.
- The AC sees further use of LPG and improved biomass cookstoves, particularly in rural areas, to bring access to clean cooking to all.

Figure 6.3F ⊳ Côte d'Ivoire fossil fuel demand and production



- Rapidly rising passenger car stocks and declining production lead to expanding import requirements for oil in both scenarios.
- Given the important share of gas in the power mix, strong growth in electricity demand underpins rapid growth in gas demand, especially in the AC.

Figure 6.3G ⊳ Côte d'Ivoire cumulative investment needs, 2019-2040



- Energy investment needs amount to $33 billion through to 2040 in the STEPS, with spending on electricity networks representing almost 40% of the total.
- The AC requires investment to increase by a further 80%, with more emphasis on gas-related spending (upstream and generation), renewables and electricity networks.

Côte d'Ivoire policy opportunities

- Increased production of natural gas provides a significant opportunity for it to be used extensively in power generation and industry.
- Prioritising energy efficiency is essential to helping Côte d'Ivoire make the most of its limited resources. With the anticipated increase in demand for cooling and other household uses, efficiency standards for appliances would materially impact the rate of energy demand growth.
- Expanding power generation capacity is crucial.

6.4 Democratic Republic of the Congo

Largest producer of cobalt **Kinshasa:** an African megacity **Most ambitious** hydro plan

Table 6.4A ⊳ DR Congo key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	29	73	132	238	195	455	5.5%	8.7%
Population (million)	47	84	120	156	120	156	2.8%	2.8%
with electricity access	7%	9%	16%	21%	100%	100%	4.1%	11.7%
with access to clean cooking	3%	3%	4%	5%	100%	100%	2.0%	17.1%
CO_2 emissions (Mt CO_2)	1	3	10	16	18	18	8.7%	9.2%

Policy	Key targets and measures
Performance targets	▪ Complete the construction of Inga 3 Basse-Chute dam. ▪ Reduce GHG emissions by 17% by 2030 compared to the business-as-usual scenario (430 Mt CO_2-equivalent), equivalent to slightly more than a 70 Mt CO_2 reduction. ▪ Plant about three million hectares of forest by 2025.
Industrial development targets	▪ Achieve high-income status by 2050 by means of rigorous implementation of the National Strategic Plan for Development.

- In the AC, DR Congo supports an economy six-times larger than today's with only 35% more energy by diversifying its energy mix away from one that is 95% dependent on bioenergy.
- The power sector sees more growth than any other sector; a big increase in the use of hydropower leads to its share of the overall energy mix increasing to 23% in the AC.

Figure 6.4A ⊳ DR Congo primary energy demand and GDP

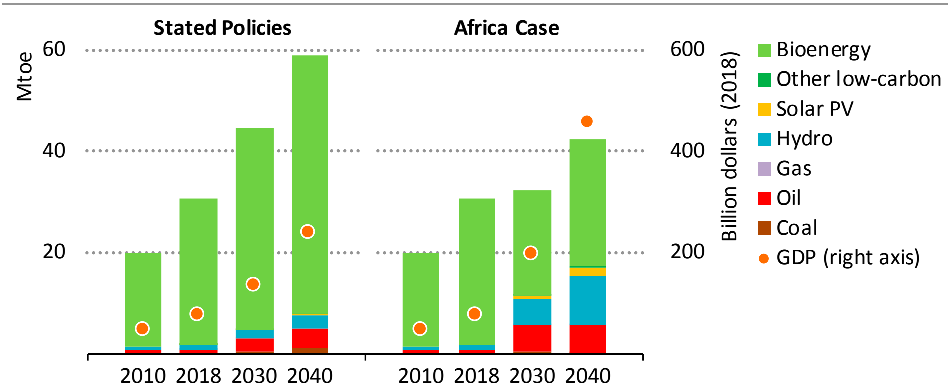
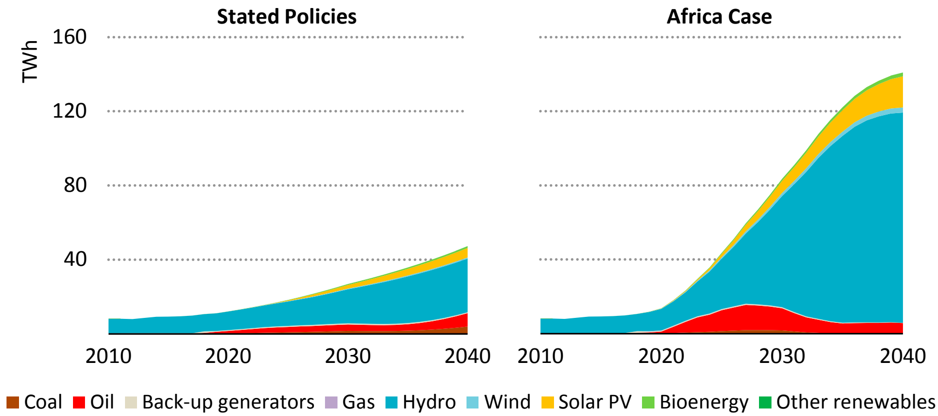
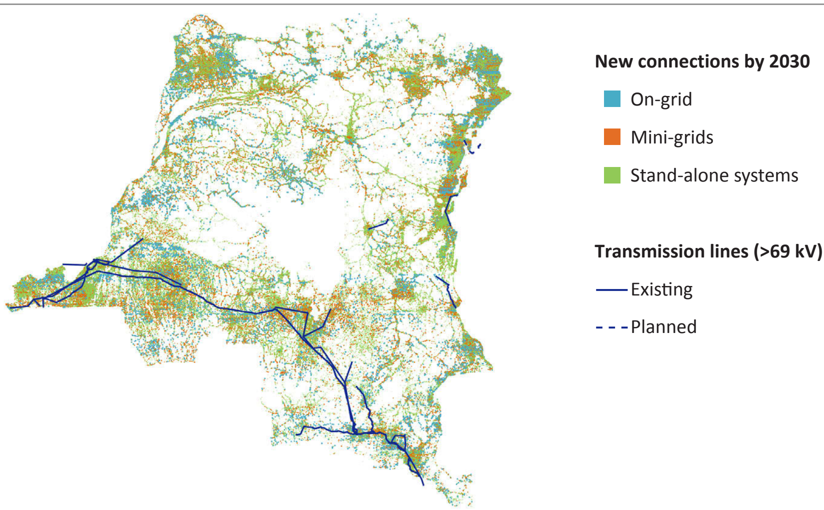


Figure 6.4B ▷ DR Congo electricity generation by technology



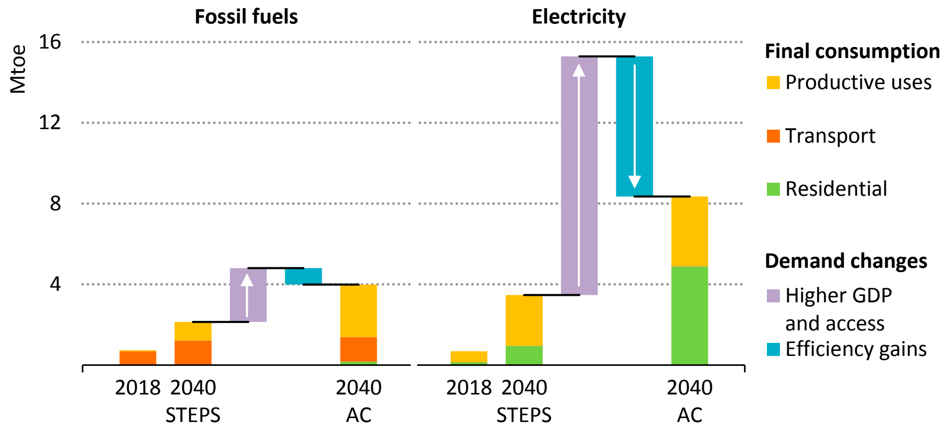
- Almost all electricity generation today comes from hydropower and the Inga project has the potential to provide much more. If network constraints are addressed, DR Congo could become an electricity exporter.
- In the AC, Phase 5 of the Inga project enables DR Congo to meet an eleven-fold increase in electricity demand; this increase is the result of achieving full access to electricity and of the growing electrification of productive uses.

Figure 6.4C ▷ DR Congo electricity access solutions by type in the Africa Case



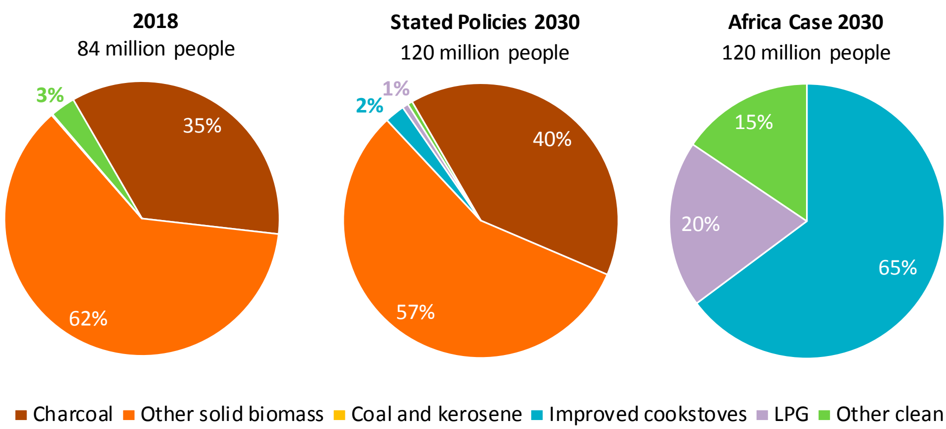
- Less than 10% of the population has access to electricity today, making DR Congo the country with the largest number of people without access in Africa after Nigeria.
- Mini-grids account for more than half of all new connections in the AC.

Figure 6.4D ⊳ **DR Congo final energy consumption**



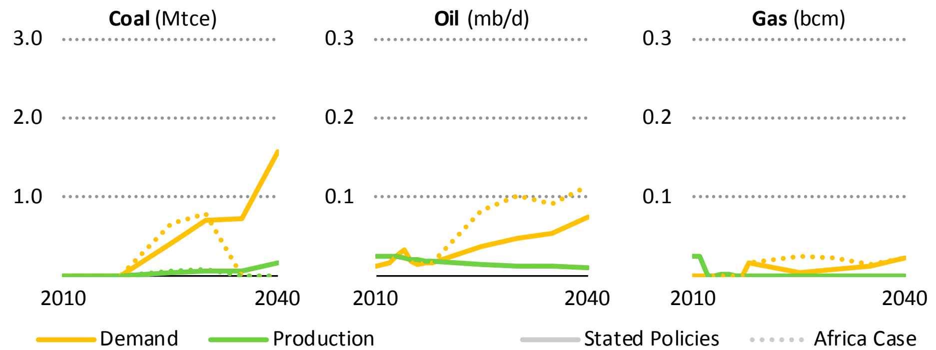
- Oil use in industry increases significantly in the AC with manufacturing and mining chiefly responsible for this growth.
- Electricity consumption is low today but is set to increase significantly in the AC as household incomes rise, access to electricity improves and mining activities increase.

Figure 6.4E ⊳ **DR Congo fuels and technologies used for cooking**



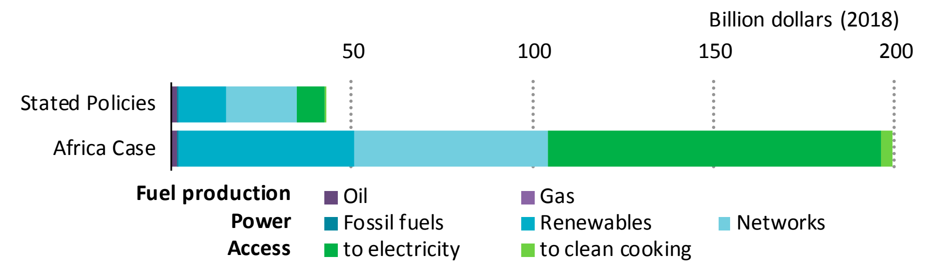
- Given the availability of fuelwood in rural areas and the affordability of charcoal in urban areas, almost all people cook with traditional stoves in 2030 in the STEPS.
- In the AC, improved cookstoves are the preferred option to provide clean cooking access in both urban and rural areas. In parallel, kilns for making charcoal are improved to increase their efficiency.

Figure 6.4F ⊳ DR Congo fossil fuel demand and production



- Fossil fuel consumption is at a low level, but growing, and almost reliant on imports in both scenarios. Further industrial development depends on a large increase in imports.
- DR Congo is a major producer of minerals. It accounts for almost two-thirds of global cobalt production; this gives it a crucial role in global clean energy transitions.

Figure 6.4G ⊳ DR Congo cumulative investment needs, 2019-2040



- The AC requires a quadrupling of investment compared with the STEPS, with emphasis on renewables, power networks and access to electricity and clean cooking.
- Investment opportunities in the AC are likely to be realised only if sound structures to regulate the sector and manage revenues from mineral production are in place.

DR Congo policy opportunities

- Cobalt mining activities will drive an increase in electricity demand. Meeting this through renewable hydropower would help to develop low-carbon electricity for DR Congo and a low-carbon value chain for the global electric vehicle fleet.
- Given the country's dispersed population centres, decentralised solutions offer the lowest cost way to overcome grid limitations and provide electricity access to the huge share of the population currently without it.
- Increased regional co-operation could help realise the potential of Inga, which has the potential to provide large quantities of reliable low-carbon electricity to DR Congo and its neighbours.

6.5 Ethiopia

Geothermal potential | **Large** hydro capacity | **Strong progress** on access

Table 6.5A ▷ Ethiopia key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	47	220	493	870	610	1 445	6.5%	8.9%
Population (million)	67	108	143	173	143	173	2.2%	2.2%
with electricity access	5%	45%	100%	100%	100%	100%	3.7%	3.7%
with access to clean cooking	1%	7%	34%	56%	100%	100%	9.7%	12.6%
CO_2 emissions (Mt CO_2)	3	14	29	46	32	52	5.5%	6.2%

Policy	Key targets and measures
Performance targets	▪ Increase generating capacity by 25 000 MW by 2030: 22 000 MW of hydro; 1 000 MW of geothermal; and 2 000 MW of wind by 2030. ▪ National Electrification Program (2017): 100% electrification in 2025, with 35% off-grid and 65% grid, while extending the grid to reach 96% grid connections by 2030.
Industrial development targets	▪ Achieve an annual average real GDP growth rate of 11% within a stable macroeconomic environment and become a lower middle-income country by 2025. ▪ Focus on ensuring rapid, sustainable growth by enhancing the productivity of the agriculture and manufacturing sectors, and stimulating competition in the economy.

- Ethiopia could supply a much larger economy than today in the AC, using only twice the energy, were it to diversify its energy mix and implement efficiency standards.
- In the AC, this diversification comes about as a result of a substantial expansion of geothermal energy along with increased use of oil within industry and for cooking.

Figure 6.5A ▷ Ethiopia primary energy demand and GDP

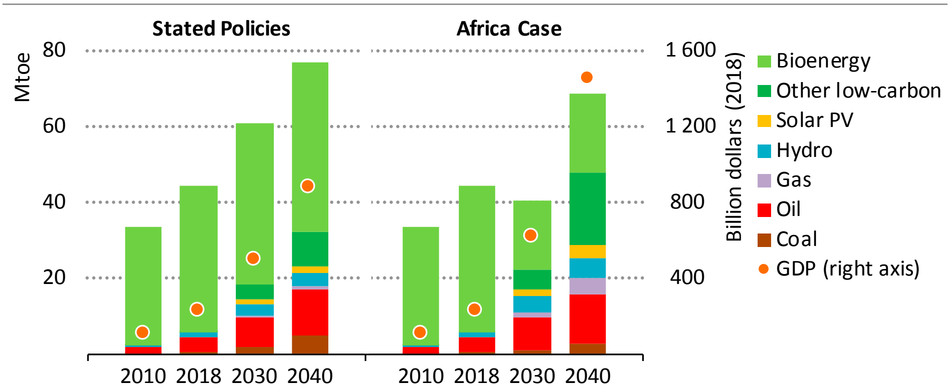
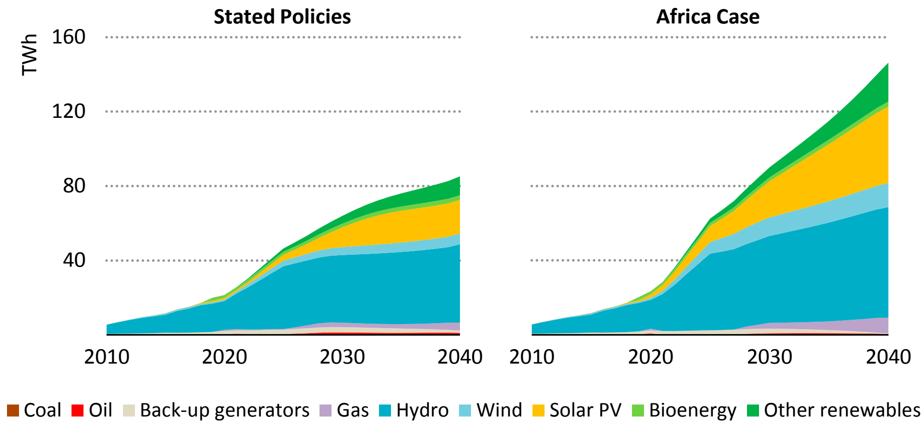
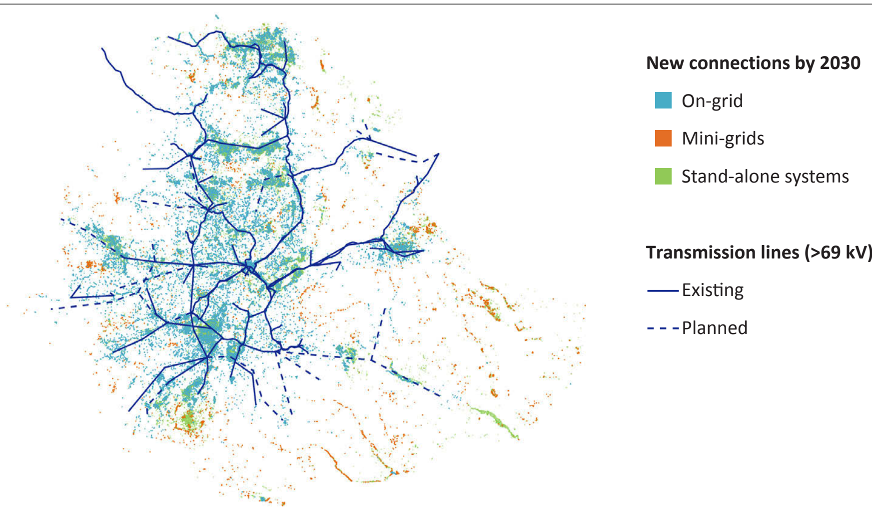


Figure 6.5B ▷ Ethiopia electricity generation by technology



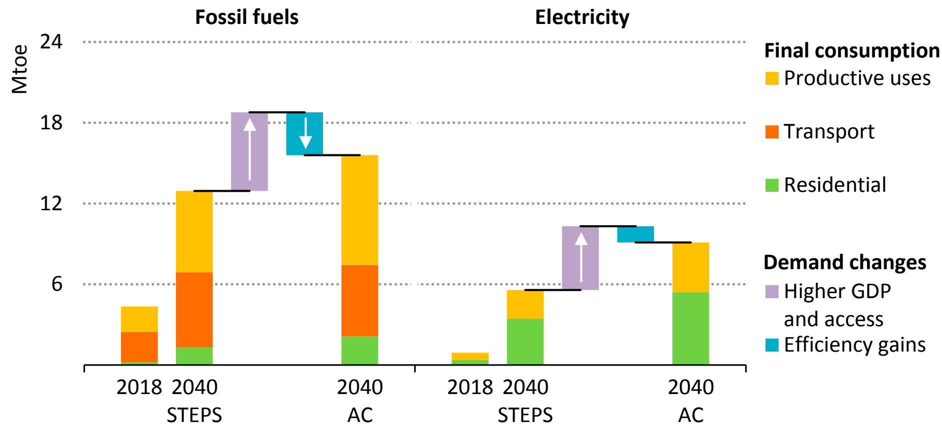
- Ethiopia is currently heavily reliant on hydropower; plans to increase capacity to 13.5 GW by 2040 would make Ethiopia the second-largest hydro producer in Africa.
- Providing electricity access to all and electrifying productive uses will lead to a fivefold increase in generation in the STEPS, and an even bigger increase in the AC; solar PV and geothermal account for almost 45% of the power mix by 2040 in the AC.

