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Africa Energy Outlook

A FOCUS ON ENERGY PROSPECTS IN SUB-SAHARAN AFRICA

World Energy Outlook Special Report

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

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- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
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The primary purpose of our energy system is to contribute to a better quality of life. To those that have it, modern energy unlocks access to improved healthcare, improved education, improved economic opportunities and, even, longer life. To those that don't, it is a major constraint on their social and economic development.

The International Energy Agency's (IEA) *Africa Energy Outlook* – a Special Report in the 2014 *World Energy Outlook* series – offers a most comprehensive analytical study of energy in Africa, specifically in sub-Saharan Africa, the epicentre of the global challenge to overcome energy poverty. More than 620 million people live without access to electricity and nearly 730 million people use hazardous, inefficient forms of cooking, a reliance which affects women and children disproportionately. Meanwhile, those who do have access to modern energy face very high prices for a supply that is both insufficient and unreliable. Overall, the energy sector of sub-Saharan Africa is not yet able to meet the needs and aspirations of its citizens.

But this challenge is surmountable and the benefits of success are immense. This report finds that increasing access to reliable, modern energy can turbo-charge economic growth in sub-Saharan Africa. The region's existing energy resources are more than sufficient to meet its overall needs, but they are unevenly distributed and under-developed, a fact that speaks strongly towards the benefits of regional energy integration, another key finding of the report.

Sub-Saharan Africa is already home to several major energy producers, including Nigeria, South Africa and Angola, and these are being joined by emerging producers, including Mozambique and Tanzania. For those in a position to reap an economic dividend from natural resources, the report highlights the need to reinvest it locally to yield yet greater gains, in the form of broad-based economic growth. African countries more generally are endowed with abundant renewable energy potential, which they can harness so that, by 2040, renewables provide more than 40% of all power generation capacity in the region, varying in scale from large hydropower dams to mini- and off-grid solutions in more remote areas.

The outlook for providing access to electricity is bitter-sweet: nearly one billion people in sub-Saharan Africa are projected to gain access by 2040 but, because of rapid population growth, 530 million people in the region are projected to remain without it at that date (mainly in rural areas). The urgent need to improve access to modern energy is a theme that the *World Energy Outlook* has pioneered for more than a decade. As a member of the Advisory Board of the UN Secretary-General's Sustainable Energy for All initiative, I have been encouraged to see that much positive action towards this goal is already underway. And yet this outlook tells us that more is needed.

We identify actions that can unlock greater levels of energy sector investment. Many of these must be taken at the national and regional level. They entail strengthening policy and regulatory frameworks so that well-functioning energy markets emerge, building on existing channels of regional co-operation, and, perhaps most importantly, achieving high standards of governance, both within and beyond the energy sector. The international community has a duty to support action in all of these areas: many countries already do so. A valuable extra step will be to make universal access to modern energy one of the post-2015 sustainable development goals.

I would like to thank Dr Fatih Birol and his team for setting their aspirations high this year, and delivering a roadmap for the sub-Saharan energy system that I know will be of great value to policymakers. In completing this study, the IEA has been privileged to work with many African governments, the African Union, the African Development Bank, and many experts across all aspects of Africa's energy sector, to all of whom we are very grateful.

This publication is produced under my authority as Executive Director of the IEA.

Maria van der Hoeven
Executive Director
International Energy Agency

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Sub-Saharan Africa is rich in energy resources, but very poor in energy supply. Making reliable and affordable energy widely available is critical to the development of a region that accounts for 13% of the world's population, but only 4% of its energy demand. Since 2000, sub-Saharan Africa has seen rapid economic growth and energy use has risen by 45%. Many governments are now intensifying their efforts to tackle the numerous regulatory and political barriers that are holding back investment in domestic energy supply, but inadequate energy infrastructure risks putting a brake on urgently needed improvements in living standards. The data gathered for this *World Energy Outlook* Special Report – the first of its kind to provide a comprehensive picture of today's sub-Saharan energy sector and its future prospects in a global context – underlines the acute scarcity of modern energy services in many countries. The picture varies widely across the region, but, in sub-Saharan Africa as a whole, only 290 million out of 915 million people have access to electricity and the total number without access is rising. Efforts to promote electrification are gaining momentum, but are outpaced by population growth. Although investment in new energy supply is on the rise, two out of every three dollars put into the sub-Saharan energy sector since 2000 have been committed to the development of resources for export.

Power to shape the future

A severe shortage of essential electricity infrastructure is undermining efforts to achieve more rapid social and economic development. For the minority that has a grid connection today, supply is often unreliable, necessitating widespread and costly private use of back-up generators running on diesel or gasoline. Electricity tariffs are, in many cases, among the highest in the world and, outside South Africa, losses in poorly maintained transmission and distribution networks are double the world average. Reform programmes are starting to improve efficiency and to bring in new capital, including from private investors, and grid-based generation capacity quadruples in our main scenario to 2040, albeit from a very low base of 90 GW today (half of which is in South Africa). Urban areas experience the largest improvement in the coverage and reliability of centralised electricity supply. Elsewhere, mini-grid and off-grid systems provide electricity to 70% of those gaining access in rural areas. Building on successful examples of electrification programmes, such as those in Ghana and Rwanda, the total number without access starts to decline in the 2020s and 950 million people gain access to electricity by 2040 – a major step forward, but not enough. More than half a billion people, mainly in rural areas, remain without electricity in 2040.

Sub-Saharan Africa starts to unlock its vast renewable energy resources, with almost half of the growth in electricity generation to 2040 coming from renewables. Hydropower accounts for one-fifth of today's power supply, but less than 10% of the estimated technical potential has been utilised. The Democratic Republic of Congo, where only 9% of the population has access to electricity, is an example of the co-existence of huge hydropower potential with extreme energy poverty. Political instability, limited access to finance, small market size and weak transmission connections with neighbouring countries have all held back exploitation of hydro resources. These constraints are gradually being lifted, not least because of greater regional co-operation and the emergence of China, alongside the traditional lenders, as a major funder of large infrastructure projects. New hydropower capacity in the Democratic Republic of Congo, Ethiopia, Mozambique and Guinea, among others, plays a major role in bringing down the region's average costs of power supply, reducing the share of oil-fired power. Other renewables, led by solar technologies, make a growing contribution to supply, with a successful auction-based procurement programme in South Africa showing how this can be achieved cost effectively. Geothermal becomes the second-largest source of power supply in East Africa, mainly in Kenya and Ethiopia. Two-thirds of the mini-grid and off-grid systems in rural areas in 2040 are powered by solar photovoltaics, small hydropower or wind. As technology costs come down, the attraction of renewable systems versus diesel generators grows (although they are often used in combination), especially where financing is available to cover the higher upfront expense.

Bioenergy is at the heart of the energy mix

Bioenergy use – mainly fuelwood and charcoal – outweighs demand for all other forms of energy combined, a picture that changes only gradually even as incomes rise. Four out of five people in sub-Saharan Africa rely on the traditional use of solid biomass, mainly fuelwood, for cooking. A 40% rise in demand for bioenergy to 2040 exacerbates strains on the forestry stock, with efforts to promote more sustainable wood production hindered by the operation of much of the fuelwood and charcoal supply chain outside the formal economy. Scarcity, along with efforts to make alternative fuels like liquefied petroleum gas available, results in some switching away from wood use, especially in towns. Promotion of more efficient biomass cookstoves reduces the health effects of pollution from indoor smoke. Nonetheless, 650 million people – more than one-third of an expanding population – still cook with biomass in an inefficient and hazardous way in 2040.

The rise of the African energy consumer brings a new balance to oil and gas

Almost 30% of global oil and gas discoveries made over the last five years have been in sub-Saharan Africa, reflecting growing global appetite for African resources. Nigeria is the richest resource centre of the oil sector, but regulatory uncertainty, militant activity and oil theft in the Niger Delta are deterring investment and production, so much so that Angola is set to overtake Nigeria as the region's largest producer of crude oil at least until the early 2020s. The value of the estimated 150 thousand barrels lost to oil theft each day – amounting to more than $5 billion per year – would be sufficient to fund universal access to electricity for all Nigerians by 2030. A host of smaller producers such as South Sudan, Niger, Ghana, Uganda and Kenya see rising output; but, by the late 2020s, production in most countries – with the exception of Nigeria – is in decline. Additions and upgrades to refining capacity mean that more of the region's crude supply is processed locally. With regional production falling back from above 6 million barrels per day (mb/d) in 2020 to 5.3 mb/d in 2040, but demand for oil products doubling to 4 mb/d – an upward trend amplified in some countries by subsidised prices – the result is to squeeze the region's net contribution to the global oil balance.

Natural gas resource-holders can power domestic economic development and boost export revenues, but only if the right regulation, prices and infrastructure are in place. The incentives to use gas within sub-Saharan Africa are expected to grow as power sector reforms and gas infrastructure projects move ahead but, for the moment, as much gas is flared as is consumed within the region. More than 1 trillion cubic metres of gas has been wasted through flaring over the years, a volume that – if used to provide power – would be enough to meet current sub-Saharan electricity needs for more than a decade. In our main scenario, natural gas nearly triples its share in the energy mix to 11% by 2040. Nigeria remains the region's largest gas consumer and producer, but the focus for new gas projects also shifts to the east coast and to the huge offshore discoveries in Mozambique and Tanzania. The size of these developments and remoteness of their location raises questions about how quickly production can begin, but they provide a 75 billion cubic metre (bcm) boost to annual regional output (which reaches 230 bcm in total) by 2040, with projects in Mozambique larger in scale and earlier in realisation. East coast LNG export is helped by relative proximity to the importing markets of Asia, but – alongside the benefits from an estimated $150 billion in fiscal revenue to 2040 – both countries are determined to promote domestic markets for gas, which will need to be built from a very low base.

Coal production and use gradually spreads beyond South Africa, but coal is overtaken by oil as the second-largest fuel in the sub-Saharan energy mix. Development of new coal resources is hindered in many cases by their remoteness and the lack of suitable railway and port infrastructure, considerations that also affect the outlook for South Africa as the existing mining areas close to Johannesburg start to deplete. Much of the 50% increase in regional output is used locally, often for power generation, with coking coal from Mozambique the only major new international export flow. Prospects for coal are also limited by policy: South Africa, the dominant player in African coal, is seeking to diversify its power mix with renewables, regional hydropower projects, gas and eventually additional nuclear capacity all playing a role in bringing the share of coal in power output down from more than 90% today to less than two-thirds by 2040. But coal's relatively low cost remains an asset in societies concerned about the affordability of electricity.

Releasing the energy brake on development

In our main scenario, the sub-Saharan economy quadruples in size and energy demand grows by 80%, but energy could do much more to act as an engine of inclusive economic and social growth. The international arena brings capital and technology, but mixed blessings in other areas. An oil price above $100 per barrel produces a continued windfall for resource-rich countries – the cumulative $3.5 trillion in fiscal revenue is higher than the $3 trillion that is invested in all parts of the region's energy supply to 2040 – but few guarantees that this revenue will be re-invested efficiently, while the region's oil product import bills grow, along with vulnerability to supply interruptions. Sub-Saharan Africa is also in the front line when it comes to the impacts of a changing climate, even though it continues to make only a small contribution to global energy-related CO_2 emissions; its share of global emissions rises to 3% in 2040. But the main challenges arise within the region, including not only the needs of a fast-growing population but also the impact of weak institutions, a difficult climate for investment, and technical and political barriers to regional trade. Overall, our main scenario outlines an energy system that expands rapidly, but one that still struggles to keep pace with the demands placed on it. And, for the poorest, while access to modern energy services grows, hundreds of millions – particularly in rural communities – are left without.

Accelerating towards an African Century?

Three actions in the energy sector, if accompanied by more general governance reforms, could boost the sub-Saharan economy by 30% in 2040, an extra decade's worth of growth in per-capita incomes:

- **An additional $450 billion in power sector investment,** reducing power outages by half and achieving universal electricity access in urban areas.
- **Deeper regional co-operation and integration,** facilitating new large-scale generation and transmission projects and enabling a further expansion in cross-border trade.
- **Better management of resources and revenues,** adopting robust and transparent processes that allow for more effective use of oil and gas revenues.

Broad improvements in governance, both inside and outside the energy sector, underpin the achievements of an African Century Case, involving, among many other things, heavy investment in the capacity to formulate and implement sound energy policies, as well as the consultation and accountability that is essential to win public consent. Although still not achieving universal access to electricity for all of the region's citizens by 2040, the outcome is an energy system in which uninterrupted energy supply becomes the expectation, rather than the exception. Unreliable power supply has been identified by African enterprises as the most pressing obstacle to the growth of their businesses, ahead of access to finance, red tape or corruption. Relieving this uncertainty helps every dollar of additional power sector investment in the African Century Case to boost GDP by an estimated $15.

A modernising and more integrated energy system allows for more efficient use of resources and brings energy to a greater share of the poorest parts of sub-Saharan Africa. A reduction in the risks facing investors, as assumed in the African Century Case, makes oil and gas projects more competitive with production in other parts of the world, allowing more of them to go ahead; and a higher share of the resulting fiscal revenue is used productively to reverse deficiencies in essential infrastructure. Electricity trade more than triples as more regional projects advance: 30% of the extra investment in the power sector goes to Central Africa, helping to unlock more of the huge remaining hydropower capacity and connect it to the rest of the continent. The addition of relatively low-cost electricity keeps the average costs of supply down, even as power demand rises by almost one-third. Of the extra 230 million people that gain access to electricity in this Case by 2040, 70% are in rural areas, the supply coming primarily from mini-grid and off-grid systems. This investment is instrumental in helping to close the gap in energy provision and economic opportunity between sub-Saharan Africa's rural communities and the people in its cities. Concerted action to improve the functioning of the sub-Saharan energy sector is essential if the 21st is to become an African century.

Each year, the International Energy Agency's (IEA) *World Energy Outlook (WEO)* conducts a detailed study of the energy sector of a particular country or region. This year – as a Special Report within its *WEO-2014* series – the IEA presents its most comprehensive analytical study to date of the energy outlook for Africa, specifically sub-Saharan Africa.

Modern economies are built upon modern energy systems, but the sub-Saharan energy sector has not yet achieved this status. This report draws on extensive new data to shine light on the existing energy system in sub-Saharan Africa, but also to illuminate the future energy outlook, showing what actions can release the energy brake on development.[1]

The report is structured as follows:

- Chapter 1 sets the scene by analysing sub-Saharan Africa's energy sector as it is today. It outlines important economic and social trends, and quantifies the number of people without access to modern energy. It details the existing energy architecture, including the power sector and other energy-consuming sectors, the scale of sub-Saharan Africa's energy resources and its energy production trends. Patterns of energy trade are mapped out and, finally, it considers the critical issue of energy affordability.

- Chapter 2 looks to the future, assessing the energy demand and supply prospects for sub-Saharan Africa through to 2040. These are analysed by fuel, by sector and by sub-region, to present a comprehensive outlook for the energy sector, including for international energy trade and some of the main environmental implications.

- Chapter 3 examines five key features of the sub-Saharan energy outlook in-depth. These include: the role of different solutions in providing access to electricity; how rapidly the region might make the transition to cleaner alternatives for cooking; the extent to which oil can fuel progress in Nigeria; the costs and benefits of South Africa diversifying its electricity system towards renewables and the policies involved; and, the opportunities and obstacles that Mozambique and Tanzania face as they seek to get the best value from their natural gas resources.

- Chapter 4 considers how to maximise the gain from sub-Saharan energy, as a means to build a path to prosperity for its citizens. An "African Century Case" shows how progress in three key areas of energy policy could deliver a major boost to economic and social development in the region. These are: increased investment in supply, in particular of electricity, to meet the region's growing energy needs; improved management of natural resources and associated revenues; and deeper regional co-operation. It concludes by setting Africa's energy choices in a global context, as many of the actions that need to be taken in the region cannot be isolated from the prevailing trends in global energy markets.

1. Annex A provides detailed data tables for energy access, energy demand and supply, and investments.

Energy in Africa today

Resource-full, but not yet power-full

Highlights

- Africa's energy sector is vital to its development and yet is one of the most poorly understood parts of the global energy system. Since 2000, much of sub-Saharan Africa (the focus of this study) has experienced more rapid economic growth than in the past, raising expectations of a new phase of development. Policies are being put in place in many countries aimed at securing a much-needed expansion in domestic energy provision. However, the current state of the energy system represents a major threat to the realisation of the region's economic hopes.

- Energy demand in sub-Saharan Africa grew by around 45% from 2000 to 2012, but accounts for only 4% of the world total, despite being home to 13% of the global population. Access to modern energy services, though increasing, remains limited: despite many positive efforts, more than 620 million people in sub-Saharan Africa remain without access to electricity and nearly 730 million rely on the traditional use of solid biomass for cooking. Electricity consumption per capita is, on average, less than that needed to power a 50-watt light bulb continuously.

- On-grid power generation capacity was 90 GW in 2012, with around half being in South Africa. 45% of this capacity is coal (mainly South Africa), 22% hydro, 17% oil (both more evenly spread) and 14% gas (mainly Nigeria). Insufficient, unreliable or inaccessible grid supply has resulted in large-scale private ownership of oil-fuelled generators (supplying 16 TWh in 2012) and greater focus on developing mini- and off-grid power systems. Renewables-based capacity is growing rapidly but from a very low base (with the exception of hydropower). Huge renewable resources remain untapped; excellent solar across all of Africa, hydro in many countries, wind mainly in coastal areas and geothermal in the East African Rift Valley.

- Sub-Saharan Africa produced 5.7 mb/d of oil in 2013, primarily in Nigeria and Angola. While 5.2 mb/d of crude oil were exported, around 1.0 mb/d of oil products were imported. Natural gas use of 27 bcm in 2012 is similar both to the volume that was exported and to the volume that was flared. In the last five years, nearly 30% of world oil and gas discoveries were made in sub-Saharan Africa; but the challenge to turn these discoveries into production and the resulting revenue into public benefits is formidable. Coal production (nearly 220 Mtce in 2012) is concentrated in South Africa; and the region accounts for 18% of world uranium supply.

- Low incomes, coupled with inefficient and costly forms of energy supply, make energy affordability a critical issue. Electricity prices are typically very high by world standards, despite often being held below the cost of supply, while oil products are subsidised in many oil-producing countries.

Context

Africa's energy sector is vital to its future development and yet remains one of the most poorly understood regions within the global energy system. The continent is huge in scale – around the size of the United States, China, India and Europe combined – and while it has energy resources more than sufficient to meet domestic needs, more than two-thirds of its population does not have access to modern energy. Those that do have access often face high prices for supply that is poor quality and rely on an under-developed system that is not able to meet their needs. The effective development of Africa's energy resources, and of the energy sector as a whole, could unlock huge gains across the economy. But how quickly can modern energy be brought to the huge population now deprived of it? How can existing and emerging energy-rich countries maximise the value of their resources? What actions in the energy sector can unleash stronger economic and social development?

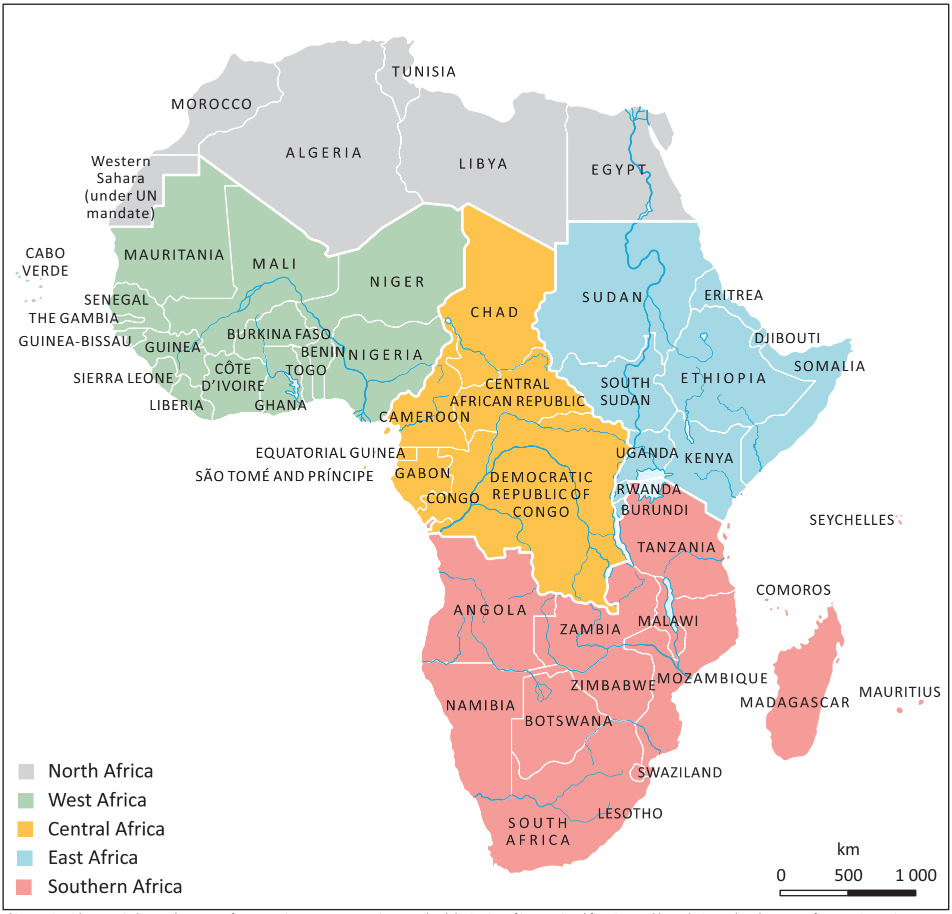
While this in-depth study presents selected energy data and projections for all of Africa, the focus of the analysis and discussion is on sub-Saharan Africa. There is a wide diversity of sub-Saharan countries from those that are energy-resource rich to many that are among the world's most energy poor. It is a region whose energy sector is not well understood, facing challenges that, in many cases, differ from those of North Africa. For example, gross domestic product (GDP) per capita in North Africa is around two-and-a-half times that of sub-Saharan Africa and less than 1% of the population are without electricity. In this study, sub-regions for which aggregated data are given include West Africa, Central Africa, East Africa and Southern Africa (defined in Annex B and shown in Figure 1.1).

There are positive signs of progress in sub-Saharan Africa, such as economic growth, higher income per capita and longer life expectancy. Areas of potential advantage that have yet to be exploited fully include rich natural resource endowments and a growing working-age population. However, there are also myriad challenges, such as high levels of poverty and inequality, a major shortage of infrastructure, poor governance and corruption, relatively low levels of productivity and skills, and varying levels of political stability. Many of these factors contribute to a business environment in which it is often judged difficult and costly to operate.

Economy

The sub-Saharan economy has more than doubled in size since 2000 to reach $2.7 trillion in 2013 (year-2013 dollars, purchasing power parity [PPP] terms). Yet, even after such strong growth, the economic output of the almost 940 million people in sub-Saharan Africa in 2013 remains significantly below that of the 82 million in Germany (Figure 1.2). Recent sub-Saharan economic growth can be attributed to a variety of factors, including a period of relative stability and security, improved macroeconomic management, strong domestic demand driven by a growing middle class, an increased global appetite for Africa's resources (coupled with the rising price of many of these resources), population growth and urbanisation. However, rapid population growth has meant that GDP per capita has increased more slowly (about 45%).

Figure 1.1 ▷ Map of Africa and main sub-regions for this study

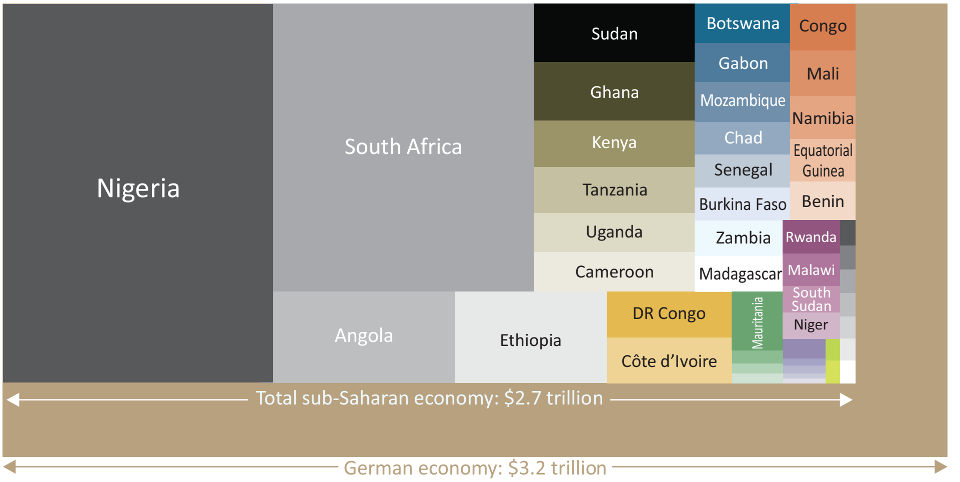


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Notes: Africa sub-regions are derived from those used by the United Nations (UN) and the existing regional power pools (bodies set up to strengthen regional power sector integration across Africa). For countries that are members of more than one power pool, such as Tanzania, a decision has been taken to assign it to just one sub-region. This is driven primarily by analytical considerations specific to this study, and so may not be consistent with other groupings (such as Africa's regional economic communities).

Nigeria and South Africa are the largest economies by far – together accounting for more than half of the sub-Saharan economy – with Angola, Ethiopia, Sudan and Ghana being the next largest. Agriculture remains a large sector in many economies, accounting for around 20% of regional GDP (compared with a 6% share globally) and around 65% of employment (AfDB, OECD and UNDP, 2014). But it also remains largely unmodernised, with huge scope for productivity gains through the application of modern energy. Mining (energy and non-energy commodities) is an important industry in several sub-Saharan economies, both as an employer and as a source of export revenue, with mining output typically exported in a raw or semi-processed state. In resource-rich countries, energy export revenues are an important source of government income but the sector is not necessarily a large employer, nor does it constitute a large share of the economy overall. Improved macroeconomic stability has been important in underpinning growth, but it has not been achieved uniformly and many countries still struggle to balance their budgets.

Figure 1.2 ▷ GDP of sub-Saharan Africa and Germany (PPP terms), 2013



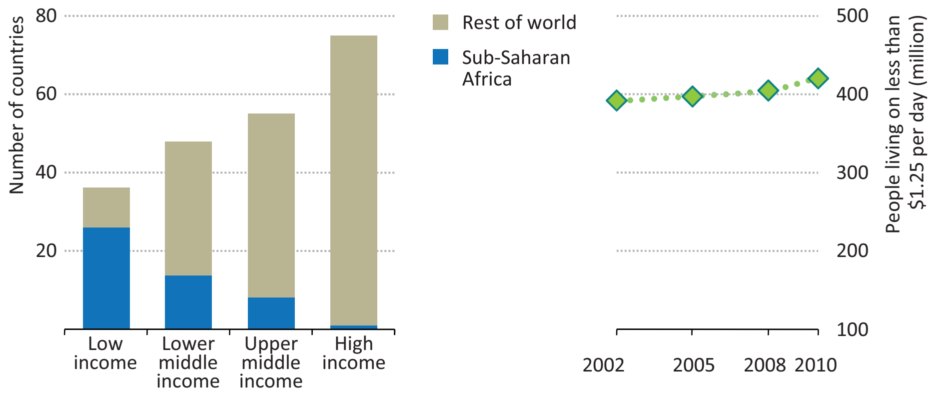
Sources: IMF; IEA analysis.

Rapid economic growth has yet to change the fact that sub-Saharan Africa is home to a large proportion of the world's poorest countries (Figure 1.3). Even though increasing average incomes across much of sub-Saharan Africa have helped to lift a large number of people out of absolute poverty, defined as living on less than $1.25 per day, sub-Saharan Africa accounts for 27 out of 36 low income countries and only one high income country (Equatorial Guinea).[1] While the share of the total population living in absolute poverty has declined (from around 56% in 1990 to below 49% in 2010), rapid population growth means that the *number* of people still living in absolute poverty has actually increased (World Bank, 2014a). Broader measures of human development, such as the Inequality-adjusted Human Development Index (IHDI), also show improvement in many sub-Saharan countries over time while also consistently ranking them very low.[2]

1. While average income levels result in Equatorial Guinea being categorised as a high-income country, it suffers from many of the issues seen in low-income sub-Saharan countries.

2. In line with the UN Human Development Index (HDI), IHDI takes account of the achievements of a country on health, education and income measures, and it also reflects how those achievements are distributed among its citizens by "discounting" each dimension's average value according to its level of inequality.

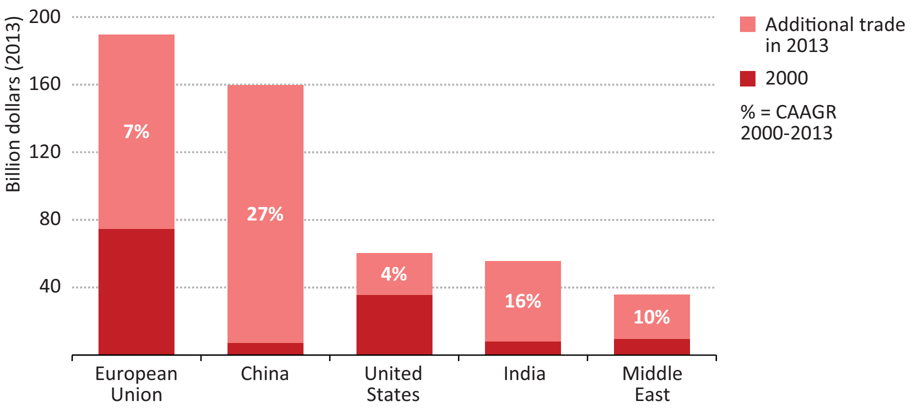
Figure 1.3 ▷ Number of countries by level of national income and number of people in sub-Saharan Africa living on less than $1.25 per day



Note: National income categories are based on gross national income per capita and follow those defined in World Development Indicators. Sources: World Bank (2014a); IEA analysis.

From very low levels, sub-Saharan Africa has seen trade and foreign direct investment (FDI) grow rapidly in recent years, with commodities continuing to dominate the export picture for most countries. While the European Union is the largest trade partner, China, India and other emerging markets have been the major drivers of growth, with China's total trade with the sub-Saharan region having increased from around $6 billion in 2000 to $160 billion in 2013 (Figure 1.4). The role of China is notable both for the increase of bilateral trade, which has grown by more than 25% a year since 2000, and its increasing willingness to invest in the region, particularly in oil, gas and other natural resources (Box 1.1), which account for 80% of China's imports from Africa (Sun, 2014).

Figure 1.4 ▷ Growth in sub-Saharan trade by region



Note: CAAGR is compound average annual growth rate. Sources: IMF (2014); IEA analysis.

Box 1.1 ▷ China's increasing investment in African energy

Chinese engagement in the sub-Saharan energy sector has grown significantly in recent years. In terms of overseas development assistance (just one form of such engagement), nearly $10 billion is estimated to have flowed from China into the sub-Saharan energy sector from 2005-2011. This is nearly double the level of the European Union and several times that of the United States over the same period, although both of these economies also direct significant assistance into North Africa (AidData). FDI in the energy sector is much more difficult to track, but the data available points both to larger overall flows and to a similar picture when comparing across these major economies.

Chinese investment is not spread evenly across the sub-Saharan region, with countries such as Angola, Ethiopia, Zimbabwe, South Africa and Nigeria receiving a greater share, or across projects, with a relatively small number of hydropower projects receiving large sums. China's increasing stake in oil and gas plays across Africa is well-known and takes in both large oil producers, like Angola, and more nascent ones, such as Chad and Uganda. It also includes emerging gas producers, as exemplified by CNPC's purchase of a 20% stake in a consortium developing part of the Rovuma Basin in Mozambique.

China's interest in African energy resources is not restricted to hydrocarbons; Chinese companies are among the largest investors in renewables across the continent, including major hydropower projects, but also solar, wind and biogas. For example, the Export-Import Bank of China has provided financing for transmission lines related to the Gilgel Gibe III hydropower project in Ethiopia and a $500 million project loan to the Transmission Company of Nigeria (TCN).

Demography

The population changes underway in sub-Saharan Africa have major implications for the development of the energy sector. Growth is rapid, having increased by 270 million people since 2000 to around 940 million in 2013, and it is expected to reach one billion well before the end of this decade. This huge increase, concentrated mainly in West and East Africa, brings new opportunities, such as a rising working-age population, but also magnifies many existing challenges, such as the quest to achieve modern energy access. Population growth has been split relatively evenly between urban and rural areas, in contrast to the strong global trend to urbanisation. Only 37% of the sub-Saharan population lives in urban areas – one of the lowest shares of any world region – which has important implications for the approach to solving the energy challenges. Average life expectancy has increased by 5.5 years since 2000, to reach 55 years (UNDP, 2013), and the young, working-age population is increasing, with both factors serving to boost the available labour force. Some elements of the existing energy sector are relatively labour-intensive, such as charcoal production and distribution, while many aspects of a modern energy sector instead are capital-intensive, such as power generation and oil and gas production.

Improving the relatively poor state of the existing energy infrastructure, as a contribution towards a more modern energy system, will require a much expanded skilled and semi-skilled workforce throughout the energy sector, including technical skills, as well as skills related to policy, regulation and project management. The need to invest in building human capacity is increasingly recognised and is reflected in projects such as the EU Energy Initiative – Partnership Dialogue Facility (EUEI PDF) and Barefoot College, which trains solar engineers in rural communities. Nevertheless, the population of sub-Saharan Africa receives less than five years of schooling on average (UNDP, 2013), suggesting that the level of education and skills will remain a key challenge.

Business environment and infrastructure

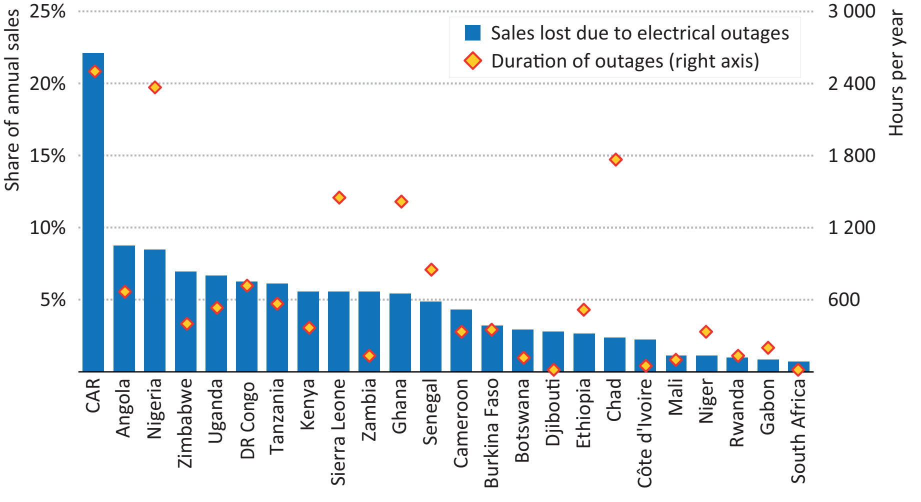
Businesses in sub-Saharan Africa most frequently cite inadequate electricity supply as a major constraint on their effective operation. It is a widespread problem that affects both countries with large domestic energy resources and those that are resource poor. Insufficient and inferior power supply has a large impact on the productivity of African businesses (Escribano, Guasch, and Pena, 2010). Examples include:

- On average, 4.9% of annual sales are estimated to be lost due to electrical outages, with very high losses reported in the Central African Republic and Nigeria, but much lower levels in South Africa (Figure 1.5) (World Bank, 2014b).
- The use of back-up power generation to mitigate poor grid-based supply increases costs for businesses. In 2012, the cost of fuel for back-up generation (across businesses and households) is estimated to have been at least $5 billion.
- Poor quality grid-based supply reduces utility revenues (non-payment) and makes it more difficult to increase tariffs (of particular importance to utilities with rates below their costs of supply), thereby constraining the availability of finance for investment.