Figure 6.5C ▷ Ethiopia electricity access solutions by type in the Africa Case



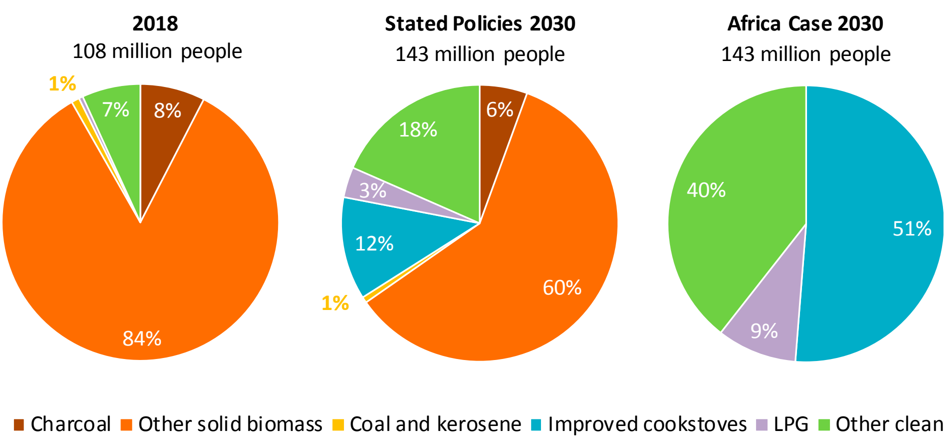
- Ethiopia currently has an electricity access rate of 45%, 11% of its population already have access through decentralised solutions. Strong government commitment to reach full access before 2030 in the STEPS.
- In both scenarios, around 80% of new connections are cost effectively delivered by grid densification and extension as a large part of the population lives close to the grid.

Figure 6.5D ⊳ Ethiopia final energy consumption



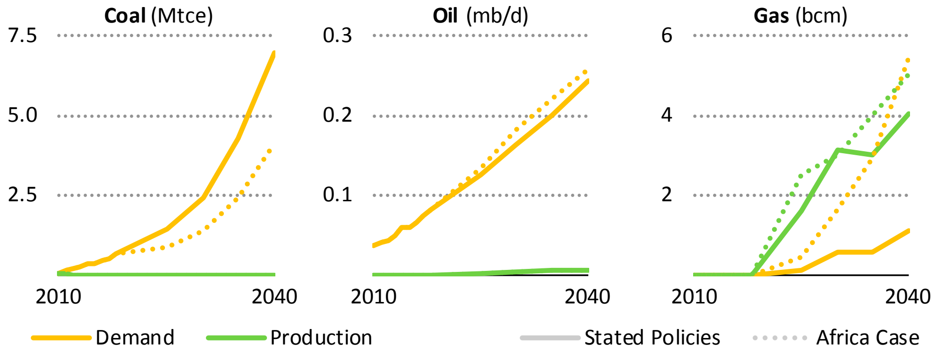
- Increased affluence in the STEPS results in a more than fourfold increase of the private vehicle stock with the number of cars reaching 700 000 by 2040. This results in a 300% increase in related oil consumption.
- To meet the needs of its growing population, Ethiopia remains a large producer of cement causing energy demand to increase significantly in both scenarios.

Figure 6.5E ⊳ Ethiopia fuels and technologies used for cooking



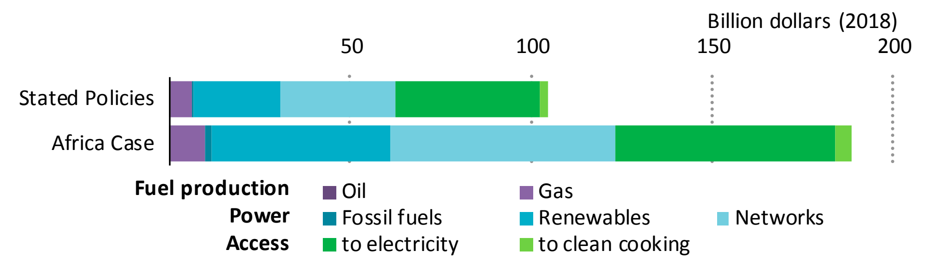
- In the STEPS, a push on improved and advanced biomass cookstoves alongside more access through LPG and electricity increases the population with access by 40 million by 2030, with 60% of this increase takes place in rural areas.
- In the AC, increased efforts using the same solutions bring access to clean cooking by 2030 to the remaining 95 million people that rely on the traditional use of biomass.

Figure 6.5F ▷ Ethiopia fossil fuel demand and production



- Growing fossil fuel consumption is met almost entirely by imports in both scenarios.
- A high degree of dependency on imported fuels in both scenarios and a range of infrastructure development challenges underline the case for the development of hydropower and other renewables.

Figure 6.5G ▷ Ethiopia cumulative investment needs, 2019-2040



- Cumulative energy investment of $100 billion is needed in the STEPS, with electricity access and networks taking the majority.
- The AC needs around 80% more capital, including a doubling of investments in renewables and electricity networks compared with the STEPS.

Ethiopia policy opportunities

- Ethiopia will remain heavily dependent on fossil fuel imports. In both scenarios, imports of oil and coal increase; a significant increase in gas consumption (and imports) would help the country to make the most of its industrial potential.
- The need for energy imports could be reduced by a determined push to develop the country's formidable hydro resources and accelerate electrification, as well as by development of its more limited natural gas reserves.
- Continuing progress on access means that fully achieving SDG 7 is well within Ethiopia's reach. Most of the additional connections to 2025 can be made through extending the current grid.

6.6 Ghana

Oil and gas producer | **Strong** access record | **Steel** producer

Table 6.6A ▷ Ghana key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	63	191	322	438	403	728	3.9%	6.3%
Population (million)	19	29	37	44	37	44	1.9%	1.9%
with electricity access	45%	84%	100%	100%	100%	100%	0.8%	0.8%
with access to clean cooking	6%	25%	58%	73%	100%	100%	5.0%	6.5%
CO_2 emissions (Mt CO_2)	5	15	25	33	33	49	3.6%	5.4%

Policy	Key targets and measures
Performance targets	▪ Accelerate the displacement of light crude oil by natural gas in electricity generation. ▪ Achieve 10% renewable energy in the national energy mix and 20% solar energy in agriculture by 2020. ▪ 15% (unconditional) to 45% (conditional) reduction in GHG emissions by 2030 compared to the business-as-usual scenario (around 74 Mt CO_2-equivalent).
Industrial development targets	▪ Produce and process estimated reserves of 300 million barrels of oil and gas by 2040. ▪ In accordance with the *One District, One Factory Initiative*, build a factory in each of the 216 districts across the country.

- Supplying an economy that is four-times the size of today's could require only three-times more energy with the implementation of efficiency standards in the AC.
- Oil remains the largest energy source in both scenarios, with nearly two-thirds of it consumed in the transport sector.

Figure 6.6A ▷ Ghana primary energy demand and GDP

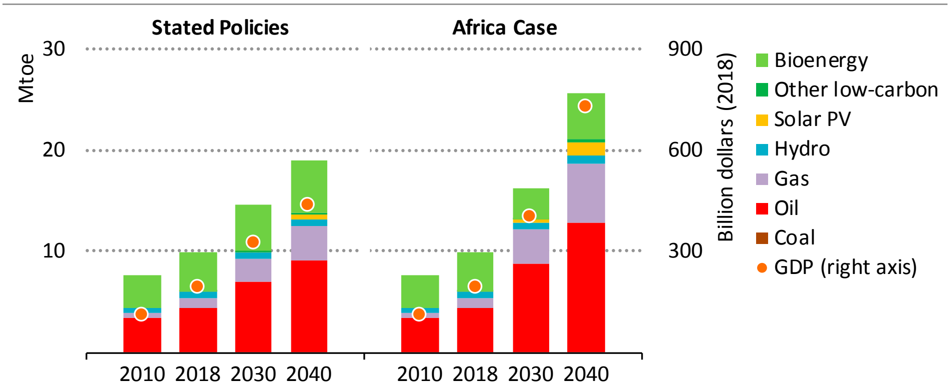
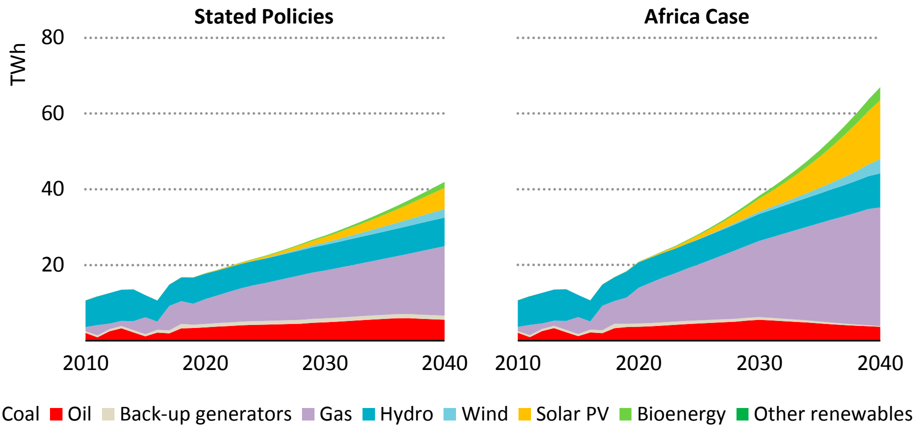


Figure 6.6B ▷ Ghana electricity generation by technology



- Almost half of today's electricity comes from hydropower; the rest comes from domestically produced gas (30%) and oil (23%).
- The 350% increase of electricity demand in the STEPS is met by increasing generation from gas, which accounts for nearly half of the power mix by 2040, and from solar PV.

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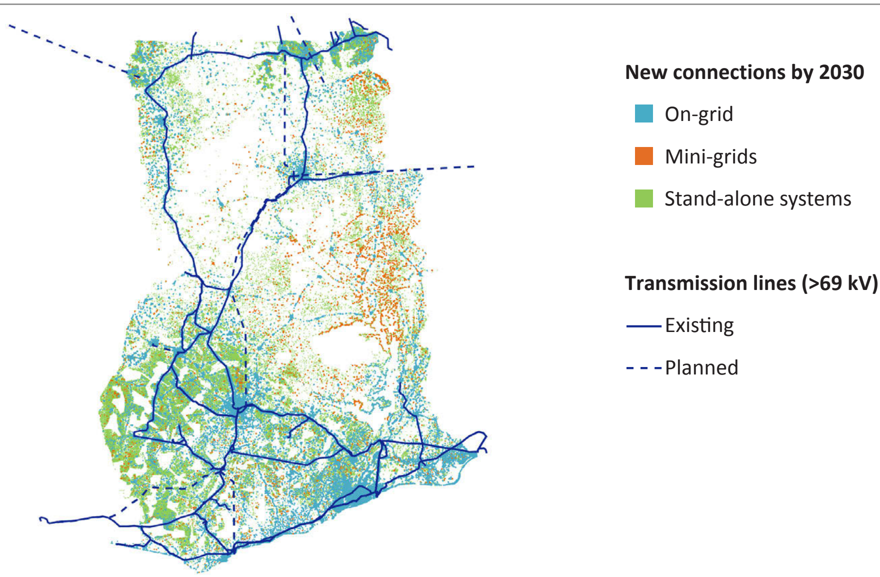
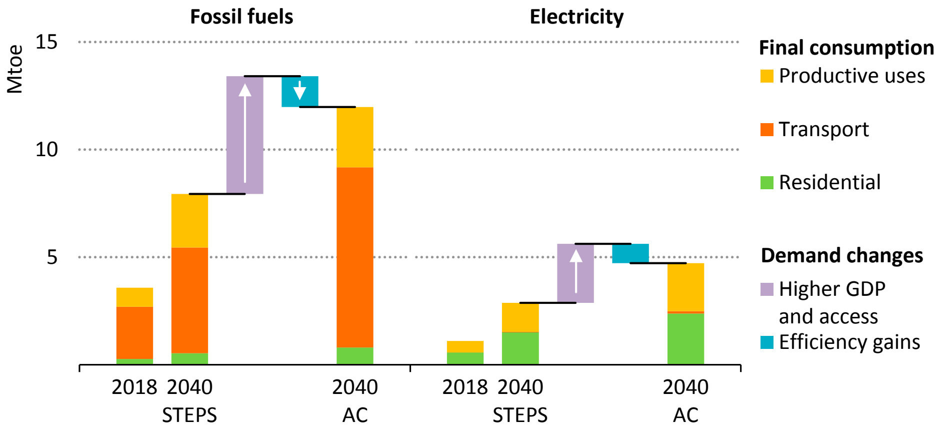
Figure 6.6C ▷ Ghana electricity access solutions by type in the Africa Case



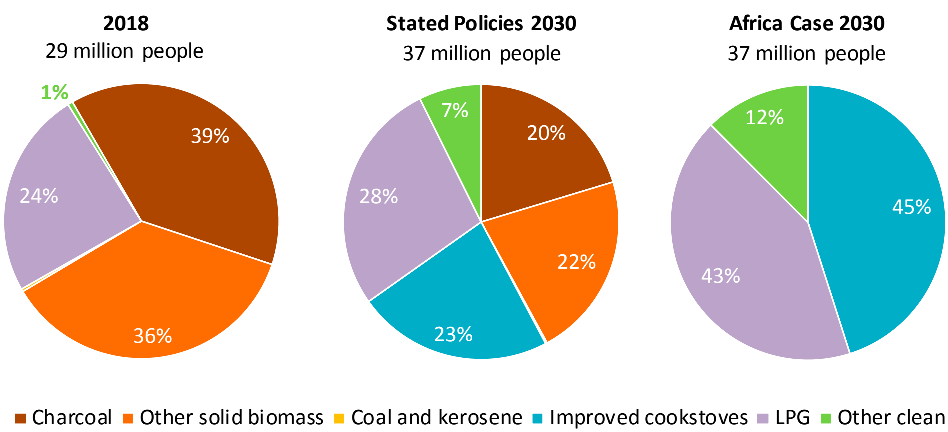
- Thanks to strong government leadership since the 1990s, Ghana had an electricity access rate of 84% in 2018, one of the highest in sub-Saharan Africa.
- To reach the remaining population, grid densification (58% of the new connections) and stand-alone systems (27%) are the two main least-cost solutions in both scenarios.

Figure 6.6D ▷ **Ghana final energy consumption**



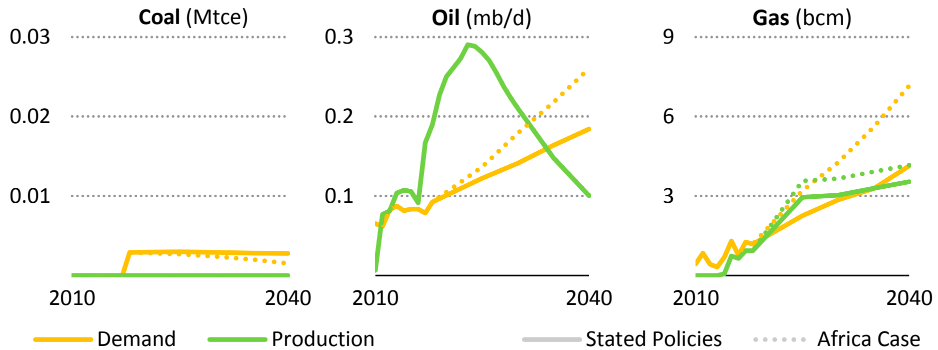
- Two/three-wheelers remain important for passenger transport; in the STEPS, an increasing number of buses accounts for nearly 70% of oil demand growth for transport.
- Millions of additional appliances and cooling systems together with the further development of bauxite mining, and steel and aluminium industries are responsible for two-thirds of the additional 45 TWh of electricity demand in the AC; around 10 TWh are avoided thanks to efficiency standards.

Figure 6.6E ▷ **Ghana fuels and technologies used for cooking**



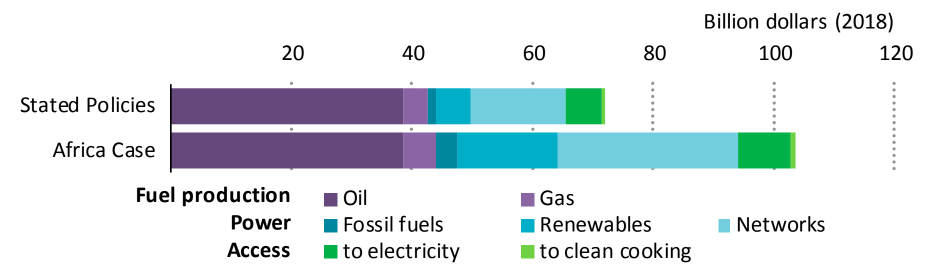
- In the STEPS, strong policies support the provision of clean cooking fuels to more than half of the population mainly through deployment of LPG and improved cookstoves.
- In the AC, 16 million people who still lack access to electricity in 2030 under the STEPS gain access through LPG, biogas or improved cookstoves.

Figure 6.6F ▷ Ghana fossil fuel demand and production



- Ghana remains a relatively minor producer of oil and gas in Africa.
- Gas demand grows strongly in the AC, lowering oil use in the power and industry sectors; this increases the need for imports of gas.

Figure 6.6G ▷ Ghana cumulative investment needs, 2019-2040



- Around $70 billion of cumulative energy supply investment is needed in the STEPS, 60% of which is for upstream oil and gas.
- Investment ramps up by nearly 45% in the AC, with a strong emphasis on renewables and electricity networks.

Ghana policy opportunities

- Thanks to notable efforts on electrification, the goal of full access is within grasp in Ghana. A mix of grid extension and stand-alone solutions would be the least-cost way to reach the decreasing share of the population that remains without access.
- Taking action to arrest (and reverse) declining oil output would reduce Ghana's reliance on imports to meet its growing future demand while a renewed push on developing domestic natural gas resources would help Ghana meet its accelerating industrial power needs.
- The government needs to develop and implement stronger efficiency policies if the potential savings identified in the AC are to be realised.

6.7 Kenya

Major access improvements **Large wind power** producer **Largest geothermal** producer

Table 6.7A ▷ Kenya key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	76	177	358	627	453	1 176	5.9%	9.0%
Population (million)	31	51	66	79	66	79	2.0%	2.0%
with electricity access	8%	75%	100%	100%	100%	100%	1.3%	1.3%
with access to clean cooking	3%	15%	46%	70%	100%	100%	7.2%	9.0%
CO_2 emissions (Mt CO_2)	8	16	27	40	33	60	4.3%	6.2%

Policy	Key targets and measures
Performance targets	▪ National Electrification Strategy: achieve universal electricity service to all households and businesses by 2022 at acceptable quality of service levels. ▪ Produce 100 000 barrels of oil per day from 2022 and develop 2 275 MW of geothermal capacity by 2030.
Industrial development targets	▪ Increase the contribution of the manufacturing sector share of GDP to 15% by 2022. ▪ Develop domestic iron and steel industries by 2030. ▪ Achieve middle-income status by 2030.

- In the AC, Kenya could supply an economy six-and half times larger than today using little more than twice its current energy consumption, if it were to move away from bioenergy and improve energy efficiency.
- Two-thirds of Kenya's energy currently comes from bioenergy. This share shrinks to 15% by 2040 in the AC thanks to increased use of geothermal resources and oil.

Figure 6.7A ▷ Kenya primary energy demand and GDP

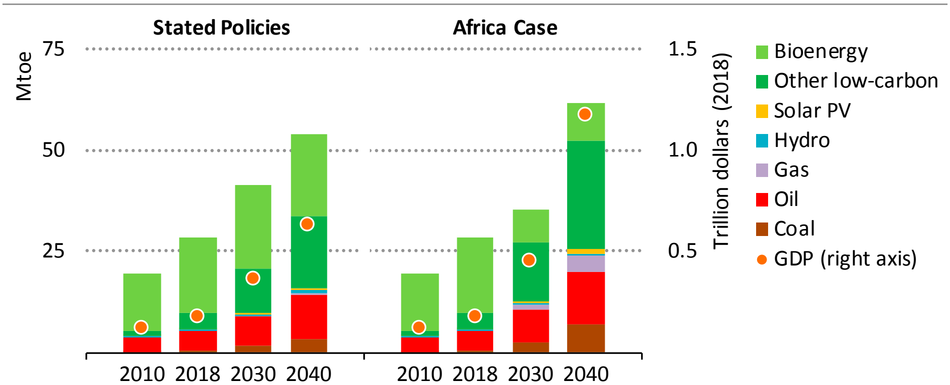
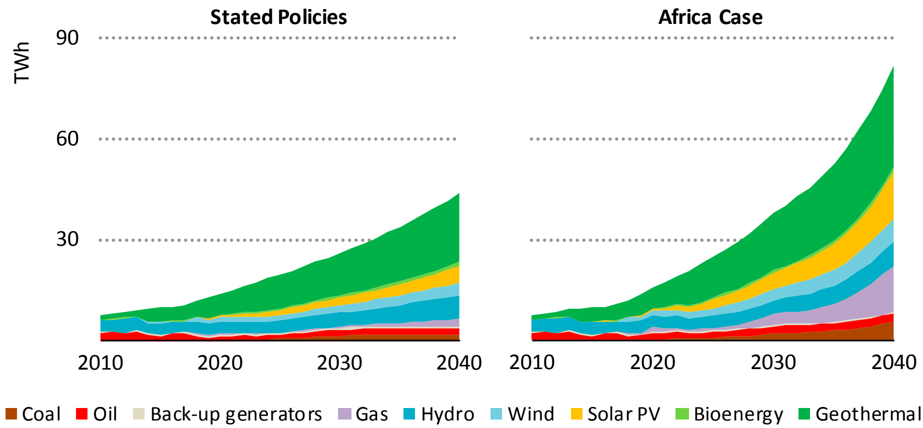


Figure 6.7B ⊳ Kenya electricity generation by technology



- Kenya is one of the few countries to develop geothermal energy: by 2040, it accounts for almost 50% of Kenya's power generation in the STEPS.
- The sevenfold increase in electricity demand in the AC relies on expansion of geothermal production (an increase to 4 GW) and new solar PV and gas capacity.

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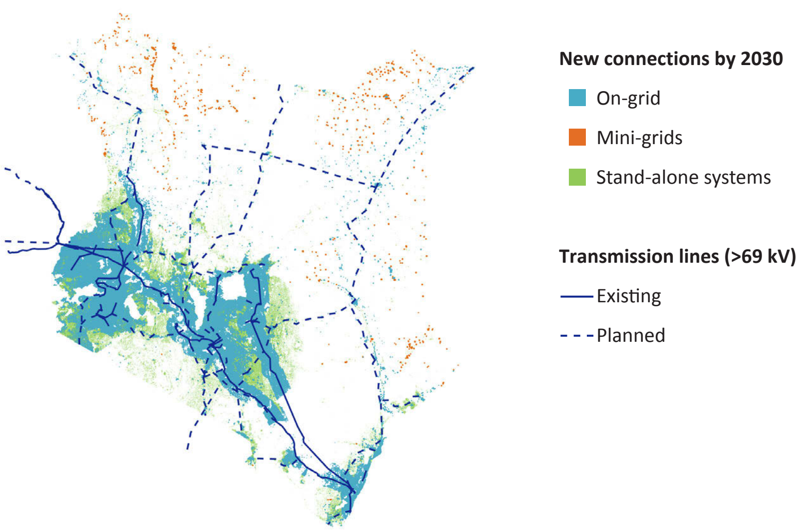
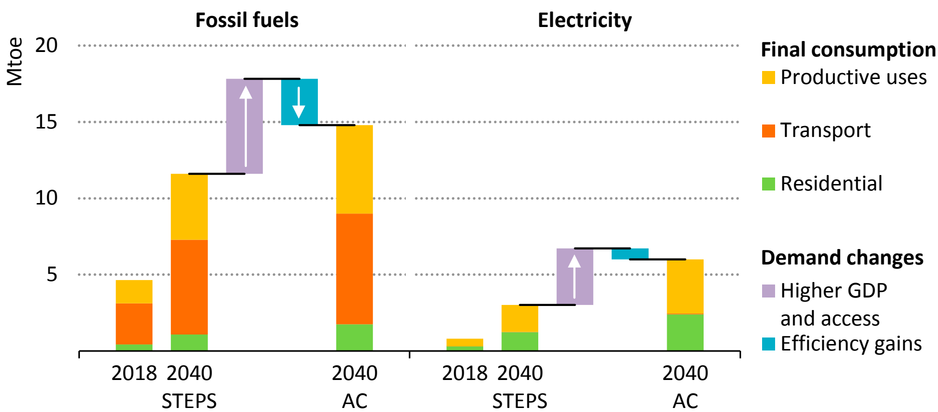
Figure 6.7C ⊳ Kenya electricity access solutions by type in the Africa Case



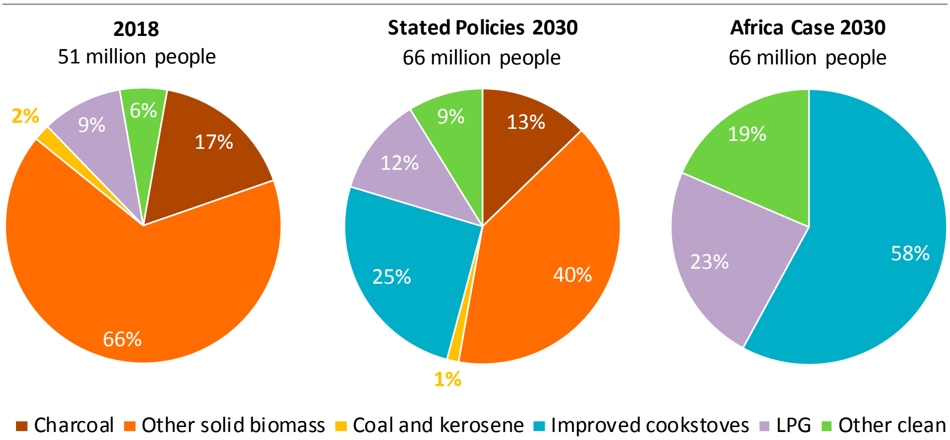
- Kenya has seen one of the fastest increases in electrification rates within sub-Saharan Africa since 2013: by 2018, 75% of the population had access.
- Kenya aims to reach full access by 2022; the grid would be the principal least-cost solution for the majority of the population (mainly in the south) still lacking access.

Figure 6.7D ⊳ Kenya final energy consumption



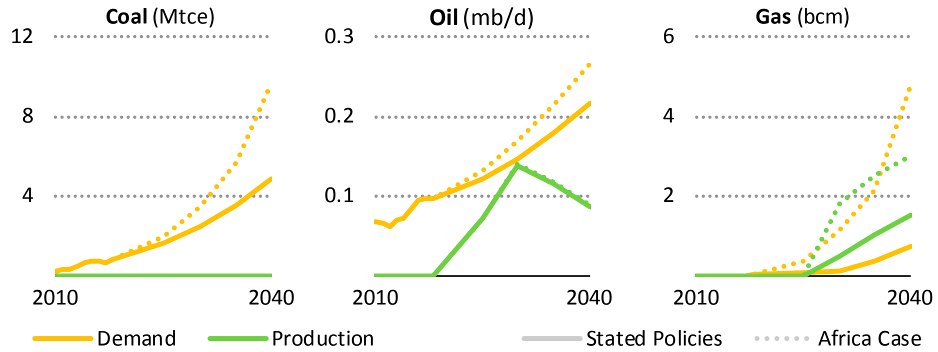
- Oil remains by far the dominant fuel in end-use sectors, and its use triples in road transport in the AC, with five million additional vehicles being added to the fleet.
- Electricity demand reaches nearly 70 TWh in the AC, as light industry grows and as ownership of household appliances and cooling systems increases; efficiency standards avoid a further 8 TWh of demand.

Figure 6.7E ⊳ Kenya fuels and technologies used for cooking



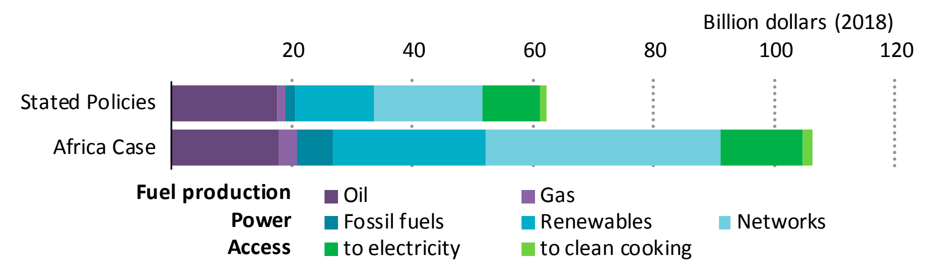
- Today three-stone fires are still used for most cooking, fuelled mostly by charcoal in urban areas and by wood in rural areas. In the STEPS, government initiatives lead to 26% of the population having access to clean cooking by 2030.
- In the AC, everybody gains access to clean cooking by 2030. Most of the 25 million people otherwise without access in rural areas gain access primarily through improved and advanced cookstoves; LPG is the least-cost fuel for most of the urban population.

Figure 6.7F ⊳ Kenya fossil fuel demand and production



- Kenya is not a notable oil and gas producer today, but it takes some steps to develop its relatively modest resources.
- Higher economic growth underpins strong growth in fossil fuel demand in the AC. Oil demand almost triples as it expands its share of the overall energy mix.

Figure 6.7G ⊳ Kenya cumulative investment needs, 2019-2040



- Energy investment amounts to around $60 billion through to 2040 in the STEPS, with renewables and electricity networks accounting for half of this.
- Investments in renewables and electricity networks need to double in the AC.

Kenya policy opportunities

- Kenya is on the cusp of reaching universal access to electricity. Concerted government policy could help reach this aim through grid and stand-alone connections in roughly equal measure.
- Kenya has made notable progress in deploying renewables in large part because it has successfully attracted the necessary private investment for renewables projects. Further development of these resources would help it meet demand growth.

6.8 Mozambique

Large hydro potential | **Important gas** discoveries | **Second-largest coal** producer

Table 6.8A ▷ Mozambique key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	11	39	74	140	98	219	6.0%	8.1%
Population (million)	18	31	43	55	43	55	2.7%	2.7%
with electricity access	6%	29%	60%	72%	100%	100%	4.2%	5.8%
with access to clean cooking	4%	6%	11%	22%	100%	100%	5.7%	13.4%
CO_2 emissions (Mt CO_2)	1	8	21	43	38	66	7.8%	9.9%

Policy	Key targets and measures
Performance targets	▪ Promote the construction of electricity infrastructure that is resilient to climate change. ▪ Ensure sustainable and transparent management of the natural resources and the environment.
Industrial development targets	▪ Five-Year Plan 2015–2019 focuses on empowering women and men for gender equity and equality, poverty reduction, economic development, and food security and nutrition. ▪ Expand and modernise roads, bridges, water, ports and other key infrastructure.

- Mozambique could supply an economy more than five times larger than today in the AC with four-times the energy demand if it were to diversify away from bioenergy and improve energy efficiency.
- Bioenergy, including the traditional use of biomass, currently accounts for more than 60% of primary energy supply, but recent discoveries of gas enable the energy mix to be diversified with gas accounting for 45% of the primary mix by 2040 in the AC.