The problem of inadequate electricity supply is multifaceted: it includes a lack of generating capacity, rundown existing stock and limited transmission and distribution infrastructure. Since GDP growth of nearly 6% per year has been achieved despite poor electricity supply, the vision of economic and social development with ample electricity supply should motivate policymakers everywhere (see Chapter 4).

The scarcity of other infrastructure such as roads also presents a massive barrier to economic activity in sub-Saharan Africa. Only 318 000 km of paved roads exist in the region (equivalent to around two-thirds of Italy's figure) and only 60% of people have access to improved water supplies. The large size and low population density of many sub-Saharan countries increases infrastructure costs and constrains the pace of improvement. The Programme for Infrastructure Development in Africa (PIDA) identifies a need for $360 billion programme of infrastructure investment through to 2040, spread across energy, transport, information and communication technologies (ICT) and trans-boundary water resources.[3] Many countries face difficulties in financing the needed infrastructure, with low domestic savings rates and tax revenues limiting the available pool of domestic finance, and the credit ratings of many countries (often below investment grade) deterring international investors (or at least highlighting the premium required for them to do so). While international oil and gas companies can often finance investments from retained earnings, power generation and transmission projects are typically more reliant on third-party finance (loans or guarantees).[4] In this respect, funding from development banks, bilateral assistance and so-called "south-south" investment have all proved important.

Figure 1.5 ▷ Duration of electrical outages and impact on business sales in selected countries



Notes: CAR = Central African Republic. Data is from the latest available business survey for a given country.
Sources: World Bank (2014b); IEA analysis.

Governance

One requirement to enable the countries of sub-Saharan Africa to realise their development ambitions is the establishment of more effective systems of governance. Governance shortcomings in the region are well documented: they relate to corruption, inadequate regulatory and legal frameworks, weak institutions or poor transparency and accountability. But the picture is not uniform across countries. The Mo Ibrahim Foundation produces an index that monitors changes in more than 130 indicators of governance in sub-Saharan countries. The index reveals an improvement across much of Africa since 2000, but also wide disparity. For example, Mauritius and Botswana have performed relatively well, but Somalia and Democratic Republic of Congo (DR Congo) relatively poorly.

3. PIDA is led by the African Union Commission (AUC), the New Partnership for Africa's Development (NEPAD) and the African Development Bank (AfDB).

4. For more on energy sector investment see the IEA's *World Energy Investment Outlook Special Report (2014)*, download at *www.worldenergyoutlook.org/investment*.

While concerns regarding poor governance are not exclusive to Africa, such failings are often cited by businesses as a constraint to invest in the continent. This is a key issue for the energy sector because it needs to attract vast sums of investment and to manage large financial flows, including energy export revenues (mainly oil, but also gas, coal, uranium and electricity), oil product import bills (all countries import oil products) and energy consumption subsidies. For significant natural resource-holders, failing to tackle these issues will squander available resource-led growth.

Many sub-Saharan countries have made progress in improving energy sector governance but action is, in a number of cases, far from complete. For instance, of the nine countries in sub-Saharan Africa that currently produce around 100 thousand barrels per day (kb/d) of hydrocarbon liquids or more, five (Nigeria, Ghana, Gabon, Congo and South Africa) have new petroleum legislation under consideration (see Chapter 3 for more on Nigeria's efforts to implement regulatory reform and reduce oil theft), and two (Chad and South Sudan) are in the process of implementing petroleum laws already enacted. Power sector reforms are also underway in many sub-Saharan countries, those in Nigeria being one notable example. An increasing number of African countries have also achieved compliance with the requirements of the Extractive Industries Transparency Initiative. In recent years, many international companies have also faced increased pressure from within their home jurisdictions to take further action to ensure that they are not complicit with illegal business practices in Africa. Transparency and accountability will continue to be important features of energy sector decision-making designed to command public acceptance and international respect (See Chapter 4 on the impact of improved governance).

Access to modern energy

Every advanced economy has required secure access to modern energy to underpin its development and growing prosperity. Modern, high quality and reliable energy provides services such as lighting, heating, transport, communication and mechanical power that support education, better health, higher incomes and all-round improvements in the quality of life. Sub-Saharan Africa has yet to conquer the challenge of energy poverty. But the barriers to doing so are surmountable and the benefits of success are immense.

In societies suffering from energy poverty, such as sub-Saharan Africa, the first step in assessing future energy demand is to measure the extent to which the population of the region lacks access to modern energy. This issue is critical to many other aspects of this study, such as electricity supply, solid biomass use and deforestation, and the assessment of the strong positive social and economic impact that broader and better access to modern energy can provide. It is the key to understanding why, in subsequent chapters, projections based simply on an extrapolation of past trends, or even on the basis of declared policy intentions, would fail to capture this crucial potential or, expressed another way, this huge pent-up energy demand. The International Energy Agency's (IEA) effort to collect comprehensive energy sector data, covering all aspects of the sub-Saharan energy system (Box 1.2), includes a full update of its energy access database, which estimates national, urban and rural populations without electricity access.

Box 1.2 ▷ Africa's energy sector data

An extensive programme of data collection and reconciliation has been undertaken for this in-depth study, with the objective of bringing together the best available energy information (See Annex A for detailed energy data and projections). In addition to the wide range of existing data sources to which the IEA has access, new energy surveys have been carried out for this study. For energy supply, government sources have been supplemented by data from power utilities, and oil and gas companies. For energy demand, new data has been sourced from many African governments, international organisations, aid agencies (such as the US Agency for International Development and its Power Africa initiative, and Germany's Gesellschaft für Internationale Zusammenarbeit [GIZ]) and, for oil demand and refinery output, from CITAC Africa Ltd. The IEA's energy access database has also been updated. The IEA conducted fact-finding missions to South Africa, Nigeria, Ghana, Mozambique and Ethiopia. It also hosted international workshops in Paris and Abuja which were attended by many African government representatives and experts.

Africa's energy data collection is improving – with efforts such as those by the African Energy Commission (AFREC) and SIE-Afrique proving important – but the situation still varies widely by country and sector. Data on oil and gas production, refinery output and, to a lesser degree, on installed power capacity and electricity generation, are relatively reliable, while data on energy trading are not yet adequate. Robust or recent energy demand data are hard to find, and in many cases the level of detail is not sufficient to give a clear picture of energy consumption.

Two areas which are particularly difficult to measure are bioenergy[5] consumption and the use of back-up power[6] generation. Bioenergy is the largest component of the energy mix, but much of it is not marketed and there are few surveys measuring its use, making it difficult to estimate consumption levels accurately. For this study, IEA data have been cross-checked using the most comprehensive data available. Analysis of collected energy data sources concludes that fuel consumption for back-up power generation is typically included in overall demand data, but that volumes are not then allocated specifically as being consumed for this purpose. This study has attempted to estimate and allocate the volumes of fuel used specifically for back-up power generation.

5. Bioenergy is the energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It covers solid biomass (fuelwood, charcoal, agricultural residues, wood waste and other solid waste), biofuels (liquid fuels, including ethanol and biodiesel) and biogas.

6. 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 from as little as a few kilowatts. Such capacity is distinct from mini- and off-grid systems, without connections to the main power grid.

There is no single internationally accepted and internationally adopted definition of "modern energy access". Yet significant commonality exists across definitions, including:

- Household access to a minimum level of electricity.
- Household access to safer and more sustainable (i.e. minimum harmful effects on health and the environment as possible) cooking and heating fuels and stoves.
- Access to modern energy that enables productive economic activity, e.g. mechanical power for agriculture, textile and other industries.
- Access to modern energy for public services, e.g. electricity for health facilities, schools and street lighting.

All of these elements are crucial to economic and social development, as are a number of related issues that are sometimes referred to collectively as "quality of supply", such as technical availability, adequacy, reliability, convenience, safety and affordability.

At different points, this study examines all of these aspects of modern energy access but its main focus when discussing "access" is on the household level, and specifically on two elements: a household having access to electricity and to a relatively clean, safe means of cooking (Box 1.3). A lack of access to such services often results in households relying on expensive, inefficient and hazardous alternatives. For example, households can typically spend 20-25% of their income on kerosene even though the cost of useful lighting (measured as $/lumen hour of light) can be 150-times higher than that provided by incandescent bulbs and 600-times higher than that from compact fluorescent lights. Each year 4.3 million premature deaths, of which nearly 600 000 are in Africa, can be attributed to household air pollution resulting from the traditional use of solid fuels, such as fuelwood and charcoal (WHO, 2014).

Box 1.3 ▷ Defining modern energy access for this study

In the energy modelling results presented in this study, households gaining access to electricity start from a low base and over time their consumption increases to reach regional average levels. The initial threshold level of electricity consumption for rural households is assumed to be 250 kilowatt-hours (kWh) per year and for urban households it is 500 kWh per year. Both are calculated based on an assumption of five people per household. In rural areas, this level of consumption could, for example, provide for the use of a mobile telephone, a fan and two compact fluorescent light bulbs for about five hours per day. In urban areas, consumption might also include an efficient refrigerator, a second mobile telephone per household and another appliance, such as a small television or a computer. The fact that electricity consumption grows over time to reach the regional average level is intended to recognise that the minimum threshold level is only sufficient to provide limited access to modern energy services. While these assumed threshold levels for electricity consumption are consistent with previous *World Energy Outlook (WEO)* analyses, it is recognised that different levels are sometimes adopted. Sanchez (2010), for example, assumes 120 kWh per person (600 kWh per household, assuming five people per household). While the Energy Sector Management Assistance Program (ESMAP) has led the development of a framework that categorises household electricity access into six tiers based on supply levels (tier 0 being no electricity, tiers 4 and 5 being greater than 2 000 watts) and different attributes of supply.

The traditional use of biomass for cooking, such as on three-stone fires, brings with it several negative health and social outcomes, such as indoor air pollution and the time-consuming and physically demanding task of fuel collection (often suffered disproportionately by women and children). In our definition of modern energy access, households also gain access to cooking facilities that are considered safer, more efficient and more environmentally sustainable than the traditional facilities that make use of solid biomass which is common practice across sub-Saharan Africa.[7] We refer to the progress as having access to "clean cooking facilities", where the means for cooking are typically in the form of either an improved solid biomass cookstove or a stove that uses alternative (cleaner) fuels, such as biogas, liquefied petroleum gas (LPG), ethanol and solar. While improved solid biomass cookstoves are both more efficient than traditional three-stone fires and produce fewer emissions, they have not been shown to deliver health benefits comparable to those achieved by the use of alternative fuels.

Access to electricity

Sub-Saharan Africa has more people living without access to electricity than any other world region – more than 620 million people, and nearly half of the global total (Figure 1.6).[8] It is also the only region in the world where the number of people living without electricity is increasing, as rapid population growth is outpacing the many positive efforts to provide access. In 37 sub-Saharan countries the number of people without electricity has increased since 2000 while the regional total rose by around 100 million people. On a more positive note, about 145 million people gained access to electricity since 2000, led by Nigeria, Ethiopia, South Africa, Ghana, Cameroon and Mozambique. Overall, the electricity access rate for sub-Saharan Africa has improved from 23% in 2000 to 32% in 2012. In North Africa, more than 99% of the total population has access to electricity.

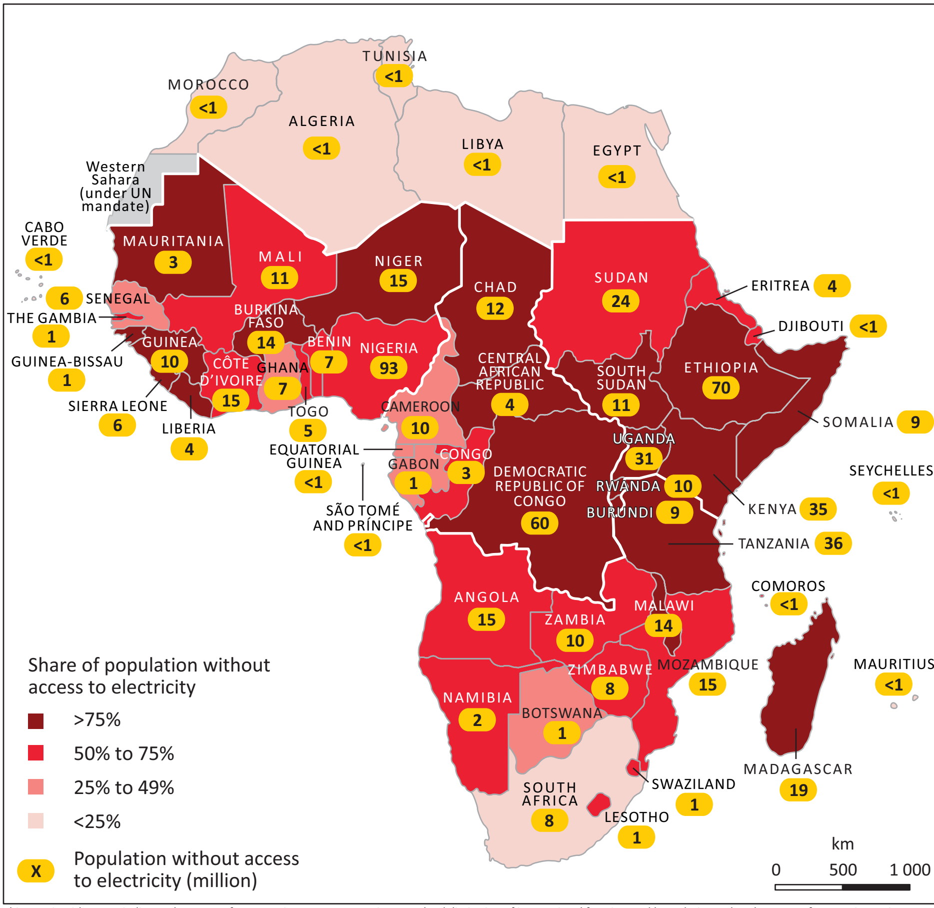
Nearly 80% of those lacking access to electricity across sub-Saharan Africa are in rural areas, an important distinction when considering appropriate energy access strategies and technical solutions. Around the world, increasing urbanisation has often facilitated increasing household access to modern energy. While it can play a similar role in sub-Saharan Africa, the extent to which this will occur is less clear because, unlike many

7. The traditional use of solid biomass refers to basic technologies used to cook or heat with solid biomass, such as a three-stone fire, often with no or poorly operating chimneys. Modern use of solid biomass refers to improved cookstoves using solid biomass and modern technologies using processed biomass such as pellets.

8. Annex A3 presents full data tables for access to electricity and clean cooking facilities.

world regions, sub-Saharan Africa is expected to continue to see significant growth in both its urban and rural populations. In this light, efforts towards universal modern energy access will require effective solutions for rural, as well as urban and peri-urban, communities.[9] Several African countries have dedicated policies, programmes or institutions to provide electricity access in rural areas. While such a tailored approach appears warranted, the success rate has been uneven.

Figure 1.6 ▷ Number and share of people without access to electricity by country, 2012



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.

In West Africa, electricity access rates range from below 20% in Liberia, Sierra Leone, Niger and Burkina Faso to more than 50% in Senegal and above 70% in Ghana. More than 90 million people in Nigeria (55% of the population), do not have access to (grid) electricity. However, the widespread use of back-up generators suggests that the population without

9. Around 62% of the urban population in sub-Saharan Africa lived in slums in 2012 (UN-Habitat, 2013).

access to any form of electricity is smaller (see power section). Nigeria's own targets are to make reliable electricity available to 75% of the population by 2020 and 100% by 2030 (Energy Commission of Nigeria, 2013). Ghana is among the most successful countries in improving electricity access, having shown long and strong political commitment since the launch of its National Electrification Scheme in 1989. Mali, a large and sparsely-populated country, has seen electricity access reach 27%, with a focus on mini-grid solutions.

Electrification rates in Central Africa show very large variation across the region, from the relatively high levels in Equatorial Guinea (66%), Gabon (60%) and Cameroon (54%) to the very low levels in Central African Republic (less than 3%), Chad (4%) and DR Congo (9%). Chad is one of many countries where low levels of energy access go hand-in-hand with low rates of access to other basic services, such as potable water, basic sanitation and paved roads. This is in spite of the fact that crude oil has become the country's primary source of export earnings. Around 60 million people in DR Congo do not have access to electricity, even though it has very large hydropower potential.

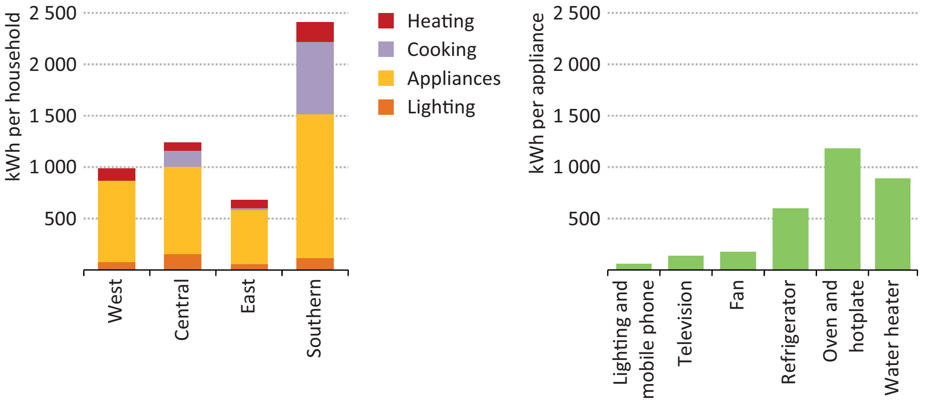
More than 200 million people in East Africa are without electricity, around 80% of its population. Ethiopia, Kenya and Uganda are among the most populous countries in East Africa, and have the largest populations both with and without access to electricity. Kenya established a Rural Electrification Authority in 2006 with the goal of achieving universal access by 2030. As of 2013, 90% of public facilities have access to electricity, but household access remains low. Rwanda's electrification rate has increased rapidly in recent years (from 6% in 2008 to 17% in 2012). Its Electricity Access Rollout Programme offers ready-to-use switchboards that can be paid for in instalments and enable low income households to connect to grid electricity without the need for expensive house wiring.

The picture in the Southern Africa sub-region is skewed by the unique situation of South Africa: at around 85%, South Africa has the highest electrification rate on mainland sub-Saharan Africa. Around 11% of households do not have access to electricity and a further 4% rely on illegal access (non-paying) or obtain access informally (from one household to another but paying) (Statistics South Africa, 2013). More than three-quarters of households use pre-paid meters, which helps overcome the problem of non-payment. Despite positive overall progress to improve access, the most recent National Development Plan in South Africa warns that reliability of supply has deteriorated and prices are rising quickly. In Mozambique, around 40% of people have access to electricity, either through the grid or mini/off-grid systems. The government has promoted solar photovoltaic (PV) and mini-hydropower solutions in rural areas, reporting that 700 schools, 600 health centres and 800 other public buildings in rural areas now have electricity from solar PV (AllAfrica, 2014). Electricity access in Tanzania increased from around 13% in 2008 to 24% in 2012, with a reduction in connection fees (by 40% in urban areas and 60% rural areas) recognised as an important contributory factor.

For those that do have electricity access in sub-Saharan Africa, average residential electricity consumption per capita is 317 kWh per year (225 kWh excluding South Africa), equivalent to around half the average level of China, 20% of Europe and 7% of the

United States.[10] Consumption per capita is significantly lower in rural areas, typically in the range of 50 to 100 kWh per year. For a five person household, annual consumption of 50 kWh per person could, for instance, allow the use of a mobile phone, two compact fluorescent light bulbs and a fan for five hours a day. In urban areas, households generally own more appliances, such as televisions, refrigerators or an electric water heater. There are also disparities in consumption levels across and within sub-regions (Figure 1.7). Levels in Central Africa average 220 kWh per capita per year but vary from less than 100 kWh in Cameroon to around 900 kWh in Gabon. In Southern Africa, average consumption per capita is the highest of all sub-regions, but this is driven principally by very high levels in South Africa and relatively high levels in Zambia, Botswana and Zimbabwe (all above 500 kWh per capita per year). Levels in Mozambique and Tanzania are much lower (below 200 kWh per capita per year).

Figure 1.7 ▷ Average electricity consumption per household in sub-Saharan Africa, 2012, and indicative consumption levels by appliance



Notes: The "appliances" category includes cooling systems. The indicative electricity consumption levels shown for various appliances are based on: charging a mobile phone three times a week; using three 10-watt compact fluorescent lights for five hours per day (almost half of light bulbs in sub-Saharan Africa are incandescent); and using a television for four hours per day. The number of people per household varies by sub-region from below four to almost six.

Sources: UNEP (2014); USAID (2014); OECD (2014); IEA analysis.

Excluding South Africa, appliances account for around 70% of residential electricity consumption across the other sub-regions, on average. There are an estimated 43 million televisions (equivalent to about one in every four households), 17 million refrigerators (around one in every ten households) and 450 million mobile phones (about one for every two people). Ownership of mobile phones in sub-Saharan Africa has risen at a brisk pace and provides access to multiple services, such as personal and business communications

10. Electricity consumption per-capita levels are estimated taking into account residential electricity consumption and population with electricity access by country.

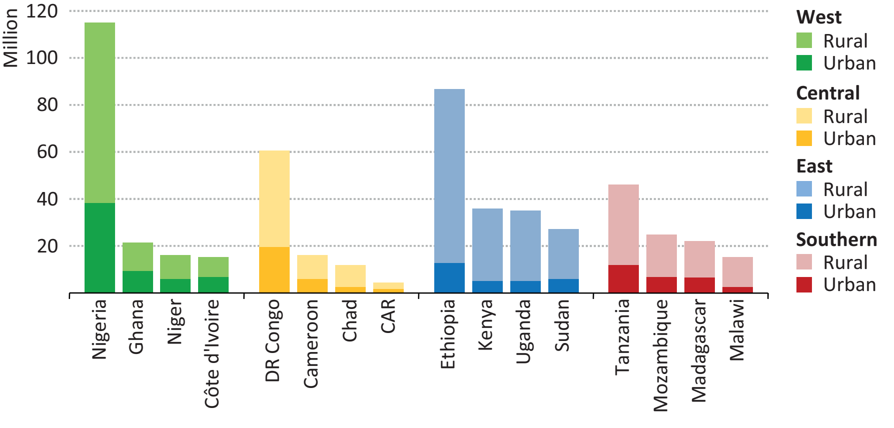
and online banking, for relatively low electricity consumption. In reality, a small share of households owns a relatively large share of electric appliances. An even smaller share use electricity for water heating or cooking, both of which consume relatively high levels of electricity (mainly households in Southern Africa).

Access to clean cooking facilities

Nearly 730 million people in sub-Saharan Africa rely on the traditional use of solid biomass for cooking typically with inefficient stoves in poorly ventilated space. A transition to cleaner cooking fuels and appliances is not straightforward, as people who have access to modern fuels, such as LPG, natural gas, biogas or electricity, may also continue to use solid biomass for cultural or affordability reasons, a phenomenon known as "fuel stacking" (see Chapter 3).

Five countries – Nigeria, Ethiopia, DR Congo, Tanzania and Kenya – account for around half of the sub-Saharan population using solid biomass for cooking (Figure 1.8). Although this seems to suggest that this situation is concentrated in just a few countries, the reality is very different. In 42 countries, more than half of the population relies on solid biomass for cooking needs and in 23 of these the share is above 90%. Nearly three-quarters of those dependent on solid biomass for cooking live in rural areas and often devote hours of each day to collect fuelwood.

Figure 1.8 ▷ Largest populations relying on the traditional use of solid biomass for cooking in sub-Saharan Africa by sub-region, 2012



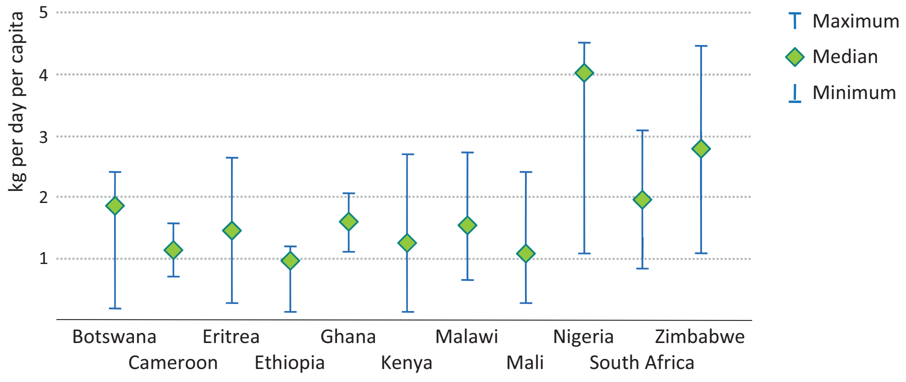
Note: CAR = Central African Republic.

Sources: World Health Organization; IEA databases and analysis.

While this issue is often given less attention than that of electricity access, several countries have implemented programmes to promote clean cooking fuels and stoves. Kenya has plans to eliminate kerosene use in households by 2022 and has a relatively developed market for improved biomass cookstoves in urban and peri-urban areas (but much less so in rural areas). In Senegal, strong policies and incentives have supported LPG use and less than 25% of the urban population now uses solid biomass. Ghana has set the ambitious goal of providing 50% of households with LPG by 2016, compared to less than 20% today. The picture is less positive in Ethiopia, with nearly all rural households and 80% of urban households dependent on solid biomass for cooking.

Around 80% of residential energy demand in sub-Saharan Africa is for cooking, compared with around 5% in Organisation for Economic Co-operation and Development (OECD) countries. This is due, mainly, to households prioritising energy for cooking (and lighting) within very restrictive budgets (when paid for) and the low efficiency of the cookstoves used (typically 10-15% efficiency for a three-stone fire, compared to 55% for an LPG cookstove). Estimates of the amount of fuelwood consumed by households differ markedly, both within and across countries, which has a huge impact on estimates of total solid biomass use (Figure 1.9).

Figure 1.9 ▹ Fuelwood consumption per capita per day in selected countries



Sources: Department of Energy at the Politecnico di Milano; IEA analysis.

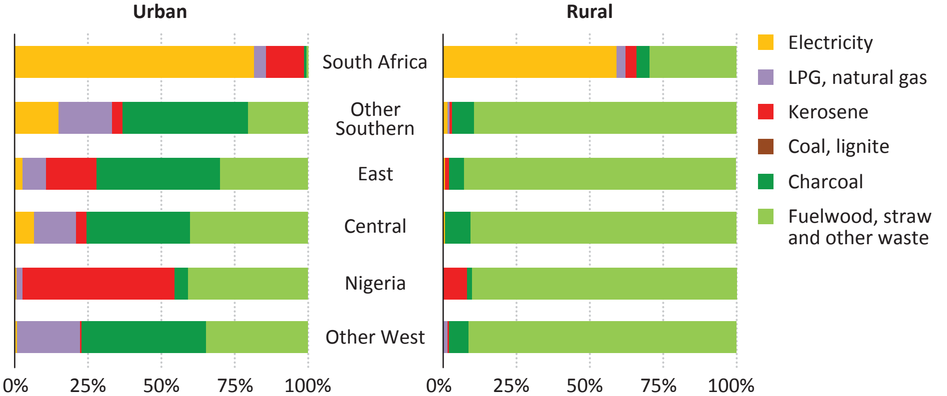
The main factors that help explain differing levels of fuelwood consumption are:

- Climate/seasonality – consumption can increase in a cold season relative to a hot one, while the moisture content of fuelwood also affects its energy content.
- Household size – significant variations in household size affect consumption patterns.
- Ease of access – scarcity of supply tends to reduce waste and overuse; while relatively easy access can increase consumption (deforestation and land degradation is discussed in Chapter 2).
- Population density – increasing urban populations are a key driver of charcoal use, which feeds through to higher levels of fuelwood depletion (see Chapter 2, Box 2.2 on charcoal production and the size of the market).
- Availability and price of alternative fuels and stoves – if solid biomass remains cheap or "free" relative to alternatives, then increasing incomes may not be a critical trigger for households to switch to modern cooking fuels.

- Alternative uses – Competing uses for solid biomass for other activities (such as brick-making and tobacco curing) can affect whether it is used for cooking.
- Cultural factors and nutritional habits – there is a complex relationship between solid biomass consumption, cultural factors and food choices.

There is almost exclusive use of solid biomass for cooking in rural areas (mainly fuelwood and agricultural waste), but a more diverse use of fuels in urban areas (Figure 1.10). In rural areas, solid biomass use (mainly in the form of fuelwood and agricultural waste) dominates in all regions except South Africa, where electricity is commonly used for cooking. Even in South Africa, traditional use of solid biomass is concentrated heavily in rural areas and among those with the lowest incomes. The choice of fuels for cooking is much more varied in urban areas. Solid biomass is still very common, but there is a greater tendency to use charcoal as it has higher energy content and is easier to transport than fuelwood. Kerosene use is common in urban parts of Nigeria (where it is supported by subsidies), as well as in South Africa and Kenya. While LPG use is less common in Nigeria, it is used by one-fifth of urban households in the rest of West Africa.

Figure 1.10 ▷ Main fuel used by households for cooking



Sources: USAID (2014); Department of Energy, South Africa (2013); WHO (2013); IEA analysis.

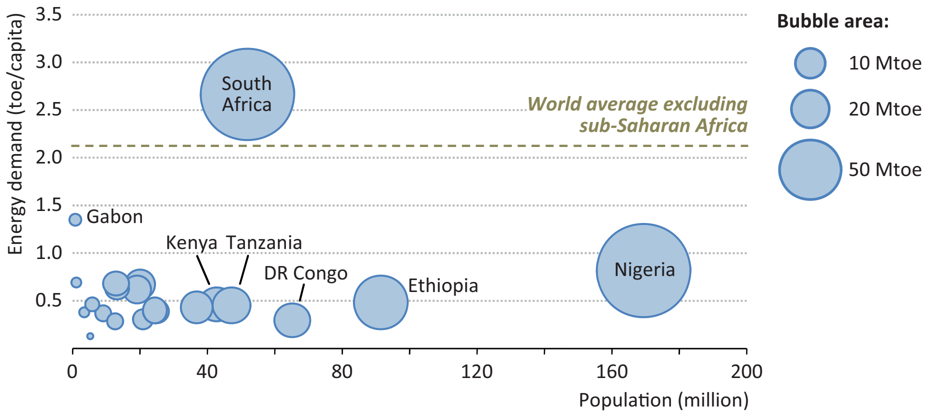
Overview of energy demand

Primary energy demand in Africa stood at 739 million tonnes of oil equivalent (Mtoe) in 2012, of which North Africa accounted for 23%. Since 2000, energy demand in sub-Saharan Africa has increased by half – reaching 570 Mtoe in 2012 – but still accounts for only 4% of the world total. While growth in sub-Saharan energy demand has outpaced that in the rest of the world, it has lagged behind economic expansion, as in many countries it was led by sectors with relatively low energy intensity such as tourism and agriculture. The energy intensity of the sub-Saharan economy has decreased by around 2.5% per year since 2000, but remains significantly higher than North Africa and is more than double the world average. The region's largest energy demand centres are Nigeria (141 Mtoe) and

South Africa (141 Mtoe) together accounting for more than 40% of total demand (but only a quarter of the population) (Figure 1.11). Ethiopia, the next largest consumer, is a distant third (45 Mtoe), followed by Tanzania, DR Congo and Kenya.

Energy use per capita is, on average, one-third of the world average (2.1 tonnes of oil equivalent [toe] per capita excluding sub-Saharan Africa) and only half of the level of developing Asia, the world's second most energy-poor region. Only South Africa's per capita energy demand exceeds the world average, while Nigeria's demand per capita is lower than that of Gabon and Mauritius. Ethiopia, DR Congo, Tanzania and Kenya also have relatively large populations but low demand on a per-capita basis. Across sub-Saharan Africa, there are large differences in per-capita consumption between urban and rural areas, with those in cities tending to be wealthier, and often enjoying better access to energy than those in rural areas (either through the grid or the use of back-up generators).

Figure 1.11 ▷ Population and per capita energy demand by country in sub-Saharan Africa, 2012



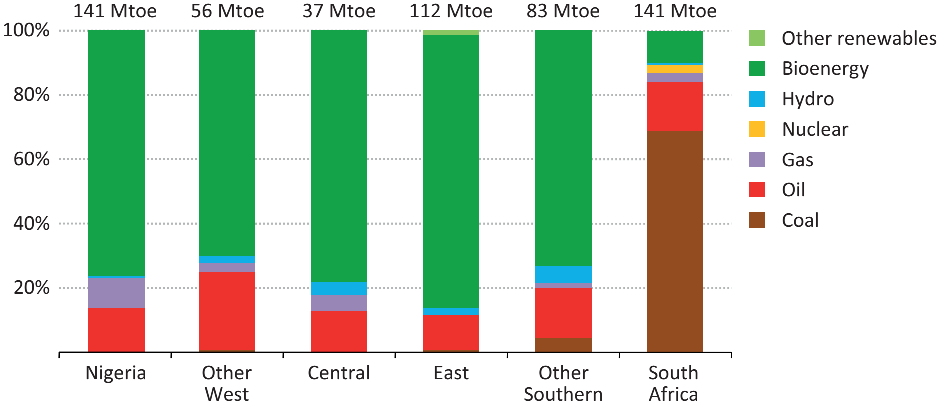
Note: The size of the bubble indicates the relative size of total primary energy demand.

Bioenergy is dominant in the energy mix of sub-Saharan Africa, accounting for more than 60% of total energy use. Despite rising incomes, bioenergy consumption continues to increase in the region and its growth since 2000 has been greater than that of all other fuels combined. This is largely driven by the traditional use of biomass for cooking, which constitutes a large industry in some areas (typically to supply charcoal to urban areas) and a non-traded commodity in others (collected and consumed by individual households, often in rural areas). South Africa and Namibia are the only countries in mainland sub-Saharan Africa where bioenergy does not dominate the energy mix (Figure 1.12).

Oil demand in sub-Saharan Africa stood at 1.8 million barrels per day (mb/d) in 2012 and made up 15% of total energy demand. South Africa accounts for around 30% of oil demand and Nigeria for more than 20%, with the remaining 40-plus countries collectively consuming less oil than the Netherlands (even though their aggregate population is

30 times higher than that of the Netherlands). Diesel – a versatile fuel that can be used in many sectors – accounted for 30% of the oil demand growth since 2000, increasing significantly across most parts of sub-Saharan Africa (Figure 1.13). Gasoline accounted for nearly 40% of demand growth over the same period but this growth was concentrated in Nigeria, where the official selling price is around 40% lower than diesel. Demand for LPG rose more strongly than that for kerosene (increasing by around 60% since 2000) but starting from a lower point. While growth has been particularly strong in parts of West and East Africa, LPG is still seen as a premium cooking fuel in many countries compared with solid biomass (see Chapter 3).