Figure 6.8A ▷ Mozambique primary energy demand and GDP

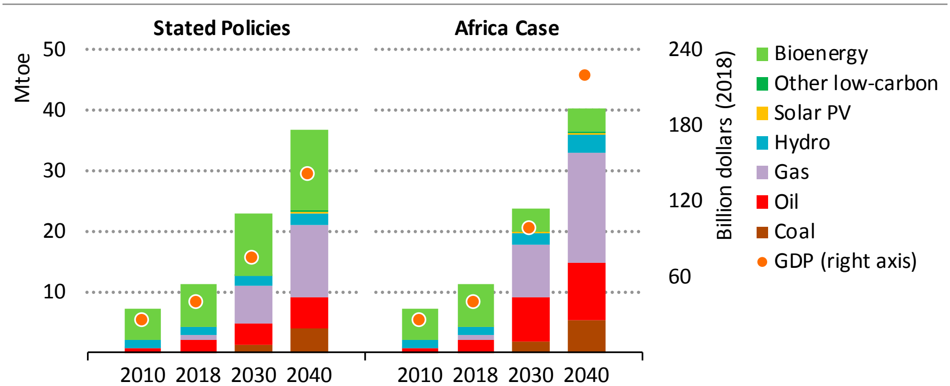
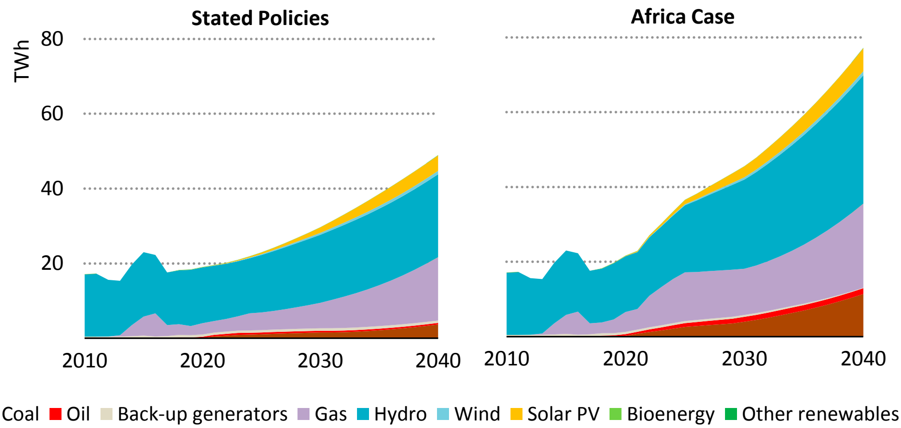
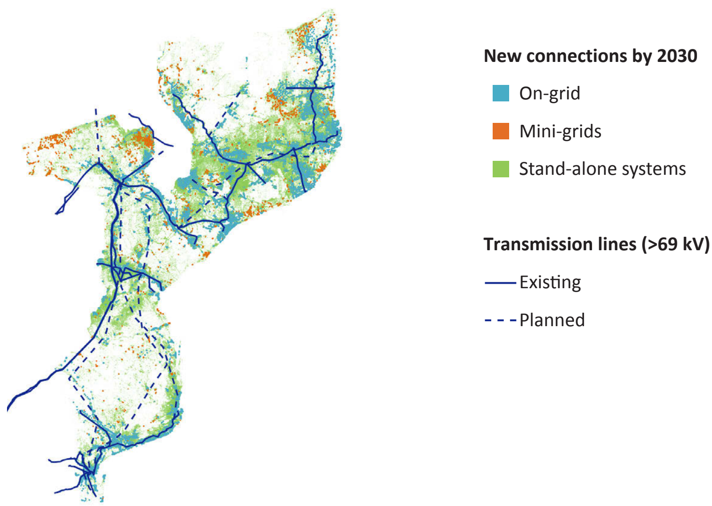


Figure 6.8B ⊳ Mozambique electricity generation by technology



- Providing access to all and increasing electrification of productive uses almost quadruples electricity demand in the AC.
- Hydropower remains an important source of electricity in each scenario, but its share of generation declines from four-fifths today to more than 40% in the AC; gas grows in importance as increasing use is made of domestic resources.

Figure 6.8C ⊳ Mozambique electricity access solutions by type in the Africa Case



- Currently 71% of the population lacks access to electricity; decentralised solutions are the least-cost option for 55% of the new connections in the AC.
- In the AC, grid connections are the least-cost solution for the remaining 45% of new connections: a large share of the population lives close to existing and planned grids.

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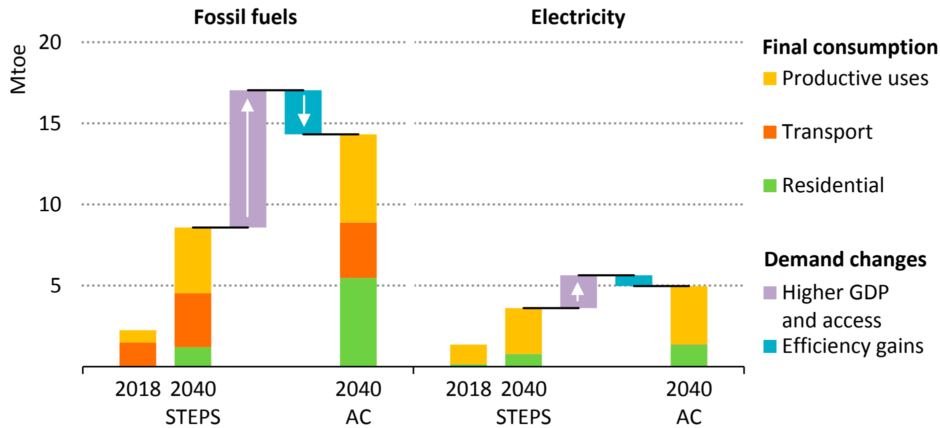
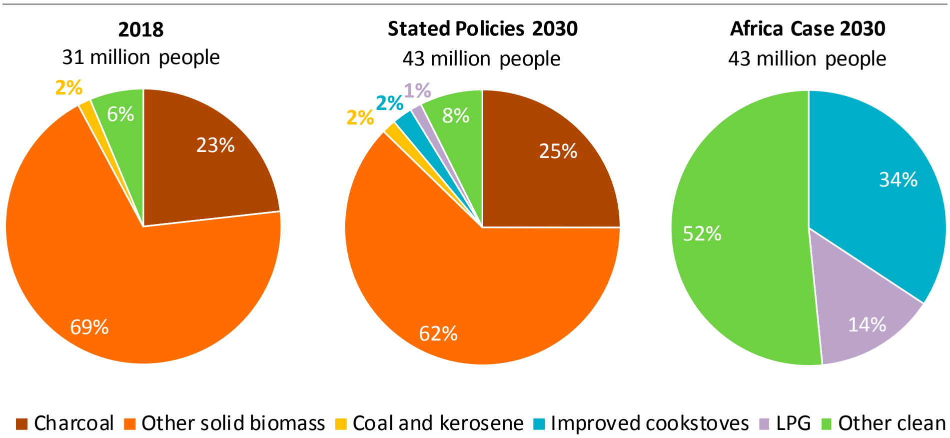
Figure 6.8D ▷ Mozambique final energy consumption



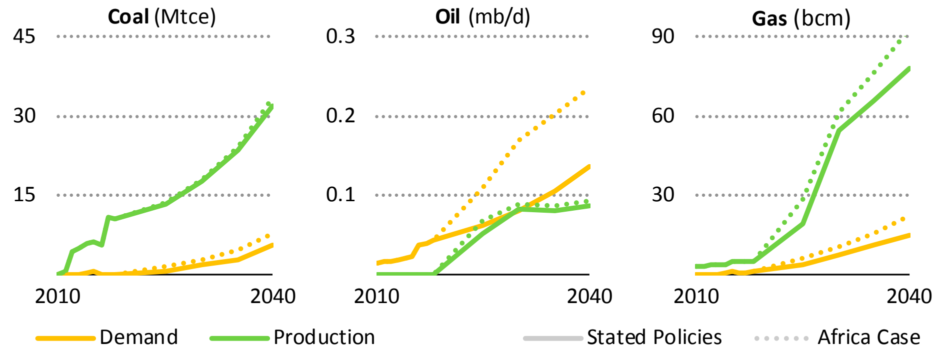
- Oil remains the major fuel used in end-use sectors, with demand growing as a result of increased use of LPG for cooking, while gas consumption exceeds electricity by 2040 in both scenarios.
- In the AC, recent gas discoveries trigger a massive increase in overall industrial gas demand: Mozambique increases production of aluminium more than fivefold by 2040, becoming a significant exporter.

Figure 6.8E ▷ Mozambique fuels and technologies used for cooking



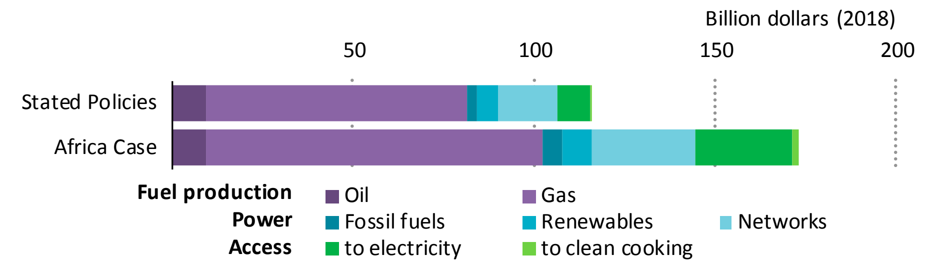
- In the STEPS, the proportion of the population relying on traditional uses of biomass decreases from 92% to 87% by 2030.
- In the AC, natural gas is the least-cost option for a quarter of the 38 million people without access in 2030; with improved cookstoves and LPG providing access for others.

Figure 6.8F ⊳ Mozambique fossil fuel demand and production



- The recent massive gas discoveries in Mozambique becoming the largest gas producer in sub-Saharan Africa by 2040 in the AC.
- While the bulk of the production is destined for export, domestic demand also grows as a result of efforts to foster gas-based industries and expand infrastructure in the AC.

Figure 6.8G ⊳ Mozambique cumulative investment needs, 2019-2040



- Energy investment needs amount to $115 billion through to 2040 in the STEPS, more than 60% of which goes to gas production and infrastructure.
- The AC requires nearly 50% more capital to promote renewables in tandem with gas infrastructure.

Mozambique policy opportunities

- Mozambique's ambitions for economic and social development depend in large measure on its ability to develop its large natural gas resources.
- In addition to providing valuable export revenue, its abundant gas resources could be used to generate electricity, act as a catalyst for domestic industrial development, and to support clean cooking.
- Large industrial consumers of gas could act as anchors for smaller industries looking to increase their use of gas. The aluminium industry could be one such anchor consumer. The success of a domestic aluminium export business will depend heavily on its ability to secure affordable gas feedstock.

6.9 Nigeria

Largest population | Largest economy | Large chemicals producer

Table 6.9A ▷ Nigeria key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	392	1 169	1 636	2 420	2 258	3 678	3.4%	5.3%
Population (million)	122	196	263	329	263	329	2.4%	2.4%
with electricity access	40%	60%	80%	85%	100%	100%	1.6%	2.3%
with access to clean cooking	1%	10%	28%	38%	100%	100%	6.4%	11.2%
CO_2 emissions (Mt CO_2)	37	83	134	191	181	257	3.8%	5.3%

Policy	Key targets and measures
Performance targets	▪ 20% (unconditional) to 45% (conditional) reduction in GHG emissions by 2030 compared to the business-as-usual scenario. ▪ Increase oil production to 2.5 mb/d and become a net exporter by 2020, and end gas flaring by 2030.
Industrial development targets	▪ Dedicate at least 30% of the federal budget to capital expenditure. ▪ Achieve GDP growth of 7% and create over 15 million jobs by 2020 and double manufacturing output to 20% of GDP by 2025.

- Nigeria remains Africa's largest economy: in the AC, supplying an economy three-times larger than today would require less energy demand if the energy mix were to be diversified.
- In the AC, gas meets a growing share of energy demand, supported by the implementation of the government's gas masterplan.

Figure 6.9A ▷ Nigeria primary energy demand and GDP

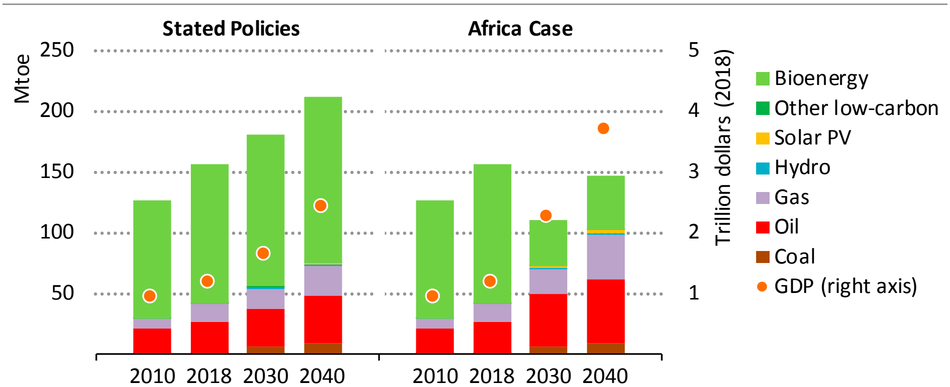
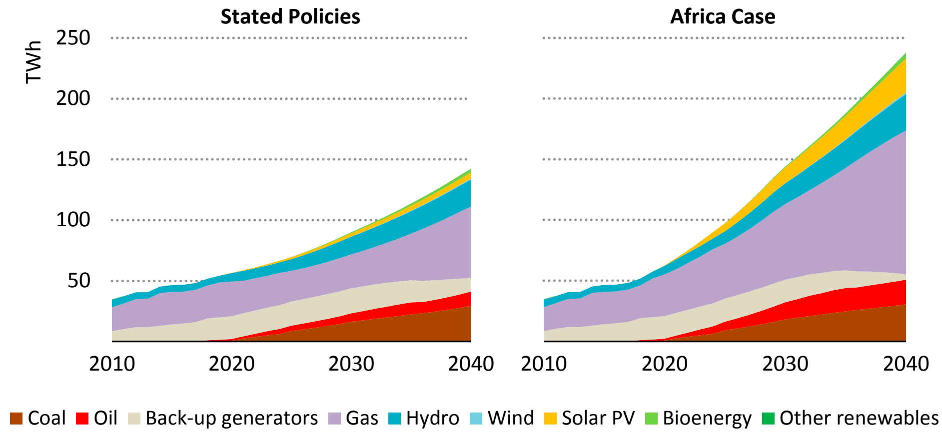
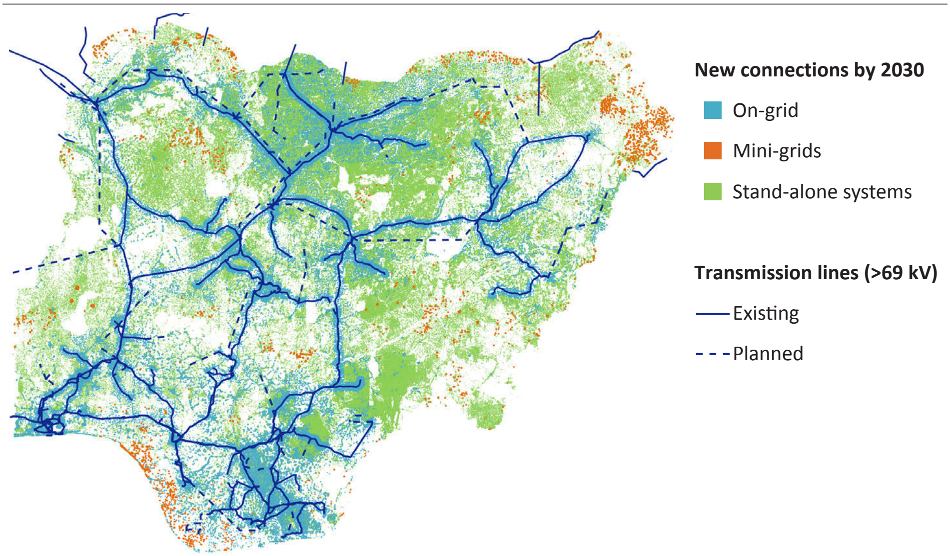


Figure 6.9B ⊳ Nigeria electricity generation by technology



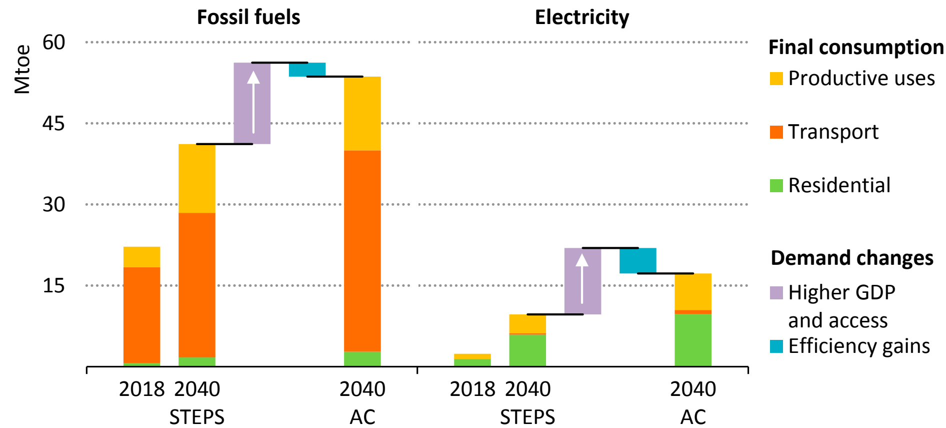
- Today, 80% of power generation comes from gas; most of the remainder comes from oil, with Nigeria the largest user of oil-fired back-up generators on the continent.
- Natural gas remains the main source of power in the AC, although there is a shift towards solar PV as the country starts to exploit its large solar potential.

Figure 6.9C ⊳ Nigeria electricity access solutions by type in the Africa Case



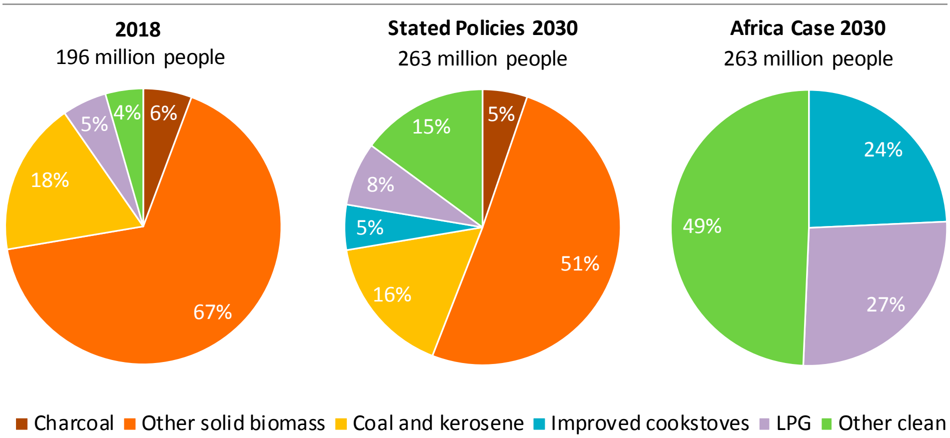
- Provided that reliability and supply improve, the grid could become the optimal solution to provide almost 60% of people with access to electricity in each scenario.
- In the AC, Nigeria achieves universal access by stepping up efforts to provide off-grid solutions to those populations that live far from a grid.

Figure 6.9D ⊳ Nigeria final energy consumption



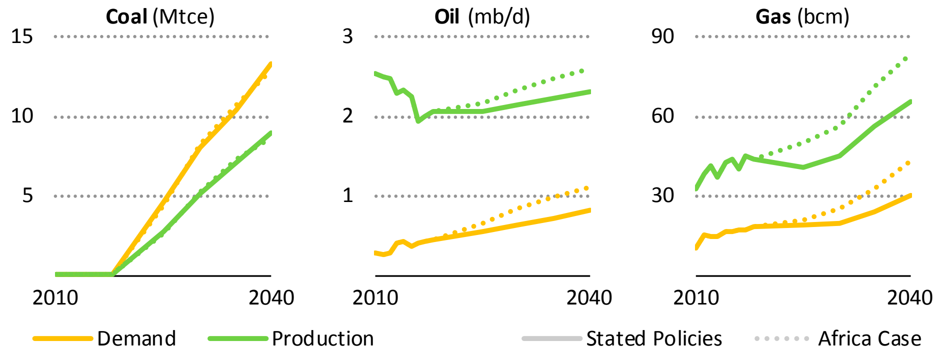
- Nigeria is a major industrial producer and large chemical exporter. In the AC, it triples chemicals production by 2040 with new gas-based methanol and ammonia plants.
- Nigeria has the second-largest vehicle stock in sub-Saharan Africa: the number of vehicles could grow from 14 to 37 million in the AC by 2040 with only two-times more oil consumption if more stringent fuel economy standards were introduced.

Figure 6.9E ⊳ Nigeria fuels and technologies used for cooking



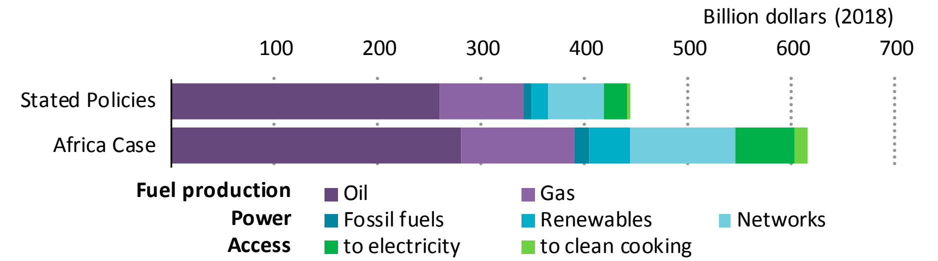
- In the STEPS, there is progress on access to clean cooking services but almost three-quarters of the population still lack access in 2030.
- In the AC, universal access is achieved through greater household access to gas networks and LPG in the main cities, and to improved cookstoves in rural areas.

Figure 6.9F ▷ Nigeria fossil fuel demand and production



- Delayed reforms and growing competition in international oil markets means that it takes time for oil production to revive.
- In both scenarios, gas demand grows strongly in the industry and power sectors, leading to action to increase production and reduce gas flaring.

Figure 6.9G ▷ Nigeria cumulative investment needs, 2019-2040



- Cumulative energy supply investment of $445 billion is needed in the STEPS, almost 80% of which goes to upstream oil and gas.
- The AC requires a significant ramp up in power sector investment. Spending on electricity networks and renewables increases by 85% and 165% respectively, compared to STEPS.

Nigeria policy opportunities

- Oil sector reforms would help to revive oil production while successful implementation of the gas masterplan would foster gas-to-power, industrial development and expansion of the gas network to industrial hubs.
- Improved power sector management and governance would help to reduce outages and transmission losses. Failure to do so would impede industrial growth and would mean continued high levels of use of polluting back-up generation.
- Reducing bioenergy use across all sectors would bring a number of benefits, not least because its use is strongly linked to deforestation and air pollution.

6.10 Senegal

Emerging local gas market **New** oil and gas discoveries **Ambitious** renewables plan

Table 6.10A ⊳ Senegal key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	27	60	154	237	176	370	6.5%	8.7%
Population (million)	10	16	22	28	22	28	2.5%	2.5%
with electricity access	31%	69%	100%	100%	100%	100%	1.7%	1.7%
with access to clean cooking	32%	30%	47%	52%	100%	100%	2.6%	5.7%
CO_2 emissions (Mt CO_2)	4	9	19	30	19	32	5.7%	5.9%

Policy	Key targets and measures
Performance targets	▪ Start producing 100 000 barrels of oil per day from 2022. ▪ Achieve 200 GWh hydropower production in electricity generation output. ▪ Reach universal access to electricity by 2025, with 95% of rural connections provided by the grid.
Industrial development targets	▪ The overall goal of *Le Plan Sénégal Emergent* 2023 is to achieve, through structural transformation of the economy, strong, inclusive and sustainable growth for the well-being of the people and reach middle-income status by 2035.

- Senegal's economy could grow six-times larger in the AC while limiting growth in energy demand to three-times its current level by utilising new gas resources and boosting the use of renewables in power.
- In the AC, gas meets a growing share of energy demand while traditional use of biomass starts to decline in rural areas.

Figure 6.10A ⊳ Senegal primary energy demand and GDP

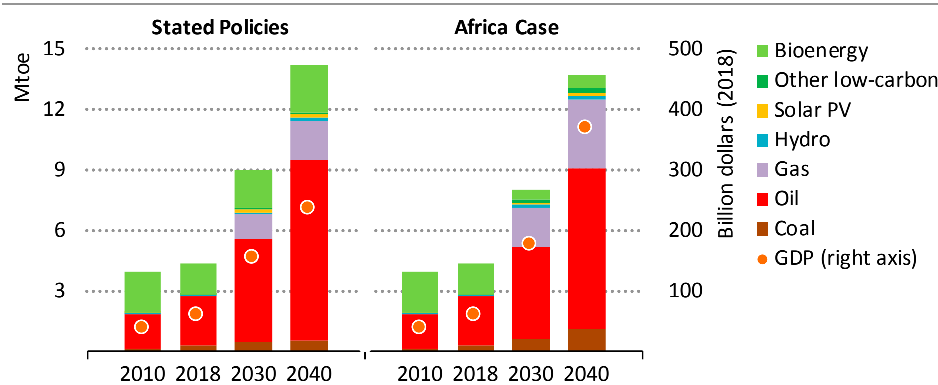
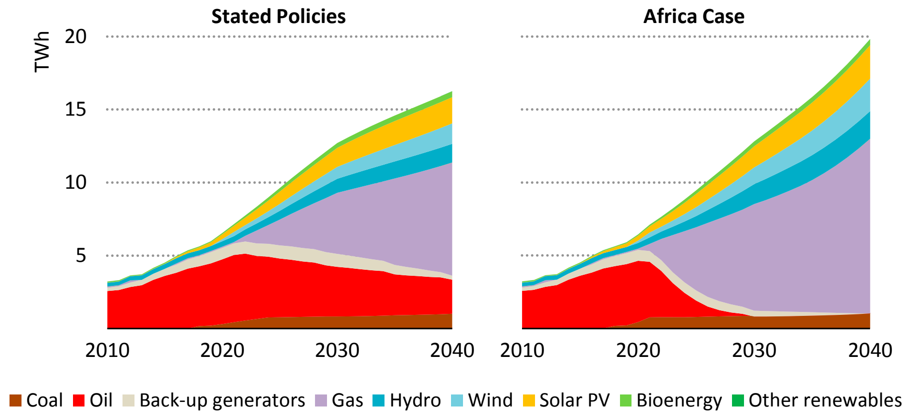


Figure 6.10B ⊳ Senegal electricity generation by technology



- Electricity demand increases sharply in both scenarios, while the power mix changes, with gas playing an increasingly important role and investments in wind and other renewables bringing more diversification.
- Plans to phase out heavy fuel oil in the AC hinge on successful implementation of new gas-to-power plans.

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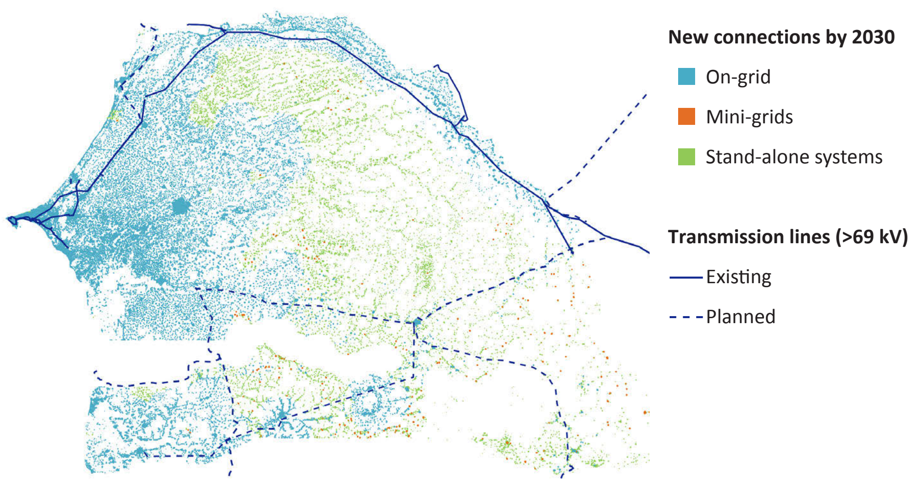
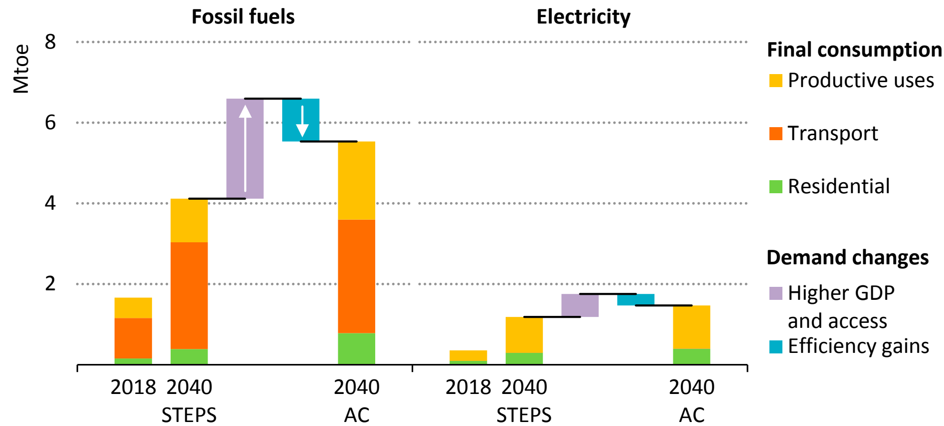
Figure 6.10C ⊳ Senegal electricity access solutions by type in the Africa Case



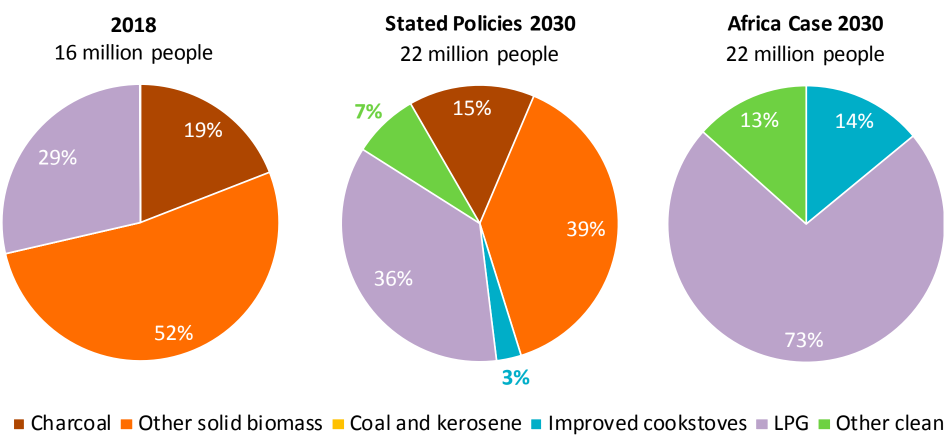
- Thanks to successful access policies, almost 70% of the population is connected today; with adoption of a comprehensive integrated plan full access is achieved by 2025.
- The grid represents the least-cost option for the majority of the population currently without electricity access today, with decentralised solutions reaching the most remote populations.

Figure 6.10D ▷ Senegal final energy consumption



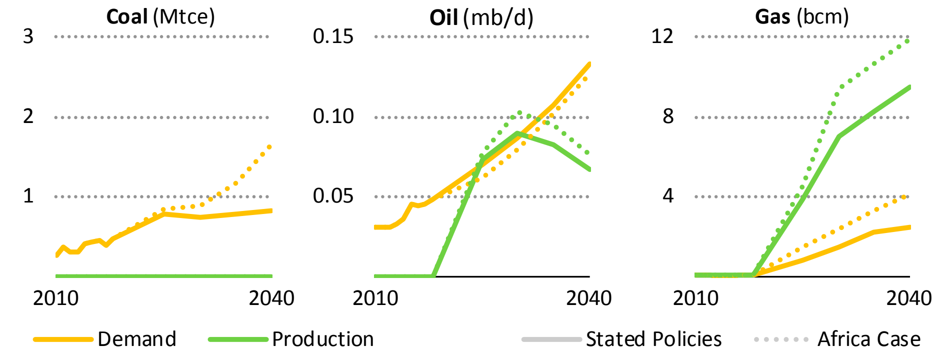
- Senegal's stock of two/three-wheelers is set to grow strongly in both scenarios and its electrification would help to free oil for other productive uses.
- In the AC, cement production could more than double to 2040, although the availability of fuels, including domestic gas, will be critical for this and for wider future industrial development.

Figure 6.10E ▷ Senegal fuels and technologies used for cooking



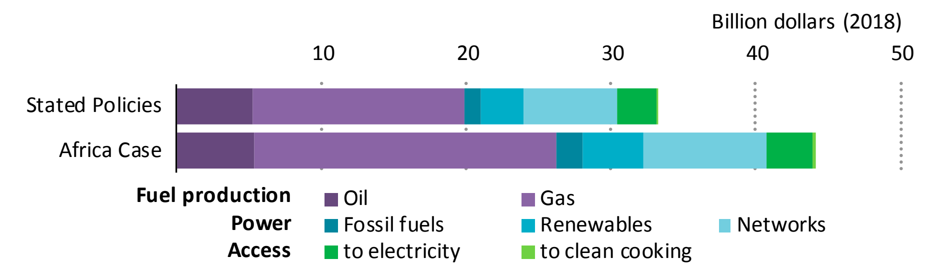
- LPG is used for cooking by almost 30% of the population today, one of the highest shares in sub-Saharan Africa. It is expected to remain the main clean cooking fuel in 2030.
- In the AC, LPG is the least-cost option in both rural and urban areas for more than 70% of the population currently still lacking access.

Figure 6.10F ⊳ Senegal fossil fuel demand and production



- Senegal is not a fossil fuel producer today, but the major gas discoveries are expected to change the picture and to lead to gas production of 9.5 bcm in 2040 in the STEPS.
- The greater availability of gas helps displace oil use in power generation in domestic markets while also bringing considerable export revenues.

Figure 6.10G ⊳ Senegal cumulative investment needs, 2019-2040



- Energy investment needs amount to $33 billion through to 2040 in the STEPS, mainly to unlock the potential for gas, expand power networks and increase electricity access.
- The AC sees this level of investment increase by a third, with more emphasis on gas and renewable generation.

Senegal policy opportunities

- Implement a robust and transparent framework for resource management and design of local content rules would help Senegal to make the most of its natural resources.
- The development of natural gas strategies that cover the entire value chain, including end-uses (gas-to-power or gas-to-industry), would help Senegal to maximise the benefits of its natural gas.
- Senegal's power sector would be strengthened by continued diversified investment in power, including renewables and natural gas, while phasing out heavy fuel oil.

6.11 South Africa

Africa's only nuclear power | **Major** commodity exporter | **Coal-fired** power sector

Table 6.11A ▷ South Africa key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	491	789	1 010	1 348	1 174	1 600	2.5%	3.3%
Population (million)	46	57	66	71	66	71	1.0%	1.0%
with electricity access	77%	95%	100%	100%	100%	100%	0.2%	0.2%
with access to clean cooking	56%	87%	90%	93%	100%	100%	0.3%	0.7%
CO_2 emissions (Mt CO_2)	280	420	321	279	289	187	-1.8%	-3.6%

Policy	Key targets and measures
Performance targets	▪ The National Development Plan 2030 envisages that adequate investment in energy infrastructure will promote economic growth and development. ▪ Decommission 35 GW (of 42 GW currently operating) of coal-fired power capacity and supply at least 20 GW of the additional 29 GW of electricity needed by 2030 from renewables and natural gas.
Industrial development targets	▪ Secure primary steel production capability and support the downstream steel sector. ▪ Automotive Masterplan 2020: raise domestic vehicle production to 1% of global output including building 20% hybrid electric vehicles by 2030.

- The economy could double in the AC with less primary energy demand compared to today by increasing the share of renewables and gas in the energy mix.
- In the AC, the role of coal in South African industry and power generation is already decreasing, while that of gas and renewables is increasing.