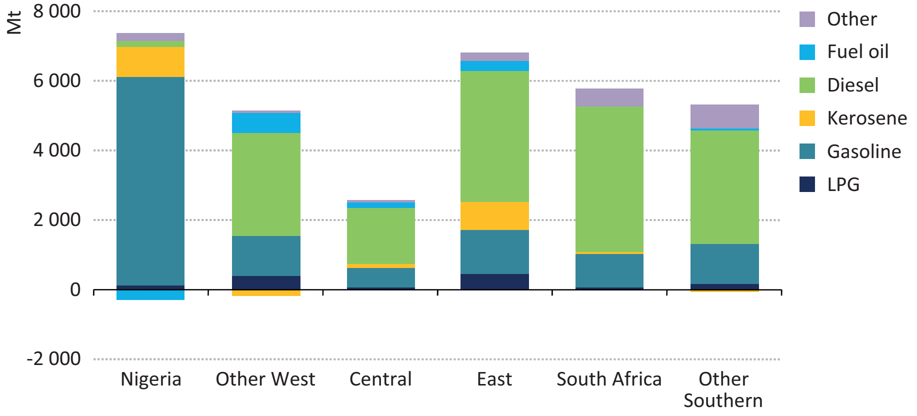
Figure 1.12 ▷ Sub-Saharan Africa primary energy mix by sub-region, 2012



Coal is the second-largest component of the sub-Saharan energy mix after bioenergy, but this is wholly attributable to its large-scale use in South Africa, where it accounts for around 70% of primary demand. Its primary use in South Africa is in the power sector, but South Africa is also one of very few countries in the world where coal-to-liquids accounts for a significant part of transport fuel. Beyond South Africa, coal appears in the mix of just a dozen countries (and in relatively small volumes), although Mozambique plans to make increasing domestic use of its vast resources. Natural gas makes up a very small share of the sub-Saharan energy mix (4% compared with 21% globally), despite existing resources and its significant role in neighbouring North Africa. Natural gas demand has been rising and reached 27 billion cubic metres (bcm) in 2012, with Nigeria accounting for nearly 60% of the total, as gas flaring declined and volumes consumed in the power sector increased. Nigeria is the largest consumer of natural gas and yet it represents just 9% of Nigeria's domestic demand. Gabon and Côte d'Ivoire rely more heavily on gas but consume much smaller volumes.

Overall, modern renewables (hydro, solar, wind, geothermal and bioenergy except the traditional use of solid biomass) account for less than 2% of the sub-Saharan energy mix, but there are countries that have achieved a significantly higher share. Modern renewables have also grown significantly in recent years, supported by policies and declining costs in many cases, but (with the exception of hydropower) this growth has been from a very low base. Hydropower has long been a part of the energy systems of several countries and yet, very little of the potential has so far been tapped. For example, only 2% in DR Congo, 4% in Angola, 5% in Ethiopia, 12% in Congo and 14% in Mozambique. The use of other modern renewables is far more limited, but there are pockets of progress, with South Africa holding auctions for new capacity and Kenya harnessing some of its geothermal resources (7% of its energy mix in 2012).

Figure 1.13 ▷ Oil product demand growth by sub-region, 2000-2012



Notes: Mt = million tonnes; kerosene includes jet fuel. Sources: CITAC; IEA analysis.

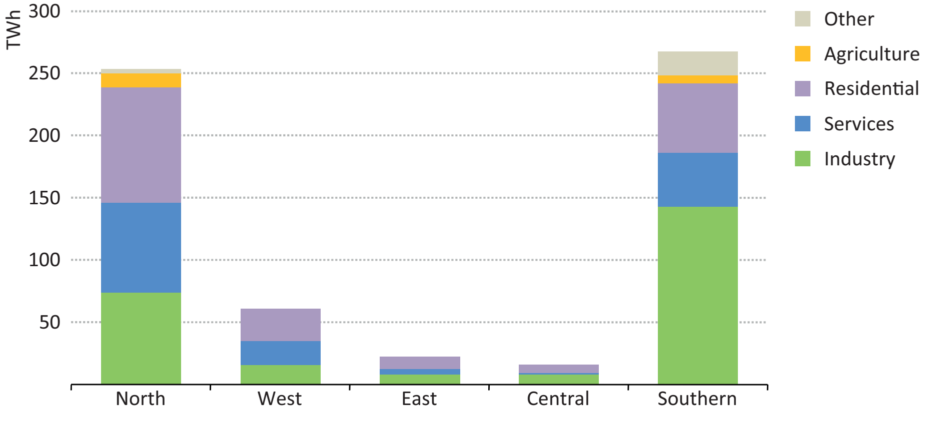
Power sector

Electricity demand

Electricity demand in much of Africa is constrained by available supply, resulting in people either not having any access or not being able to consume as much as they would like. Such unmet demand is not captured in electricity data and makes it difficult to measure electricity demand in a holistic sense. This section then focuses on electricity demand that is met by grid-based supply or by mini- and off-grid sources. Electricity demand in Africa was 605 terawatt-hours (TWh) in 2012, with North Africa accounting for around 40% of the total. In sub-Saharan Africa, total electricity demand increased by 35% since 2000 to reach 352 TWh in 2012, just 70% of the level of Korea, which has a population 5% of the size. In fact, the electricity demand of only one country in the region (South Africa) exceeded that of London in 2012. On a per capita basis electricity demand in sub-Saharan Africa has remained largely unchanged for the last decade (at close to 400 kWh), with total consumption levels rising in step with the population. This is the lowest rate of per capita consumption of any major world region, 75% below that of developing Asia and less than the electricity needed to power one 50-watt light bulb continuously for a year. For comparison, electricity demand per capita in North Africa increased by more than 80% from 2000 to 2012, reaching 1 500 kWh.

In sub-Saharan Africa, electricity constitutes 7% of final energy consumption (4% if South Africa is excluded), compared with 18% globally and 19% in North Africa. In 2012, industry (led by mining and refining activities) accounted for the largest share of electricity consumption in sub-Saharan Africa (50%), but much of it was concentrated in South Africa, Nigeria, Ghana and Mozambique (Figure 1.14). The residential sector represented only 27% of total electricity consumption, as there are relatively few electricity-consuming appliances per household and limited disposable income. Services accounted for 20% of electricity consumption in sub-Saharan Africa, though demand in this sector is burgeoning in some countries such as Nigeria. A boom in communications, particularly for mobile telephones, has helped drive up demand in the services sector rapidly in recent years.

Figure 1.14 ▻ Electricity consumption in Africa by end-use sector and sub-region, 2012



Electricity supply

Installed grid-based power generation capacity in Africa has been steadily increasing in recent years and reached 158 gigawatts (GW) in 2012.[11] Grid-based power generation capacity in sub-Saharan Africa has increased from around 68 GW in 2000 to 90 GW in 2012, with South Africa alone accounting for about half of the total. Coal-fired generation capacity is 45% of the sub-Saharan total, followed by hydropower (22%), oil-fired (17%), gas-fired (14%), nuclear (2%) and other renewables (less than 1%). Until recently, countries developed their power systems largely independently of one another, focusing on domestic resources and markets, but there has been progress towards regional co-operation to permit concentrated resources, such as large hydropower, to serve larger markets. While at varying stages of development, regional power pools aim to strengthen integration through co-operative planning and improved physical linkages, and have been playing a larger role in

11. Installed capacity refers to the sum of gross (nameplate) power generation capacity, including both power plants whose main activity is generating electricity for sale and auto-producers that generate power mainly for their own consumption (as is common in industry). The total installed capacity may not be available at all times, due to maintenance, need for repair or other outages.

the recent expansion of generation capacity. In addition to capacity linked to the main grid, there has been increasing emphasis on developing mini-grids (small grid systems linking households and other consumers, but not connected to larger regional grids) and off-grid systems (stand-alone systems for individual households or consumers (see Chapter 3). To further supplement their power supply, many individuals and businesses have access to small diesel or gasoline-fuelled generators (Spotlight).

In sub-Saharan Africa, the amount of power that is available to consumers is substantially less than the level of total installed capacity might suggest. One important reason is that the amount of capacity in operation is usually far less than the total installed capacity, due to poor maintenance which causes power stations to fall into disrepair. Many rehabilitation projects are ongoing, but much of the capacity in disrepair will never restart. Improving the operations of existing power plants is one of the most cost-effective and important ways of improving and expanding the power supply (WEC, 2010). Other factors also reduce the total capacity in operation, including lack of reliable fuel supply, particularly for gas, inefficient grid operations and insufficient transmission capacity.

The effect of fuel supply limitations is made worse by the fact that the fleet of fossil-fuelled power plants in sub-Saharan Africa consists largely of technologies with the lowest efficiencies, often favoured due to their lower upfront capital costs. For example, the average efficiency of the fleet of gas-fired power plants was 38% in 2012, due to the predominance of open-cycle gas turbines (instead of higher efficiency combined-cycle gas turbines) even though the power plants were frequently called upon to operate. Had the average efficiency been equal to that of gas-fired power plants in India (46%), the unused fuel could have generated 8 TWh (21%) more electricity. Similarly, the fleet of coal-fired power plants employs low-efficiency subcritical technologies, with a fleet average efficiency of 34%. While this technology was the most commonly available at the time the plants were built, more efficient supercritical or ultra-supercritical technologies would generate more electricity from the same amount of fuel.

Transmission and distribution (T&D) losses reduce the supply ultimately available to end-use sectors by more than 20% in some countries in sub-Saharan Africa, averaging 18% across the region, when South Africa is excluded (Figure 1.16). T&D losses are noticeably lower in South Africa and North Africa, at 10% and 14% respectively. The loss rate in sub-Saharan Africa (excluding South Africa) is more than double the world average and that of many developing countries in Asia. Similar to the problem with power plants, lack of proper maintenance is a main contributor, along with inefficient system design and operation. Such high loss rates reduce the reliability of the power supply, which is already insufficient to meet demand in most countries. In addition, high losses increase the cost of the power actually delivered. Across sub-Saharan Africa in 2012, the average cost of generating electricity was around $115 per megawatt-hour (MWh). At an 18% loss rate, this translates (for generation costs alone) into around $140 per MWh consumed, still without provision for the other substantial costs related to power supply. These additional costs, including the T&D infrastructure and retail costs, can add $50-$80 per MWh to the average cost to the consumer (as in China).

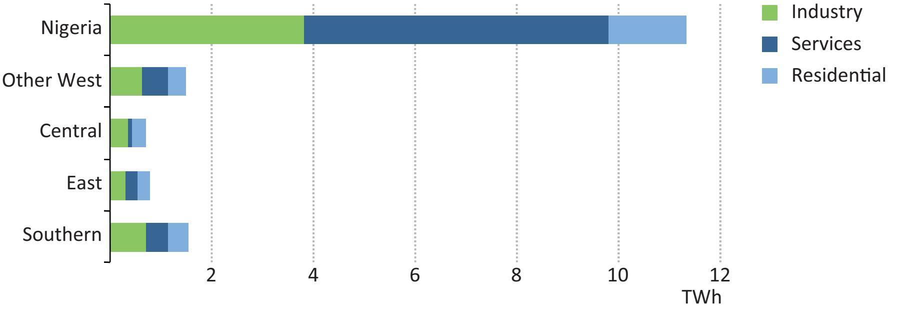
S P O T L I G H T

Falling back on back-up generators

Grid-based electricity supply is insufficient to meet electricity demand in sub-Saharan Africa. It is reported to be unavailable for 540 hours per year on average (6% of the year), but this figure is much higher in some countries, such as Nigeria, Guinea and the Central African Republic. In grid-connected areas, the high frequency of power outages means that demand is either unmet or met by other means (mostly by diesel-fuelled back-up generators). However, relative to grid supply, back-up power generation is expensive and levels of use are generally not recorded in energy statistics.

We estimate that the amount of electricity demand served by back-up generators in sub-Saharan Africa was almost 16 TWh in 2012, more than 80% of which went to services and industry (Figure 1.15).[12] This implies that total electricity supply was around 3% higher than reported and that around 90 kb/d of oil was used to generate the additional electricity, at an estimated cost of over $5 billion. Nigeria accounts for almost three-quarters of electricity supply provided by back-up generators, while levels are relatively low in East and Central Africa, where grid access is more limited.

Figure 1.15 ▷ Electricity demand met by back-up generators by sub-region, 2012

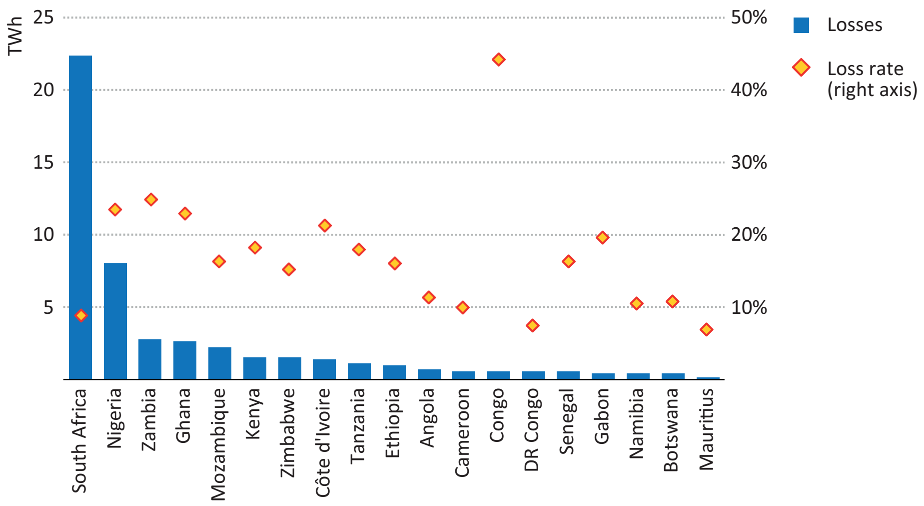


Source: IEA analysis and estimates.

Even after back-up generation has been included, there is still electricity demand that remains unmet. Those without a generator are left without electricity during outages, while those with them face significant costs and often make do with a reduced level of supply. Also, where outages are frequent and long-standing, consumers may have changed their equipment purchases – and, hence, use of energy services – to reflect this. Where reliable grid-based electricity is established, the level of additional demand can be expected to increase well beyond the existing level of back-up power generation. Furthermore, electricity prices in parts of sub-Saharan Africa are among the highest in the world. If end-user prices were to fall following power system improvements, such as reducing transmission and distribution losses, then additional hidden electricity demand could be expected to materialise.

12. Estimate is based on fuel consumption data from CITAC and World Bank Enterprise Surveys.

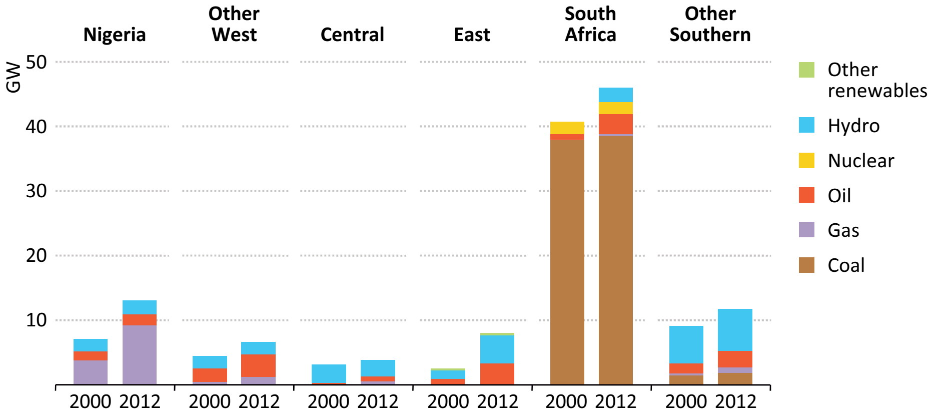
Figure 1.16 ▷ Transmission and distribution losses and loss rates, 2012



Southern Africa has more installed grid-based capacity than any of the other sub-regions with 58 GW, of which 46 GW is in South Africa (Figure 1.17). By far most of South Africa's capacity is coal-fired at 85% with 6% oil-fired, 5% hydropower and 4% nuclear from the continent's only nuclear power plants (Koeberg I and II [900 MW each]). Since 2000, oil and hydropower have provided the bulk of net capacity additions, while coal capacity remained stable. Excluding South Africa, the remaining three-quarters of the population of Southern Africa rely on some 12 GW, just 21% of the installed generation capacity. Their technology mix has a very different complexion, with hydropower accounting for more than half of capacity, oil for 22%, coal for 16% and gas for 8%. In some cases, such as Angola and Mozambique, a number of sub-national systems serve different parts of the country and there is no integrated national grid. The average cost of grid generation across Southern Africa is relatively low – at around $55 per MWh – due to the reliance on low-cost coal generation in South Africa and hydropower in other countries.

Grid-based capacity in West Africa was 20 GW in 2012. More than half of this capacity is gas-fired, mostly in Nigeria where it is the dominant power generation technology. Oil accounts for almost 30% of total West African capacity and is spread across the region, while hydropower accounts for 20% of capacity (but a larger share of generation). While hydropower had long been the major source of power in the region (led by large projects such as the Akosombo dam in Ghana), oil-fired capacity increased rapidly in the 1990s and gas-fired capacity has done so more recently, as Nigeria boosted efforts to capture and utilise its associated gas production. Despite being rich in oil and gas resources, Nigeria suffers from significant under-capacity in electricity generation, with frequent power outages driving consumers towards large-scale use of expensive back-up generation. Some countries in the region, such as Benin, Burkina Faso and Niger are reliant on electricity imports for a significant share of their supply. The high share of fossil fuels results in a relatively high average cost of generation in West Africa, at around $140 per MWh.

Figure 1.17 ▷ **Installed grid-based capacity by type and sub-region**



In Central Africa, grid capacity is 4 GW, equivalent to 4% of the sub-Saharan total despite the population being 12% of the whole. The average pace of capacity additions has been very slow since 2000 (less than 60 MW per year), but the pace of gas-fired capacity additions has increased in the last few years. Hydropower accounts for a large share of installed capacity (65%), followed by oil (20%) and gas (15%). At around $95 per MWh, the average cost of generation is relatively low for sub-Saharan Africa, with the high cost of oil-fired generation offset by the low cost of hydropower. Several countries rely heavily on hydropower (such as DR Congo, Cameroon and Congo), although regional capacity is particularly concentrated in DR Congo. A lack of maintenance (Inga I and II, in DR Congo, were built in the 1970s and 1980s) and hydrological variability means that only around half of the capacity of Inga I and II is available to the system. Central Africa nonetheless has the largest hydropower potential of any sub-region (mainly in DR Congo). There are ongoing efforts to add a third dam at Inga of 4.8 GW, and possibly additional phases that collectively make up the Grand Inga project.

Grid-based capacity in East Africa totals 8.1 GW: hydropower is more than half, oil-fired capacity about 45% and the remainder made up of geothermal and gas-fired capacity. Total capacity has more than tripled since 2000, mainly as a result of oil-based additions and hydropower projects coming online in 2009 and 2010. The Merowe hydropower dam in Sudan began operations in 2009 (1.25 GW capacity) and accounts for more than 15% of total power supply in East Africa. Ethiopia's Beles II hydropower project (460 MW) and Gilgel Gibe II (420 MW) began operation in 2010. Gilgel Gibe III (1.87 GW) is nearing completion, while the Grand Renaissance Dam (6 GW) is in progress. Such projects reflect Ethiopia's ambition to become an electricity supplier to east coast neighbours such as Kenya, Burundi, Tanzania, Uganda and Rwanda. More than half of this region's total oil-based capacity is in Sudan, but oil is present in the mix of all countries to some extent. Geothermal is mainly in Kenya, with around 250 MW of capacity in 2012 in the southern part of the Rift Valley, and further developments being undertaken by the state-owned Geothermal Development Company. The existing power mix (and relatively high losses) results in an average cost of generation of around $110 per MWh.

End-use sectors

In many sub-Saharan countries, economic development is at an early stage, a point reflected by the fact that two-thirds of total energy use occurs in the residential sector – mostly for cooking – compared with an average of 25% in other developing countries and just 20% across the OECD. The share of energy consumption in other end-use sectors is much lower than in other world regions, reflecting the very low availability of energy services: transport accounts for only 11% of final energy consumption, and productive uses (including industry, agriculture and services) together account for only 21%. A share of residential energy use is also directed to productive uses, in the form of energy used by cottage industries, but this proportion is, by its nature, difficult to quantify.

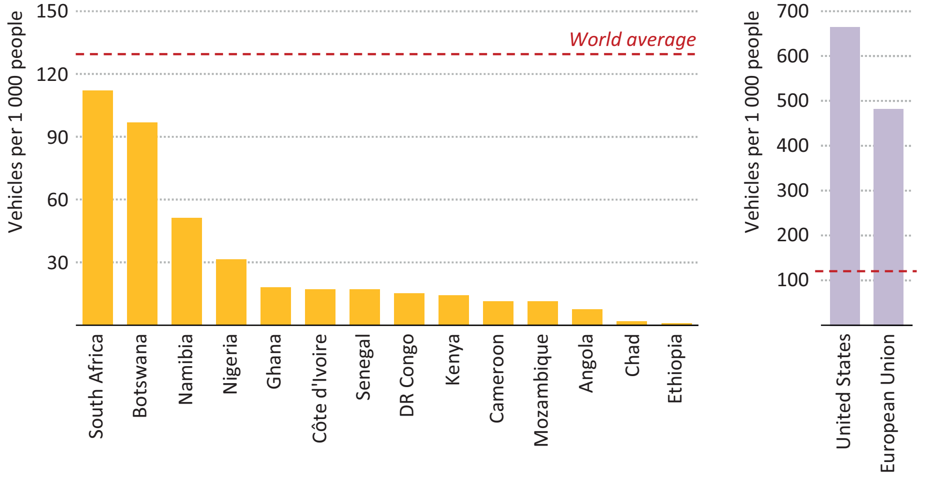
Transport

Energy consumption in transport in sub-Saharan Africa has increased by 4% per year since 2000 and was around 50 Mtoe in 2012. The geography of the region is vast, and urbanisation rates are low, implying a high latent demand for transport services. However, the reality is that the transport sector is largely under-developed in most countries and, where it does exist, mass transport infrastructure is often poorly maintained. There is little rail infrastructure in most countries and only around 5% of global airline traffic originates from or goes to Africa (Boeing, 2013). Energy use in transport in sub-Saharan Africa is therefore heavily concentrated on vehicles, but the road infrastructure is also under-developed. Road density is extremely low, at 89 km per 1 000 km^2 of area, it is less than a third of the world average. In addition, less than 20% of African roads are paved (compared with to almost 55% in Middle East, for example), while around 60% of the rural population (400 million people) live more than 2 km from an all-season road (AfDB, 2014).

The affordability of transport services is an important issue in many African countries. This is reflected in very low (albeit increasing) levels of car ownership, with only South Africa, Botswana and Namibia having ownership rates of at least 50 cars per 1 000 people (Figure 1.18). The price of vehicles can be relatively low, but this effect can be offset by high import costs. For example, importing a car from China to Kenya costs around $4 000 and to then transport it to neighbouring Uganda can cost around the same again (UNECA, 2010). Transport fuel is subsidised in several countries (see affordability section), but is still expensive relative to average incomes. The generally poor condition of the roads and the low affordability of fuels also lead to relatively low use of cars and trucks, compared with the global average. As a result, the cost of transporting goods in Africa is among the highest in the world – another barrier to growth. Despite the low level of car ownership, congestion in cities is frequent and public transport by bus and minibus is largely unregulated and informal, which leads to delays in commuting to work in many African cities, creating another obstacle to income generation.

Road transport in sub-Saharan Africa is typically characterised by a high degree of diesel use (almost 0.4 mb/d), with buses and trucks dominating demand. Diesel accounts for 39% of oil consumption in road transport across sub-Saharan Africa, but the figures are heavily influenced by countries with a comparatively high level of vehicle ownership (such as South Africa, with 42% diesel) and those where gasoline prices are relatively low (such as Nigeria, with only 12% diesel). Most of the rest of Africa has diesel shares of around 45% in road transport.

Figure 1.18 ▷ Car ownership in selected countries, 2012



Sources: World Bank (2014a); country communications; IEA databases and analysis.

Improving vehicle efficiency has not been a major focus of policy, in part because only South Africa has domestic manufacturing capacity for passenger cars and other countries rely on imports, often of second-hand vehicles.[13] In 2012, around 2.2 million cars and motorbikes were imported to Africa (UN COMSTAT). Directly or indirectly, Japan and Europe are among the main suppliers of these vehicles, indicating that fuel-economy standards in these regions will progressively impact on energy consumption in Africa, albeit with a significant time lag and depending on proper vehicle maintenance (which is often not the case today). Nevertheless, policy efforts are increasing, with Nigeria and South Africa being among the first countries in the region to adopt Euro 2 emissions standards. Angola, Botswana and Kenya are examples of countries that have introduced import restrictions on vehicle age. Another handful of sub-Saharan countries have introduced fuel quality standards, although poor fuel quality can reduce vehicle efficiency, even where such standards exist. While there is already some limited auto manufacturing and assembly plants (such as Foton, a Chinese producer), several global car manufacturers, such as Renault-Nissan, Kia and Tata are reported to be considering locating assembly plants in Africa. This is an opportunity not only for job creation and growth, but could provide stronger grounds upon which to introduce and enforce stricter fuel-economy standards.

13. General Motors leads a joint venture in Kenya that manufactures trucks and buses.

Productive uses

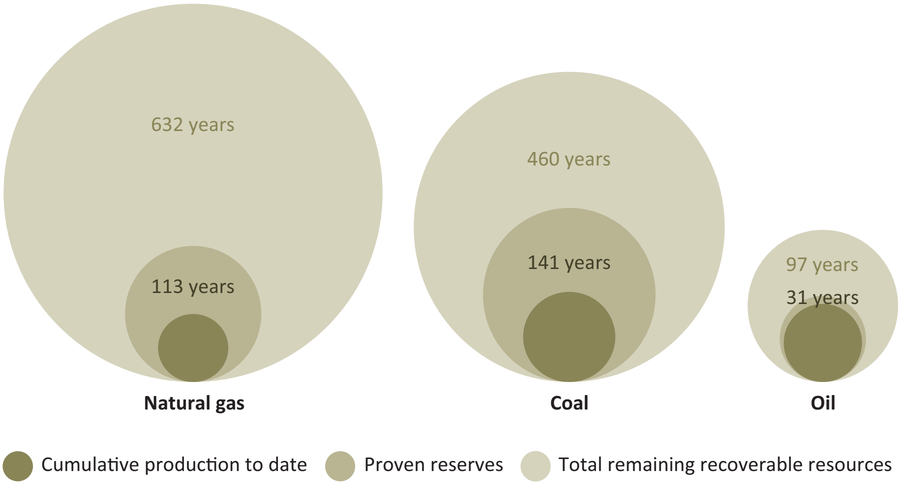
Despite employing far less people than agriculture, and generating less value added than services, industry uses more than two-thirds of the energy used for productive purposes in sub-Saharan Africa. Agriculture accounts for one-quarter of value added (excluding South Africa) and employs most of the working population, but makes very little use of modern energy. Fertilisers are seldom used and subsistence farming still represents a significant portion of total activity. As a result, energy use in agriculture, at 6 Mtoe, is very low by world standards. The services sector – mainly telecommunications and a variety of small businesses – also has limited energy use, but at 22 Mtoe it is still almost four-times larger than agriculture.

While data on energy consumption in specific industries is poor, it is clear that mining is a key energy consumer. Mining is a significant component in a number of economies (e.g. copper in Zambia, copper and cobalt in DR Congo, gold in Ghana, diamonds in Botswana, uranium in Namibia and iron ore in Guinea, Liberia and Sierra Leone), and extraction of these resources requires modern energy. Energy demand for cement production is showing signs of growth, starting in Nigeria with the Dangote plant, the largest in Africa. South Africa and Nigeria are the only countries with a significant petrochemical industry, while other notable energy-intensive large manufacturing activities include aluminium smelting in Mozambique (the Mozal plant near Maputo accounts for more than half of the country's demand) and the automotive, and iron and steel sectors in South Africa. Despite ambitions for manufacturing, to date most economic activity and growth is focused in non energy-intensive sectors, such as agriculture, tourism and textiles.

Overview of energy resources and supply

Energy resources in sub-Saharan Africa as a whole are more than sufficient to meet regional needs, both now and into the foreseeable future. This holds true across the range of energy resources, with remaining recoverable resources of oil sufficient for around 100 years at the current level of production, coal for more than 400 years and gas for more than 600 years (Figure 1.19). Uranium is also present in large quantities in some countries and the region has a range of high quality renewable resources, including solar, hydro, wind and geothermal. Many of these resources are spread unevenly across the huge continent and are at differing stages of development. A significant proportion of them are, as yet, undeveloped (particularly non-hydro renewables). In fact, many of the known resources are not yet fully surveyed or understood, and there remains good reason to believe that sub-Saharan Africa's energy resources will increase as exploration and assessment continue. The opportunity is present to develop a modern energy sector across Africa that draws on these varied resources; but the path from theoretical potential to harnessed supply is likely to be long and complicated.

Figure 1.19 ▷ **Sub-Saharan Africa natural gas, coal and oil resources, end-2013**



Notes: All bubbles are expressed as a number of years production based on estimated production levels in 2013. Production numbers for gas include flaring – if flaring were to cease today, there would be sufficient resources for around 960 years of production at 2013 production levels. Remaining recoverable oil and gas resource numbers include conventional and unconventional resources.

Sources: USGS (2000); USGS (2012a); USGS (2012b); Cedigaz (2013); BGR (2013); IEA analysis.

Oil and natural gas

Resources

Recent discoveries are bringing about a transformation in our understanding of sub-Saharan Africa's oil and gas resources, with traditional, mainly West African, sources of supply being joined by new resource-holders, such as Kenya and Uganda in the East African Rift and Mozambique and Tanzania with their offshore gas finds. Overall, sub-Saharan Africa holds around 7% of world conventional oil resources and 6% of world gas resources.[14]

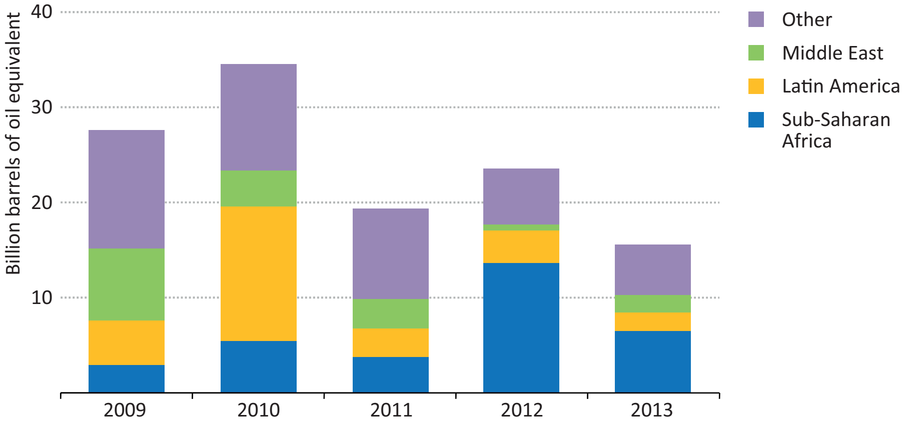
Sub-Saharan Africa accounted for nearly 30% of global oil and gas discoveries made in the last five years (Figure 1.20). In particular, 2012 saw an estimated 14 billion barrels of oil equivalent (boe) discovered, nearly 60% of the world total. While large gas discoveries in Mozambique (mainly in the offshore Rovuma Basin) and in Tanzania dominated the overall picture, these were complemented by pre-salt oil and gas discoveries in the Kwanza Basin in Angola.[15] Sub-Saharan Africa also led global discoveries in 2013, with oil finds in the Keta-Togo-Benin Basin in Nigeria and further natural gas finds in Mozambique. African discoveries this century have been across a range of basins (Box 1.4 and Figure 1.21) and countries: aside from Nigeria, Angola, Mozambique and Tanzania, ten countries have

14. Includes unconventional gas volumes.

15. "Pre-salt" oil and gas resources are referred to as such because they predate the formation of a thick salt layer, which overlays the hydrocarbons and traps them in place.

collectively discovered nearly 10 billion barrels of oil equivalent (boe) of resources. Chad, Ghana and Equatorial Guinea have already started production, while discoveries in Kenya and Uganda offer the potential to open up production in the East African Rift Basin before the end of this decade. Improved seismic and drilling technologies, supported by general improvements in the business environment, have meant that a number of African countries with little or no current production have seen higher rates of exploration and exploration success.

Figure 1.20 ▷ Global discoveries of oil and gas



Sources: Rystad Energy AS; IEA analysis.

As of 2013, remaining recoverable oil resources in sub-Saharan Africa are estimated at over 200 billion barrels (Table 1.1), of which around 70% are located offshore. Nigeria holds the largest oil resources by far (63 billion barrels), with a significant share being proven reserves. Further down the west coast, Congo, Gabon and Angola also hold significant resources, with the latter seeing particularly active exploration in the pre-salt Kwanza Basin. East Africa has around 18 billion barrels of oil resources, with South Sudan, Sudan and Uganda holding the majority; most East African countries are at a very early stage of resource development. Sub-Saharan Africa also has unconventional oil potential, particularly heavy oil in Madagascar, with resources estimated to be 2 billion barrels. USGS also estimates that Madagascar has 16 billion barrels of conventional oil yet to be discovered. Overall, the scale of oil resources is not transformative in a global sense, but it has the potential to be important both for meeting domestic needs, which are currently very small, and providing a source of much-needed export revenue.

Box 1.4 ▷ Major hydrocarbon basins in sub-Saharan Africa

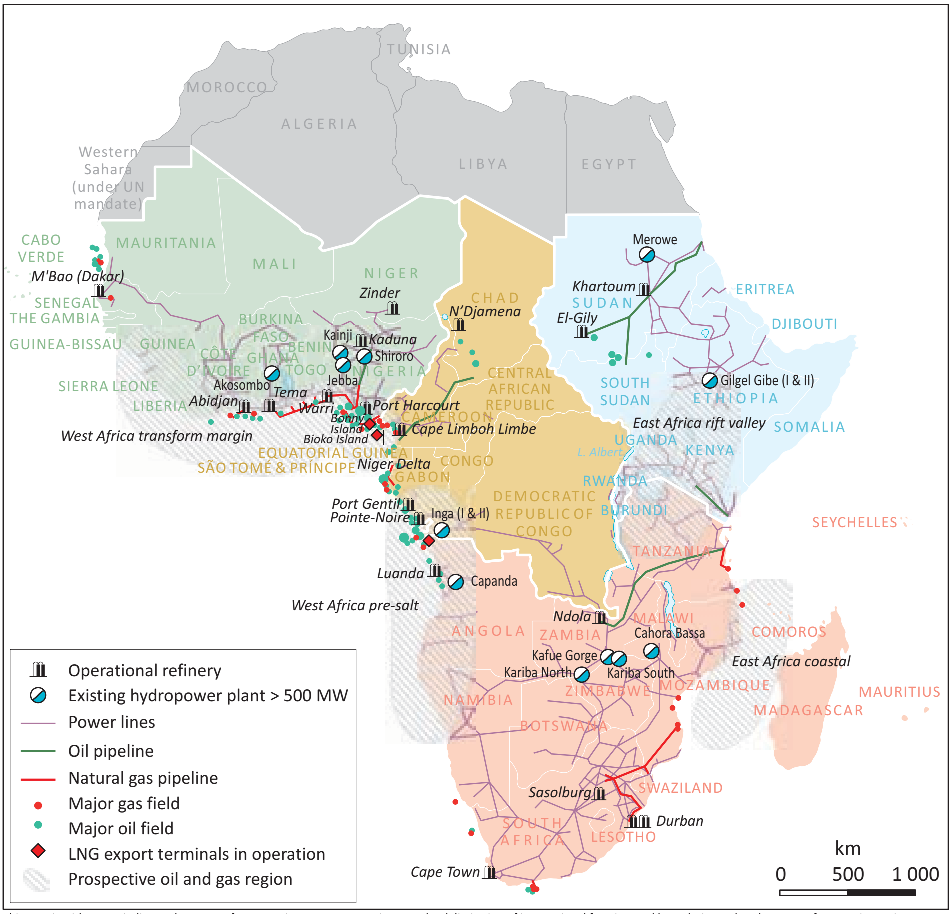
Exploration and production is underway across many hydrocarbon basins, including:

- **Niger Delta Basin** – A long-standing source of oil and gas production in Africa, the majority of the basin lies in Nigerian waters and produces high quality sweet crude from its hundreds of small deposits. The eastern edge of the Niger Delta extends into Cameroon and Equatorial Guinea (Rio Del Rey Basin) and accounts for most of their production. The US Geological Survey (USGS) ranks the Niger Delta as the 12th richest basin in undiscovered petroleum resources in the world, with over 30 billion barrels of undiscovered oil resources and 60 billion barrels of total remaining recoverable oil resources.
- **East African Rift** – The East African Rift Basin has recently brought the prospect of oil production to Uganda, Kenya and several of their neighbours (such as DR Congo, Rwanda, Burundi, Tanzania and Ethiopia). Recent drilling activity has been most intense in Uganda, with the Kingfisher discovery in 2007 and others in the vicinity amounting to 1.7 billion barrels of recoverable oil. Exploration in Kenya has so far discovered 600 million barrels of recoverable resources, principally in the Lokichar Basin. Ethiopia is thought to hold further promise in the Ogaden Basin.
- **East African Coastal** – Over 5 trillion cubic metres (tcm) of gas resources have been discovered in East African coastal waters off Mozambique and Tanzania in the last five years, predominantly in the Rovuma and Tanzanian coastal basins. USGS estimate that there are 41 billion barrels of oil and 13 tcm of gas to be found in the four geologic provinces off the east coast of Africa (including the Seychelles and Madagascar).
- **West African Transform Margin** – The discovery of the Jubilee field in Ghana in 2007 has fed expectations of more to come in this relatively under-explored basin stretching from Mauritania to the Niger Delta. The area under license has doubled in the last five years, with technical discoveries being made in Liberia, Sierra Leone and Côte d'Ivoire, but further appraisal is required to ascertain their commerciality.
- **West Coast Pre-Salt** – Gabon (Diaman discovery), Congo (Marine XII block) and Angola (Lontra and Mavinga) have seen discoveries below salt layers, proving that such pre-salt systems exist in West Africa. Volumes discovered so far have been modest and mainly natural gas, but explorers hope that larger finds await and there is particular interest in Angola's Kwanza and Benguela basins. Pre-salt prospects are also being explored in Cameroon, Equatorial Guinea and Namibia.