Figure 6.11A ▷ South Africa primary energy demand and GDP

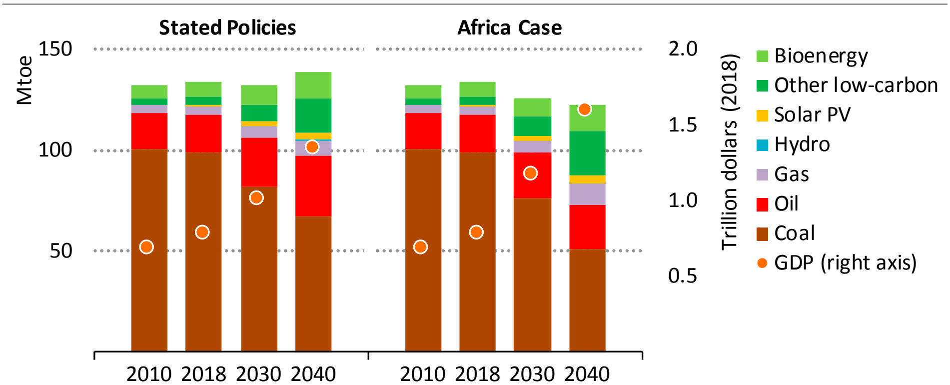
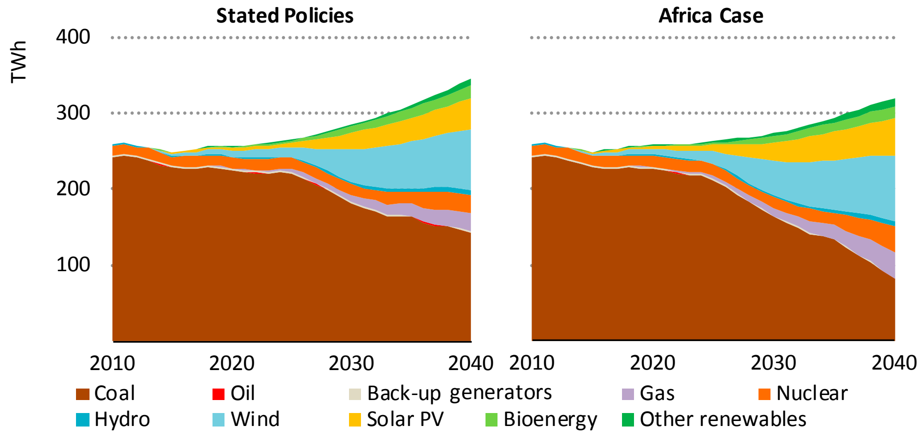


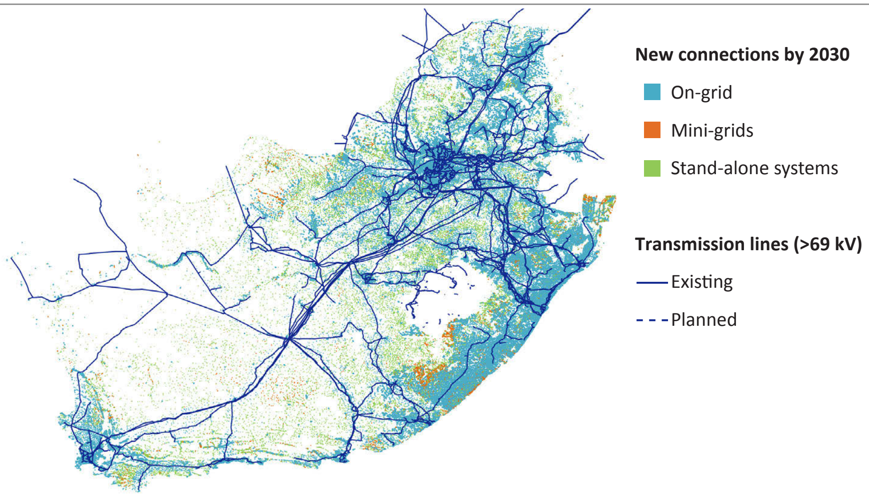
Figure 6.11B ▷ South Africa electricity generation by technology



- South Africa is reliant on coal but is making efforts to diversify as its coal-fired fleet is ageing; new projects will not fully compensate for the decline of the existing fleet.
- The government is focussing on diversifying the power mix by introducing natural gas and renewables, including concentrating solar power (CSP); South Africa has excellent natural resources for CSP development.

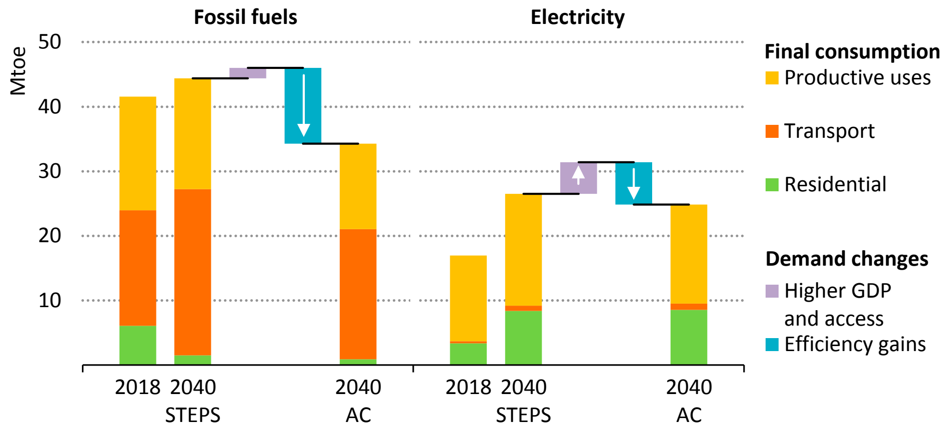
6

Figure 6.11C ▷ South Africa electricity access solutions by type in the Africa Case



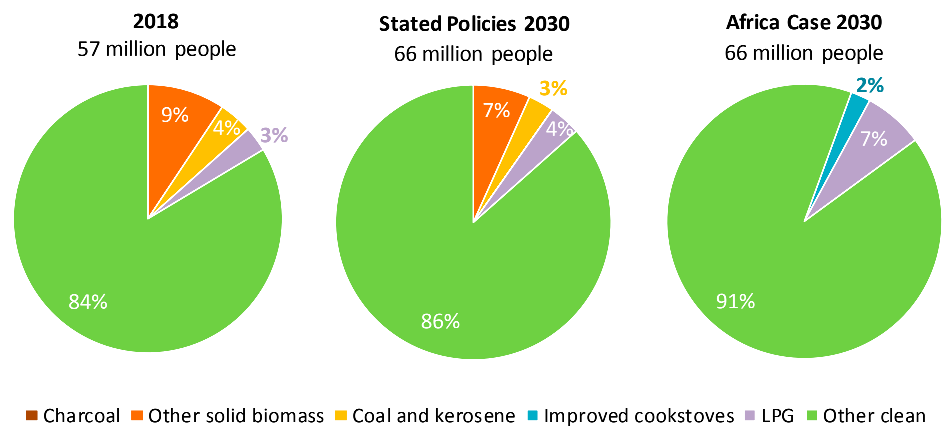
- South Africa has a well-developed electricity network and one of the highest rates of electricity access in sub-Saharan Africa.
- The least-cost way to connect those without access is in most cases via the grid (81%) with the residual population served by mini-grids (12%) and stand-alone systems.

Figure 6.11D ▷ South Africa final energy consumption



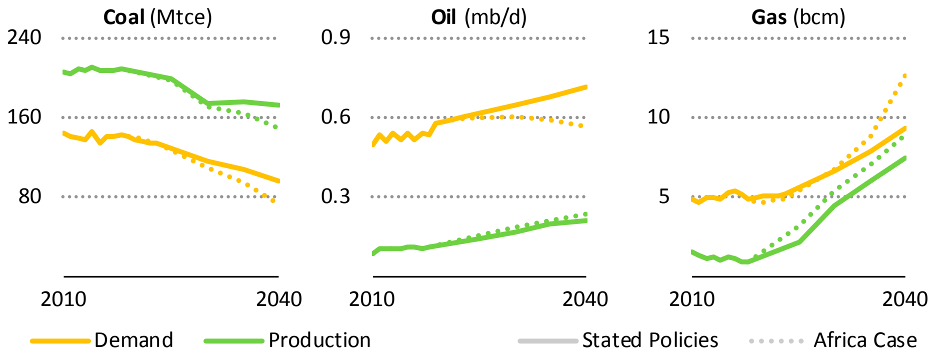
- Oil is the largest fuel in the end-use sectors; more stringent fuel economy standards would mean that a 25% increase in demand could be met with a slight increase in the amount of oil used.
- The role of coal in South African industry dwindles in the AC as gas and bioenergy are increasingly used, especially in steel production and in light industries.

Figure 6.11E ▷ South Africa fuels and technologies used for cooking



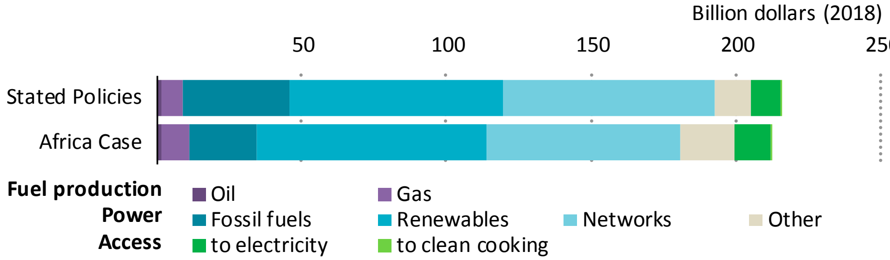
- In both urban and rural areas, electricity is the favourite option for cooking in South Africa, but more than 4 million living mainly in rural areas continue to use fuelwood for heating and cooking in 2030 in the STEPS.
- Improved cookstoves and LPG would help close the gap between the STEPS and the AC and eliminate the use of traditional biomass, reducing household premature deaths by 80% in 2030.

Figure 6.11F ⊳ South Africa fossil fuel demand and production



- South Africa continues to dominate coal production in Africa. Despite declining production, falling domestic demand boosts export volumes in both scenarios.
- South Africa also relies on oil and gas for its energy needs, but recent gas discoveries could reduce its import needs.

Figure 6.11G ⊳ South Africa cumulative investment needs, 2019-2040



- Nearly $220 billion of cumulative energy investment is needed in the STEPS, with renewables and electricity networks accounting for the majority.
- The AC requires more investment in gas production, but overall efficiency improvements moderate the additional spending needs.

South Africa policy opportunities

- Diversifying energy supply away from coal would have many benefits, including a reduction in the number of premature deaths from pollution, but the social implications of changes would need careful management.
- Reforming and restructuring ESKOM would strengthen the reliably of the power system, support increased industrialisation and help efforts to diversify the energy mix.
- Strengthening efficiency throughout the economy would reduce demand for both materials and energy, while the implementation of minimum energy performance standards for electric motors in the industry and mining sectors would be an important first step towards unlocking further efficiency gains.

6.12 Tanzania

Strong economic growth | **Major** gas discovery | **Plans** for urban transport

Table 6.12A ▷ Tanzania key indicators and policy initiatives

			Stated Policies		Africa Case		CAAGR 2018-40	
	2000	2018	2030	2040	2030	2040	STEPS	AC
GDP ($2018 billion, PPP)	57	176	314	585	475	1 233	5.6%	9.3%
Population (million)	34	59	83	108	83	108	2.8%	2.8%
with electricity access	11%	37%	70%	80%	100%	100%	3.6%	4.7%
with access to clean cooking	2%	6%	46%	76%	100%	100%	12.2%	13.7%
CO_2 emissions (Mt CO_2)	3	12	24	41	36	74	5.9%	8.8%

Policy	Key targets and measures
Performance targets	▪ Reduce GHG emissions by 10-20% by 2030 compared to the business-as-usual scenario (138-153 Mt CO_2-equivalent gross emissions). ▪ Increase electricity generation capacity from 1 500 MW in 2015 to 4 910 MW and achieve 50% energy from renewable energy sources by 2020.
Industrial development targets	▪ Raise annual real GDP growth to 10% by 2021. ▪ Build a semi-industrialised country by 2025 in which the contribution of manufacturing to the national economy reaches at least 40% of GDP.

- With annual GDP growth of more than 9% in the AC, Tanzania's economy could be seven-times larger in 2040 than today, but with an increase in energy demand limited to 150% driven by fuel efficiency gains.
- In the AC, diversifying the energy mix and improving energy efficiency are the keys to achieving economic growth while limiting growth in energy demand, with oil, gas and geothermal reducing the share of bioenergy in the energy mix.

Figure 6.12A ▷ Tanzania primary energy demand and GDP

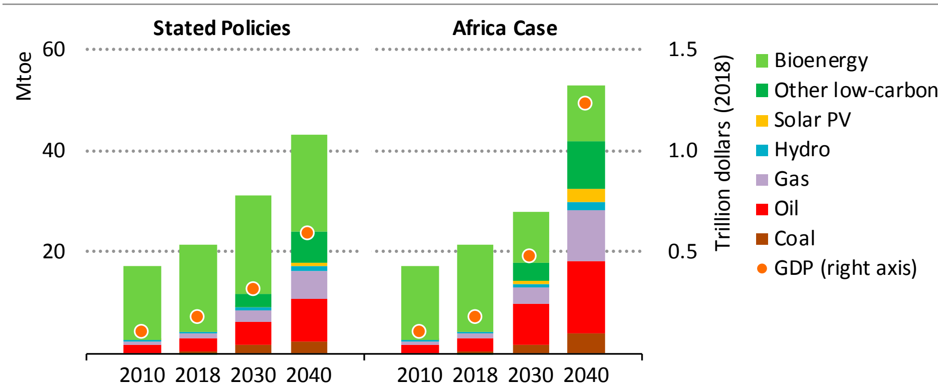
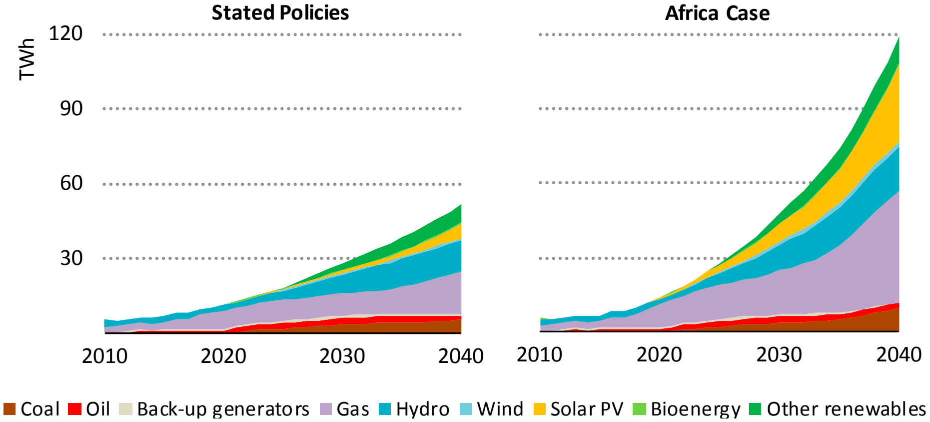


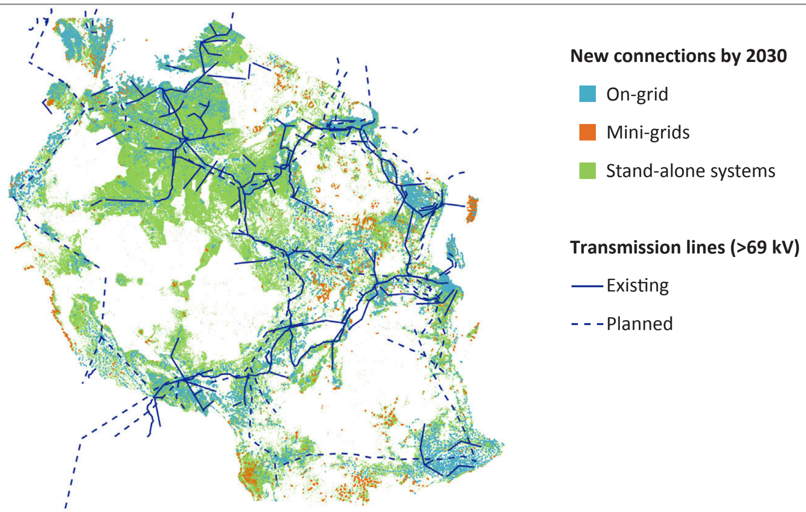
Figure 6.12B ▷ Tanzania electricity generation by technology



- Gas accounts for more than half of current power generation, with the remainder coming from hydropower and oil, the latter used mostly for back-up generators.
- Providing access for all and a growth in productive uses lead to a thirteen-fold increase of electricity demand by 2040 in the AC: this is met with an expansion of gas, hydropower and solar PV.

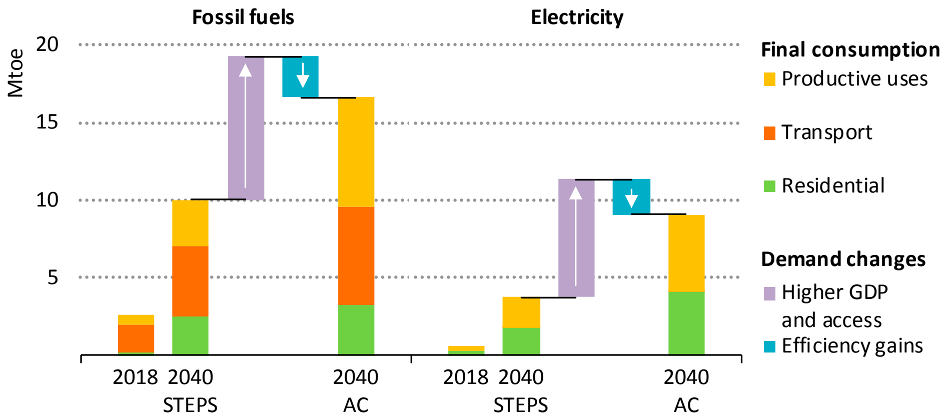
6

Figure 6.12C ▷ Tanzania electricity access solutions by type in the Africa Case



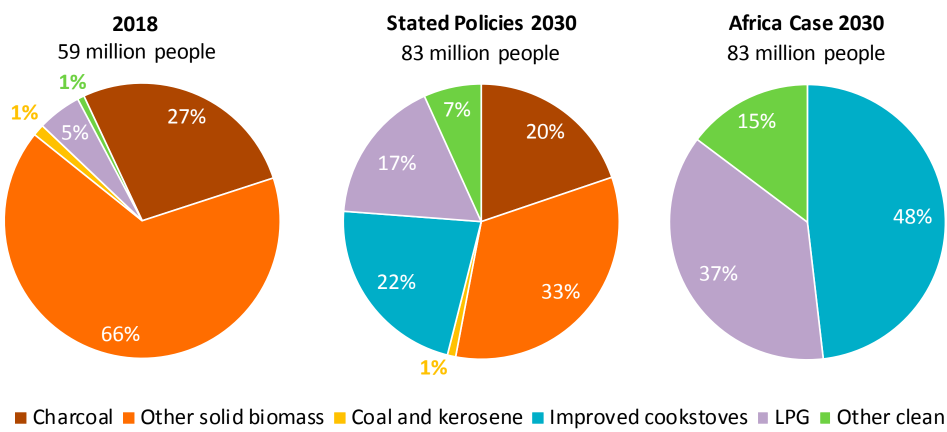
- Despite the low access rate (37%) today, the grid represents more than half of new connections by 2030 in the AC given its existing and planned coverage.
- In the AC, around one-third of the remaining population, mainly located in sparsely populated areas far from the grid, would be best reached by stand-alone systems.