Sub-Saharan Africa as a whole has around 65 billion barrels of proven oil reserves, equivalent to around 5% of the world total. Three-quarters of these oil reserves are held in two countries (Nigeria and Angola), with the next largest (South Sudan and Uganda) accounting collectively for only 9% of the total. In the case of Nigeria, proven oil reserves have stagnated at 37 billion barrels since 2008, and will decline unless more exploration takes place. A serious challenge for many African countries is how best to turn resources into reserves and, ultimately, production.

Africa is estimated to have 52 tcm of remaining recoverable conventional natural gas resources, of which 31 tcm are in sub-Saharan Africa (Table 1.2). Proven gas reserves in sub-Saharan Africa have increased by 80% since 2000 and now stand at 9 tcm (5% of the global total), of which around 70% is in deepwater and 18% on land. One-sixth of proven sub-Saharan natural gas reserves are associated with oil. Until recently much of this gas was flared; an estimated total of 1 tcm of gas has been flared to date. Over the past five years, flared volumes have dropped from around 35 bcm per year to 28 bcm. Most of this reduction (6 bcm) is in Nigeria which now flares around 17 bcm per year, slightly more than the country's annual consumption. While gas flaring in other West African producing countries has remained around 12 bcm per year, it has done so while total gas supply (including flared and reinjected) from the same countries has increased significantly, reaching 34 bcm in 2012 (Cedigaz, 2013), meaning that the share of total production that is flared has declined. In lieu of flaring, increased volumes of available gas have been delivered to markets (mainly as liquefied natural gas [LNG] exports from Equatorial Guinea since 2007) or re-injected to sustain oil production (mainly in Congo).

Figure 1.21 ▷ Major energy infrastructure and main hydrocarbon basins



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.

Table 1.1 ▷ Africa oil resources and reserves (billion barrels)

	Proven reserves end-2013	Ultimately recoverable resources	Cumulative production end-2013	Remaining recoverable resources	Remaining % of ultimately recoverable resources
Africa	**131**	**454**	**115**	**339**	**75%**
North Africa	**65**	**196**	**60**	**136**	**69%**
Sub-Saharan Africa	**65**	**258**	**55**	**203**	**79%**
West Africa	38	107	32	75	70%
Ghana	0.7	1.1	0.1	1.0	88%
Côte d'Ivoire	0.1	3.4	0.3	3.1	92%
Nigeria	37	94	32	63	66%
Central Africa	7	47	10	37	78%
Cameroon	0.2	3.7	1.4	2.3	62%
Chad	1.5	3.4	0.5	2.9	84%
Congo	1.6	14	2.6	12	82%
Equatorial Guinea	1.7	4.0	1.5	2.4	61%
Gabon	2.0	21	3.9	17	81%
East Africa	8	20	1.7	18	92%
Kenya	-	1.5	-	1.5	100%
South Sudan	3.5	9	1.2	8	87%
Sudan	1.5	5.4	0.5	4.9	91%
Uganda	2.5	2.5	-	2.5	100%
Southern Africa	13	84	11	73	87%
Angola	13	36	11	25	70%
Madagascar	-	16	-	16	100%
Tanzania	-	3.5	-	3.5	100%
*Unconventional**	*-*	*40*	*<0.1*	*40*	*100%*

* Unconventional volumes are not included in the regional/country totals.

Sources: USGS (2000), (2012a) and (2012b); O&GJ (2013); IEA databases and analysis.

Nigeria has enormous resources of natural gas but, as in much of the rest of sub-Saharan Africa, gas development has not been a priority until recently. Mozambique and Tanzania have been established as significant natural gas resource-holders within a very short period of time, with the challenge now of proving up the resources by progressing production and export projects through the approval process. Substantial shale gas resources have also been identified in South Africa: three formations in the Karoo Basin have recoverable gas volumes estimated at 11 tcm. Some early exploratory drilling has taken place, but progress was delayed by a moratorium on exploration that was lifted in 2012.

Table 1.2 ▷ Africa natural gas resources and reserves (trillion cubic metres)

	Proven reserves end-2013	Ultimately recoverable resources	Cumulative production end-2013*	Remaining recoverable resources	Remaining % of ultimately recoverable resources
Africa	**17**	**56**	**4.1**	**52**	**93%**
North Africa	**8**	**24**	**3.3**	**21**	**86%**
Sub-Saharan Africa	**9**	**32**	**0.8**	**31**	**98%**
West Africa	5	10	0.6	10	94%
Ghana	<0.1	0.2	<0.1	0.2	100%
Côte d'Ivoire	<0.1	0.7	<0.1	0.6	96%
Nigeria	5	8	0.6	7	93%
Central Africa	0.4	2.4	0.1	2.3	97%
Cameroon	0.2	0.4	<0.1	0.4	99%
Chad	-	0.3	<0.1	0.3	100%
Congo	0.1	0.6	<0.1	0.6	99%
Equatorial Guinea	0.1	0.3	<0.1	0.2	82%
Gabon	<0.1	0.8	<0.1	0.8	99%
East Africa	0.2	2.8	<0.1	2.8	100%
Ethiopia	<0.1	<0.1	-	<0.1	100%
Kenya	-	0.6	-	0.6	100%
South Sudan	0.1	1.0	<0.1	1.0	100%
Sudan	<0.1	<0.1	<0.1	<0.1	100%
Uganda	<0.1	<0.1	-	<0.1	100%
Southern Africa	3.2	17	0.1	17	99%
Angola	0.3	1.5	<0.1	1.5	98%
Madagascar	<0.1	4.7	-	4.7	100%
Mozambique	2.8	5	<0.1	5	99%
South Africa	<0.1	1.1	<0.1	1.0	96%
Tanzania	<0.1	1.4	<0.1	1.4	100%
*Unconventional***	*0.1*	*49*	*<0.1*	*49*	*100%*

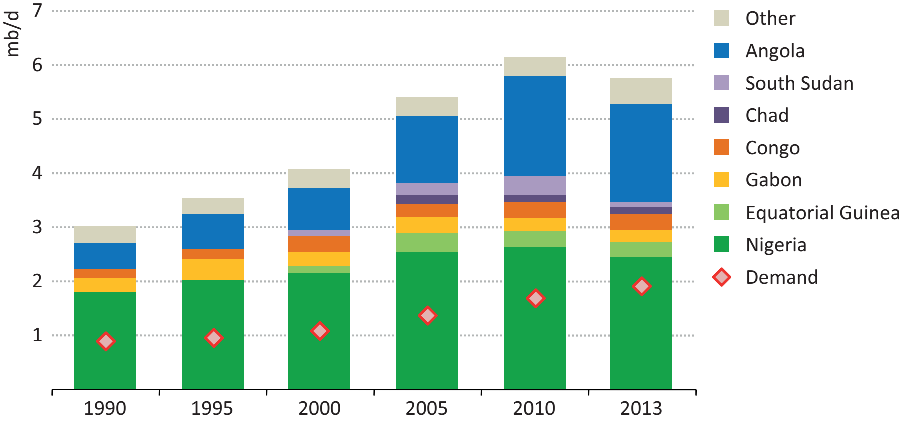
* Figures exclude cumulative gas production that has been flared. Flared volumes include Côte d'Ivoire (1 bcm), Nigeria (745 bcm), Cameroon (42 bcm), Congo (46 bcm), Equatorial Guinea (19 bcm), Gabon (61 bcm) and Angola (131 bcm). ** Unconventional volumes, which are concentrated in South Africa and Nigeria in sub-Saharan Africa, are not included in the regional/country totals.

Sources: USGS (2000), (2012a) and (2012b); Cedigaz (2013); O&GJ (2013); IEA databases and analysis.

Oil production

Oil production in sub-Saharan Africa has doubled since 1990, reaching 6.2 mb/d in 2011, before dropping back to 5.7 mb/d in 2013 (Figure 1.22). Over the years, an increasing share of production has come from offshore fields, with more than 40% of the total now coming from deep or ultra-deep water. Nigeria and Angola alone account for three-quarters of total sub-Saharan oil production, but the evolution of production in the two countries has been very different in recent decades. Nigeria has consistently been the largest oil producer in sub-Saharan Africa and has seen production levels increase gradually and sporadically, to 2.5 mb/d in 2013. Angolan oil production has quadrupled since 1990, reaching 1.8 mb/d in 2013, and accounting for 30% of total sub-Saharan production. Angolan production growth has come exclusively from offshore developments, such as Dalia, Girassol and Greater Plutonio.

Figure 1.22 ▷ Sub-Saharan Africa oil production by country and total demand

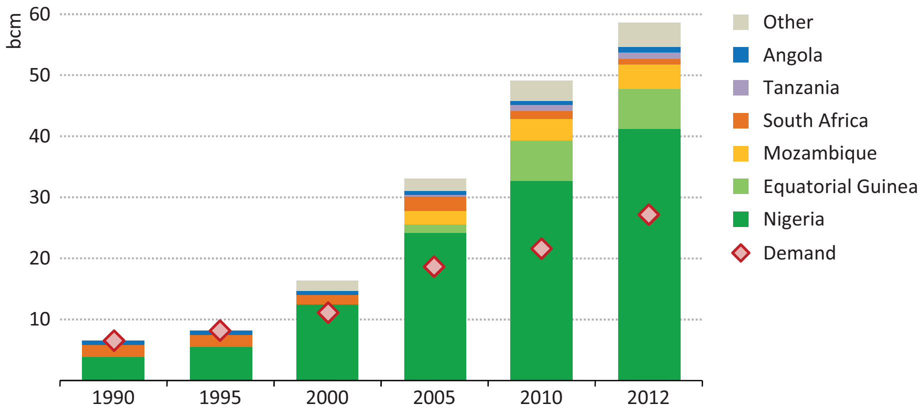


New deepwater discoveries came on-stream in Gabon and Congo to boost production levels to around 240 kb/d and 280 kb/d respectively in 2013. Chad started oil production in 2003, when the Chad-Cameroon pipeline (CCP) was finished, allowing exports to the Atlantic coast. Output peaked at around 170 kb/d in 2004, but stood at 130 kb/d in 2013. In Cameroon, production peaked at 180 kb/d in 1985 and has declined gradually to reach 70 kb/d in 2013. Equatorial Guinea saw oil production take-off in the late 1990s, when the Zafiro complex of fields to the northwest of Bioko Island came on-stream, reaching a plateau of around 350 kb/d for the five-year period from 2004; production in 2013 had dipped to 270 kb/d. Production from Ghana comes almost entirely from the Jubilee field, which came on-stream in late-2010 and produces around 100 kb/d. For the moment, associated gas is being re-injected, limiting oil production to below the 120 kb/d expected from the field, pending completion of the Jubilee gas project (expected later this year). South Africa contributes 100 kb/d to total hydrocarbon liquids production by converting coal-to-liquids, at Sasol's Secunda plant, and gas-to-liquids. Despite fairly modest levels of oil production in most sub-Saharan countries, even lower levels of domestic demand and refining capacity mean that 13 countries in sub-Saharan Africa were exporters of crude oil in 2013 (albeit importers of oil products) (see energy trade section). Apart from Cameroon, Niger and Sudan, all of these countries exported more than 85% of their oil production (namely Angola, Chad, Congo, DR Congo, Equatorial Guinea, Gabon, Ghana, Mauritania, Nigeria, and South Sudan).

Natural gas production

Sub-Saharan gas production increased from around 7 bcm in 1990 to 58 bcm in 2012, making it a small but growing contributor to global gas supply (Figure 1.23). Growth has come largely from associated gas linked to the West African offshore oil boom. Historically, much of the produced gas has been flared, but more stringent regulations have excluded this option for most new developments in the last decade. Production made available to the market is five-times greater than it was in 2000, mainly from Nigeria, which now has six LNG trains, but also from Equatorial Guinea and Angola, which joined the ranks of global LNG exporters in 2007 and 2013 respectively.[16] The only other gas exporting country in sub-Saharan Africa is Mozambique, which exports around 3.5 bcm per year by pipeline to South Africa. The main countries currently making use of their gas resources domestically are Cameroon, Congo, Côte d'Ivoire, Nigeria, South Africa (mainly at the Mossel Bay gas-to-liquids [GTL] plant) and Tanzania. Huge scope remains across many countries to increase natural gas supply, exports and domestic consumption. Putting gas gathering and processing facilities in place, building gas networks and developing effective markets and pricing are major tasks for governments in the region, as local availability of gas for power generation or industrial use is very low in most countries.

Figure 1.23 ▷ Sub-Saharan Africa natural gas production by country and total demand



Renewables

Renewable energy technologies (mainly hydropower) make up a large share of total power supply in Africa and there is potential for this to expand as a wider range of technologies is deployed. Many countries are actively developing or considering developing their renewable energy resource potential. Renewables potentially improve energy security by

16. The Angola LNG installation that started operation in 2013 is currently shut down for remedial work and is expected to resume operations in 2015.

reducing the reliance on imported fuels and help diversify the power mix. They can be deployed in a decentralised manner, which may enable them to be deployed faster than centralised power plants (although small-scale projects can be costly in terms of scarce administrative skills), and can provide local employment for deployment and maintenance. Renewables are also critical technologies to help provide access to remote communities.

Bioenergy

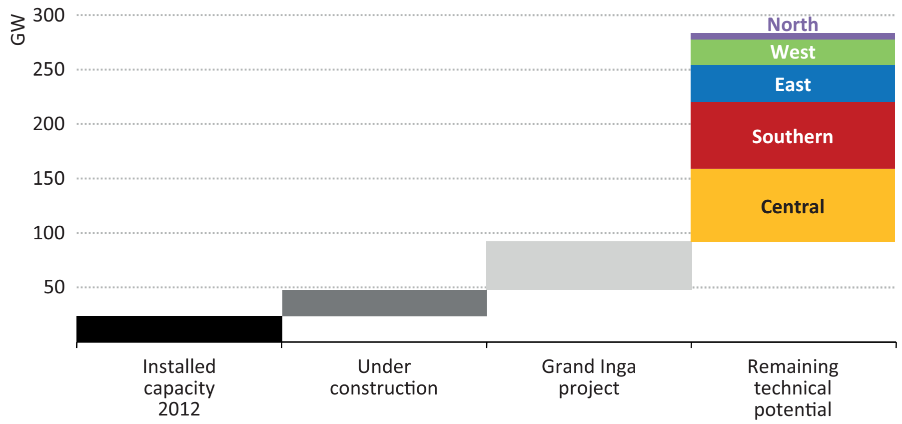
Bioenergy dominates the sub-Saharan energy mix, mainly accounted for by the traditional use of solid biomass in the residential sector, while the modern use of solid biomass and biogas for power generation and heat make up only a very small share. Around one-third of sub-Saharan Africa is covered by forest, with total forest biomass stock estimated to be 130 billion tonnes in 2010, but the amount available annually without causing deforestation is much smaller (see Chapter 2). In addition to forest products and residues, agricultural residues represent a significant portion of the available biomass resources, though some residues must be left in-field to maintain the agricultural productivity of the land. Biomass is spread throughout much of the African continent, with forested areas most prevalent in Central Africa and parts of Southern Africa, while agricultural activities occur largely in East and West Africa. Tapping into these available resources could provide fuel for a significant share of electricity supply in some countries. For example, sustainably extracted agricultural and forestry residues could supply close to 40% of Cameroon's electricity consumption (Ackom, et al. 2013). There is existing installed capacity of around 325 MW of electricity from bioenergy, mainly spread across 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 feedstocks.

Hydropower

Hydropower has long been an important part of many African power systems and is the most used renewable energy source (excluding bioenergy). Hydropower is attractive because of the large-scale of potential development and the low average costs of electricity generated, lower than any other technology, renewable or otherwise. The technical hydropower potential in Africa is estimated at 283 GW (Figure 1.24), and is able to generate close to 1 200 TWh per year – 8% of the global technical potential. This amount of electricity is more than three-times the currect electricity consumption in sub-Saharan Africa. Less than 10% of the technical potential has so far been tapped. More than half of the remaining potential is in Central and East Africa, particularly in Cameroon, Congo, DR Congo, Ethiopia and Mozambique, but there are also significant opportunities in Southern Africa (Angola, Madagascar, Mozambique and South Africa) and West Africa (Guinea, Nigeria and Senegal). The large hydropower potential in DR Congo has long been a focus of policy makers, both in terms of the Inga III project (4.8 GW) that is planned and the several phases of the long-discussed Grand Inga project (around 44 GW) which, if constructed, could transform the African power supply picture.

Several barriers exist to exploiting the economic hydropower potential in sub-Saharan Africa. Large hydropower projects require large sums of upfront capital and, often, for power purchase agreements to be in place to raise the necessary financing. Low levels of regional interconnection mean that there are limited opportunities to export large volumes of electricity, while domestic markets can be small. While hydropower is a low-cost source of baseload power generation, it can also be subject to seasonal and annual variations. Environmental concerns, social considerations and competition for water resources also require very careful consideration and public consultation, as hydropower dams may require flooding large land areas, potentially displacing communities and reducing the flow of water available for other uses downstream, such as agriculture. In addition, a lack of required technical expertise is a brake on hydropower development in some countries.

Figure 1.24 ▷ Existing hydropower capacity and potential in Africa



Sources: IPCC (2011); IJHD (2009) and (2010); IEA analysis.

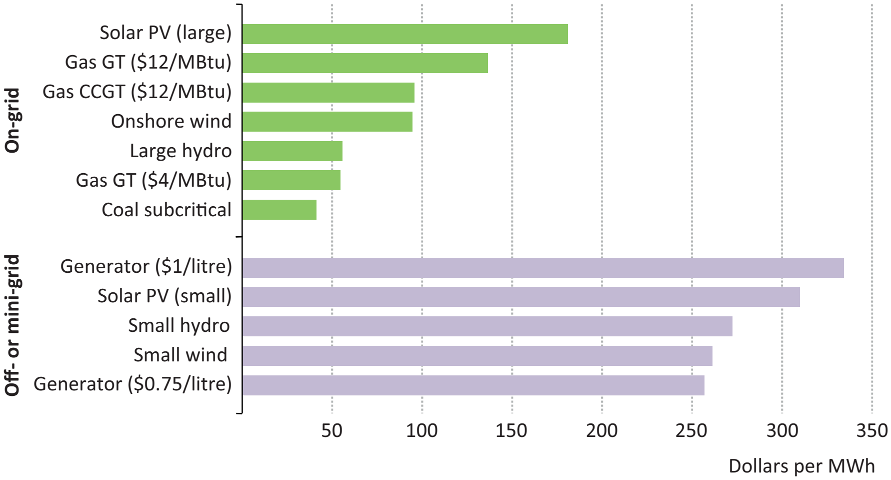
Currently, 20 GW of hydropower capacity is installed in sub-Saharan Africa, with several countries, including Mozambique, DR Congo, Uganda and Kenya, relying on it for a significant share of power generation. Many large projects are planned e.g. further developments at the Inga site in DR Congo and Mphanda Nkuwa in Mozambique. Many smaller projects are also being developed, as perennial rivers cover much of sub-Saharan Africa. Small hydropower may be an economic means of electricity access for communities near these waterways.

Solar power

Solar technologies have played a limited role in the power sector in Africa, but are gaining attention in many countries. Africa is particularly rich in solar energy potential, with most of the continent enjoying an average of more than 320 days per year of bright sunlight and experiencing irradiance levels of almost 2 000 kWh per square metre (kWh/m^2) annually (twice the average level in Germany) (European Commission JRC, 2011). The best solar resources stretch across the Sahara, North Africa and parts of Southern Africa, with irradiation levels close to 2 500 kWh/m^2. Central and West Africa generally have lower irradiance levels, particularly near the Gulf of Guinea. Potential solar power generation far exceeds electricity demand today and into the foreseeable future, though vast areas of land or rooftops would be required. For example, to generate the same amount of power as current electricity consumption in sub-Saharan Africa (352 TWh) would require more than 200 GW of solar PV, spanning an area close to 7 000 km^2.

The average cost to generate electricity from solar PV in sub-Saharan Africa currently exceeds $175 per MWh, which is above the average cost of electricity generated from other grid technologies (Figure 1.25). In some cases, the existence of very high quality solar resources and technology that is readily available can result in lower costs, as recent bids in the Renewable Energy Independent Power Producer Procurement Programme in South Africa have indicated. Despite the apparent cost disadvantage, solar is gaining a foothold in sub-Saharan Africa where installed capacity increased from 40 MW in 2010 (mainly small-scale PV) to around 280 MW in 2013 (including some large PV and concentrating solar power [CSP] plants). There are several grid-connected projects under construction, including the 155 MW Nzema plant in Ghana and 150 MW of projects in South Africa, for example. In addition, other countries are considering projects on the scale of 100 MW or more, including Mozambique, Sudan, Nigeria and Ethiopia.

Figure 1.25 ▷ Indicative levelised costs of electricity for on-grid and off-grid technologies in sub-Saharan Africa, 2012



Notes: Costs are indicative and figures for specific projects could vary significantly, depending on their detailed design. GT = gas turbine; CCGT = combined-cycle gas turbine; MBtu = million British thermal units.

Solar PV is much more competitive in off-grid or mini-grid applications, where the main alternative at present is generation fuelled by diesel or gasoline (see Chapter 3). Where adequate resources are available, small hydro and wind projects can compete with solar

PV for off- or mini-grid uses. Solar can also be an effective element in a broader suite of modern energy solutions, such as solar lanterns, ovens and water heaters.

Wind power

Wind power deployment to date has been very limited when compared to hydropower, with only 190 MW in all of sub-Saharan Africa, even though the levelised cost of electricity from onshore wind technologies has declined significantly in recent years. Sub-Saharan Africa's wind potential is estimated at around 1 300 GW (Mandelli, et al, 2014), which would produce several times the current level of total African electricity consumption. Much the same as solar, there are medium to high quality wind resources across most of North Africa (European Commission JRC, 2011), though harsh desert conditions pose a significant challenge to the long-term operation of wind turbines. In sub-Saharan Africa, high quality wind resources are confined to a few areas, mainly the Horn of Africa, eastern Kenya, parts of West and Central Africa bordering on the Sahara and parts of Southern Africa. Somalia has the highest onshore potential of any country, followed by Sudan, Libya, Mauritania, Egypt, Madagascar and Kenya (AfDB, 2013). The offshore wind energy potential is best off the coast 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 instance, in East and West Africa, where the greatest potential lies, domestic markets are small and the power grids are not well developed, meaning that variable generation from wind would introduce additional challenges to an already unstable and intermittent system. With improvements in the operations of power systems in Africa and the increasing size of the systems, the amount of wind power that can be added without creating formidable operational challenges will increase. For those systems with hydropower, the variability of wind power can be accommodated more readily. South Africa and parts of East Africa are leading the way in increasing their wind capacity with, for example, Kenya planning to add over 400 MW of wind capacity by 2020.

Geothermal

Geothermal technologies make up a small fraction of Africa's power supply, but can be an attractive option adequate resources exist. These resources are concentrated in the East African Rift Valley, which is considered one of the most exciting prospects in the world for geothermal development, with total potential estimated at between 10 GW and 15 GW – more than East Africa's total existing power generation capacity, a large share of which is concentrated in Ethiopia and Kenya. The cost of generation is competitive with fossil fuels and geothermal power is not characterised by the variability issues associated with some renewables, so that it can serve as baseload generation. Kenya has around 250 MW of installed geothermal capacity and a further 280 MW is under development. More than 40 wells a year currently are being drilled in Kenya, and the target is to develop more than 5 000 MW by 2030 (about half of the estimated potential). Ethiopia is also actively developing its geothermal resources, led by the Corbetti Power Project that aims to add 1 GW of capacity over the next decade. A number of other countries are exploring their geothermal potential, but projects are challenging and typically have long-lead times. Zambia has a number of sites planned, while Tanzania is carrying out exploration (and has potential of around 650 MW), and Eritrea, Djibouti, Rwanda and Uganda have also carried out geothermal exploration.

Other

Coal

Africa's estimated 120 billion tonnes of coal resources are concentrated in the southern part of the continent. They amount to less than 1% of world coal resources, but this relatively low figure reflects, in part, the lack of exploration in much of the continent. South Africa dominates Africa's coal industry with over 90% of the 36 billion tonnes of proven reserves and virtually all of the continent's production. However, other southern African nations, including Mozambique, Zimbabwe, Botswana, Tanzania, Zambia, Swaziland and Malawi, are endowed with significant coal reserves. In particular, Mozambique is one of the largest undeveloped coal regions in the world (with estimated coal resources of 25 billion tonnes) and international companies have started exports and are announcing expansion plans. The profitability of exports is expected to be high (due to the abundant and shallow coal deposits) once the necessary infrastructure is fully developed. The ports of Beira and Nacala are far from the coal basins and the Zambezi River is environmentally sensitive and so unlikely to carry coal barge traffic. Plans to expand rail and port capacity are advanced and big investments have been announced, but construction will take several years. Zimbabwe holds large hard coal reserves (totalling 500 Mt), and resources of 25 billion tonnes, many of which can be mined using low cost open-cast methods. However, a lack of transportation facilities and an adverse investment climate are substantial barriers to development. Botswana also has limited production but plenty of potential, with estimated resources of 21 billion tonnes. Several projects to develop various coalfields have been proposed, but again it will not be easy to build the infrastructure required for exports to target markets in Asia.

Nuclear

Sub-Saharan Africa includes three of the ten-largest uranium resource-holders in the world (Namibia, Niger and South Africa). While exploration has increased uranium resource estimates over the last decade, prevailing prices dictate when mining commences. At prices lower than $80 per kilogramme of uranium (kgU), $130/kgU and $260/kgU respectively, Africa holds over 6%, 19% and 21% of world uranium resources (IAEA/NEA, 2011). Sub-Saharan African resources are relatively accessible, regulators are flexible and labour costs are low, resulting in it providing a significant share of global production (18%). Namibia provides 8.2% of global production, Niger 7.7%, Malawi 1.2% and South Africa 1.1%. South Africa is the only country with existing nuclear power generation capacity, and has stated its intention of expanding it. Some other countries have stated their interest in introducing nuclear power into their domestic mix (e.g. Kenya and Namibia). However, the introduction of nuclear power brings many challenges, not least of which is the very large upfront capital investment required, the need to develop technical and regulatory capacity, and to have the electricity demand and infrastructure capacity to absorb the resulting baseload supply.

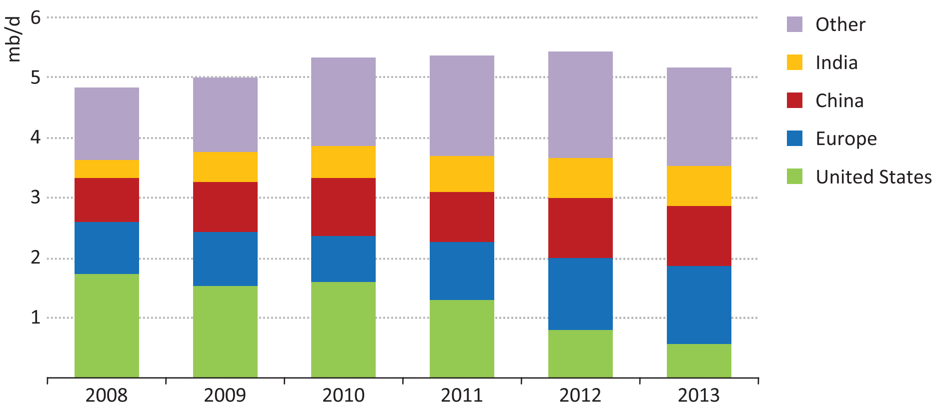
Energy trade

Crude oil and oil products

As a region, sub-Saharan Africa is a significant exporter of crude oil, behind only the Middle East and Russia in global terms. Countries on the west coast account for the bulk of exports (more than 5 mb/d), with around 2.3 mb/d from Nigeria and 1.8 mb/d from Angola. Congo, Equatorial Guinea and Gabon export between 200-270 kb/d each. East African exports are limited, and are currently constrained by political uncertainty in South Sudan. Other small producers (some land-locked) make up the remaining sub-Saharan exports.

The destination of crude oil exports from the west coast of Africa (rather than just West Africa) has undergone a rapid shift as a result of the tight oil boom in the United States (Figure 1.26). Since 2008, when the first significant volumes of tight oil came on-stream, exports to the United States have reduced by two-thirds, to less than 600 kb/d in 2013, as the United States cut the import of light crude oil, mostly at the expense of Nigeria and Angola. At the same time, Europe has increased purchases from sub-Saharan Africa to replace its own decreasing oil production and to compensate for Libyan output disruption. As a result, Nigerian exports to the United States now account for only 10% of the total, compared with around 26% in 2008, with increased flows to Europe and India now accounting for around one-third and one-quarter of Nigerian exports respectively. Chinese refinery expansions have provided additional markets, proving particularly important for Angola, whose exports to China account for almost half of the country's total crude output.

Figure 1.26 ▷ Crude oil exports from Africa's west coast by destination



Note: Includes crude oil exports from Angola, Cameroon, Chad, Congo, Côte d'Ivoire, DR Congo, Equatorial Guinea, Gabon, Ghana, Niger and Nigeria.

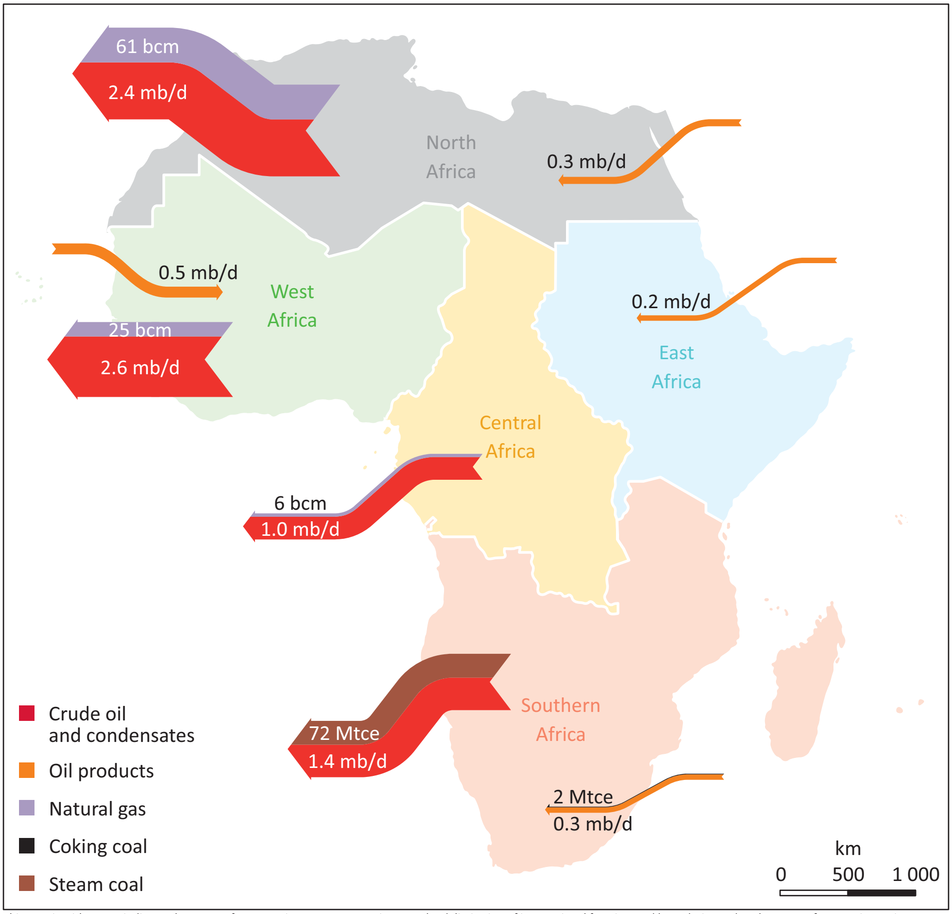
Sub-Saharan Africa's refining operations are severely constrained by the state its refining assets. These are mostly decades old and in relatively poor condition due to years of under-investment and neglect, making their operation less economic. As a result, despite increasing crude oil output by 2 mb/d from 2000, sub-Saharan Africa's oil product imports doubled (to around 1 mb/d in 2012), with diesel and gasoline each accounting for one-third of the volume. European and, more recently, US refiners have been successful in selling excess or lower-specification gasoline, kerosene and diesel in sub-Saharan Africa, where fuel quality standards tend to be lower. South Africa and countries in East Africa import oil products from the Middle East or India. South Africa has an adequate refining system that runs at around 90% utilisation rates and supplies more than two-thirds of the domestic market (which was just under 0.5 mb/d in 2012). Nigeria has the second-largest refining capacity, at 0.45 mb/d, which if run optimally could meet total demand. However, run rates can be as low as 20%, meaning that over 80% of the oil products consumed in the country are imported. Ghana also imports most of its oil products despite producing sufficient levels of crude oil, as its refinery operates at extremely low rates. Côte d'Ivoire, Cameroon, Niger and Chad cover most of their demand from local refinery supplies, with the latter two having had new (but small) refineries built by Chinese upstream investors. In East Africa, only Sudan and Zambia have active refineries. Rapidly growing oil product imports into sub-Saharan Africa need not be a critical concern, within a well-supplied and functioning global market. However, the energy security risk needs to be watched, particularly when considered together with the growing strain on the energy import and distribution infrastructure, which has struggled to expand.

Two key factors play an important role in sub-Saharan oil product trade flows – geography and subsidies. Land-locked countries are, for the most part, reliant on importing supplies from the nearest port (which can be a thousand kilometres or more away) and the lack of pipeline and rail infrastructure means that much of these supplies are transported by road. This can leave these countries vulnerable to supply disruptions and to very high import prices. Relative pricing can also play an important role in shaping cross-border trade in oil products, particularly in Nigeria, where low domestic prices spur unofficial exports to Togo, Ghana, Burkina Faso and Benin. As well as having a significant impact on Nigerian state revenues through a subsidy cost whose (limited) benefits are not captured locally, smuggled products also deny the government of Benin an important source of tax revenue.