Figure 6.12D ▷ Tanzania total final consumption



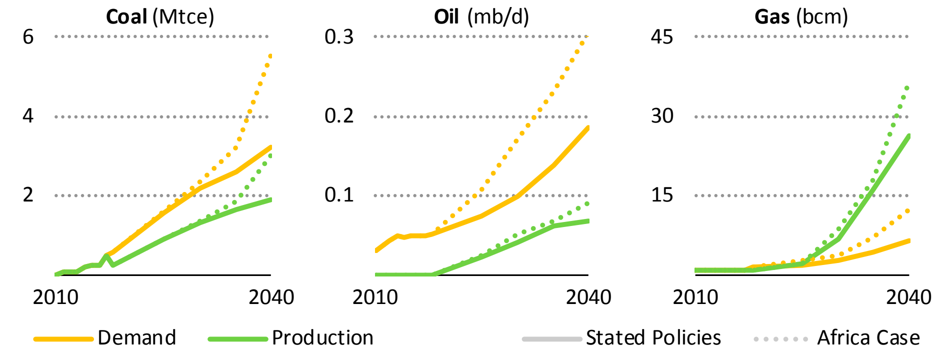
- Oil continues to play an important role in end-use sectors, not least as a result of its use by the increasing number of buses on the road as Tanzania has a large bus fleet.
- Gas and electricity use in industry is growing strongly, especially in manufacturing industries, but in the AC, energy efficiency measures have prevented consumption from being 20% higher than current levels.

Figure 6.12E ▷ Tanzania use of fuels and technologies for cooking



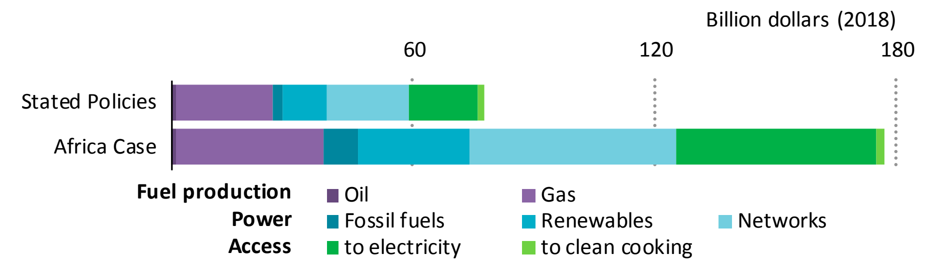
- Despite policies to promote clean cooking solutions, the number of people relying on traditional use of biomass for cooking declines from 55 million people today to 44 million in 2030 as efforts to improve access outrun by high population growth in STEPS.
- In the AC, LPG and biogas are the least-cost options for almost half of the population, with improved cookstoves the main way to extend access in rural areas.

Figure 6.12F ⊳ Tanzania fossil fuel demand and production



- Recent large discoveries push up gas production to almost 30 bcm by 2040 in the STEPS. Existing infrastructure helps Tanzania to increase domestic gas consumption.
- Gas demand in 2040 is twice as high in the AC, helped by efforts to promote the use of gas to displace traditional biomass and by support for gas-based industries.

Figure 6.12G ⊳ Tanzania cumulative investment needs, 2019-2040



- Almost $80 billion of cumulative energy supply investment is needed in the STEPS, with most of it being used to widen access to gas and electricity.
- This level of investment doubles in the AC, with higher amounts of capital allocated to electricity access and networks.

Tanzania policy opportunities

- A rapid development of offshore resources would help to ensure greater availability of gas, and a robust framework to use export revenues in an effective manner would help to ensure that the country makes the most of those revenues.
- Maintaining investment in public transport, notably in Dar es Salaam, but also in other cities and between cities and rural areas, would help to facilitate economic growth. Government should also ensure public transport is affordable for all.

Tables for scenario projections

This annex includes historical and projected data for the Stated Policies Scenario and Africa Case for energy demand, gross electricity generation, electrical capacity, and CO_2 emissions from fossil fuel combustion.

Both in the text of this book and in the tables, rounding may lead to minor differences between totals and the sum of their individual components. Growth rates are calculated on a compound average annual basis and are marked "n.a." when the base year is zero or the value exceeds 200%. Nil values are marked "-".

Data sources

Much of the data on energy supply, transformation and demand, as well as CO_2 emissions from fuel combustion, are obtained from the IEA's own databases of energy and economic statistics (www.iea.org/statistics/). Additional data from a wide range of external sources are also used. Historical data for gross power generation capacity are drawn from the S&P Global Market Intelligence World Electric Power Plants Database (March 2019 version) and the International Atomic Energy Agency PRIS database (www.iaea.org/pris).

The formal base year for this year's projections is 2017, as this is the last year for which a complete picture of energy demand and production is in place. However, we have used more recent data wherever available, and we include our 2018 estimates for energy production and demand in this annex. Estimates for the year 2018 are based on an update of the Global Energy and CO_2 Status Report which is derived from a number of sources, including the latest monthly data submissions to the IEA's Energy Data Centre, other statistical releases from national administrations, and recent market data from the IEA *Market Report Series* that cover coal, oil, natural gas, renewables and power.

Definitional notes

Total primary energy demand (TPED) is equivalent to power generation plus "other energy sector" excluding electricity and heat, plus total final consumption (TFC) excluding electricity and heat. TPED does not include ambient heat from heat pumps or electricity trade. Sectors comprising TFC include industry, transport, buildings (residential, services and non-specified other) and other (agriculture and non-energy use).

Projected **gross electrical capacity** is the sum of existing capacity and additions, less retirements. While not itemised separately, other sources are included in total electricity generation, and battery storage in total power generation capacity.

Total CO_2 includes carbon dioxide emissions from "other energy sector" in addition to the power and final consumption sectors shown in the tables. CO_2 emissions do not include emissions from industrial waste and non-renewable municipal waste. For more information please visit www.iea.org/statistics/CO2emissions.

Abbreviations used: Mtoe = million tonnes of oil equivalent; CAAGR = compound average annual growth rate; Petrochem. feedstock = petrochemical feedstock.

Energy demand – Africa

	Stated Policies Scenario									
	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total primary demand	**681**	**817**	**838**	**992**	**1 100**	**1 202**	**1 318**	**100**	**100**	**2.1**
Coal	108	110	112	116	112	112	113	13	9	0.0
Oil	161	193	194	237	266	298	333	23	25	2.5
Natural gas	90	126	133	154	184	220	263	16	20	3.2
Nuclear	3	4	4	4	7	9	11	0	1	5.2
Hydro	9	11	12	17	21	24	30	1	2	4.4
Bioenergy	308	368	378	449	471	470	471	45	36	1.0
Other renewables	2	6	7	16	39	68	97	1	7	13.0
Power sector	**142**	**168**	**175**	**194**	**230**	**275**	**327**	**100**	**100**	**2.9**
Coal	66	65	66	69	64	60	54	38	17	-0.9
Oil	17	18	19	20	19	20	19	11	6	-0.1
Natural gas	44	64	67	67	75	88	109	38	33	2.2
Nuclear	3	4	4	4	7	9	11	2	3	5.2
Hydro	9	11	12	17	21	24	30	7	9	4.4
Bioenergy	1	1	1	2	6	9	11	1	3	11.7
Other renewables	1	6	6	15	37	65	93	4	28	12.9
Other energy sector	**101**	**126**	**127**	**164**	**179**	**183**	**190**	**100**	**100**	**1.9**
Electricity	12	16	16	17	20	24	29	13	15	2.7
Total final consumption	**496**	**594**	**611**	**727**	**804**	**881**	**970**	**100**	**100**	**2.1**
Coal	17	21	22	22	23	24	26	4	3	0.7
Oil	137	165	167	207	238	271	308	27	32	2.8
Natural gas	29	42	46	61	77	96	114	8	12	4.2
Electricity	47	57	59	75	92	114	141	10	15	4.0
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	266	309	317	359	372	374	377	52	39	0.8
Other renewables	0	0	0	1	2	3	4	0	0	13.6
Industry	**83**	**95**	**98**	**119**	**135**	**157**	**184**	**100**	**100**	**2.9**
Coal	12	11	12	14	16	17	20	12	11	2.3
Oil	17	18	17	21	23	26	31	18	17	2.7
Natural gas	14	24	27	34	40	48	57	27	31	3.5
Electricity	20	23	24	28	33	38	44	24	24	2.8
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	20	18	18	22	24	27	32	19	17	2.5
Other renewables	-	-	-	0	0	0	0	-	0	n.a.
Transport	**86**	**116**	**118**	**147**	**168**	**187**	**207**	**100**	**100**	**2.6**
Oil	85	114	116	144	163	181	199	98	96	2.5
Electricity	0	1	1	1	1	2	2	0	1	6.8
Biofuels	0	0	0	1	1	1	2	0	1	20.8
Other fuels	1	1	1	2	2	3	3	1	2	3.9
Buildings	**297**	**358**	**369**	**426**	**460**	**490**	**525**	**100**	**100**	**1.6**
Coal	3	8	8	6	5	4	4	2	1	-3.7
Oil	19	19	19	23	28	37	47	5	9	4.2
Natural gas	6	12	14	20	28	37	44	4	8	5.4
Electricity	24	31	33	43	55	70	90	9	17	4.7
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	244	288	295	333	342	340	337	80	64	0.6
Traditional biomass	236	277	283	320	326	321	314	77	60	0.5
Other renewables	0	0	0	1	2	3	4	0	1	13.0
Other	**30**	**25**	**26**	**35**	**41**	**47**	**54**	**100**	**100**	**3.4**
Petrochem. feedstock	12	6	6	11	13	15	17	25	32	4.6

Energy demand – Africa

	Africa Case									
	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total primary demand	**681**	**817**	**838**	**872**	**888**	**1 024**	**1 204**	**100**	**100**	**1.7**
Coal	108	110	112	110	105	104	100	13	8	-0.5
Oil	161	193	194	257	304	335	362	23	30	2.9
Natural gas	90	126	133	171	198	229	290	16	24	3.6
Nuclear	3	4	4	4	7	9	19	0	2	7.6
Hydro	9	11	12	19	27	36	44	1	4	6.3
Bioenergy	308	368	378	280	180	197	212	45	18	-2.6
Other renewables	2	6	7	31	68	115	179	1	15	16.1
Power sector	**142**	**168**	**175**	**229**	**285**	**348**	**451**	**100**	**100**	**4.4**
Coal	66	65	66	65	58	52	41	38	9	-2.1
Oil	17	18	19	22	27	27	26	11	6	1.3
Natural gas	44	64	67	86	94	104	137	38	30	3.3
Nuclear	3	4	4	4	7	9	19	2	4	7.6
Hydro	9	11	12	19	27	36	44	7	10	6.3
Bioenergy	1	1	1	4	8	11	15	1	3	13.2
Other renewables	1	6	6	29	63	108	169	4	37	16.1
Other energy sector	**101**	**126**	**127**	**122**	**114**	**123**	**137**	**100**	**100**	**0.4**
Electricity	12	16	16	21	27	33	42	13	31	4.5
Total final consumption	**496**	**594**	**611**	**633**	**637**	**739**	**859**	**100**	**100**	**1.6**
Coal	17	21	22	21	21	22	24	4	3	0.3
Oil	137	165	167	226	269	302	333	27	39	3.2
Natural gas	29	42	46	61	77	97	123	8	14	4.6
Electricity	47	57	59	90	120	153	200	10	23	5.7
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	266	309	317	232	145	158	169	52	20	-2.8
Other renewables	0	0	0	2	4	7	10	0	1	18.0
Industry	**83**	**95**	**98**	**120**	**140**	**168**	**205**	**100**	**100**	**3.4**
Coal	12	11	12	13	14	16	19	12	9	2.1
Oil	17	18	17	21	25	29	35	18	17	3.2
Natural gas	14	24	27	34	40	49	62	27	30	3.9
Electricity	20	23	24	27	31	40	52	24	25	3.6
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	20	18	18	25	30	33	36	19	18	3.2
Other renewables	-	-	-	0	0	1	1	-	1	n.a.
Transport	**86**	**116**	**118**	**159**	**186**	**206**	**222**	**100**	**100**	**2.9**
Oil	85	114	116	154	176	189	198	98	89	2.4
Electricity	0	1	1	1	1	2	3	0	2	9.0
Biofuels	0	0	0	1	2	3	4	0	2	24.3
Other fuels	1	1	1	3	6	12	18	1	8	12.0
Buildings	**297**	**358**	**369**	**317**	**266**	**311**	**365**	**100**	**100**	**-0.1**
Coal	3	8	8	6	5	4	3	2	1	-5.0
Oil	19	19	19	29	42	52	61	5	17	5.4
Natural gas	6	12	14	19	22	25	29	4	8	3.4
Electricity	24	31	33	58	83	106	138	9	38	6.7
Heat	-	-	-	-	-	-	-	-	-	n.a.
Bioenergy	244	288	295	203	110	119	127	80	35	-3.8
Traditional biomass	236	277	283	186	88	95	101	77	28	-4.6
Other renewables	0	0	0	2	4	6	9	0	2	17.1
Other	**30**	**25**	**26**	**37**	**45**	**54**	**66**	**100**	**100**	**4.4**
Petrochem. feedstock	12	6	6	11	14	17	23	25	35	6.0

Electricity and CO_2 emissions – Africa

	Stated Policies Scenario Electricity generation (TWh)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total generation	**671**	**827**	**866**	**1 056**	**1 284**	**1 564**	**1 897**	**100**	**100**	**3.6**
Coal	259	254	258	284	268	256	240	30	13	-0.3
Oil	64	75	79	84	79	82	78	9	4	-0.0
Natural gas	220	335	351	377	433	523	651	40	34	2.9
Nuclear	12	14	14	14	28	35	44	2	2	5.2
Renewables	115	147	163	296	474	668	882	19	46	8.0
Hydro	110	123	135	202	245	283	348	16	18	4.4
Bioenergy	1	2	2	7	22	32	40	0	2	14.9
Wind	2	12	14	39	84	120	159	2	8	11.7
Geothermal	1	5	5	9	23	41	59	1	3	12.1
Solar PV	0	5	6	34	90	172	241	1	13	18.1
CSP	-	1	2	5	9	19	34	0	2	13.9
Marine	-	-	-	-	-	-	-	-	-	n.a.

	Stated Policies Scenario Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total capacity	**228**	**244**	**315**	**400**	**501**	**614**	**100**	**100**	**4.3**
Coal	48	48	55	55	51	48	20	8	0.0
Oil	42	43	35	36	37	36	18	6	-0.8
Natural gas	92	103	129	146	171	207	42	34	3.2
Nuclear	2	2	2	4	5	6	1	1	5.0
Renewables	44	48	90	154	225	299	20	49	8.7
Hydro	35	36	49	57	67	83	15	13	3.9
Bioenergy	1	1	2	6	8	9	0	1	11.9
Wind	5	5	15	30	41	53	2	9	10.9
Geothermal	1	1	1	4	6	9	0	1	12.6
Solar PV	3	4	21	55	98	135	2	22	16.8
CSP	1	1	2	3	6	10	0	2	11.3
Marine	-	-	-	-	-	-	-	-	n.a.

	Stated Policies Scenario CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total CO_2	**1 017**	**1 181**	**1 215**	**1 357**	**1 464**	**1 621**	**1 797**	**100**	**100**	**1.8**
Coal	385	391	395	382	346	332	318	32	18	-1.0
Oil	450	541	551	668	750	846	948	45	53	2.5
Natural gas	182	248	269	307	368	443	532	22	30	3.1
Power sector	**420**	**466**	**480**	**495**	**490**	**508**	**530**	**100**	**100**	**0.4**
Coal	263	257	261	275	255	239	215	54	41	-0.9
Oil	54	59	62	63	59	62	60	13	11	-0.2
Natural gas	103	150	158	157	176	208	256	33	48	2.2
Final consumption	**496**	**620**	**641**	**776**	**892**	**1 021**	**1 163**	**100**	**100**	**2.7**
Coal	66	83	85	84	85	89	96	13	8	0.5
Oil	382	472	480	590	675	767	871	75	75	2.8
Transport	257	345	351	436	495	549	603	55	52	2.5
Natural gas	48	65	76	102	131	165	197	12	17	4.4

Electricity and CO_2 emissions – Africa

Africa Case	Electricity generation (TWh)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total generation	**671**	**827**	**866**	**1 268**	**1 662**	**2 107**	**2 740**	**100**	**100**	**5.4**
Coal	259	254	258	255	228	210	171	30	6	-1.8
Oil	64	75	79	91	108	107	102	9	4	1.2
Natural gas	220	335	351	506	567	646	850	40	31	4.1
Nuclear	12	14	14	14	28	34	71	2	3	7.6
Renewables	115	147	163	400	729	1 109	1 544	19	56	10.7
Hydro	110	123	135	218	312	420	512	16	19	6.3
Bioenergy	1	2	2	13	27	40	54	0	2	16.4
Wind	2	12	14	64	136	198	264	2	10	14.3
Geothermal	1	5	5	17	34	59	95	1	3	14.5
Solar PV	0	5	6	79	196	341	533	1	19	22.4
CSP	-	1	2	10	24	51	87	0	3	18.8
Marine	-	-	-	0	0	0	0	-	0	n.a.