Natural gas

Sub-Saharan Africa exports around half of the natural gas that it produces, but only from a small number of countries (Figure 1.27). In 2012, Nigeria, Equatorial Guinea and Mozambique exported gas, predominantly through LNG shipments, with 26 bcm being exported from Nigeria and 5 bcm from Equatorial Guinea. Mozambique (over 3 bcm to South Africa) and Nigeria (0.6 bcm) are key exporters to other countries on the continent. In the case of Nigeria, gas is exported through the West African Gas Pipeline, which links Nigeria to Benin, Togo and Ghana (see Chapter 4, Box 4.3 on the West African Gas Pipeline). At the end of 2013, Angola started exporting LNG from its first train at Soyo (capacity of 5.2 million tonnes per year [around 7 bcm]), sending cargoes to China, Japan and South Korea, but these exports have since been disrupted by operational problems.

Figure 1.27 ▷ Africa's major international energy trade flows by sub-region, 2012



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.

Note: Mtce = million tonnes of coal equivalent. Sources: CITAC; IEA databases and analysis.

Electricity

There are clear ambitions to increase electricity trade across sub-Saharan Africa. While at varying stages of development, regional power pools have been established with the aim of achieving greater efficiency through co-operative planning and improved transmission interconnections. At present electricity trade in sub-Saharan Africa is relatively limited, and is concentrated in the Southern Africa Power Pool, where over 5.3 TWh of electricity were traded in 2012-13 (SAPP, 2013). The bulk of this trade involved supply from South Africa to Botswana (meeting almost all of Botswana's demand) and Namibia (nearly half of its demand). South Africa also imported electricity from Mozambique's Cahorra Bassa project (around 10 TWh in 2012), but much of this was then exported back to Mozambique's southern region to supply Maputo (and particularly the Mozal smelter). Despite being the most developed regional power pool, Southern Africa's electricity trade is heavily constrained by the limitations of the transmission network.

Elsewhere in sub-Saharan Africa, Ghana and Côte d'Ivoire have successfully traded electricity in both directions for many years, with current supplies going from Côte d'Ivoire to Ghana, and some of this then transiting to meet demand in Togo and Benin. Burkina Faso and Niger also import electricity from neighbouring countries. In East Africa, Kenya imports some electricity from Uganda, while Djibouti imports from Ethiopia. Ethiopia has plans to increase electricity exports to other parts of East Africa, based on new hydropower generation, and construction is underway to boost interconnections with Kenya. As well, there are hydropower projects that share output between countries, including the Manantali dam in Mali and the Ruzizi dam on the border between Rwanda and DR Congo.

Coal

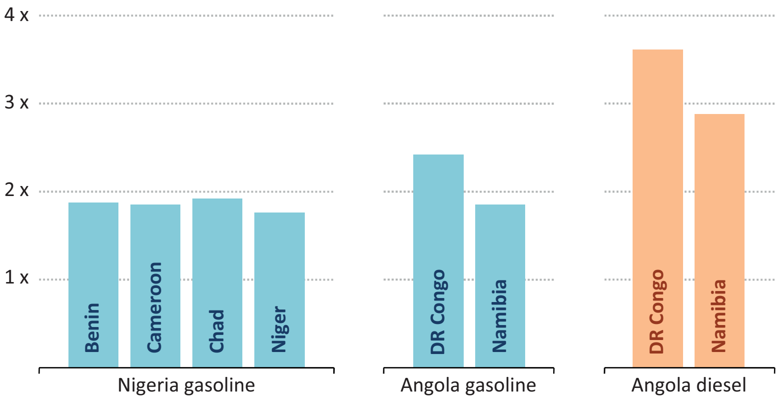
Sub-Saharan Africa exported around 71 million tonnes of coal equivalent (Mtce) in 2012, bouncing back from the lower exports seen in 2008-2009 to reach new highs. South Africa is the epicentre of African coal trade (accounting for all but a fraction of the sub-Saharan total). It has been a coal exporter since the late-1970s and has one of the world's largest coal export terminals at Richards Bay. It exports around one-third of its total production and has seen the balance of trade shift more towards Asian markets in recent years. Remaining sub-Saharan exports are made up of coking coal from Mozambique, which, in light of high prices (although these have subsided somewhat) and rapidly growing demand from Asia, has attracted international coal companies to invest in the Tete province. Despite difficult geology, mining costs are on the low side for coking coal in Mozambique and, while the lack of export infrastructure (railway lines and ports) has impeded a rapid increase of exports to date, the intention is to increase exports over time.

Energy affordability

Energy prices

End-user energy prices vary significantly across sub-Saharan Africa (Figure 1.28), with much of the variability reflecting the relative ease of energy supply and the extent to which energy prices are subject to government controls. Consumer oil product prices are regulated in most countries and therefore not responsive to changes in international markets. In most non oil-producing countries, prices are regulated but not subsidised when assessed against a benchmark price, while in several oil-producing countries prices are set lower than such a benchmark. Where subsidies exist, they are often designed to support energy access for the poor, but they are frequently not well targeted to that end. In 2013, the subsidisation rate (relative to the benchmark price) for gasoline in Nigeria was estimated to be around 29% and 32% in Angola. Angola also has a 58% subsidy rate on diesel. Other oil exporters, including Congo, Equatorial Guinea, Gabon and Sudan, also subsidise gasoline, diesel or both. Such subsidies serve to incentivise fuel smuggling into nearby markets with higher prices.

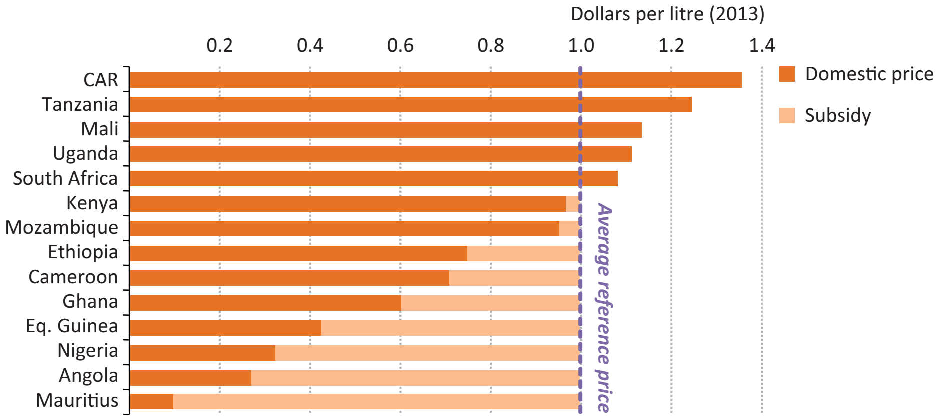
Figure 1.28 ▷ **Oil product price differentials between Nigeria, Angola and neighbouring countries, 2013**



Note: CAR = Central African Republic. Sources: CITAC; IEA analysis.

Kerosene subsidies are relatively common across sub-Saharan Africa, reflecting deliberate policies to promote its use by households. Prices for kerosene intended for domestic use vary from $0.10 per litre in Mauritius and $0.27 per litre in Angola, to $1.36 per litre in the Central African Republic (Figure 1.29). Based on available pricing and demand data, the weighted average subsidisation rate for kerosene is estimated to be around 45% in 2013. LPG prices are also subsidised to encourage fuel switching. Based on analysis of countries accounting for more than three-quarters of consumption, the average subsidisation rate for LPG is estimated to be around 40%. However, not all LPG sales within a country may be subsidised, so this estimate is likely to be high. Total sub-Saharan oil product subsidies are estimated to be $10.2 billion in 2013, with Nigeria and Angola accounting for nearly 75% of this sum.

Figure 1.29 ▷ **Kerosene price and subsidy in selected countries, 2013**

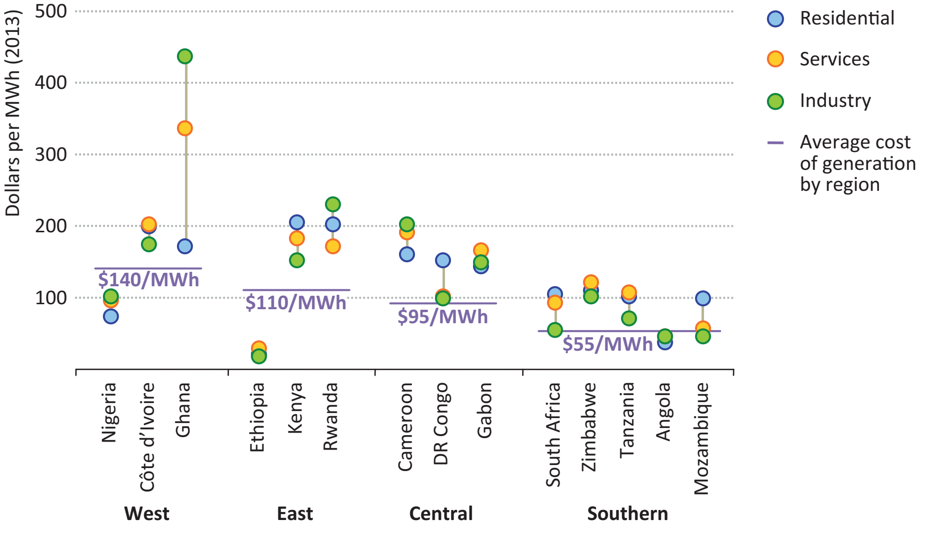


Note: CAR = Central African Republic.

Sources: CITAC; IEA analysis.

End-user electricity tariffs in many parts of sub-Saharan Africa do not fully reflect the cost of electricity supply. While tariffs may be higher than the average cost of generation (Figure 1.30), additional costs such as those relating to T&D losses, T&D investment and retail can add $60-$100 per MWh to the total cost of electricity supply. Poor quality of supply, low household income and high T&D losses are all obstacles to full cost recovery. Such prices serve as a deterrent to greater levels of investment in the power sector. Even so, sub-Saharan electricity tariffs, though varying by country and by type of customer, are in many instances among the highest anywhere in the world. On average, sub-Saharan electricity tariffs are between $130-140/MWh, with those for services and industries being 5% and 8% higher (on average) than those charged to households. In comparison, electricity tariffs in Latin America, Eastern Europe and East Asia are around $80/MWh (Briceño-Garmendia and Shkaratan, 2011). The inability to set electricity tariffs at levels that reflect both costs and a reasonable return on capital is a major obstacle to the long-term sustainability of many utilities in sub-Saharan Africa. According to the International Monetary Fund, state-owned electricity companies across the region were, in 2010, operating with deficits equivalent to 1.4% of sub-Saharan GDP (IMF, 2013).

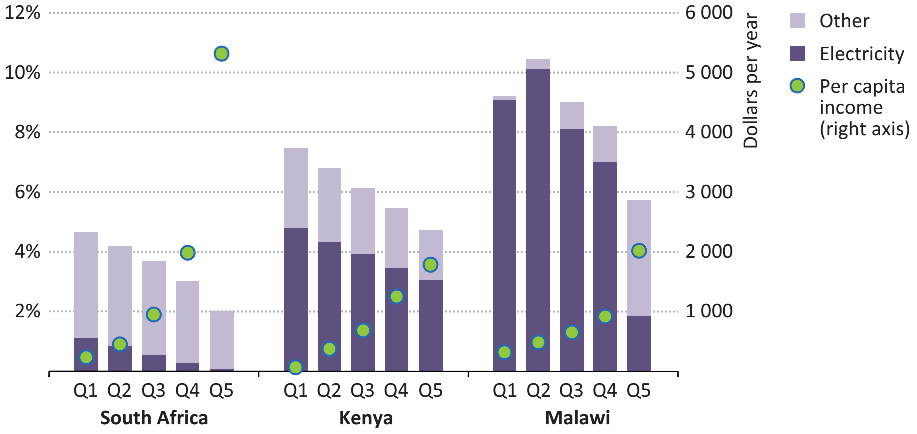
Figure 1.30 ▷ Grid electricity prices by end-use sector in selected countries, 2013



Energy expenditure

In a region where average incomes are low, the importance of the relationship between incomes, energy prices and energy expenditure is starkly evident. Across sub-Saharan Africa, the wealthiest 20% of households account for about half of total residential spending on energy, on average, while the poorest 20% account for around 5%. Around 40% of total energy expenditure is on electricity and 25% is on kerosene, but this picture is distorted by the consumption of unpriced solid biomass.[17] In general, as one would expect, the heavy burden of energy expenditures tends to get lighter as household incomes increase (Figure 1.31). For instance, energy expenditures in South Africa account for around 3.5% of total income, while in Malawi, where income levels are typically much lower, the share is more than double. Large disparities in electricity consumption are also evident: in countries with intermediate levels of income, the wealthiest 20% of households tend to account for around 40% of consumption while, in the extreme case of Malawi, the richest 20% consume more than 80% of the total. Urban and rural households are also very different, with urban households typically having higher incomes and greater access to electricity services. In Rwanda, for example, more than 40% of urban households report electricity spending, while in rural areas the figure is 4% (National Institute of Statistics of Rwanda, 2012).

Figure 1.31 ▻ Household energy spending as share of income



Note: Q1 is the lowest income quintile (20%) in a country, while Q5 is the highest.

Sources: Statistics South Africa (2012); IFC (2012); Barnes, Singh and Shi (2010); IEA analysis.

17. Based on World Bank (2012).

Outlook for African energy to 2040

Energy to grow or a growing need for energy?

Highlights

- The sub-Saharan energy system expands rapidly to 2040, but so do the demands placed upon it. The economy quadruples in size, the population nearly doubles (to 1.75 billion) and energy demand grows by around 80% in the New Policies Scenario. The capacity and efficiency of the system improves, and access to modern energy services grows; but many of the existing energy challenges are only partly overcome.

- Bioenergy demand grows by 40% in absolute terms by 2040, exacerbating stress on the forestry stock. However, the share of bioenergy in the energy mix declines from above 60% to below half and the share of modern fuels edges higher. Oil demand more than doubles to 4 mb/d in 2040 (over 0.5 mb/d is residential use of LPG and kerosene) and becomes the second-largest fuel in the mix, overtaking coal. Natural gas use grows by nearly 6% per year, to reach 135 bcm.

- The sub-Saharan power system expands rapidly, with generation capacity quadrupling to 385 GW. The power mix becomes more diverse, with coal (mainly South Africa) and hydropower (all regions), being joined by greater use of gas (Nigeria, Mozambique, Tanzania), solar (notably in South Africa and Nigeria) and geothermal (East Africa). The share of renewables in total capacity more than doubles to 44%. Total power sector investment averages around $46 billion per year, with just over half of it in transmission and distribution.

- Oil production rises above 6 mb/d by 2020 but then tails off to 5.3 mb/d in 2040. Nigeria and Angola remain the dominant producers, although Uganda and Kenya ramp up oil output in the 2020s. Gas production rises to 230 bcm in 2040, led by Nigeria and the expansion of output from Mozambique (60 bcm in 2040), and Angola and Tanzania (each 20 bcm). Coal supply grows by 50% to reach 325 Mtce, still concentrated in South Africa but joined increasingly by Mozambique and others.

- Sub-Saharan energy exports are drawn increasingly towards Asian markets. Crude oil net exports decline to just over 3.8 mb/d in 2040, partly due to a greater share being refined and consumed domestically. Rising gas output from Mozambique and Tanzania brings sub-Saharan LNG export towards 100 bcm by 2040 (around 17% of inter-regional LNG trade), and Mozambique also joins South Africa as a key coal exporter.

- Sub-Saharan Africa makes only a small contribution to global energy-related CO_2 emissions, accounting for merely 3% of the total in 2040, but is on the front line when it comes to the potential impacts of a changing climate. In particular, hydropower prospects can be affected by changing patterns of rainfall and run-off. The fuelwood and charcoal sectors operate largely outside the formal economy, meaning that policymakers have few levers to promote more sustainable forestry.

Projecting future developments

The successful development of the energy sector will be a crucial factor in determining the pace of economic and social development in Africa. As noted in Chapter 1, understanding the directions in which Africa's energy sector is set to develop is therefore essential for policymakers and investors: if the picture which emerges is unacceptable, action can be taken to change it. This chapter accordingly presents energy projections and analysis for the period to 2040 based upon the **New Policies Scenario**, the central scenario of the *World Energy Outlook 2014 (WEO-2014)*. This scenario describes the probable pathway for energy markets based on the continuation of existing policies and measures, and the implementation, albeit often cautiously, of the commitments and plans announced as of mid-2014, even if they are yet to be formally adopted. It allows for the existence of a range of institutional, political and economic circumstances that affect the pace and extent of implementation and, in some cases, a lack of detail about new initiatives and how they will be executed. The projections also take into account prospective technology developments in the energy sector and how they might affect supply costs, energy efficiency and fuel choice, without assuming any fundamental technological breakthroughs. Long-term projections are always subject to a range of uncertainties, including extreme events such as war and famine, but projections are not forecasts – they describe trends – and such events are not taken into account. Instead, a level of stability is assumed to prevail that allows for the expectations of economic and population growth which underlie the analysis (both of which are consistent with those of other international organisations) to be realised. Chapter 4 goes beyond the projections of the New Policies Scenario to illustrate, in an **African Century Case**, the energy and economic implications of a more ambitious, yet attainable future.[1]

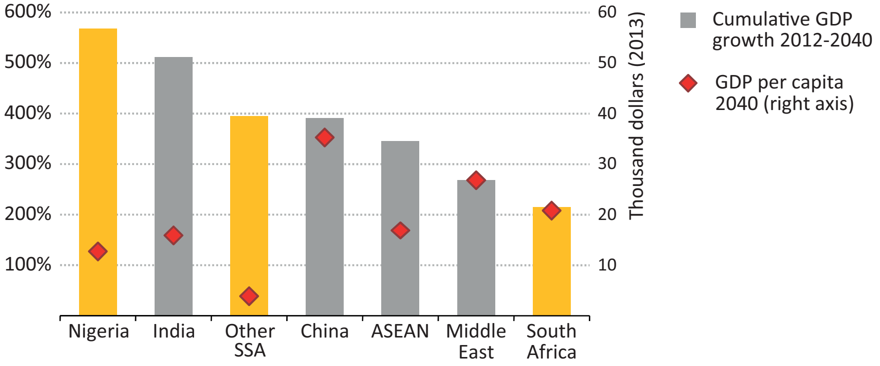
Economic and population growth

The sub-Saharan economy grows by nearly $8 trillion in the New Policies Scenario (expressed in year-2013 dollars in purchasing power parity [PPP] terms) to reach four-times its current size by 2040 (Figure 2.1). The rate of growth (which averaged 5.7% from 2000 to 2012) slows gradually over time – from 5.5% per year to 2020 to 4.9% per year after 2030 – as a number of economies, having grown fast, start to mature. This economic growth path for sub-Saharan Africa as a whole is higher than those in the *World Energy Outlook 2013* by 1% per year on average, a revision consistent with the medium-term economic outlooks of other international organisations, including the International Monetary Fund and African Development Bank. Over the longer term, it reflects an improved methodology that includes region-by-region analysis of labour, capital, and overall productivity across sub-Saharan Africa. In the period to 2040, sub-Saharan Africa is among the world's most rapidly growing regions and sees its share of global gross domestic product (GDP) rise from 3% to nearly 5%. However, in many cases this rapid growth is from a very low starting level and is nowhere near enough to achieve a significant convergence between sub-Saharan Africa and other major economies on a per-capita basis. In 2040, sub-Saharan GDP per

1. See Annex A for data and projections tables for the New Policies Scenario and the African Century Case.

capita remains less than one-quarter of the average level of the rest of the world, as strong economic growth is matched by strong population growth.

Figure 2.1 ▻ Growth in GDP and GDP per capita by region in the New Policies Scenario (year-2013 dollars, PPP terms)



Notes: Other SSA = other sub-Saharan Africa; ASEAN = Association of Southeast Asian Nations.

West Africa experiences the most rapid economic growth of the sub-Saharan regions, at more than 6% per year on average (Table 2.1).[2] Nigeria grows faster than the region as a whole, based on its expanding services and industrial sectors, and accounts for 42% of the entire sub-Saharan economy by 2040 (up from 30% today). Nigeria's economy is more than three-times the size of the South African economy by 2040 and yet it is still only around 60% of the South African level in per-capita terms. East and Central Africa are smaller economies and grow at slightly slower rates (5.4% and 4.5% respectively), while Southern Africa's average growth rate is moderated by the more mature economy of South Africa. The composition of many of the sub-Saharan economies changes, with the very high share of agriculture gradually being eroded by rapid growth in industrial and services activity. For example, in East Africa, where agriculture is currently a large component of the economy, its share of total GDP falls from around one-third in 2012 to one-quarter in 2040 (still high relative to most other world regions).

Population dynamics are an important driver of energy trends and the assumptions adopted in this study follow the "medium variant" of the latest United Nations projections (UNPD, 2013). The population of sub-Saharan Africa continues to grow very rapidly, expanding by more than 850 million, to exceed 1.75 billion people by 2040, equivalent to one-fifth of the global population (Figure 2.2). The growth rate slows over time, from 2.6%

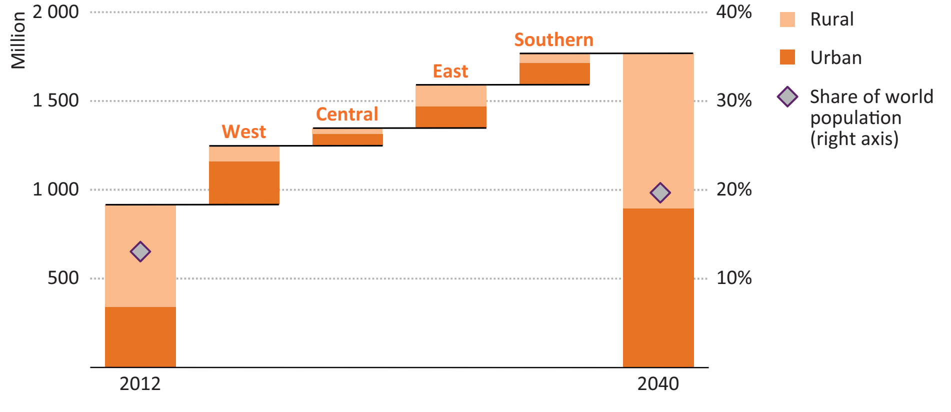
2. A study by the World Bank finds that beyond the human cost the Ebola epidemic currently afflicting parts of West Africa it is having a measurable economic impact. These impacts include the costs of health care and forgone productivity of those directly affected but, more importantly, from the aversion behaviour of others in response to the disease. The report estimates the short-term (2014) impact on GDP to be around 2.1 percentage points in Guinea; 3.4 percentage points in Liberia and 3.3 percentage points in Sierra Leone. However, the analysis finds that economic costs can be limited if swift national and international responses succeed in containing the epidemic and mitigating aversion behaviour (World Bank, 2014).

Table 2.1 ▷ GDP growth rates in Africa by sub-region in the New Policies Scenario (year-2013 dollars, PPP terms)

	GDP ($ billion)	Compound average annual growth rates			
	2012	2012-2020	2020-2030	2030-2040	2012-2040
Africa	**3 751**	**5.1%**	**4.8%**	**4.4%**	**4.7%**
North Africa	**1 175**	**4.2%**	**3.8%**	**3.1%**	**3.7%**
Sub-Saharan Africa	**2 577**	**5.5%**	**5.2%**	**4.9%**	**5.1%**
West Africa	1 052	6.6%	6.1%	5.8%	6.1%
Nigeria	785	6.7%	6.4%	6.2%	6.4%
Central Africa	194	5.0%	4.3%	4.4%	4.5%
East Africa	366	6.4%	5.4%	4.6%	5.4%
Southern Africa	965	3.9%	3.8%	3.3%	3.7%
Mozambique and Tanzania	101	7.2%	5.8%	4.1%	5.6%
South Africa	585	2.8%	2.9%	2.6%	2.8%
World	**84 938**	**3.7%**	**3.6%**	**3.0%**	**3.4%**

per year on average before 2020 to 2.2% per year after 2030, but it is consistently more than twice the average global rate of population growth. The urban population increases from 340 million in 2012, to 645 million in 2030 and 900 million by 2040 (exceeding the rural population in the late-2030s). The rural population (decreasing in most other parts of the world) also increases, albeit more slowly, from 575 million in 2012 to 780 million in 2030 and 875 million in 2040 – then making up more than one-quarter of the world total. All regions grow significantly, with the highest growth in West Africa (2.6% per year). Nigeria doubles in size, making it the world's fourth most populous country in 2040 (after India, China and the United States).

Figure 2.2 ▷ Population growth in sub-Saharan Africa by sub-region



Policy environment

While it is not practical here to present all energy policies for each country in sub-Saharan Africa, an extensive review of national and regional energy policies and plans has been undertaken for this study. As is to be expected, a patchwork of policies exists that are at varying levels of development, revision and implementation (Table 2.2). Many countries, such as Angola, Cameroon, Ethiopia, Ghana, Kenya, Rwanda and South Africa, have national energy strategies, but the time horizon often varies (typically from five to twenty years), as does the extent to which they are regularly updated or systematically implemented. Ethiopia, Ghana and South Africa have a relatively integrated set of energy policy documents. In some cases, energy or sectoral strategies are part of broader strategies designed to boost economic development or reduce poverty, such as in Rwanda. Some other countries are characterised more by strategies or plans for particular sectors, such as Mozambique (natural gas master plan), Nigeria (gas and renewables master plans) and Tanzania (power system master plan). Most countries have electricity access targets and policies in place, but fewer have objectives and approaches related to clean cooking.

Policy development and co-ordination at continental and regional level is undertaken by the African Union (AU) and the New Partnership for Africa's Development (NEPAD), which have formulated the AU/NEPAD African Action Plan, and, with the African Development Bank, the Programme for Infrastructure Development in Africa (PIDA) Priority Action Plan. Relevant efforts are also undertaken by the regional economic communities and the regional power pools and their associated master plans (discussed in Chapter 1). Much of the policy focus at this level is on trans-national infrastructure development. A number of multilateral and bilateral initiatives interplay with national plans, such as: the US Power Africa initiative; Sustainable Energy for All Initiative; Energising Development initiative (European Union); Energy+ (Norway, United Kingdom and others); EnDev programme (Germany, Norway and others). An example of policy co-operation is the Africa-EU Energy Partnership 2020 targets and its related programme to develop renewable energy markets (the Africa-EU Renewable Energy Co-operation Programme). In addition, there is a broad range of civil society-led initiatives that are often in line with national energy objectives while not necessarily linked to them explicitly.

In the New Policies Scenario, the existence of a policy or target is not assumed to be sufficient to achieve complete success. While implementation can be improved, the track record of past policy implementation is an important criterion against which the likelihood of achieving a given policy goal is judged. The level of active commitment by government and other stakeholders is considered, as is the extent to which regulatory and financing issues have been resolved, whether plans have been developed in lock-step with related policy areas and whether the necessary implementation capacity is in place. For this study, the IEA's World Energy Model has undergone several important developments in order to better reflect the situation in sub-Saharan Africa (Box 2.1).

Table 2.2 ▷ Selected energy policies and targets in sub-Saharan Africa

Country	Sector	Policies and targets
Angola	Power	Implement new power market model with a single power purchaser and equal rights for public and private power producers.
	Access	Increase electrification rate from 30% to 60% by 2025.
	Integration	Establish transmission lines with Namibia and Congo.
DR Congo	Access	Increase electrification rate from 9% to 14% by 2015 and 26% by 2020.
	Power	Announcement of stricter standards for electric motors.
Ethiopia	Renewables	Targets in place for new renewables capacity (geothermal, hydro, wind).
	Access	Disseminate 9 million improved cookstoves by 2015.
Ghana	Oil and gas	Strategy to intensify exploration, utilise revenues to reduce poverty, maximise local participation and develop a petrochemical industry.
	Efficiency	Reduce transmission losses to 18% by 2018. Standards and labels in place for lighting and air conditioners.
	Renewables	Feed-in tariff established by the Renewable Energy Act in 2011.
Kenya	Efficiency	Standards for electrical appliances; energy efficiency obligations for utilities. Energy Bill 2014 provides for the creation of an Energy Efficiency and Conservation Agency to enforce energy efficiency standards.
	Buildings	Eliminate kerosene as a household fuel by 2022. Requirement to install solar water heaters in buildings served by the grid.
Mozambique	Gas	Master plan to maximise the value of gas resources approved in 2014.
	Access	Increase electrification rate from 39% to 85% by 2035.
	Renewables	Install 100 000 solar water heaters, 50 000 lighting systems, 5 000 refrigeration systems and 2 000 televisions powered by solar PV or wind turbine systems in off-grid areas by 2025.
Nigeria	Oil and gas	Draft Petroleum Industry Bill intended to revise several areas of the existing framework.
	Power	As laid out in the Roadmap for Power Sector Reform, continue sector-wide reforms to enable private sector investment, establish a competitive electricity market and achieve stable power supply.
	Access	Make reliable electricity available to 75% of the population by 2020 and 100% by 2030 (45% today). Connect an average of 1.5 million households per year.
	Buildings	Announced the design and implementation of minimum energy performance standards for appliances and industrial equipment.
Rwanda	General	Reduce share of bioenergy in primary energy demand to 50% by 2020. Expand the transmission network by 2 100 km by 2017.
	Access	Increase electrification rate from 17% to at least 60% by 2020 and give access to all schools and hospitals by 2017.
Senegal	Renewables	Target 20% of total energy supply from renewable sources by 2017.
South Africa	Renewables	The 2013 update of the Integrated Resource Plan sets out a strategy to diversify the power mix, moving strongly towards low-carbon sources of electricity supply.
	Energy prices	Electricity prices to be adjusted gradually to better reflect costs. CO_2 tax under consideration.

Energy prices in the New Policies Scenario are determined in the World Energy Model, and vary by region, sector and fuel. These prices are linked to variations in international price movements, but also include assumptions regarding price subsidies and the extent to which these are phased out over time. It is assumed that oil product subsidies are removed in all net oil-importing countries and in those oil exporting countries that have policies in place or have a stated intention to do so. After accounting for subsidy regime changes, average oil product prices increase over the projection period, but by less than international prices (between 15% and 18% depending on the region). Fuelwood and charcoal prices adjust to reflect relative scarcity in each sub-region, but also the different "market" dynamics in rural and urban areas. For example, regions with extensive forestry, like Central Africa, see smaller price increases than Nigeria, while urban areas generally see more pronounced price increases than rural areas (where fuelwood remains untraded and has a zero price in many cases). Average end-user electricity prices also vary by region, but are generally assumed to adjust gradually over time to reflect the average cost of electricity supply, including domestic generation and the cost of electricity imports, network, retail and other costs.

Box 2.1 ▷ Modelling energy demand and supply in sub-Saharan Africa

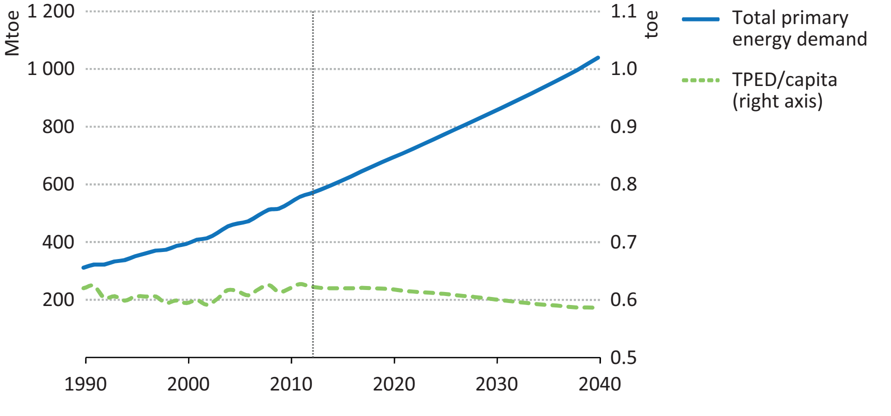
For this African energy outlook, the IEA's World Energy Model (WEM) has undergone several important developments to represent more closely the specificities of the region.[3] New country and regional level energy models have been developed, providing a much greater level of detail. Consistent with the regional definitions set out in Chapter 1, the following countries and sub-regions are modelled separately for energy demand and the power sector: Nigeria, Other West Africa (West Africa other than Nigeria), Central Africa, East Africa, Mozambique and Tanzania collectively (to examine the impact of new gas resources), South Africa and Other Southern Africa (Southern Africa other than South Africa, Mozambique and Tanzania). Modelling of access to modern energy has undergone significant development to better reflect access to electricity (grid, mini-grid and off-grid) and access to clean cooking facilities (different solutions and fuels). Power generation modelling has been modified to incorporate back-up generation explicitly. For oil and gas supply, the number of sub-Saharan countries modelled separately has increased to 35. Investment cost assumptions have been updated based upon those in the IEA's *World Energy Investment Outlook,* published in June 2014. The economic outlook is derived from an interaction between the WEM and a GDP model developed specifically for this study, which takes account of developments in the labour force, accumulation of capital stock (investment) and total factor productivity. In some cases, data limitations have resulted in the scope being narrowed, such as energy demand in some sub-sectors in some regions.

3. Details of the World Energy Model are available at *www.worldenergyoutlook.org/weomodel*.

Overview of energy demand trends

Energy demand in sub-Saharan Africa is very low – at 570 million tonnes of oil equivalent (Mtoe) – but there are several factors pointing towards potentially rapid and prolonged growth: strong economic expansion, increasing urbanisation, industrialisation and modernisation, a burgeoning middle class in many countries and a legacy of unmet energy demand. In the New Policies Scenario, the sub-Saharan economy quadruples in size, the population almost doubles and primary energy demand increases by around 80% to exceed 1 000 Mtoe in 2040 (Figure 2.3). Average energy demand growth moderates from more than 3% per year since 2000 to around 2% per year over the outlook period, reflecting changes to the mix of fuels demanded and the increased efficiency with which they are consumed. Total energy demand grows in absolute terms by less than half the growth in India and less than 40% that of China, even though the region overtakes them both in terms of population. Relative to other regions, sub-Saharan Africa remains energy poor in 2040, with one-fifth of the global population accounting for only around one-twentieth of world energy demand.

Figure 2.3 ▻ **Total primary energy demand and demand per capita in sub-Saharan Africa in the New Policies Scenario**

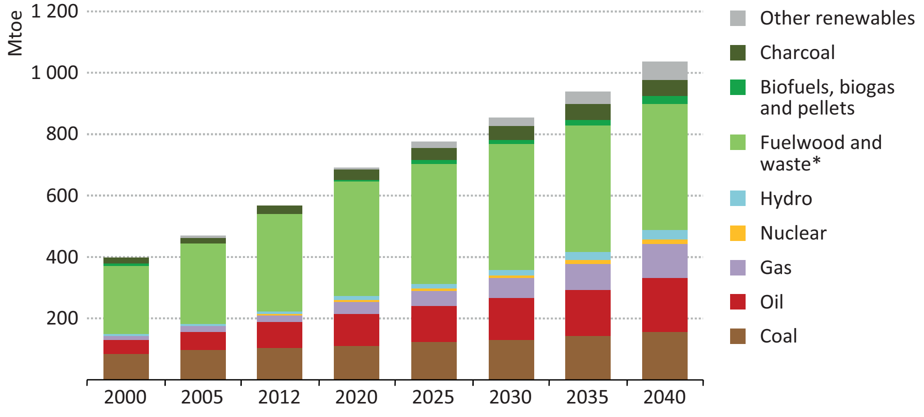


Energy use per capita in sub-Saharan Africa declines slightly over the projection period, dropping just below 0.6 tonnes of oil equivalent (toe) per capita and remaining far below the average of the rest of the world (which increases from 2.1 toe per capita in 2012 to 2.4 toe per capita in 2040). While such a trend may appear surprising for a region that grows so strongly, it masks a number of important interrelated developments. These include: rapid population growth alongside energy demand growth, the move towards much more efficient forms of cooking (a major factor in dampening energy demand growth), gradual efficiency improvements in the power, transport and other sectors, and constraints in supply that translate to a significant level of unmet energy demand in the New Policies Scenario. Considerable disparities remain within sub-Saharan Africa in 2040, with Nigerian energy demand per capita (0.7 toe per capita) being around double that of Central Africa and many other parts of West Africa in 2040, but still only a fraction of that in South Africa (3 toe per capita).