Africa Case	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total capacity	**228**	**244**	**398**	**550**	**709**	**924**	**100**	**100**	**6.2**
Coal	48	48	53	50	45	37	20	4	-1.2
Oil	42	43	48	51	52	53	18	6	1.0
Natural gas	92	103	148	167	183	228	42	25	3.7
Nuclear	2	2	2	4	5	10	1	1	7.6
Renewables	44	48	144	273	414	579	20	63	12.0
Hydro	35	36	57	77	99	117	15	13	5.5
Bioenergy	1	1	4	7	9	11	0	1	13.0
Wind	5	5	25	51	72	94	2	10	13.8
Geothermal	1	1	2	5	9	14	0	2	14.9
Solar PV	3	4	52	124	209	316	2	34	21.5
CSP	1	1	4	9	17	26	0	3	16.2
Marine	-	-	0	0	0	0	-	0	n.a.

Africa Case	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2010	2017	2018	2025	2030	2035	2040	2018	2040	2018-40
Total CO_2	**1 017**	**1 181**	**1 215**	**1 450**	**1 590**	**1 719**	**1 886**	**100**	**100**	**2.0**
Coal	385	391	395	358	314	295	264	32	14	-1.8
Oil	450	541	551	738	872	959	1 032	45	55	2.9
Natural gas	182	248	269	353	405	465	590	22	31	3.6
Power sector	**420**	**466**	**480**	**529**	**536**	**538**	**567**	**100**	**100**	**0.8**
Coal	263	257	261	257	230	208	163	54	29	-2.1
Oil	54	59	62	69	85	85	82	13	14	1.3
Natural gas	103	150	158	203	221	245	322	33	57	3.3
Final consumption	**496**	**620**	**641**	**839**	**986**	**1 113**	**1 244**	**100**	**100**	**3.1**
Coal	66	83	85	79	77	78	85	13	7	-0.0
Oil	382	472	480	646	763	850	927	75	75	3.0
Transport	257	345	351	466	533	573	599	55	48	2.5
Natural gas	48	65	76	115	146	184	232	12	19	5.2

A

Definitions

This annex provides general information on terminology used throughout the report including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; and abbreviations and acronyms.

Units

Area	Ha	hectare
	km^2	square kilometre
Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
	Mtpa	million tonnes per annum
Emissions	ppm	parts per million (by volume)
	Gt CO_2-eq	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	kg CO_2-eq	kilogrammes of carbon-dioxide equivalent
	g CO_2/km	grammes of carbon dioxide per kilometre
	g CO_2/kWh	grammes of carbon dioxide per kilowatt-hour
Energy	boe	barrel of oil equivalent
	toe	tonne of oil equivalent
	ktoe	thousand tonnes of oil equivalent
	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kcal	kilocalorie (1 calorie x 10^3)
	Gcal	gigacalorie (1 calorie x 10^9)
	MJ	megajoule (1 joule x 10^6)
	GJ	gigajoule (1 joule x 10^9)
	TJ	terajoule (1 joule x 10^{12})
	PJ	petajoule (1 joule x 10^{15})
	EJ	exajoule (1 joule x 10^{18})
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	mcm	million cubic metres
	bcm	billion cubic metres
	tcm	trillion cubic metres
	scf	standard cubic foot
Mass	kg	kilogramme (1 000 kg = 1 tonne)

	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
Monetary	$ million	1 US dollar x 10^6
	$ billion	1 US dollar x 10^9
	$ trillion	1 US dollar x 10^{12}
Oil	b/d	barrels per day
	kb/d	thousand barrels per day
	mb/d	million barrels per day
	mboe/d	million barrels of oil equivalent per day
Power	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)
	TW	terawatt (1 watt x 10^{12})
Water	bcm	billion cubic metres
	m^3	cubic metre

General conversion factors for energy

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11 630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3 412	1

Note: There is no generally accepted definition of boe; typically the conversion factors used vary from 7.15 to 7.40 boe per toe.

Definitions

Advanced biofuels: Sustainable fuels produced from non-food crop feedstocks, which are capable of delivering significant lifecycle greenhouse gas emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts. This definition differs from the one used for "advanced biofuels" in the US legislation, which is based on a minimum 50% lifecycle greenhouse gas reduction and which, therefore, includes sugar cane ethanol.

Agriculture: Includes all energy used on farms, in forestry and for fishing.

Back-up generation capacity: Households and businesses connected to the main power grid may also have some form of "back-up" power generation capacity that can, in the event of disruption, provide electricity. Back-up generators are typically fuelled with diesel or gasoline and capacity can be as little as a few kilowatts. Such capacity is distinct from mini-grid and off-grid systems that are not connected to the main power grid.

Biodiesel: Diesel-equivalent, processed fuel made from the transesterification (a chemical process that converts triglycerides in oils) of vegetable oils and animal fats.

Bioenergy: Energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid biomass, biofuels and biogas.

Biofuels: Liquid fuels derived from biomass or waste feedstocks and include ethanol and biodiesel. They can be classified as conventional and advanced biofuels according to the technologies used to produce them and their respective maturity. Unless otherwise stated, biofuels are expressed in energy-equivalent volumes of gasoline and diesel.

Biogas: A mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment.

Buildings: The buildings sector includes energy used in residential, commercial and institutional buildings, and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.

Bunkers: Includes both international marine bunkers and international aviation bunkers.

Clean cooking facilities: Cooking facilities that are considered safer, more efficient and more environmentally sustainable than the traditional facilities that make use of solid biomass (such as a three-stone fire). This refers primarily to improved solid biomass cookstoves, biogas systems, liquefied petroleum gas stoves, ethanol and solar stoves.

Coal: Includes both primary coal (including lignite, coking and steam coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included.

Coking coal: Type of coal that can be used for steel making (as a chemical reductant and source heat), where it produces coke capable of supporting a blast furnace charge. Coal of this quality is also commonly known as metallurgical coal.

B

Conventional biofuels: Fuels produced from food crop feedstocks. These biofuels are commonly referred to as first-generation and include sugar cane ethanol, starch-based ethanol, fatty acid methyl esther (FAME) and straight vegetable oil (SVO).

Dispatchable: Dispatchable generation refers to technologies whose power output can be readily controlled - increased to maximum rated capacity or decreased to zero - in order to match supply with demand.

Electricity demand: Defined as total gross electricity generation less own use generation, plus net trade (imports less exports), less transmissions and distribution losses.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own-use. This is also referred to as gross generation.

Energy sector CO_2 emissions: CO_2 emissions from fuel combustion (excluding non-renewable waste). Note that this does not include fugitive emissions from fuels, CO_2 transport, storage emissions or industrial process emissions.

Energy sector GHG emissions: CO_2 emissions from fuel combustion plus fugitive and vented methane and N_2O emissions from the energy and industry sectors.

Energy services: see useful energy.

Ethanol: Refers to bio-ethanol only. Ethanol is produced from fermenting any biomass high in carbohydrates. Today, ethanol is made from starches and sugars, but second-generation technologies will allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

Hydropower: The energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

Industry: The sector includes fuel used within the manufacturing and construction industries. Key industry branches include iron and steel, chemical and petrochemical, cement, and pulp and paper. Use by industries for the transformation of energy into another form or for the production of fuels is excluded and reported separately under other energy sector. Consumption of fuels for the transport of goods is reported as part of the transport sector, while consumption by off-road vehicles is reported under industry.

International aviation bunkers: Includes the deliveries of aviation fuels to aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split is determined on the basis of departure and landing locations and not by the nationality of the airline. For many countries this incorrectly excludes fuels used by domestically owned carriers for their international departures.

International marine bunkers: Covers those quantities delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is also excluded and included in residential, services and agriculture.

Investment: All investment data and projections reflect spending across the lifecycle of a project, i.e. the capital spent is assigned to the year when it is incurred. Investments for oil, gas and coal include production, transformation and transportation; those for the power sector include refurbishments, uprates, new builds and replacements for all fuels and technologies for on-grid, mini-grid and off-grid generation, as well as investment in transmission and distribution, and battery storage. Investment data are presented in real terms in year-2018 US dollars unless otherwise stated.

Liquids: Refers to the combined use of oil and biofuels (expressed in energy-equivalent volumes of gasoline and diesel).

Mini-grids: Small grid systems linking a number of households or other consumers.

Modern energy access: Includes household access to a minimum level of electricity; household access to safer and more sustainable cooking and heating fuels and stoves; access that enables productive economic activity; and access for public services.

Modern renewables: Includes all uses of renewable energy with the exception of traditional use of solid biomass.

Modern use of solid biomass: Refers to the use of solid biomass in improved cookstoves and modern technologies using processed biomass such as pellets.

Natural gas: Comprises gases occurring in deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both "non-associated" gas originating from fields producing hydrocarbons only in gaseous form, and "associated" gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas). Natural gas liquids (NGLs), manufactured gas (produced from municipal or industrial waste, or sewage) and quantities vented or flared are not included. Gas data in cubic metres are expressed on a "gross" calorific value basis and are measured at 15 °C and at 760 mm Hg ("Standard Conditions"). Gas data expressed in tonnes of oil equivalent, mainly for comparison reasons with other fuels, are on a "net" calorific basis. The difference between the net and the gross calorific value is the latent heat of vaporisation of the water vapour produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

Natural gas liquids (NGLs): Liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. These are those portions of natural gas which are recovered as liquids in separators, field facilities or gas processing plants. NGLs include but are not limited to ethane (when it is removed from the natural gas stream), propane, butane, pentane, natural gasoline and condensates.

Non-energy use: Fuels used for chemical feedstocks and non-energy products. Examples of non-energy products include lubricants, paraffin waxes, asphalt, bitumen, coal tars and oils as timber preservatives.

Nuclear: Refers to the primary energy equivalent of the electricity produced by a nuclear plant, assuming an average conversion efficiency of 33%.

Off-grid systems: Stand-alone systems for individual households or groups of consumers.

Oil: Oil production includes both conventional and unconventional oil. Petroleum products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin, waxes and petroleum coke.

Other energy sector: Covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses by gas works, petroleum refineries, blast furnaces, coke ovens, coal and gas transformation and liquefaction. It also includes energy used in coal mines, in oil and gas extraction and in electricity and heat production. Transfers and statistical differences are also included in this category.

Peri-urban: Peri-urban areas are zones of transition from rural to urban which often form the urban-rural interface and may evolve into being fully urban.

Power generation: Refers to fuel use in electricity plants, heat plants and combined heat and power (CHP) plants. Both main activity producer plants and small plants that produce fuel for their own use (auto-producers) are included.

Productive uses: Energy used towards an economic purpose: agriculture, industry, services, and non-energy use. Some energy demand from the transport sector (e.g. freight) could also be considered as productive, but is treated separately.

Refining processing gains: Processing gains are volume increases that occur during crude oil refining.

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaic (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking equipment.

Services: Energy used in commercial (e.g. hotels, offices, catering, shops) and institutional buildings (e.g. schools, hospitals, offices). Services energy use includes space heating and cooling, water heating, lighting, equipment, appliances and cooking equipment.

Shale gas: Natural gas contained within a commonly occurring rock classified as shale. Shale formations are characterised by low permeability, with more limited ability of gas to flow through the rock than is the case with a conventional reservoir. Shale gas is generally produced using hydraulic fracturing.

Solid biomass: Includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid wastes.

Tight oil: Oil produced from shales or other very low permeability formations, using hydraulic fracturing. This is also sometimes referred to as light tight oil. Tight oil includes tight crude oil and condensate production except for the United States, which includes tight crude oil only (US tight condensate volumes are included in natural gas liquids).

Total final consumption (TFC)**:** Is the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total primary energy demand (TPED)**:** Represents domestic demand only and is broken down into power generation, other energy sector and total final consumption.

Traditional use of solid biomass: Refers to the use of solid biomass with basic technologies, such as a three-stone fire, often with no or poorly operating chimneys.

Transport: Fuels and electricity used in the transport of goods or persons within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Fuel delivered to international marine and aviation bunkers is presented only at the world level and is excluded from the transport sector at a domestic level.

Useful energy: Refers to the energy that is available to end-users to satisfy their needs. This is also referred to as energy services demand. As result of transformation losses at the point of use, the amount of useful energy is lower than the corresponding final energy demand for most technologies. Equipment using electricity often has higher conversion efficiency than equipment using other fuels, meaning that for a unit of energy consumed electricity can provide more energy services.

Variable renewable energy (VRE)**:** Refers to technologies whose maximum output at any time depends on the availability of fluctuating renewable energy resources. VRE includes a broad array of technologies such as wind power, solar PV, run-of-river hydro, concentrating solar power (where no thermal storage is included) and marine (tidal and wave).

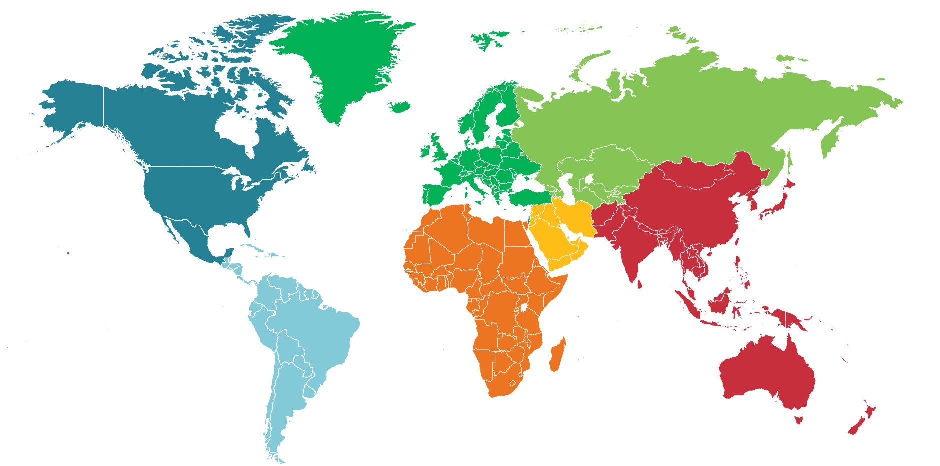
Water consumption: The volume withdrawn that is not returned to the source (i.e. it is evaporated or transported to another location) and by definition is no longer available for other uses.

Water sector: Includes all processes whose main purpose is to treat/process or move water to or from the end-use: groundwater and surface water extraction, long-distance water transport, water treatment, desalination, water distribution, wastewater collection, wastewater treatment and water re-use.

Water withdrawal: The volume of water removed from a source; by definition withdrawals are always greater than or equal to consumption.

Regional and country groupings

Figure B.1 ▷ *World Energy Outlook* main country groupings



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Africa: North Africa and sub-Saharan Africa regional groupings.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

Sub-Saharan Africa: Angola, Benin, Botswana, Cameroon, Republic of the Congo (Congo), Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Zambia, Zimbabwe and other African countries and territories.[1]

Advanced economies: OECD regional grouping and Bulgaria, Croatia, Cyprus[2,3], Malta and Romania.

Asia Pacific: Southeast Asia regional grouping and Australia, Bangladesh, China, India, Japan, Korea, Democratic People's Republic of Korea, Mongolia, Nepal, New Zealand, Pakistan, Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[4]

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories.[5]

China: Includes the (People's Republic of) China and Hong Kong, China.

Developing Asia: Asia Pacific regional grouping excluding Australia, Japan, Korea and New Zealand.

Developing economies: All other countries not included in the "advanced economies" regional grouping.

Eurasia: Caspian regional grouping and the Russian Federation (Russia).

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel[6], Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Turkey and Ukraine.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus[2,3], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and United Kingdom.

IEA (International Energy Agency)**:** OECD regional grouping excluding Chile, Iceland, Israel, Latvia, Lithuania and Slovenia.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

North America: Canada, Mexico and United States.

OECD (Organisation for Economic Co-operation and Development)**:** Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Country notes

[1] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Equatorial Guinea, Kingdom of Eswatini, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Réunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia and Uganda.

[2] Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

[3] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[4] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Lao People's Democratic Republic (Lao PDR), Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste and Tonga and Vanuatu.

[5] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saba, Saint Eustatius, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten, Turks and Caicos Islands.

[6] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Abbreviations and Acronyms

AC	Africa Case
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
CAAGR	compound average annual growth rate
CCGT	combined-cycle gas turbine
CCUS	carbon capture, utilisation and storage
CH_4	methane
CHP	combined heat and power; the term co-generation is sometimes used
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
CPS	Current Policies Scenario
CSP	concentrating solar power
EU	European Union
EV	electric vehicle
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
GDP	gross domestic product
GHG	greenhouse gases
ICE	internal combustion engine
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LCOE	levelised cost of electricity
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
MEPS	minimum energy performance standards
NDCs	Nationally Determined Contributions
NOC	national oil company
NO_X	nitrogen oxides
OECD	Organisation for Economic Co-operation and Development

PM	particulate matter
$PM_{2.5}$	fine particulate matter
PPP	purchasing power parity
PV	photovoltaics
R&D	research and development
SDS	Sustainable Development Scenario
SO_2	sulfur dioxide
STEPS	Stated Policies Scenario
T&D	transmission and distribution
TFC	total final consumption
TPED	total primary energy demand
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
US	United States
USGS	United States Geological Survey
VRE	variable renewable energy
WACC	weighted average cost of capital
WEM	World Energy Model
WEO	*World Energy Outlook*
WHO	World Health Organization

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Chapter 1: Africa today

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World Energy Outlook Special Report

Rapid economic and population growth in Africa, particularly in the continent's burgeoning cities, will have profound implications for the energy sector, both regionally and globally. The stage is set for a new wave of dynamism among African policy makers and business communities, with falling costs of key renewable technologies opening up new avenues for innovation and growth. Chief among the challenges is providing universal access to reliable, modern, affordable and sustainable energy. How to do this is a crucial component of Africa's Agenda 2063 strategic framework for the continent's future and of global Sustainable Development Goals. Realising the potential of the continent's natural gas and mineral resources presents another key challenge.

Five years after the World Energy Outlook's first special report on Africa, the International Energy Agency has updated and expanded its outlook for the continent based on in-depth, data-rich and country-specific analysis. This new report provides important policy insights to help African energy stakeholders achieve the continent's growth ambitions in a sustainable and inclusive manner. It also explores how the rise of consumerism in Africa might affect global trends.