The energy intensity of the sub-Saharan economy falls by 3% per year on average and by 2040 is 55% lower than in 2012. While this drop in energy intensity is encouraging, it is also a signal of how inefficiently energy is used at present: energy intensity levels today in sub-Saharan Africa are double the world average and triple the OECD average. By 2040, sub-Saharan Africa still uses 50% more energy than the world average for each unit of economic output and 40% more than China, though less than India and the Middle East. Across sub-Saharan Africa, the largest reductions occur in Nigeria, where energy intensity falls by 4.1% per year, other West Africa (2.9%) and East Africa (2.6%).

Despite increasing incomes and a move towards other fuels, the primary energy mix of sub-Saharan Africa continues to be dominated by bioenergy, with demand growing by 40%, to reach 490 Mtoe in 2040 (Figure 2.4). However, the share of bioenergy in the primary energy mix declines over time, from 61% in 2012 to 47% in 2040, and the mix between different types of bioenergy shifts, reflecting more modern use (improved cookstoves) and a shift to more modern forms (such as biogas and pellets). Sub-Saharan Africa accounts for around one-quarter of world bioenergy demand today (in primary energy demand terms) and this share declines only a little by 2040. Oil demand experiences strong growth, more than doubling to reach 4 million barrels per day (mb/d) in 2040, with 60% of this growth coming from the transport sector. Oil overtakes coal to become the second-largest fuel in the sub-Saharan Africa energy mix by the mid-2020s and accounts for 17% of total energy demand in 2040. Nigeria alone sees a larger increase in oil use than any other sub-Saharan country or sub-region, followed by East Africa and Southern Africa.

Figure 2.4 ▹ Primary energy demand in sub-Saharan Africa by fuel in the New Policies Scenario



* Waste includes agricultural, animal, municipal and industrial waste.

Coal demand in sub-Saharan Africa increases by around 50% to reach 220 million tonnes of coal equivalent (Mtce) in 2040 (Table 2.3), but the share of coal in the demand mix declines from 18% to 15% (much below the world average). Demand remains concentrated in South Africa though also expands in some other countries, mostly in other parts of Southern Africa, but also in Nigeria and parts of East Africa. Collectively, Southern Africa accounts for more than half of coal demand growth predominantly for use in power generation but also for coal-to-liquids production (in South Africa). Among fossil fuels, demand for natural gas grows the most with an annual average of nearly 6%, to reach 135 billion cubic metres (bcm) by 2040. Half of this growth occurs in resource-rich Nigeria, where gas use reaches 72 bcm, predominantly for use in power generation and industry; but Mozambique and Tanzania also see significant growth, following increased domestic production. Overall, Southern Africa accounts for 30% of gas demand growth, while natural gas use remains relatively small in Central and East Africa.

Table 2.3 ▹ Primary energy demand in Africa in the New Policies Scenario (Mtoe)

2012	Oil	Gas	Coal	Nuclear	Bioenergy	Hydro	Other*	Total
Africa	**168**	**100**	**105**	**3**	**352**	**10**	**2**	**739**
North Africa	**82**	**78**	**4**	**-**	**4**	**1**	**0.2**	**170**
Sub-Saharan Africa	**85**	**22**	**101**	**3**	**348**	**8**	**1**	**570**
West Africa	33	14	0.4	-	147	1	<0.1	197
Nigeria	20	13	<0.1	-	108	0.5	-	141
Central Africa	5	2	-	-	29	1	-	37
East Africa	13	<0.1	0.4	-	95	2	1	112
Southern Africa	34	6	101	3	76	4	<0.1	223
Mozambique and Tanzania	3	1	<0.1	-	27	1	<0.1	33
South Africa	21	4	97	3	15	0.2	<0.1	141

2040	Oil	Gas	Coal	Nuclear	Bioenergy	Hydro	Other*	Total
Africa	**278**	**243**	**164**	**12**	**496**	**38**	**91**	**1 322**
North Africa	**98**	**133**	**10**	**-**	**8**	**3**	**31**	**284**
Sub-Saharan Africa	**180**	**110**	**154**	**12**	**488**	**35**	**60**	**1 039**
West Africa	76	69	15	-	180	9	6	355
Nigeria	46	58	12	-	124	5	5	251
Central Africa	10	7	-	-	55	8	1	81
East Africa	37	3	11	-	131	8	42	232
Southern Africa	56	31	127	12	121	11	11	371
Mozambique and Tanzania	8	16	4	-	57	5	1	91
South Africa	27	9	101	12	26	0.4	10	186

* Other includes geothermal, wind, solar PV, concentrating solar power and marine.

Renewables other than bioenergy experience strong growth across sub-Saharan Africa, growing from 2% of energy demand today to 9% in 2040 (95 Mtoe). Hydropower is already part of the mix in many countries, and its role in power supply increases in nearly all regions by 2040. Other renewables, including solar, wind and geothermal grow more rapidly, but from a lower base. South Africa and Nigeria see particularly strong growth in solar, while East Africa sees strong growth in geothermal, and South Africa and East Africa see some (albeit more modest) increase in wind. Despite some stated aspirations to build capacity, nuclear energy remains confined to South Africa in the New Policies Scenario, continuing to account for around 1% of primary energy demand in 2040.

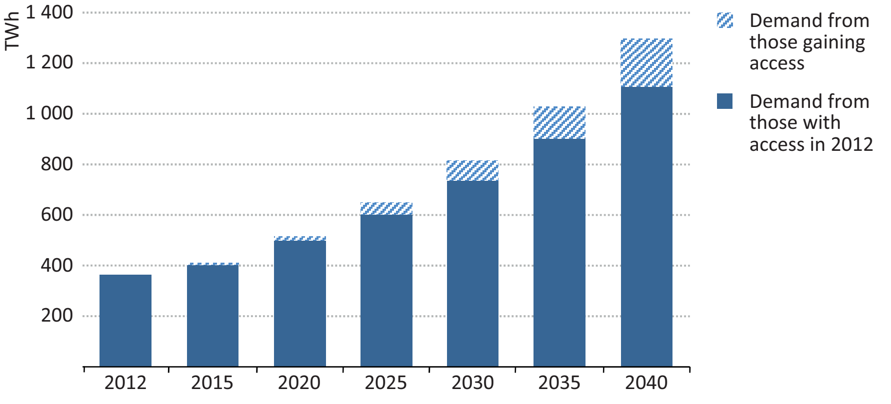
Future energy demand prospects are very diverse across the continent. Nigeria becomes the unrivalled centre of energy demand, almost doubling to more than 250 Mtoe in 2040. Over the projection period, Nigeria continues to account for one-quarter of total sub-Saharan demand, while South Africa sees its share decline from one-quarter to below one-fifth. Other countries in West Africa see their collective demand double by 2040 but, this collective demand is still lower than that of Nigeria today. Central Africa, which is home to 12% of the sub-Saharan population, accounts for only 7% of energy demand today and this share increases only marginally (to 8%), despite annual demand growth of 2.8%. Energy demand in East Africa grows by 2.6% per year, to reach around 230 Mtoe in 2040. Half of this increase is the result of an expansion of electricity supply to meet increasing demand. Southern Africa, led by South Africa, Mozambique and Tanzania, experiences the second-largest energy demand growth of any sub-region (behind West Africa). Across Mozambique and Tanzania, demand growth is particularly strong, increasing by an annual average of 3.7%, driven by strong economic growth that is in part due to new gas and coal production.

Outlook for the power sector

Electricity demand

Despite all sub-Saharan sub-regions seeing a significant increase in the number of people with access to electricity, 530 million people remain without it in 2040 – far short of the progress desired (see Chapter 3 for detailed analysis of the outlook for electricity access). Sub-Saharan electricity demand more than triples by 2040 in the New Policies Scenario, to reach 1 300 terawatt-hours (TWh). Of this expansion, only 20% is attributable to those that gain electricity access over the period (Figure 2.5). Industry is currently the largest end-user of electricity in sub-Saharan Africa and its demand more than doubles by 2040: national economies grow (boosting demand) while, at the same time, industries use energy more efficiently over time (restraining demand growth). Residential demand rises to more than five-times current levels to reach 520 TWh in 2040. At more than 6% per year, this rapid growth rate exceeds that of GDP growth over the period, and yet even this leaves unsatisfied the very large latent electricity demand that could emerge as access to electricity increases and the quality of supply improves.

Figure 2.5 ▷ Electricity demand in sub-Saharan Africa and the share from those that gain access in the New Policies Scenario



Electricity demand increases fastest in Nigeria and East Africa, each averaging more than 7% per year (Table 2.4); but the rest of West Africa and Central Africa also grow by 6% per year or close to it. South Africa's current high levels of access and of electricity consumption mean that its demand growth rate is slower (2%) but, by 2040, South Africa is still the largest electricity consumer in sub-Saharan Africa by some way (both in aggregate and per-capita terms). At the other end of the spectrum, electricity demand in Central Africa is, and remains, lower than in all other regions.

Table 2.4 ▷ Electricity demand* in Africa in the New Policies Scenario (TWh)

						2012-2040	
	2000	2012	2020	2030	2040	Delta	CAAGR**
Africa	**385**	**621**	**852**	**1 258**	**1 869**	**1 248**	**4.0%**
North Africa	**116**	**253**	**338**	**447**	**572**	**319**	**3.0%**
Sub-Saharan Africa	**269**	**368**	**514**	**812**	**1 297**	**929**	**4.6%**
West Africa	29	61	107	216	417	356	7.1%
Nigeria	14	37	68	146	291	254	7.7%
Central Africa	9	16	26	45	74	58	5.7%
East Africa	9	23	44	95	177	154	7.6%
Southern Africa	222	268	337	456	630	361	3.1%
Mozambique and Tanzania	4	16	30	60	99	83	6.6%
South Africa	190	212	248	298	364	152	2.0%

* Electricity demand is calculated as the total gross electricity generated, less own-use in the production of electricity, less transmission and distribution losses. ** Compound average annual growth rate.

Electricity supply

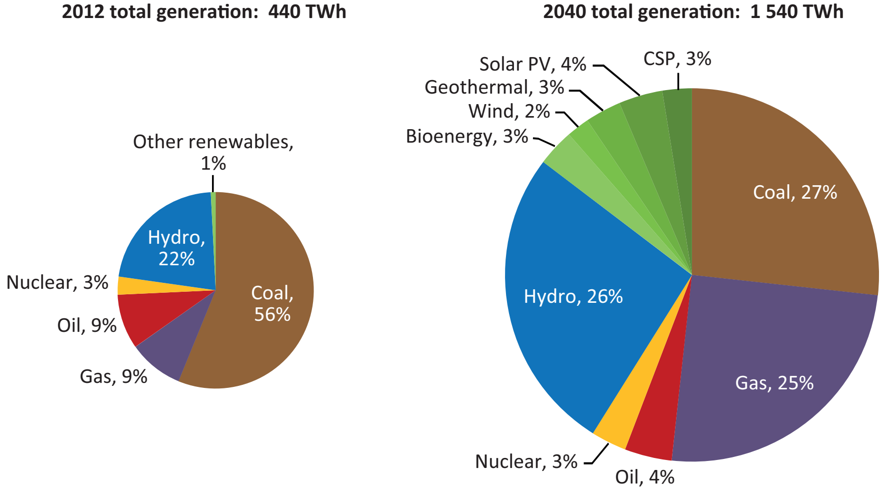
In sub-Saharan Africa, total power generation capacity (which includes on-grid, mini- and off-grid and back-up generation capacity) quadruples to reach 385 gigawatts (GW) in 2040. This reflects efforts to improve the quality of electricity supply and to expand supply to meet rapidly growing demand. Capacity additions increase over time, averaging around 7 GW per year this decade, to around 10 GW in the 2020s and over 13 GW per year in the 2030s. This reflects a power sector that is gradually expanding and maturing, but is still far behind some other developing countries (India expands three-times as much, for example). The expansion of the power sector projected in the New Policies Scenario requires a significant increase in investment, relative to historical levels: a cumulative total of $1.25 trillion (2014-2040) is invested – around $46 billion per year – with generating capacity accounting for nearly half of the total and transmission and distribution (T&D) the remainder (see Chapter 4 for more on investment). The relatively high share of investment in T&D is not unusual for emerging economies that are building their grid networks.

The sub-Saharan power generation capacity mix becomes increasingly diverse, with the large shares of coal (South Africa) and hydropower (all regions) supplemented by natural gas and an increasing share of other renewables (including solar, wind, geothermal and biomass). The share of installed capacity that is fossil-fuelled declines from 77% in 2012 to 54% in 2040, and also sees the relative share of gas grow strongly. Installed natural gas capacity increases by around 7.5% per year, on average, its share of installed capacity going from less than 60% of the level of oil in 2012 to overtake it by 2020 and then overtake coal and hydropower (just) before 2040. While coal is overtaken by gas and hydropower in terms of capacity, its role as a source of reliable, baseload electricity means that coal continues (narrowly) to be the largest source of electricity supply. Oil capacity remains stable, with back-up generation capacity declining in grid-connected areas as grid supply becomes more reliable. In contrast, oil-fuelled capacity grows in peri-urban and rural areas as an off-grid electricity access solution or as part of a hybrid solution.

Renewables increase to make up 44% of sub-Saharan Africa's power generation capacity in 2040, more than double the share of today. The expansion of hydropower capacity (reaching 93 GW in 2040) closely matches that of gas, with several major projects (such as Inga III and the Grand Renaissance dam) coming online incrementally over the projection period. Hydropower as a share of electricity supply increases from 22% of the total today to 26% in 2040. From their low base, solar photovoltaics (PV) and concentrating solar power (CSP) both see double-digit growth, collectively growing to account for 12% of total generation capacity and 6% of electricity supply in 2040. While solar PV capacity increases throughout the projection period, deployment of CSP starts around the mid-2020s (following cost reductions) and, by 2040, CSP provides around the same level of capacity as wind (both around 12 GW). Unlike in some other world regions, wind capacity expands relatively modestly, although there is no shortage of potential, as alternatives prove to be more competitive in many cases. Geothermal energy makes an increasing impact, reaching 3% of total electricity generation in 2040, mainly concentrated in East Africa.

In the New Policies Scenario, the greater part of electricity supplied to businesses and households in sub-Saharan Africa continues to come from centralised power plants, and is delivered through national and regional power grids (Figure 2.6). This is largely because these grids dominate supply in urban areas, which account for the lion's share of electricity consumption. Electricity access improves in both urban and rural areas in the New Policies Scenario, but urban electrification rates continue to be higher and, on average, business and households in urban areas consume more electricity. Grid-based systems do provide electricity to rural populations when those communities are in close proximity to transmission lines and extending the grid to them is a viable option.

Figure 2.6 ▷ Electricity generation by fuel in sub-Saharan Africa in the New Policies Scenario, 2012 and 2040



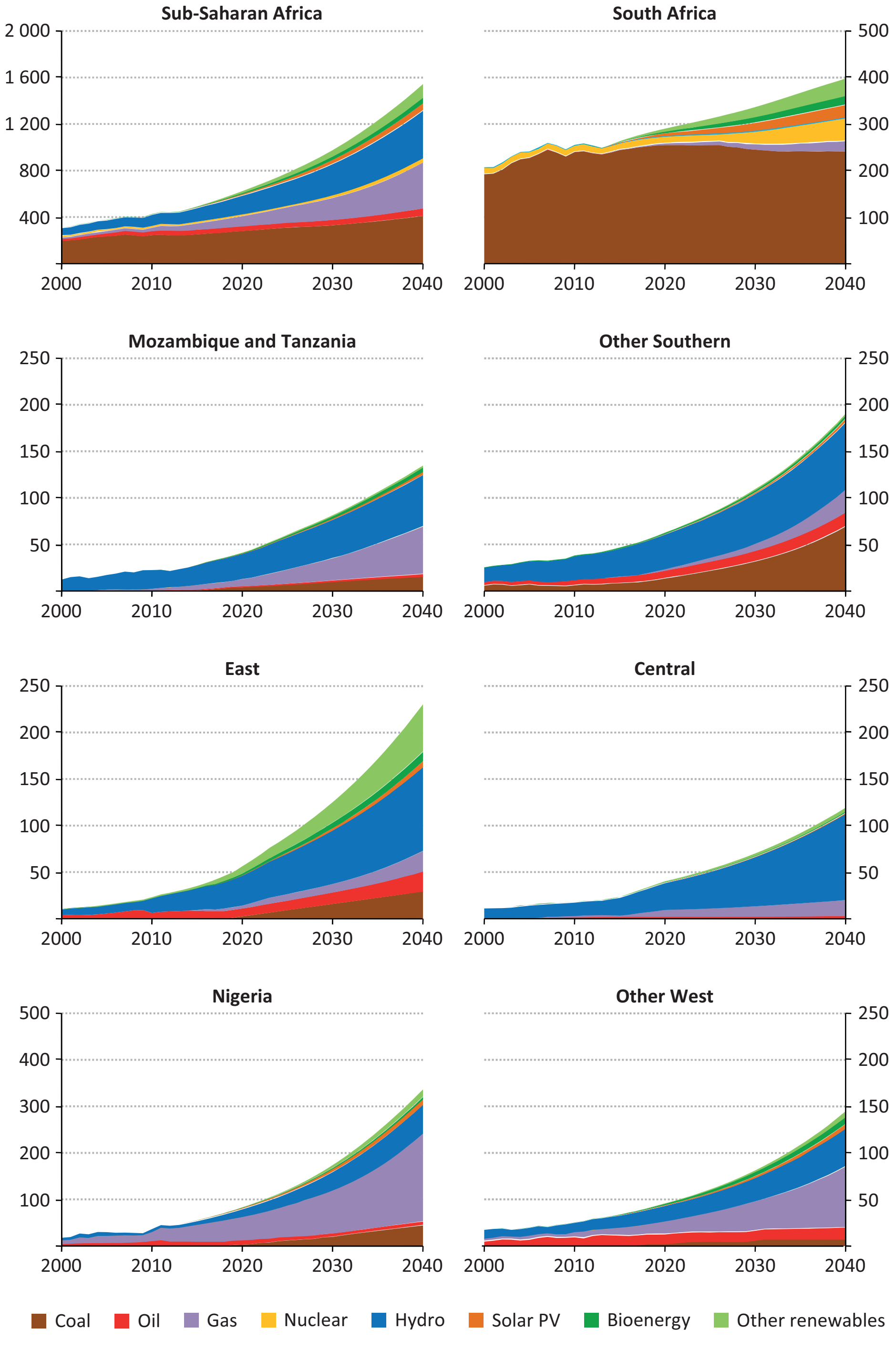
For the large rural population that is distant from power grids, mini-grid or off-grid systems provide the most viable means of access to electricity (see Chapter 3 for a focus on different routes to electricity access). In the New Policies Scenario, 315 million people in rural areas gain access to electricity, with around 80 million of these being through off-grid systems, and around 140 million people through mini-grids requiring the development of between 100 000 and 200 000 mini-grids, depending on the number of households connected to each system. The mix of technologies is quite distinct from the centralised power mix, with solar PV and oil being the dominant sources of supply. Small-scale hydropower, wind and bioenergy also play a more significant role in these small systems, when the resources are available. The systems installed in the New Policies Scenario do not come close to satisfying the full potential demand of a huge and growing rural population. The shortfall reflects the existing impediments to higher levels of adoption – such as the lack of proven business models, of adequate and appropriate forms of financing, of established supply chains and of implementation capacity – all of which deficiencies must be overcome in order to replicate the positive examples at the scale that is required.

West Africa sees its grid-based power generation capacity grow to more than four-times its current size, to around 110 GW in 2040, and generating nearly 475 TWh of electricity (Figure 2.7). Nigeria sees a large increase in installed capacity, reaching 77 GW. The power mix expands, mainly based on domestic resources. Associated gas from domestic oil production fuels strong growth in gas-fired generation, and forms the core of the Nigerian power sector for the foreseeable future. Also drawing on domestic resources, coal-fired generation increases substantially. Large hydropower expands to fully utilise Nigeria's available potential (over 11 GW), starting with the Mambilla dam, as well as significant growth in smaller-scale projects. Taking advantage of impressive resources, solar PV and CSP together reach 12 GW by 2040 – 15% of the total installed capacity. Back-up generation reduces significantly as the reliability and quality of grid-based power improves. As the West African Power Pool develops, Nigeria imports more electricity via the improved interconnections and, in addition, imports electricity from Cameroon. Power sector expansion in Nigeria requires investment in new power plants of $4 billion per year, on average, and $6 billion per year in T&D. The recent move towards power sector privatisation in Nigeria is assumed to help to mobilise investment. More than two-thirds of the investment in generation capacity is for renewables.

Elsewhere in West Africa, installed capacity expands by 5.8% per year, on average, to reach 36 GW in 2040. The generation mix is led by gas (46% in 2040), hydropower (28%) and oil (9%). The completion of the West African Power Transmission Corridor (currently under construction) improves interconnectivity and enables priority hydropower projects in Guinea, Liberia and Côte d'Ivoire to be developed. Gas-fired generation expands, largely in Ghana, where domestic supply grows and liquefied natural gas (LNG) regasification terminals come online to supply power plants. Oil continues to be a significant part of the power mix, though it expands little, with many relatively small power plants spread across the region. Non-hydro renewables account for a growing share of generation, driven by the Economic Community of West African States (ECOWAS) long-term target of 12% of electricity demand by 2030, with deployment of bioenergy, solar PV, CSP and wind.

Installed capacity in Central Africa increases from very low levels to reach 36 GW in 2040. Hydropower remains dominant in terms of capacity and generation, with the development of Inga III (4.5 GW) in Democratic Republic of Congo (DR Congo), early stages of the Grand Inga project and additional projects in Cameroon all reflected in the New Policies Scenario. Much of this capacity is developed to export electricity to other countries, including South Africa and Nigeria. Scale can often reduce the levelised cost of electricity per unit of capacity, provided the market is large enough to absorb the output. The scale of Central Africa's domestic demand and the relative lack of cross-border transmission capacity therefore continue to constrain the full development of the Grand Inga project. Gas-fired capacity accounts for one-third of installed capacity in 2040, serving to back-up and supplement hydropower during dry periods so as to ensure reliable power. During average years, in terms of rainfall and river flows, this capacity would operate at relatively low capacity factors, limiting fuel costs.

Figure 2.7 ▷ **Electricity generation by fuel in the New Policies Scenario** (TWh)



In East Africa, installed capacity grows from over 8 GW to 55 GW in 2040, with hydropower and oil joined increasingly by a range of other fuels resulting in a more diversified power mix. Hydropower remains the largest source of electricity, as Ethiopia develops several large projects, including the Grand Renaissance dam, Gilgel Gibe III and Gilgel Gibe IV, which collectively have a capacity of 9.4 GW. Much of the capacity developed in Ethiopia provides electricity for export to neighbouring countries and regions. Geothermal energy becomes the second-largest source of electricity in East Africa by the mid-2020s, with notable development in Kenya and Ethiopia. Other non-hydro renewables contribute 9% of the total generation in 2040. Coal-fired generation becomes the largest fossil fuel source of power in the second-half of the projection period, overtaking oil.

In Southern Africa, power generation capacity expands to 180 GW, with South Africa seeing its share of the regional total decrease from 78% to around 60% in 2040. Even though the power sector in South Africa is already relatively well-developed, installed capacity more than doubles to nearly 110 GW. Capacity expansion in South Africa requires investment of $7.1 billion per year, with an additional $3.4 billion for T&D infrastructure. Cumulative power sector investment in South Africa over the period tops $285 billion. The power mix becomes very diverse, tapping nearly every available technology. Coal, which accounted for 94% of total generation in 2012, remains the dominant fuel for power generation, but falls to 61% by 2040, despite an increase in coal-fired capacity of 14 GW. Gas-fired capacity increases by 9 GW, though gas continues to play a supporting role in the power mix. With strong emphasis being placed on their deployment, non-hydro renewables emerge as the favoured option to meet rising electricity demand. Installed capacity of non-hydro renewables increases from below 1 GW to over 30 GW, making up 21% of the power mix in 2040. Solar PV capacity increases the most of any technology over the projection period (increasing by 15 GW). CSP, wind and bioenergy all expand substantially, representing close to 5% of the power mix each. South Africa is the only country in sub-Saharan Africa with a nuclear power plant today, and its nuclear capacity expands after 2025, reaching 6.6 GW in 2040, and generating 12% of total electricity (See Chapter 3 for more detailed analysis on the development of South Africa's power generation mix).

In Mozambique and Tanzania collectively, installed capacity increases to 28 GW in 2040, more than six-times the current level. Expansion is focused on hydropower projects and gas-fired capacity, with more than 8 GW of each added over the projection period. Hydropower projects, including Mphanda Nkuwa in Mozambique and Stiegler Gorge in Tanzania, are developed as a source of electricity exports to other countries, mainly South Africa. Gas-fired capacity increases to capitalise on some of the additional domestic supply (see Chapter 3). Coal-fired capacity and generation grows, using domestically produced coal, to reach 12% of total generation in 2040. Non-hydro renewables also increase, though they make up less than 10% of the power mix.

In the remaining parts of Southern Africa, total installed capacity increases five-fold as a result of average annual capacity additions of 1.5 GW, and total installed capacity reaches 44 GW in 2040. Hydropower remains the largest source of electricity over the projection period, with additional capacity of 11 GW, led by the Laúca dam now under construction in

Angola. With domestic coal resources available in several countries in the Southern Africa region, the importance of coal in the power mix increases. There are coal-fired capacity additions in Botswana, Madagascar, Zambia and Zimbabwe. Angola sees new oil-fired and gas-fired capacity come online to serve domestic consumers with indigenous resources. Non-hydro renewables remain very limited in this region.

Electricity transmission and trade

The expansion of generation capacity needs to be matched by a similar step-change in transmission and distribution (T&D) infrastructure. In the New Policies Scenario, annual investments in T&D increase to about nine-times today's level by 2040 and, in total, outpace those for new power generation capacity over the period. Investment is unsurprisingly concentrated in expansion rather than replacement, and distribution networks account for two-thirds of the total T&D investment. The length of sub-Saharan transmission lines increases more than five-fold to reach 0.8 million kilometres (km), while distribution lines increase more than three-fold to reach nearly 5 million km in 2040 – a large expansion, but still short of the ultimate requirements. Grid expansions are supplemented by mini- and off-grid systems in more remote areas.

National grids expand gradually across sub-Saharan Africa, supporting wider electricity access, improving reliability of supply and, in cases such as Mozambique, connecting elements of the sub-national infrastructure. Electricity trade within sub-regions grows (as the power pools support greater regional cooperation), as does trade across sub-regions. DR Congo, Ethiopia and Mozambique are the largest net exporters of electricity by 2040, each developing large hydropower projects for the purpose, while South Africa (net imports meet 5% of demand in 2040), Nigeria (the second-largest importer, after South Africa) and some other parts of Southern Africa are the main net importers. Expansion of cross-border transmission lines broadly follows the plans as outlined by the regional power pools and in the Programme for Infrastructure Development in Africa (PIDA), but are only partially implemented by 2040. The degree to which Central Africa is connected to other sub-regions is an important constraint in the New Policies Scenario when compared to the African Century Case (see Chapter 4). In parallel with expanding the power supply infrastructure, investment will be required to build the necessary human technical capacity.

Outlook for other energy-consuming sectors

Total final energy consumption in sub-Saharan Africa increases by 70% to reach 722 Mtoe in 2040 in the New Policies Scenario (Table 2.5), equivalent to half the level of the United States today. Bioenergy remains, by a big margin, the largest fuel in final consumption (around 380 Mtoe in 2040), but its share of the total declines from around 70% to just over half. At a growth rate of less than 1% per year, growth is slower than that of any fuel and essentially plateaus by 2040 – a major milestone in sub-Saharan energy sector development. The use of bioenergy becomes slightly less concentrated in the residential sector, though it still accounts for more than 80% of household final consumption in 2040, compared with 42% in India, 24% in China and 18% in Europe.

Table 2.5 ▷ Total final energy consumption in Africa in the New Policies Scenario (Mtoe)

2012	Residential	Transport	Productive uses*	Total
Africa	307	90	142	538
North Africa	27	42	47	116
Sub-Saharan Africa	280	48	94	422
West Africa	120	16	26	161
Nigeria	93	10	18	121
Central Africa	24	3	7	33
East Africa	74	6	8	88
Southern Africa	62	24	54	139
Mozambique and Tanzania	19	2	6	26
South Africa	17	17	39	72

2040	Residential	Transport	Productive uses*	Total
Africa	435	161	313	909
North Africa	51	53	83	187
Sub-Saharan Africa	384	109	230	722
West Africa	152	40	93	286
Nigeria	99	26	73	198
Central Africa	43	6	17	67
East Africa	90	19	23	132
Southern Africa	99	43	96	238
Mozambique and Tanzania	36	5	24	64
South Africa	25	28	50	102

* Productive uses includes industry, services, agriculture and non-energy use.

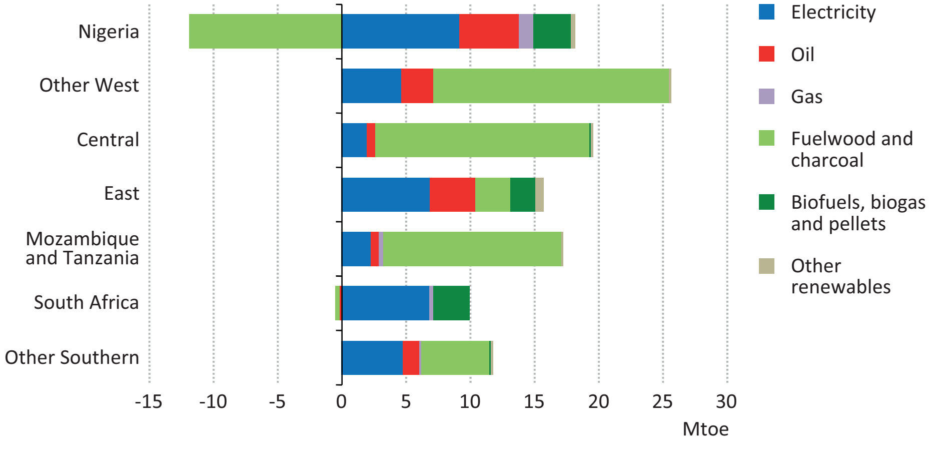
Oil consumption more than doubles to reach 4 mb/d in 2040. The share of oil in final consumption increases gradually to reach around one-quarter, reflecting its increased use in transport and industry, as well as in the residential sector in the form of liquefied petroleum gas (LPG). The share of electricity in final consumption increases from 7% in 2012 to 15% in 2040, with significant growth in all sub-regions across the residential, services and industrial sectors. Gas consumption overtakes coal in the late-2030s, but remains relatively low in 2040 (around 40 bcm), with little used for heating or cooking and limited distribution networks. Use of coal increases by around 13 Mtce (led by industry), but its share of total final consumption declines slightly. Of the end-use sectors, services and industry grow most quickly (both more than 3% per year), and industry increases its share of final consumption from 14% to 20% in 2040. Nigeria continues to account for nearly 30% of final consumption in sub-Saharan Africa. South Africa sees its share of total sub-Saharan final consumption decline slightly to 14%, as does East Africa to 18%. In contrast, the strong growth in consumption in Mozambique and Tanzania results in their collective share of total final consumption in sub-Saharan Africa increasing to 9% in 2040, even though they account for around 4.5% of the total economy.

Residential

The residential sector continues to be a very large energy consumer in sub-Saharan Africa, but demand only increases by just over 1% per year in the New Policies Scenario (despite the population growth), reaching 384 Mtoe in 2040. Energy demand per household drops by almost 40%, from 1.5 toe to 0.9 toe in 2040. This masks an even larger decrease for cooking, which is partially offset by higher consumption for lighting, appliances and cooling. The decline for cooking is driven by changes in the fuels and stoves used: traditional use of solid biomass is gradually reduced on a per household basis, with households switching to more efficient, less polluting cookstoves, such as improved biomass cookstoves, or fuels, such as LPG, biogas or solar (see Chapter 3).

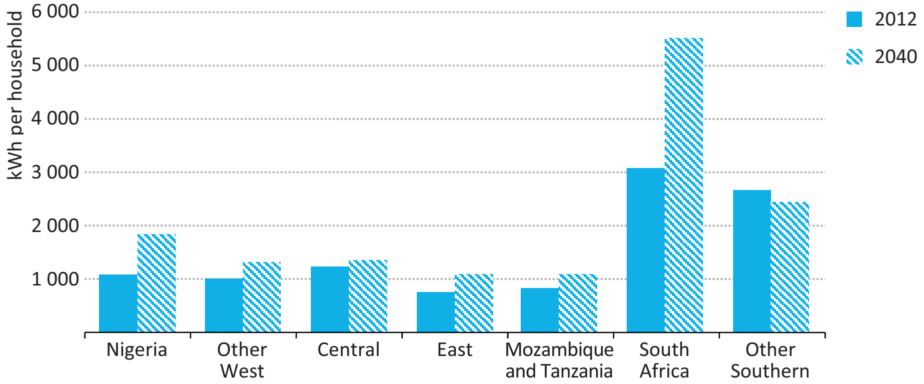
By fuel type, solid biomass, electricity and oil lead the increase in total residential energy consumption (Figure 2.8). Oil use in the residential sector increases from 165 thousand barrels per day (kb/d) to around 510 kb/d in 2040 (around 65% LPG and the rest kerosene). Growth in gas use is much smaller and is focused on cooking and water heating in gas-rich countries, mainly Nigeria, Mozambique and Tanzania. Use of solid biomass declines in some regions, either due to its scarcity or successful policy action to encourage switching; but, overall it increases by 0.6% per year (while the total population grows by 2.4% and the rural population by 1.5% per year).

Figure 2.8 ▷ Change in residential energy demand by fuel in sub-Saharan Africa in the New Policies Scenario, 2012-2040



Total residential electricity demand in the sub-Saharan region grows by 6% per year to 2040, with increasing and more reliable supply, and rising incomes funding the purchase of more appliances. Electricity use per electrified household grows by 14%, to just over 1 800 kilowatt-hours (kWh) in 2040; but this relatively modest increase hides efficiency improvements that take place in parallel. Consumption per capita is still only one-third of the world average in 2040. There are disparities in consumption levels across and within sub-regions (Figure 2.9). In South Africa, high levels of electricity access and relatively low prices spur its use for various end-uses, so electricity, which accounts for 20% of residential consumption today, more than doubles its share. Household electricity consumption in Nigeria grows by around 70%, though it still lags South Africa and other Southern African countries in aggregate terms. Growth in other sub-regions is more modest and generally in the range of 1 000-1 500 kWh per electrified household by 2040 (average consumption in electrified households in India today is 1 000 kWh and in China it is 1 700 kWh).

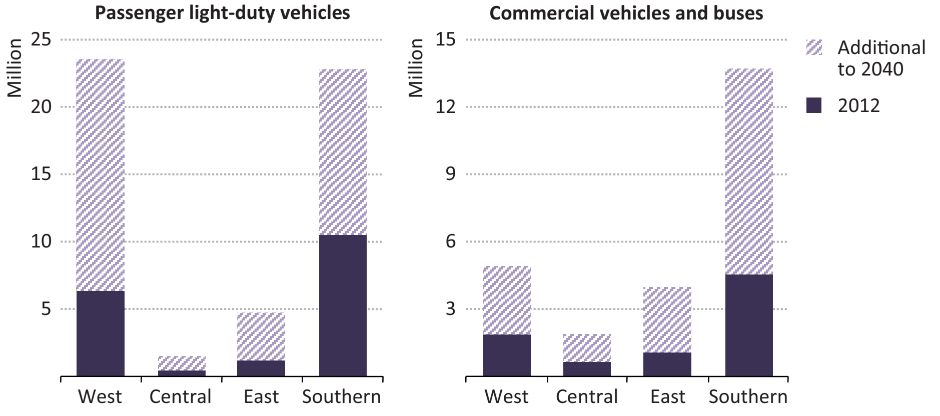
Figure 2.9 ▷ Electricity demand per electrified household in sub-Saharan Africa in the New Policies Scenario



Transport

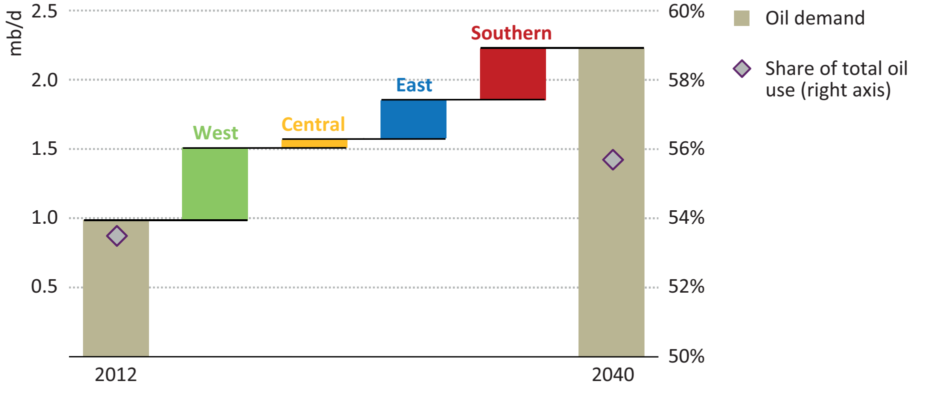
Today only 2% of the sub-Saharan population owns a passenger light-duty vehicle (PLDV), compared with 70% in the United States, 50% in Europe and 6% in China, indicating huge growth potential. The number of PLDVs in sub-Saharan Africa almost triples to 2040 (to exceed 50 million vehicles), with more than half of the growth in Nigeria and South Africa (Figure 2.10). South Africa is already a rapidly growing vehicle market, while Nigeria's GDP per capita exceeds $5 000 before 2030, a level at which PLDV ownership often accelerates rapidly (Chamon, Mauro and Okawa, 2008). Throughout much of the rest of Africa, GDP per capita remains at much lower levels, impeding vehicle demand growth. This, combined with a growing population, means that only around 3% of the sub-Saharan population owns a PLDV in 2040, with even this low level being overshadowed by the ownership concentration in South Africa (20%) and Nigeria (5%). The number of commercial vehicles and buses grows from around 8 million vehicles in 2012 to 25 million in 2040. East Africa leads the way with average growth of nearly 5% per year, driven by a rapidly growing population and demand from the services and industry sectors. Mozambique and Tanzania see average growth of more than 4% per year, but from lower levels. As urban areas grow significantly in size in sub-Saharan Africa, urban development policies can play an important role in guiding users of transport services towards private or public forms of transportation, and therefore influence future transport energy demand.

Figure 2.10 ▷ Vehicle stock in sub-Saharan Africa by type in the New Policies Scenario



Over the projection period, types of transport other than road and aviation remain relatively under-developed, as the policies and investment of the New Policies Scenario are not sufficient to promote a widespread modal shift. However, some expansion plans do exist, for example the new line that is planned from the Kenyan port of Mombasa to the capital Nairobi and on to neighbouring states in East Africa, to be built with Chinese support. In other cases it is anticipated that an expansion of the rail network will be driven by industrial interests to transport commodities from inland to ports. The transport sector remains almost entirely reliant on oil products, with few policies in place to promote the use of alternative fuels, such as biofuels. Total transport demand for oil more than doubles to reach 2.2 mb/d – 55% of which is gasoline and 40% is diesel (Figure 2.11).

Figure 2.11 ▷ Oil demand in transport in sub-Saharan Africa in the New Policies Scenario

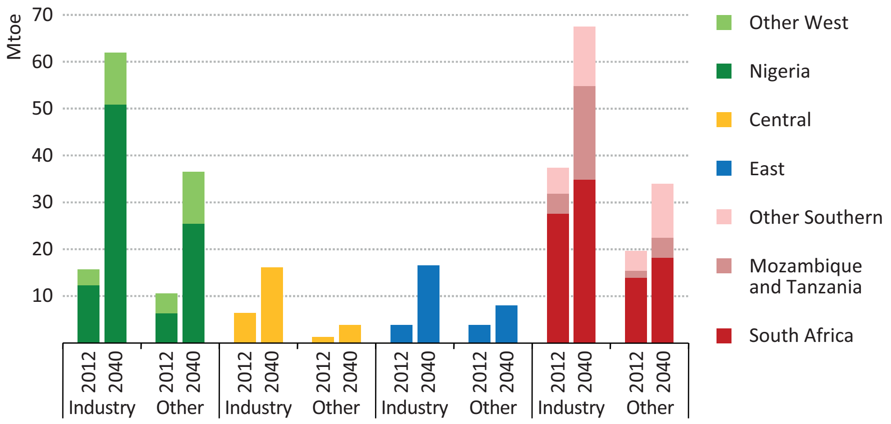


A constraint on fuel demand for road transport is the severe lack of paved roads. This improves over time, but far below the full potential. A second and more positive factor is vehicle fuel efficiency, which for new vehicles improves across sub-Saharan Africa by more than 20%, on average, to reach 7.2 litres per 100 km in 2040. However, this still means that by 2040, average vehicle efficiency in the region falls some way short of the level of the European Union today. Sub-Saharan Africa relies heavily on imports of second-hand vehicles from Japan and Europe, in particular, which both have comprehensive fuel-economy standards in place. To a degree, these standards are progressively imported helping to improve the region's average efficiency. Interest in building vehicle manufacturing or assembly plants in Africa is also expected to be a factor in pushing policymakers to consider fuel-economy policies more seriously or, where they exist, to impose them more stringently.

Productive uses[4]

Energy consumption by productive sectors in sub-Saharan Africa grows by nearly two-and-a-half times to reach 230 Mtoe in 2040 (Figure 2.12), but this is less than one-third of the energy consumed by industry in China today. In 2012, South Africa accounted for 41% and Nigeria for 19% of total sub-Saharan energy consumption for productive uses. However, by 2040 these positions are reversed, with Nigeria's strong economic growth boosting its share to nearly one-third while South Africa grows more slowly and its share drops to around one-fifth. East and Central Africa see energy consumption in 2040 for productive uses increase to 23 Mtoe and 17 Mtoe respectively, both still very low absolute levels.

Figure 2.12 ▷ Final energy consumption in productive uses in sub-Saharan Africa in the New Policies Scenario



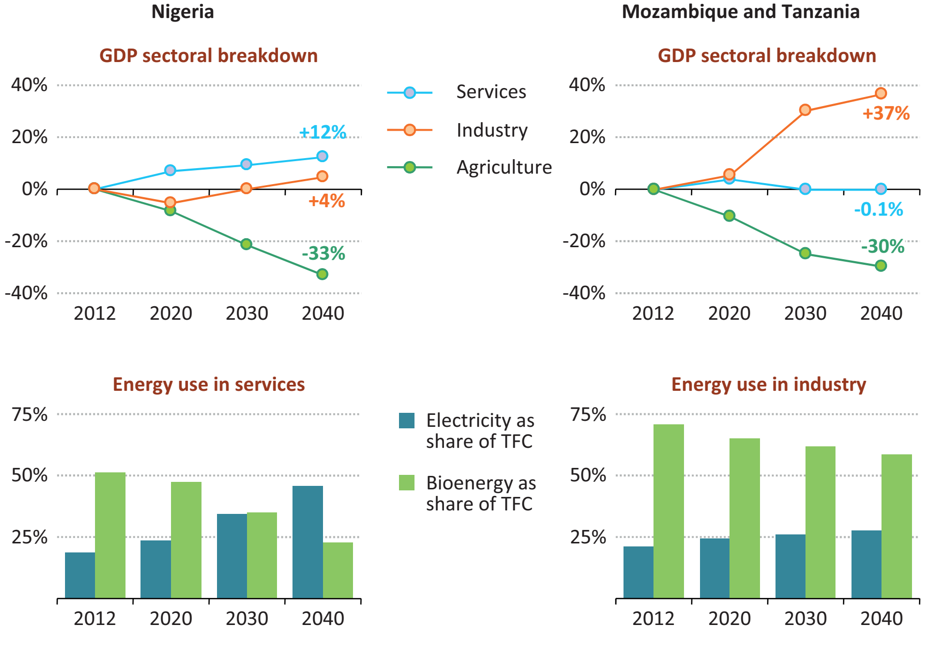
Note: Other is an aggregate of services, agriculture and non-energy use.

4. Industry, services, agriculture and non-energy use. Some energy demand from the transport sector (e.g. freight-related) could also be considered as productive, but is covered separately in this analysis.

Together with power generation, these productive sectors are key sources of economic growth. Their share of sub-Saharan final energy consumption increases from around 20% in 2012 to 30% in 2040. The trend of energy consumption is driven by the energy-intensive industries, including mining, and cement and iron and steel sub-sectors that are, in turn, stimulated by dynamic economic growth. Overall, industry represents 70% of total productive energy use and services another quarter. Agriculture, which benefits from progressive mechanisation and enhanced productivity through wider use of modern means such as fertilisers and irrigation, continues to account for around 5%. Improving agricultural productivity is a priority area in the African Union's "Agenda 2063" and the scope for doing so is far from exhausted within the New Policies Scenario. The progressive modernisation of the agricultural sector will reduce its role as the mainstay of rural employment, requiring a greater focus on policies to develop other rural industries to support local economies.

In the New Policies Scenario, patterns of economic growth and diversification differ across sub-regions, but generally result in the industrial and services sectors growing more quickly than agriculture and, as a consequence the share of agriculture in the overall economy declines by one-third in Nigeria, Mozambique and Tanzania by 2040 (Figure 2.13). In Nigeria, both industry and the services sector act as strong drivers of growth, with services raising its share of GDP to nearly 60% by 2040. In Mozambique and Tanzania, industry plays a relatively greater role in economic growth, boosted by rising energy supply, mainly gas, and related downstream chemical activities, including feedstock production.

Figure 2.13 ▷ Change in GDP by sector and related energy use in the New Policies Scenario



Note: TFC is total final consumption.

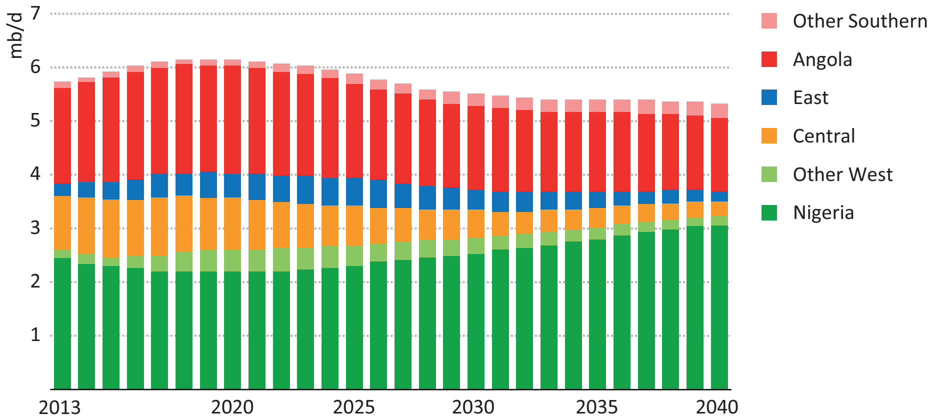
The fuel mix in productive energy consumption is largely sector dependant. Moreover, countries tend to specialise in certain industrial sub-sectors and make fuel choices based on their specific requirements and domestic resource availability. More than 85% of coal consumed for productive uses is consumed in South Africa, while almost half of gas consumption for this purpose is in Nigeria. While the causality between energy use and economic growth is difficult to establish, the creation of value in sub-Saharan countries is accompanied by a rise in modern and more efficient energy use. This is evident in the increased use of electricity throughout the economy, often at the expense of less efficient alternatives. One example is Nigeria's services sector, where electricity consumption grows by more than 25 percentage points to meet almost half of the sector's energy needs.

Outlook for energy supply

Oil

Sub-Saharan oil production reaches its historical peak of nearly 6.2 mb/d before 2020 and then sees a gradual decline to reach 5.3 mb/d in 2040 (Figure 2.14). Nearly 75% of the production in 2040 comes from new fields brought online to offset the production declines from existing fields, illustrating that this production profile requires significant new investment and development. Our figures necessarily incorporate judgements on several sources of uncertainty, such as the success of exploration and development in pre-salt deposits off the west coast of Africa and the evolution of the multitude of "above ground" challenges discussed throughout this study (Spotlight). The trends and the drivers vary from place to place in sub-Saharan Africa, but the cumulative effect is that, by the end of the projection period, oil production becomes more heavily concentrated in its two largest producers (Nigeria and Angola, which are Organization of the Petroleum Exporting Countries [OPEC] members) and in Nigeria in particular (increasing from around 40% in 2013 to nearly 60% in 2040). (See Chapter 3 for detailed analysis on Nigeria's oil outlook.)

Figure 2.14 ▷ Oil production in sub-Saharan Africa in the New Policies Scenario



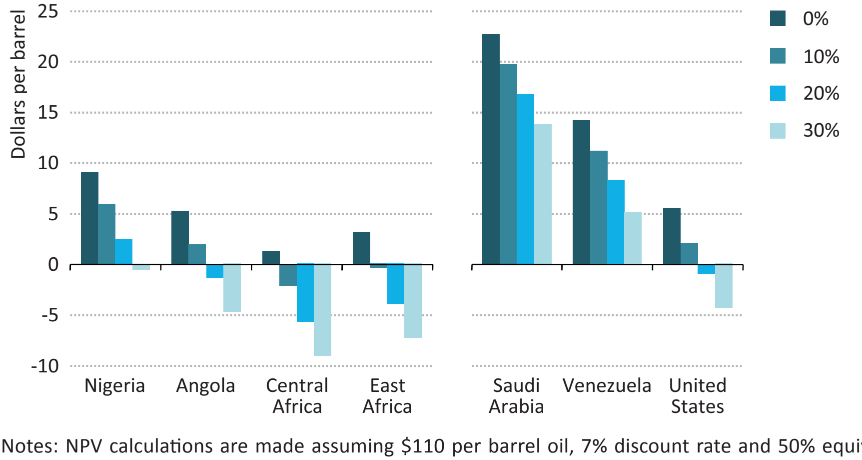
SPOTLIGHT

Why does oil production not directly reflect resource potential?

At first glance, upstream capital and operating costs in sub-Saharan Africa compare reasonably well with those in many oil and gas provinces worldwide. Over time, these costs tend to be influenced by the fundamentals of the remaining resource size and accessibility which, for sub-Saharan Africa, favour (for example) Nigeria over its West African neighbours or those of the East African Rift. The overall calculation of a project's expected profitability inevitably includes a risk factor, and beyond the medium term (where a pipeline of projects is visible) our modelling prioritises the most profitable projects for development based on their net present value (NPV) after adjusting for risk.

Based on such an analytical process, projects in Central and East Africa would look favourable in the longer term only at low rates of assumed risk in our projections, whereas those in Nigeria look profitable even at a higher residual risk level (Figure 2.15). Compared with developments in other parts of the world, sub-Saharan projects tend to look relatively less attractive. The evaluation of the appropriate risk factor takes into account political and economic risk, the risk of instability in the legal or fiscal environment, and more operational or security-related risks. There is inevitably a significant degree of subjectivity in such an assessment, with different types of companies (national oil companies versus international oil companies) or those with various existing portfolios or expertise judging the same situation very differently. Governments can influence many of the factors that play into such an assessment through actions to improve political, economic, fiscal and legal stability and the physical infrastructure (see the African Century Case in Chapter 4).

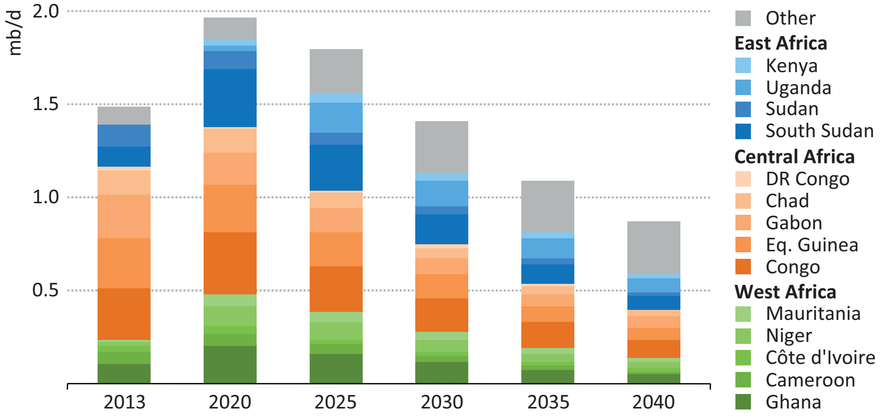
Figure 2.15 ▷ Net present value of oil developments at different risk levels using post-2030 cost assumptions



Notes: NPV calculations are made assuming $110 per barrel oil, 7% discount rate and 50% equivalent profit tax in all cases. Risk rates represent a factor multiplying the future cash flow (i.e. if the risk = 10% there is a 10% chance that future earnings do not materialise).

In the period to 2020, total sub-Saharan oil production increases by more than 400 kb/d, breaking through the 6 mb/d level around 2016 and remaining close to that level at end of the decade. Growth in this period is dominated by the region's smaller producers, which collectively increase production from under 1.5 mb/d in 2013 to nearly 2 mb/d in 2020 (Figure 2.16). Overall, increases from South Sudan (over 200 kb/d), Ghana (around 100 kb/d) and, to a lesser extent, Niger, Mauritania and Congo serve to more than offset a dip in Nigerian production (around 250 kb/d). For South Sudan, this represents a return to around the 2011 level of production, following recent disruption. Ghana's oil production is boosted by around 80 kb/d from the Tweneboa Enyenra Ntomme (TEN) fields, which come on-stream later this decade, and from the Jubilee field, which produces close to its 120 kb/d capacity once the related gas project is completed next year.

Figure 2.16 ▷ Oil production in sub-Saharan countries other than Nigeria and Angola in the New Policies Scenario



While Congo's oil production has relied heavily on mature offshore fields, there has been a revival in the last decade in new offshore projects, such as N'Kossa, N'Soko and the pre-salt M'Boundi field coming on-stream. In the New Policies Scenario, Congo produces more than 300 kb/d in 2020, with contributions from the Chevron Lianzi deepwater field and Eni's shallow water Nene Marine development. The government is currently considering revision of its fiscal terms to encourage further exploration. Exploration has recently intensified in Niger and its oil production is set to increase to five-times the current level by 2020, reaching more than 100 kb/d. While the China National Petroleum Company-funded Zinder refinery processes the 20 kb/d of crude production from the Agadem Basin, much of the remaining volumes are exported via a new 600 km pipeline linking to the Chad-Cameroon pipeline (allowing export through the port of Kribi in Cameroon).

A different production picture emerges in the 2020s, with Nigerian production starting to bounce back, and Uganda and Kenya emerging, while Angola and several smaller producers show signs of decline (Table 2.6). The size of Nigeria's resource base (nearly one-third of the sub-Saharan total), and permissive investment conditions, underpin Nigeria's production increase to around 2.5 mb/d in 2030 and 3.1 mb/d in 2040. Uganda and Kenya collectively bring about 160 kb/d of new onshore production online by 2030, a significant development for their respective economies. Ugandan oil production ramps up in the early-2020s, exploiting recently discovered volumes in the Albert-Edward rift basins. Production is expected to go to the 60 kb/d refinery planned for the eastern shore of Lake Albert and also to export markets, once the 1 400 km export pipeline to Lamu at the Kenyan coast is completed. Production starting in the early-2020s from the Gregory Rift discoveries in Kenya's Lokichar basin will feed into this pipeline. South African coal is the third-largest source of hydrocarbon liquids in sub-Saharan Africa, with coal-to-liquids output increasing with the assumed construction of long-discussed additional capacity by Sasol.

Table 2.6 ▷ Oil production in Africa in the New Policies Scenario (mb/d)

	2013	2020	2030	2040
Africa	**9.0**	**9.2**	**9.4**	**9.8**
North Africa*	**3.3**	**3.1**	**3.9**	**4.5**
Sub-Saharan Africa	**5.7**	**6.2**	**5.5**	**5.3**
West Africa	2.6	2.6	2.8	3.2
Ghana	0.1	0.2	0.1	<0.1
Nigeria	2.5	2.2	2.5	3.1
Central Africa	1.0	1.0	0.5	0.3
Congo	0.3	0.3	0.2	0.1
Equatorial Guinea	0.3	0.3	0.1	<0.1
East Africa	0.2	0.5	0.4	0.2
South Sudan	<0.1	0.3	0.2	<0.1
Southern Africa	1.9	2.1	1.8	1.6
Angola	1.8	2.0	1.6	1.4

* Much of the growth reflects the assumed gradual return of Libyan output to pre-war levels.

Elsewhere in sub-Saharan Africa, the post-2020 picture is less rosy, with an expectation of gradual decline in production. Angola leads this decline, with production going from 2.0 mb/d in 2020 to 1.4 mb/d in 2040: in the medium term the projected path is only modestly below Angola's stated aim, but the overall outlook is prompted by the fast decline rates typically observed in deepwater fields and a cautious assessment regarding pre-salt oil. In the 2030s, the pattern of slow decline continues for several producers, including Equatorial Guinea, Congo, Côte d'Ivoire, Cameroon, South Sudan and Chad.

Refining outlook

Around half of sub-Saharan oil product demand is met by imports and, even if existing refining capacity was able to be fully utilised, the region would still be reliant on imports. In the New Policies Scenario, sub-Saharan Africa sees consumption of almost all oil products grow significantly, with gasoline and diesel increasing the most in absolute terms (Table 2.7).

LPG sees the largest relative growth over the projection period (from very low levels) and overtakes the level of kerosene by 2040, the use of which increases in both aviation and the buildings sector (residential and services). Residual fuel oil demand has the slowest growth rate, while demand for oil products used exclusively in the petrochemicals sector, such as naphtha and ethane, remains small.

Table 2.7 ▷ Oil product demand in sub-Saharan Africa in the New Policies Scenario (mb/d)

	2012	2020	2030	2040	CAAGR* 2012-2040
LPG	<0.1	0.1	0.2	0.4	7.3%
Gasoline	0.6	0.8	1.0	1.3	2.5%
Kerosene	0.2	0.2	0.3	0.4	2.5%
Diesel	0.6	0.7	0.9	1.3	2.7%
Other	0.4	0.4	0.5	0.6	2.1%
Total	**1.8**	**2.3**	**3.0**	**4.0**	**2.8%**

* CAAGR = compound average annual growth rate. Sources: CITAC; IEA analysis and projections.

The average utilisation rates of installed refining capacity, outside South Africa, are very low and major investment is required if they are to expand output and switch to higher-quality products. Refineries in Nigeria and Ghana, for example, have been running at under 30% of capacity in recent years because of inefficient management and a lack of regular maintenance. In the New Policies Scenario, we assume that 400 kb/d of current capacity is eventually shut down, sufficient investments are made to upgrade the remaining capacity for higher runs, and another 0.8 mb/d of new refinery capacity comes online between now and 2040. Before 2020, only two mini-refineries are expected to be built, in Uganda and South Sudan. More significant capacity additions start to come online in the second half of the 2020s, with new refineries in Angola, Nigeria and East Africa. Overall, capacity additions are heavily skewed towards West Africa, close to the sources of oil production. Nigeria accounts for the majority of the retired capacity as it eventually shuts down some of its oldest, most inefficient refineries, and this also contributes to an improvement in the overall refinery utilisation rate. When examined together, it is clear that the gap between operational sub-Saharan refining capacity and oil product demand grows significantly in the New Policies Scenario, resulting in an increasing need for oil product imports over the projection period.

The case for building up Africa's local refining capacity would appear to be strong, yet – as in other parts of the world – relatively few projects actually make it off the drawing board. There are a number of reasons why. To realise economies of scale, refineries are now typically built with a minimum of 200 kb/d capacity, with a view to high operating rates. At present, only Nigeria and South Africa have demand higher than this level. By the end of the projection period, some four or five other countries are expected to meet this demand threshold, but the rest will still have smaller national markets.

Availability of local crude oil supply is another key constraint. In the New Policies Scenario, almost all the new capacity is projected to be for countries that have local crude production (only one new refinery in East Africa is expected to rely on imported crude). The availability of local production can even justify relatively small-scale refineries in land-locked countries with a growing internal market (as the logistical costs of crude export and product imports justify otherwise uneconomic projects). This has already been the case in Chad and Niger (both with 20 kb/d refineries). Uganda and South Sudan have similar projects that are very likely to materialise. Elsewhere, though, the most efficient solution is to build refineries that are capable of meeting not just domestic product needs, but also those of neighbouring countries: as with other projects looking to realise economies of scale, this implies a strong degree of regional co-operation.

The calculation of the costs and benefits of local refining also depends on which products are being imported. Although it is sometimes assumed that refining locally is cheaper than importing products, it makes a big difference in practice if the product required is a premium product on the market (with strong interest among buyers elsewhere – and high margins for refiners) or a by-product (potentially more readily and cheaply available). Prices for naphtha and residual fuel oil, for example, tend to be lower than the crude oil price. Gasoline in the European market in winter, which is the low driving season in Europe and the United States, can also at times be worth less than crude oil. In the case of LPG, refining crude oil is not the only source of supply, as the yields of LPG are quite low in refining and it can be produced from natural gas liquids at lower cost. In short, if a country is importing mainly gasoline and LPG, then a local refinery in Africa may not be able to produce these products at lower cost.

Another important consideration is the opportunity cost of a new refinery. Refineries require significant upfront investments. In the New Policies Scenario, new refining capacity (including upgrading existing capacity) requires investment of $40 billion, while a further $15 billion is required to cover maintenance costs (assuming an adequate maintenance programme), which contributes to higher availability of refining capacity. There are many competing and deserving possibilities for infrastructure spending and investment in refinery capacity may not be high on the list of priorities. Nor is it clear, in many cases, who will do the investing, whether governments or local or international private investors, particularly in cases where local oil product prices are subsidised. On balance, the projections assume that governments and investors do see some opportunities in the expanding market to realise new refineries. But capacity additions do not keep pace with growing demand, meaning that sub-Saharan Africa remains a net importer of products.

Natural gas

Sub-Saharan Africa makes the fourth-largest contribution globally to incremental gas supply through to 2040, behind the Middle East, China and the United States but ahead of Latin America, the Caspian region, Russia and Australia. In the New Policies Scenario, production increases to four-times existing levels, from 58 bcm in 2012 to around 80 bcm in 2020, 160 bcm in 2030 and 230 bcm in 2040 – average annual growth of 5% (Table 2.8). Production growth derives from the large undeveloped resources of Nigeria, Mozambique, Angola and Tanzania, with the speed of resource development being determined by a range of factors including, but not limited to, the levels of domestic demand and gas liquefaction capacity and the volumes of LNG that can be sold on the global market. While total gas production grows in all four sub-regions, this occurs at very different speeds and reaches very different levels. The current concentration of production in West Africa (mainly Nigeria) is diminished over time, with the Southern Africa region (which includes Mozambique, Angola and Tanzania) overtaking it as the largest producing region around 2025. Overall, Nigeria produces over 40% of all sub-Saharan gas over the projection period, followed by Mozambique (20%) and Angola (13%). The remaining quarter of production is spread across more than 30 producers, led by Tanzania and South Africa, and smaller contributions from Equatorial Guinea, Côte d'Ivoire and Congo.

Table 2.8 ▷ Natural gas production in Africa in the New Policies Scenario (bcm)

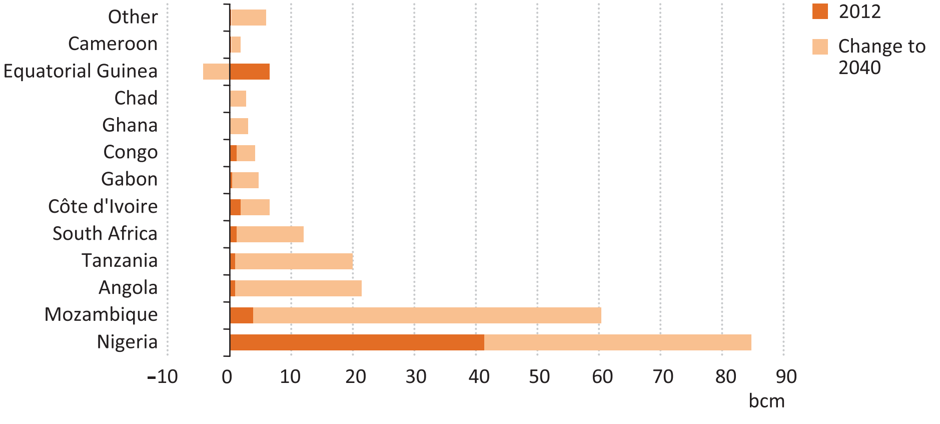
	2012	2020	2030	2040
Africa	**213**	**235**	**347**	**469**
North Africa	**154**	**157**	**186**	**240**
Sub-Saharan Africa	**58**	**78**	**161**	**230**
West Africa	43	48	69	98
Nigeria	41	45	60	85
Central Africa	8	9	13	16
Equatorial Guinea	6	5	3	3
East Africa	<1	<1	1	1
Southern Africa	7	21	78	114
Angola	<1	16	22	21
Mozambique	4	3	36	60
Tanzania	<1	<1	10	20
South Africa	1	1	9	12

Nigeria is, and remains, the largest gas producer in sub-Saharan Africa over the period, with production of 85 bcm in 2040. Nigeria's Gas Master Plan details the aim to increase domestic supply and to bring in new pricing and policy regulations, and provides a blueprint for gas infrastructure. The strategy is to anchor gas supply around "gas to power" in the immediate term while also developing a broader agenda for gas to support industrialisation and provide gas for export. One of the clearest examples is the envisaged Ogidigben gas industrial park in Delta State, which is estimated to require $15-20 billion in investment and includes gas processing, petrochemicals, fertiliser production and a gas-fired power plant. Also, Nigeria saw first production of gas-to-liquids at its plant at Escravos this year. Not all of the elements required to underpin the objectives of the master plan are yet in place, such as the necessary gas and electricity pricing mechanisms and appropriate upstream incentives. Within the New Policies Scenario, it is assumed that these will be forthcoming in time and that, in line with the Master Plan, domestic supply commands first priority. Following this approach, all incremental supply between 2020 and 2040 goes to the domestic market, of which 50% is for power generation and 30% goes to supply industry.

A critical uncertainty for Nigeria's gas supply outlook is its ability to stimulate significant production of non-associated gas. Huge resources exist, sufficient to cover both domestic demand and exports. Production of non-associated gas increases in our projection period, but it is gradual. Exploiting this resource requires a change in focus by the upstream sector and, importantly, the government to establish a framework to incentivise the necessary large-scale capital investment. This will require a stable, attractive investment environment generally and the development of a bankable commercial structure in Nigeria's gas sector which includes price reforms, improvements in regulatory arrangements, a redefinition of the role of public companies in the gas sector and an alternative to the current Nigerian National Petroleum Corporation (NNPC) joint venture financing model. Failure to achieve this would lower the supply outlook significantly.

Mozambique joins Nigeria as the other major gas producer in sub-Saharan Africa and, in 2040, these two countries collectively account for nearly two-thirds of regional production (Figure 2.17). Mozambique sees the largest growth in gas production in the sub-Saharan region, starting in the early-2020s, to reach 35 bcm in 2030 and 60 bcm in 2040, and is joined by neighbouring Tanzania (which also grows from the early-2020s to 20 bcm by 2040) to bring online a large source of supply on Africa's east coast. (See Chapter 3 for further analysis on natural gas outlook for Mozambique and Tanzania).

Figure 2.17 ▷ Natural gas production in sub-Saharan countries in 2012 and change to 2040 in the New Policies Scenario



Note: Production in Equatorial Guinea is 3 bcm in 2040, declining by around 3 bcm from 2012.

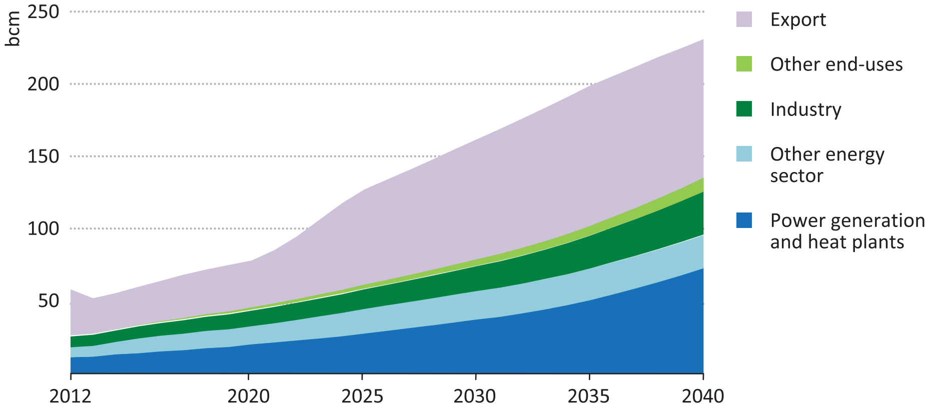
Angola has the third-largest proven gas reserves in sub-Saharan Africa (behind Nigeria and Mozambique) and yet is currently only a small producer. Like Nigeria, its primary focus has tended to be on oil, gas becoming a concern only recently. In the last decade, Sonangas (a state-owned company) has been established, increased action has been taken to limit flaring and reinjection and a process begun to establish a new regulatory framework. In the New Policies Scenario, production in Angola increases early in the projection period, with the stalled Angola LNG project achieving its expected export volumes in 2016, reaching around 20 bcm in 2025 and maintaining about that level to 2040. While production remains focused on associated gas, non-associated gas production also gradually comes on-stream.

South African supply increases from its current relatively low levels to reach 12 bcm in 2040, with new supply coming in the form of unconventional gas from the Karoo basin. While environmental concerns regarding water usage and hydraulic fracturing led to a moratorium on new exploration licenses being imposed in 2011, this has since been lifted and South Africa's cabinet has proposed new technical regulations to govern petroleum exploration, particularly standards for shale gas exploration and hydraulic fracturing. Implicit in these projections are the assumptions that exploration will provide a much clearer understanding of the geology and economics of the resource base, a commercial basis for production will be put in place and that environmental concerns will be addressed (see analysis on the future of the energy mix in South Africa in Chapter 3).

Gas production in Central Africa grows modestly, staying flat overall for the first decade of the projection period before gradually increasing to reach 16 bcm by 2040. Equatorial Guinea – the second-largest producer in sub-Saharan Africa today – is the only existing producer in the region whose output is lower than today in 2040, holding at around 6 bcm in the early years of the projection period, before gradually declining. The government has stated an ambition to construct more gas-fired power generation capacity and develop a domestic petrochemicals industry, but consideration of a second LNG train is at the feasibility stage, pending greater certainty regarding gas supply. Elsewhere in Central Africa, the outlook is more positive. Cameroon, Gabon, Chad and Congo all produce more gas in 2040 than in 2012, despite a reduction in oil supply. While volumes are insufficient for LNG exports, they are very significant relative to existing levels of domestic demand, pointing strongly towards a domestic-led gas strategy.

Many gas producers have stated that priority should be given to domestic power use and then, where volumes are sufficient, to other domestic sectors, such as industry, or to exports. However, in the New Policies Scenario around 40% of the growth in gas supply goes to exports (mainly Mozambique), while more than one-third goes to power generation and 13% to industry (Figure 2.18). The trade-offs between different uses of gas vary by country. In Mozambique, expected production volumes comfortably exceed domestic needs, even before accounting for the fact that it has other competitive power generation options (hydropower and coal). Tanzania's resources are smaller, meaning that decisions regarding gas use are more of a trade-off rather than a simpler question of balancing large resources across sectors. For a number of the other small producers, the scale of production is typically well in excess of domestic demand, and using gas for power generation would, in many cases, be replacing expensive liquid fuels. This makes it an attractive economic option, although not necessarily an easy option to implement.

Figure 2.18 ▷ **Destination of gas production in sub-Saharan Africa in the New Policies Scenario**



Notes: Other energy includes gas used in oil and gas extraction (largely for on-site power generation) and in refineries. Other end-uses include transport, residential, services, agriculture and other non-energy use.

Coal

Coal production in sub-Saharan Africa is projected to increase by around 50% by 2040, reaching 325 Mtce. South Africa continues to lead the way, seeing its production increase gradually over time (0.5% per year) to 240 Mtce, 75% of the regional total. But South Africa is joined increasingly by other countries in the region, at a low level initially but increasing by more than 7% per year to reach 30 Mtce in 2025 and 85 Mtce in 2040, a level similar to that of Latin American coal production today. Increased production outside of South Africa is led by Mozambique, where coking coal reaches 20 Mtce in 2040 (virtually all of which is exported) and steam coal reaches nearly 15 Mtce (around 65% is consumed domestically and the remainder is exported). Around 55% of sub-Saharan coal production in 2040 comes from greenfield projects, highlighting the importance of infrastructure development. Overall, the share of sub-Saharan coal production retained for domestic consumption remains steady at around two-thirds, albeit at an increasing level of supply.

A key factor in sub-Saharan coal resource development – particularly in Southern Africa – is the remoteness of the coal fields and the present lack of suitable railway and port infrastructure. Future production increases are driven primarily by growing domestic coal demand and (except in the case of Mozambique) to a lesser extent by export considerations. For Zimbabwean coal, transport distances to export ports are 1 400-2 200 km and for Botswana 1 300-1 500 km; but in neither case is there sufficient railway infrastructure in place. The Waterberg, a coal field in South Africa's northern Limpopo province, is considered a key growth centre for South Africa's future coal production and yet shares a similar constraint, as it is 1 300 km away from the port of Richard's Bay. Compared to major coal exporters like Colombia, Indonesia or Australia, these distances are very long, although shorter than those in the United States or Russia (where the transport infrastructure exists).

Investment in export infrastructure has been proposed, but the railway development cost is high and, since coal-rich countries like Botswana and Zimbabwe are land-locked, co-ordination and commitment will be required from both the producing countries and the terminal countries. Such large-scale cross-border infrastructure investments can be secured with long-term take-or-pay contracts but they typically require political stability over many decades as a prerequisite. Moreover, development at such a scale would require modern technology and a skilled workforce.

Low mining costs – in the range of $10-30 per tonne – are a key element in decisions to undertake production, either for domestic consumption or export markets. Much of the coal in Southern African has high ash content and would require upgrading to cut transportation costs and bring it to international quality standards. This poses two additional problems that would need to be overcome: scarcity of water may impede washing (or drive the washing costs up) and the process results in at least two distinct coal fractions of very different value (product for export and low rank coal that would need to find a domestic market or be disposed of). The free on board (FOB) cash-cost of coal from Botswana, Zimbabwe or the South African Waterberg is expected broadly to fall in a range of $60-80 per tonne, which is comparable with other long-term supply options for the international market, like the Galilee Basin in Australia. However, the Galilee Basin benefits from an established and efficient coal mining industry, economies of scale, political stability and cash-rich investors from India and China.

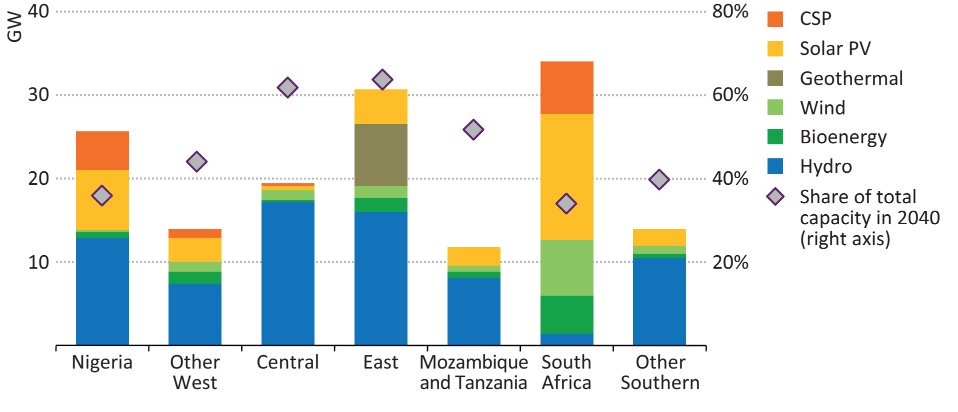
Yet, the outlook for coal production in the Southern Africa region is not as bleak as it may appear. Mozambique has seen rapid development of a coal export industry, driven by large private sector investors, like Vale. Mozambique has good quality coking coal reserves that command a higher price than the steam coal prevalent in neighbouring countries. Furthermore, by Southern African standards, the transport distances are relatively low (600-900 km). That being said, the existing infrastructure has reached its limits and profitability is low at today's coal prices. Sufficient economies of scale and further export growth hinges crucially on the development of a new railway line and deepwater port (e.g. the proposed corridor to Nacala in northern Mozambique). The remote South African Waterberg region, near the border with Botswana, hosts one of the largest coal mines in the world and a project to expand the railway line that links the Waterberg with the main coal fields in the Witbank region (east of Pretoria) is underway. Most of the coal that leaves the Waterberg will be consumed in domestic power plants but, depending on how fast output and shipments increase, this could in turn free-up coal in the Witbank region for export and indirectly boost coal exports. Madagascar also has production coming to fruition in the projection period, with the most promising coal fields located 150-200 km from the Western shoreline. Moreover, there are coal-fired power plant projects in the pipeline in most of Southern Africa's countries. These projects rely on domestic coal or land borne imports from neighbouring countries and support low but steady growth for the regional mining industry.

Renewables

Sub-Saharan Africa has untapped renewable resources which could deliver levels of supply in excess of domestic consumption to 2040 and far beyond. In the New Policies Scenario, energy supply from renewables (including bioenergy) increases by nearly 65%, to reach around 585 Mtoe in 2040, but its share of total energy supply decreases to below 60% (the share excluding bioenergy increases from 2% to 9%, reflecting a gradual reorientation of the energy mix). The supply of solid biomass for cooking continues to dominate the overall picture for renewables. However, the power sector sees rapid growth of renewables-based capacity, which grows from around 20 GW to nearly 170 GW. Renewables account for more than 50% of the increase in total capacity over the projection period. The share of renewables-based capacity in the power mix increases from 21% to 44%. This share is higher in 2040 than that of China, the United States or India. Bioenergy finds its way increasingly into industry to produce heat for industrial processes accounting for around one-third of industrial energy consumption in 2040; but, in the absence of supportive policies and supply infrastructure, biofuels play no more than a minor role in transport across the region.

Renewables supply expands across sub-Saharan Africa, with South Africa, Nigeria and East Africa leading the way (Figure 2.19). Nigeria already has plans to expand hydropower and in the New Policies Scenario, accounting for half of its total renewables expansion, and also with a significant increase in solar capacity (PV and CSP), mainly in the second half of the projection period. Elsewhere in West Africa, renewables make up over 40% of electricity generation by 2040, mainly from hydropower, but also from solar PV, wind and bioenergy.

Figure 2.19 ▻ Increase in renewables-based capacity by sub-region and type in sub-Saharan Africa in the New Policies Scenario, 2012-2040



Central and East Africa see a similar increase in hydropower capacity (over 16 GW), despite Central Africa having much the greater overall potential. East Africa leads the way in geothermal capacity, with a significant increase in Kenya, followed by Ethiopia, and, to a much smaller degree, in wind; but solar plays only a small role, despite strong technical potential. South Africa – consistent with its Integrated Resource Plan to 2030 – sees a large increase in solar and wind capacity, with capacity auctions already underway. While South Africa does not significantly increase its hydropower capacity, it does import increasing volumes of hydropower from other parts of Southern Africa and Central Africa.

Bioenergy

Supply grows to meet a 40% increase in bioenergy demand in the New Policies Scenario, reaching 490 Mtoe in 2040 – one-quarter of world demand at that time. The rate of growth slows over the projection period as different factors interact. On one hand, growth is restrained by a shift towards other fuels for cooking and improved cookstoves that consume solid biomass more efficiently (see Chapter 3). On the other, a rising urban population boosts charcoal consumption relative to fuelwood (Box 2.2) and, despite greater use of semi-industrialised kilns over time (improving the conversion efficiency), this also boosts fuelwood demand. Biogas, biofuels and pellets collectively account for just 6% of total supply in 2040. Fuelwood, charcoal and waste dominate the picture, with over one billion tonnes of wood needed to meet demand (including that which is lost in the charcoal conversion process) (Table 2.9).

Table 2.9 ▷ Forest biomass stock and fuelwood* consumption in sub-Saharan Africa in the New Policies Scenario

	Forest area per capita (ha/cap)	**CAAGR**	**Biomass forestry stock** (Gt)	**Fuelwood consumption** (Mt)	
	2010	**1990-2010**	**2010**	**2012**	**2040**
Sub-Saharan Africa	**0.7**	**-2.7%**	**132**	**694**	**1 071**
West Africa	0.3	-2.6%	14	247	389
Nigeria	<0.1	-5.6%	2.5	147	253
Central Africa	2.4	-3.1%	75	75	142
East Africa	0.4	-3.5%	6	218	291
Southern Africa	0.9	-2.7%	37	153	250
South Africa	0.3	<0.1%	1.7	36	40

* Includes fuelwood consumed directly by households and fuelwood used to produce charcoal.

Notes: ha/cap = hectare per capita; CAAGR = compound average annual growth rate; Gt = gigatonnes; Mt = million tonnes. Sources: FAO (2010); IEA analysis.

While wood is considered as renewable, it is exhaustible unless used carefully and stocks managed sustainably. In 2010, the total forest biomass stock (including dead wood) in sub-Saharan Africa is estimated to have been around 130 billion tonnes. However, even an annual consumption rate that is equivalent to 1% or less of the existing stock should not be taken to imply that current levels of use are sustainable. Forest biomass stock is not uniformly spread across the region, and so may be relatively abundant in some areas while scarce elsewhere. Current levels of consumption are already reducing the stock of biomass in some regions of sub-Saharan Africa, but the exact extent and the implications vary.

Box 2.2 ▷ Charcoal production and the size of the market

The availability of wood in many parts of sub-Saharan Africa at low or no-cash cost relative to alternative energy sources is a crucial factor in its status as the fuel of choice for a large part of the sub-Saharan population. In addition, its supply can be an important source of employment and therefore income for the local population. The charcoal industry, for example, creates jobs for wood producers, charcoal producers, transporters and vendors. In Rwanda, in 2007, the value of transactions at fuelwood and charcoal markets was estimated to be $122 million, amounting to 5% of GDP, 50% of these revenues stayed in the rural areas.

Within urban areas, charcoal is a popular fuel choice as it offers higher energy content per weight than wood, making it easier to transport, store and distribute. Over the projection period, the urban population increases by 560 million people, driving up charcoal demand and thereby diminishing the availability of fuelwood, unless it is produced sustainably. At present the conversion of fuelwood to charcoal is highly inefficient in sub-Saharan Africa, as most of it is produced using traditional earth-mound kilns that have a conversion efficiency of 8% to 12%, compared to industrial kilns, which have an efficiency of above 25%. However, such improved kilns increase the unit costs of charcoal production even though the amount of charcoal produced is higher and negative environmental impacts are reduced. Policies and effective regulation of the charcoal market are needed to increase the share of more efficient kilns as the charcoal market is not expected to diminish in the future. As in the case of improved cookstoves, greater adoption of improved kilns will depend upon the availability of simple, small-scale, fast-cycle and economical charcoal producers.

In the New Policies Scenario, we have assumed a smooth switch from traditional kilns to more efficient ones at varying rates in the sub-Saharan regions. As forest reserves around towns are exhausted, wood for charcoal must be sourced from further away, increasing the transportation costs and the price to the consumer. Charcoal prices have increased in recent year across Africa, but price changes rarely reflect shifts in the availability of the fuel. In 2012, charcoal production in sub-Saharan Africa is estimated to have amounted to 36 million tonnes, with an estimated market value of $11 billion. In the New Policies Scenario, a combination of increasing levels of consumption and higher prices result in the market value growing to almost $70 billion by 2040. The large size and unregulated nature of the charcoal industry can lead to criminal activity. For example, in DR Congo the industry is a lucrative source of illicit income that provides funding to militias (UNEP and INTERPOL, 2014).

Since 1990, Nigeria has experienced a decrease of its forest area in excess of 3% per year, one of the highest deforestation rates observed on a global scale. Loss of almost 50% of its forest area has resulted. Some other countries in West Africa have also seen significant reductions in their forest area, such as Togo, which experienced a decrease of more than

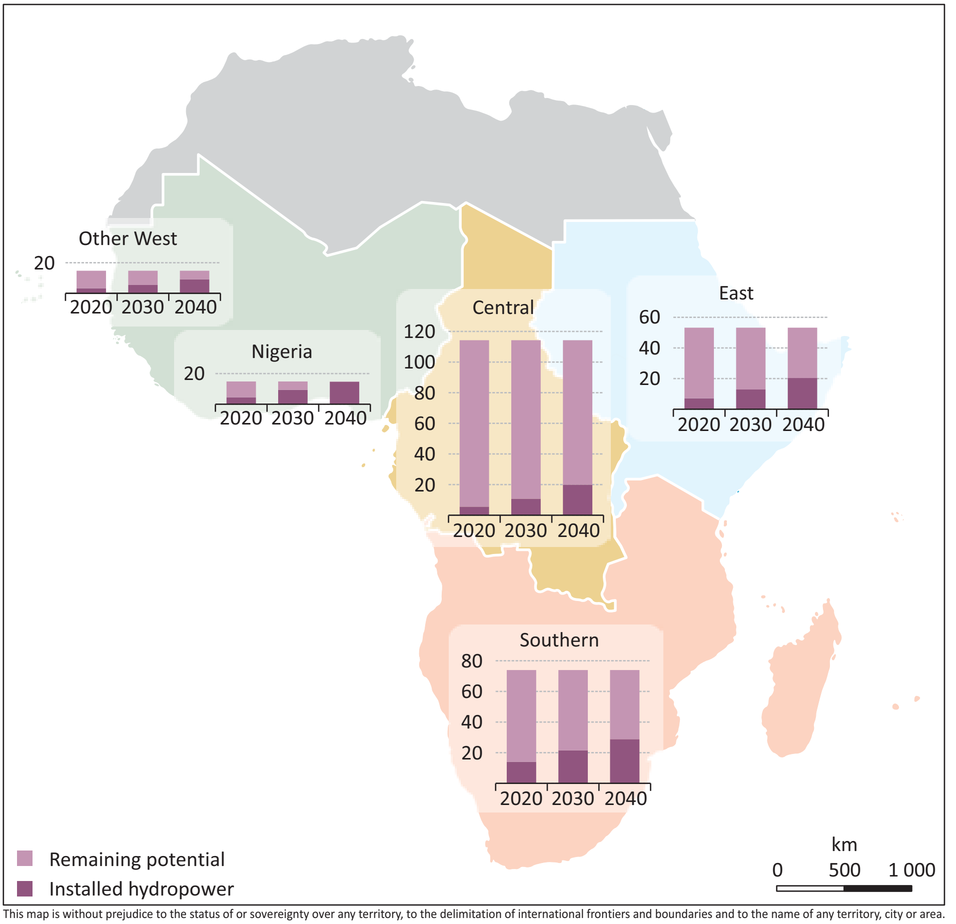
4% per year between 1990 and 2010. In East Africa, there has been a decrease of just 0.6% per year over the same period, though the forest area per capita is lower than in many other parts of Africa. But the situation is not uniform across eastern countries. The deforestation rate in Uganda has been increasing since 1990, reaching almost 3% per year between 2005 and 2010, while the forest area in Rwanda has increased over the same period (see the energy and environment section). Scarcity of fuelwood around cities and villages increases the distance that people must travel to collect it, amplifying the burden that often falls on women and children. Currently, people spend from less than one hour to up to five hours daily collecting wood. Overall, the extent to which the use of solid biomass in sub-Saharan Africa could be considered sustainable is doubtful. Besides contributing to land degradation, the typical partial combustion of fuelwood emits carbon dioxide, methane and black carbon, and is a major cause of indoor air pollution, with damaging health effects.

Hydropower

In the New Policies Scenario, installed hydropower capacity in sub-Saharan Africa increases from around 20 GW in 2012 to nearly 95 GW in 2040, and accounts for one-quarter of the growth in total power generation capacity. Capacity grows by more than 7% per year to 2020, then slows to around 6% per year in the 2020s and below 5% in the 2030s. Sub-Saharan Africa's share of world hydropower capacity increases to 5% and hydropower's share of regional electricity generation increases from 22% to 26%. In West Africa, Nigeria is developing its hydropower potential (Mambilla and Zunguru projects) and is expected to continue to do so to help meet rapidly rising electricity demand. In the New Policies Scenario, its capacity increases to around 15 GW by 2040, utilising by this time, most of its remaining economically viable hydropower potential (Figure 2.20). In the rest of West Africa, expansion occurs across several countries, including Côte d'Ivoire, Ghana, Guinea, Niger, Senegal and Sierra Leone, drawing on resources such as those of the Niger and Senegal river basins (although this is highly seasonal). The highly seasonal river flows in parts of this region lead to relatively low average capacity factors for hydropower. By 2040, capacity in other West Africa countries reaches 9.4 GW, leaving several gigawatts of untapped potential in 2040.

Central Africa has the richest hydropower resources in Africa (concentrated in but not limited to, DR Congo). However, presently it does not have sizeable demand centres and lacks interconnections that would be essential for large hydropower development. The Congo River – the main source of hydropower potential – has strong and relatively stable flows throughout the year, lending itself to power generation. In the New Policies Scenario, Inga III reaches full output by the mid-2020s and early phases of Grand Inga come online before 2040. However, the scale, cost and complexities of Grand Inga give rise to significant uncertainty regarding its development. If it is pushed ahead vigorously, it can be transformational for sub-Saharan electricity supply (see Chapter 4). Smaller scale hydropower comes online elsewhere, for example in Cameroon and Gabon. Overall, Central Africa sees capacity grow from 2.6 GW to 20 GW in 2040.

Figure 2.20 ▷ Sub-Saharan hydropower capacity and remaining potential in the New Policies Scenario (GW)



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: IPCC (2011); IJHD (2009); IJHD (2010); IEA analysis.

In East Africa, there is already a lot of activity underway to expand hydropower capacity, with Ethiopia dominating the picture. In the New Policies Scenario, Gilgel Gibe III and IV and the Grand Renaissance dam make the largest contributions to the increase in hydropower capacity, which reaches 20 GW by 2040; but capacity is also expected to grow in Sudan and Uganda. Several countries in Southern Africa have significant untapped hydropower potential, especially those in the Zambezi River basin, such as Mozambique, Angola, Zambia and Zimbabwe. The Southern Africa Power Pool has plans for the expansion of hydropower: developments are already underway at Cambambe (Angola) and Kafue Gorge (Zambia) and other major projects are also being taken forward in Tanzania and Mozambique, for example. Overall, hydropower capacity in Southern Africa more than triples to reach 29 GW by 2040, with 11 GW located collectively in Mozambique and Tanzania.

Large hydropower naturally accounts for the bulk of installed capacity, with small hydropower projects playing a growing role in terms of the number of projects. Small hydropower projects are, in a number of circumstances, an attractive option because they take less time to build, require less capital and can often be located near demand centres. Some parts of Africa experience significant seasonal hydropower variability and water stress, including occasional periods of prolonged drought. For dam-based projects, reservoirs can help manage the variability of water flow but entail additional social and environmental concerns that need to be diligently addressed. In some cases, water availability may be limited due to requirements for other uses, such as irrigation.

Two key factors dictating the pace of large-scale hydropower development are the availability of finance and the degree of regional co-operation. The fiscal positions of many sub-Saharan countries puts funding for such projects beyond their own capacity, which often makes access to bilateral, multilateral and international private finance necessary. Effective regional co-operation typically involving inter-state agreements can make large projects viable by aggregating demand to the level necessary for a viable commercial case for investment. It also offers opportunities to share the output and benefits among countries to address electricity supply deficits and support economic development.

Solar power

In the New Policies Scenario, sub-Saharan Africa progressively taps its vast solar potential with South Africa and Nigeria installing most new capacity. Sub-Saharan solar capacity exceeds 6 GW by 2020 and is around 45 GW in 2040, with solar PV then accounting for nearly three-quarters of the total and CSP the remainder. Solar capacity additions rise from around 0.9 GW per year on average to 2020 and then to 2.2 GW per year on average thereafter. By the end of the projection period, solar (PV and CSP) accounts for 12% of total capacity and 6% of electricity supply. South Africa has a clear intention to increase the role of solar power and around half of the total capacity in sub-Saharan Africa in 2040 is located there, taking advantage of excellent solar resources. Solar PV in South Africa grows strongly over the entire projection period (reaching 15 GW by 2040), while CSP capacity comes online from around the mid-2020s (reaching 6 GW in 2040). Nigeria's solar capacity increases to 12 GW in 2040, nearly one-quarter of peak electricity demand at that time. In other parts of sub-Saharan Africa, solar capacity increases steadily, but, despite significant cost reductions over time, its growth is still held back in places by its expense relative to competing fuels and technologies.

Other renewables

Potential supply of energy from geothermal resources is limited to the East African Rift Valley. It is already proving itself to be a valuable element in the generation mix in Kenya and other countries have stated their intention to explore their national potential. In the New Policies Scenario, East Africa's geothermal capacity grows to over 1 GW in 2020, more than 3 GW in 2030 and around 8 GW by 2040 – an average rate of 0.3 GW capacity additions per year, but weighted towards the second-half of the projection period. The costs of geothermal-based electricity are competitive with thermal power generation and it has a high capacity factor, although regular drilling of new wells is often required. By 2040, geothermal sources make up nearly 15% of East Africa's power generation capacity. While development remains centred in Kenya, developments occur also in other countries over time, including in Ethiopia, Rwanda and Tanzania.

Wind power capacity in sub-Saharan Africa increases by around 12 GW by 2040 in the New Policies Scenario, with average annual capacity additions of 0.5 GW. South Africa is most active in developing wind capacity, with average annual capacity additions of 0.3 GW, to reach 2 GW in 2020 and nearly 7 GW in 2040 (more than half of the sub-Saharan total). Most of the wind development is located onshore. All other sub-regions introduce wind capacity, but to a smaller extent and typically later in the projection period. Capacity factors are around 26-27%, on average, which is comparable to that of many other parts of the world. Wind accounts for just over 3% of total power generation capacity and 2% of electricity supply in 2040. Factors holding back a more rapid expansion of wind capacity include the lack of a developed wind power industry in most countries and constraints on the ability (or desire) of many countries to manage a significant volume of variable capacity within their systems.

International energy trade

The growth in sub-Saharan energy demand and supply that is projected in the New Policies Scenario affects not just the region, but also the balance of its energy trade with the rest of the world. This is felt in a gradual decline in crude oil exports, as well as a rise in net oil product imports, although net exports of natural gas and of coal both grow as the increase in production (notably in Mozambique) outpaces that of regional consumption. With all exported commodities, there is a shift in destination markets, away from the Atlantic basin and towards the major import markets of the Asia-Pacific.

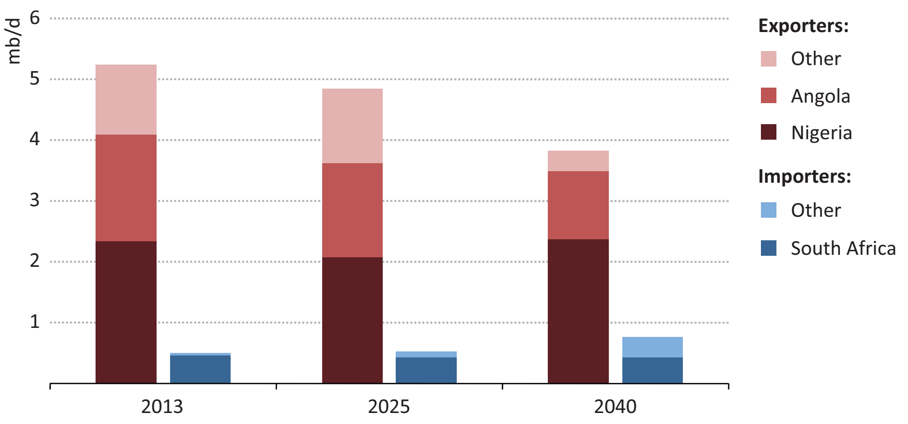
Crude oil

There is a shift both in volumes and in destination for crude oil exports from sub-Saharan Africa to other parts of the world. Net crude oil exports, which remain dominated by Nigeria and Angola, decline by 1.7 mb/d to just over 3 mb/d in 2040 (Figure 2.21). This is due to the decline in overall output, and to increased volumes of African refining to meet the increase in regional consumption. Of the major exporters, only Nigeria manages to keep exports at a similar level in 2040 compared with today, as the eventual rise in oil production keeps pace with the increase in refinery runs to 450 kb/d. Angola's crude oil exports decline by a third to just over 1 mb/d, as production declines and refinery runs increase to 200 kb/d.[5] All the other countries that are currently net crude exporters either become net importers by 2040 to feed crude into their refineries (Cameroon and Sudan), or they see exports dropping significantly (Chad, Congo, Equatorial Guinea, Gabon, Ghana

5. Nonetheless, our projections suggest that Nigeria remains a net importer of oil products in 2040 while Angola becomes a net oil product exporter.

and South Sudan). In terms of external markets, exporters on Africa's west coast face a rapidly changing picture with the continued growth of production in North and South America over the coming decades.

Figure 2.21 ▷ Sub-Saharan Africa crude oil exports and imports in the New Policies Scenario



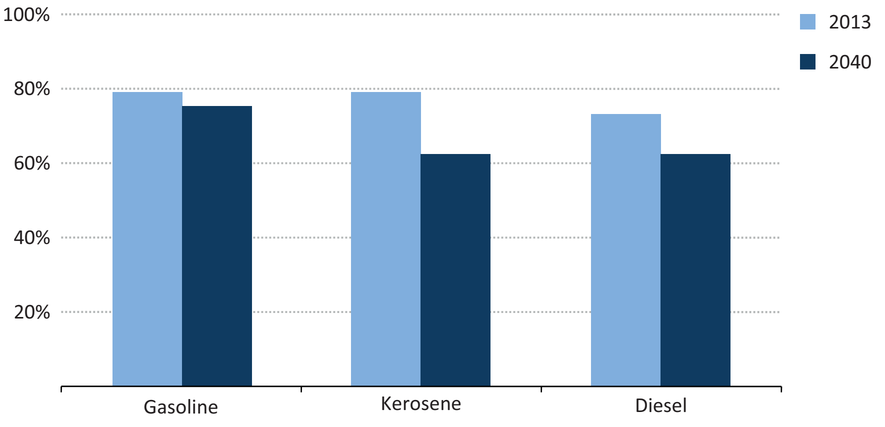
Note: This includes only exports and imports to/from countries outside of sub-Saharan Africa.

As noted in Chapter 1, exports from Nigeria and Angola to the United States have reduced by two-thirds since 2008. We project that westward export volumes continue to shrink in aggregate, although Europe continues to be an important market, but that a larger share of exports are drawn eastwards towards Asia, to India, China and South Asia. Among those buying crude from international markets, Kenya becomes a significant importer (of about 120 kb/d in 2040) as we expect a refinery to be built here for the growing and highly undersupplied East African market, but South Africa remains the largest buyer of international crude. It supplies its refineries mainly with crude imported from the Middle East, a trade flow that is expected to continue, although with a greater share of West African crudes added to the mix.

Oil products

In the New Policies Scenario, we assume that 400 kb/d of current refining capacity in sub-Saharan Africa is eventually shut down, sufficient investments are made to upgrade the remaining capacity for higher runs, and another 0.8 mb/d of new refinery capacity comes online between now and 2040. The net result is that total product imports increase in volume terms to reach 1.8 mb/d in 2040, but overall dependence on imports (as a share of regional demand) for some key oil products edges lower (Figure 2.22). With the exception of a couple of countries with very small local markets and a working refining system, all countries in sub-Saharan Africa are expected to remain net importers of oil products.

Figure 2.22 ▷ **Import dependence for selected oil products in sub-Saharan Africa (excluding South Africa) in the New Policies Scenario**

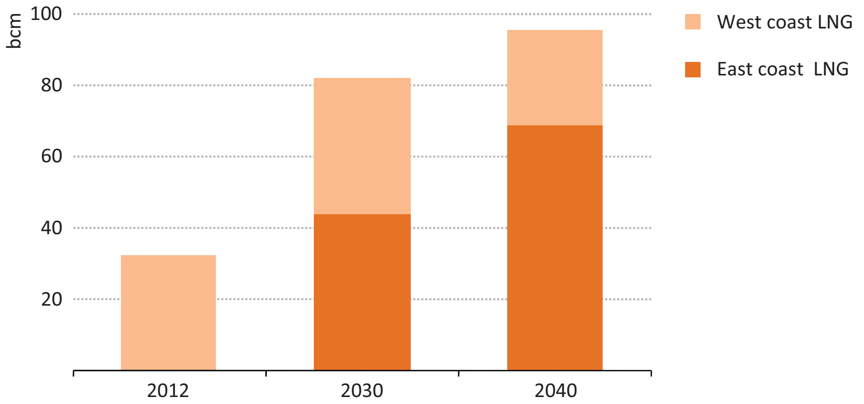


What are the implications of these projections for the security of oil product supply? With domestic demand set to more than double in the projection period, product imports would increase to 2.7 mb/d if no new refining capacity were added and if existing refineries did not ramp up runs. Such high reliance on imports would bring with it some important hazards: oil products imports to Africa come primarily from European and US ports for West Africa, and from the Middle East or India for East Africa, some 5 to 20 sailing days away. The flow of products can be disrupted for a variety of reasons, affecting either the physical availability of the product or its transportation: a refinery going into an unplanned shutdown or an unexpectedly cold winter spell might affect the supply of gasoline, diesel or kerosene. In addition to the shipping distance from major refining hubs, very often an importing country in Africa (and, often, its land-locked neighbour) depends on a single jetty in a sole coastal terminal to unload all imported products: this is the case, for example, in Ghana. Land-locked countries are particularly vulnerable to the risks of long-distance supply lines: inland storage capacity is inadequate and product pipelines largely non-existent. Experience shows that the effects of a supply disruption or of bottlenecks in transportation are felt quickly by end-users, either through higher prices or physical scarcity. Setting up emergency stocks can offer a buffer against this risk, but these are expensive and can be difficult to develop in markets where demand is growing.

Natural gas

In the New Policies Scenario, sub-Saharan Africa's net contribution to inter-regional natural gas exports triples, growing from 31 bcm in 2012 to around 95 bcm in 2040 (Figure 2.23). The focus also changes from the west coast of Africa to the east coast, with the rise of LNG exports from Mozambique and Tanzania (discussed in detail in Chapter 3). Africa's west coast remains a steady source of LNG exports to global markets, but does not see scope for the sort of expansion that is anticipated in Nigeria, where four new LNG projects are under consideration (Brass LNG, OK LNG and trains 7 and 8 at Nigeria LNG). There are sufficient gas resources to satisfy a greater volume of export projects in Nigeria, as well as meeting projected domestic demand (only around one-quarter of ultimately recoverable gas resources have been used in Nigeria by 2040 in our projections). However, the government faces a challenge to mobilise the necessary upstream investment and, even if the netback prices are less attractive, the government is assumed to prioritise domestic supply over export.[6] Overall LNG exports from Nigeria fall to 13 bcm in 2040, a level that could, in principle, be supplied from today's liquefaction capacity.

Figure 2.23 ▷ LNG exports from sub-Saharan Africa in the New Policies Scenario



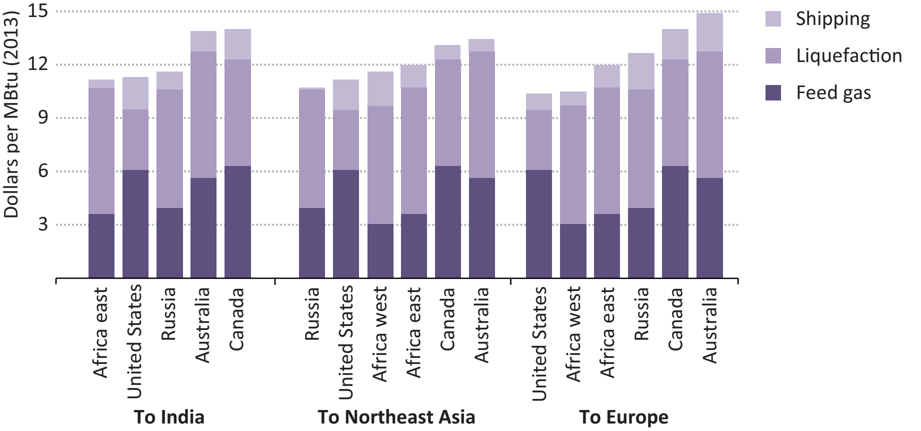
As with oil, the anticipated markets for LNG exports from the west coast have shifted with rising production from North America. Atlantic basin LNG markets have become less attractive and more competitive; Europe is the main remaining importer, although there are smaller opportunities available also in Latin America. Being based mainly on relatively cheap associated gas, these LNG projects can absorb some of the additional costs of seeking more distant export markets. Although more expensive to produce, LNG projects on the east coast of Africa are much more advantageously positioned in relation to the main sources of LNG import growth in Asia, in particular India, although slightly less so for Northeast Asia, because of the additional distance (Figure 2.24).

As a new source of gas, Mozambique and Tanzania are of interest to buyers as a means of diversifying their LNG portfolios. The task of marketing the gas in Mozambique is eased by the presence of large Asian importers in the main producing consortia, including companies from China (CNPC), India (ONGC, Bharat Petroleum and Oil India), Thailand (PTT), Japan (Mitsui) and Korea (KOGAS). Geography also helps, with LNG delivery distances meaning that those exporters on Africa's east coast are well placed to benefit

6. As a 49% partner in the LNG facilities, the government gains significant benefit from gas exports, sharing in the margin between the domestic supply price and the international LNG price, in addition to receipt of taxes and royalties. However, it is assumed that political factors (including the importance of improved electricity supply) and a gradual increase in domestic gas prices outweigh these factors.

from arbitrage between Asia-Pacific markets and Europe (the position currently enjoyed by Qatar). Indeed, we project that, although most east coast LNG export volumes go to Asian markets, a small share ends up going to meet Europe's gas import needs.

Figure 2.24 ▷ Indicative delivered costs of LNG from selected sources to Europe and main Asian import markets, 2025



Notes: MBtu = million British thermal units. Africa east is LNG exports from sub-Saharan Africa's east coast. Africa west is LNG exports from the west coast. Cost estimates are indicative and figures for specific projects could vary significantly, depending on their detailed design. The calculation of life-cycle costs is based on generic capital and operating cost assumptions, including a 10% discount rate and 30-year asset lives.

The anticipated evolution of the LNG market does present some challenges to Africa's exporters, particularly around the end of the current decade, when the project developers in both Mozambique and Tanzania plan first LNG deliveries. The competition for LNG buyers looks set to intensify into the early 2020s, as the first wave of Australian LNG is followed by projects in the United States, Canada and Russia, as well as the anticipated start of pipeline deliveries from Russia to China. The 2018-2019 start dates for LNG delivery claimed by the consortia in both Mozambique and Tanzania, if realised, would give the them a head-start against some of these competitors; but the risk of delay is substantial in these remote locations with very little local infrastructure or industrial capacity to support construction. In the New Policies Scenario, it is assumed that the first four trains of Mozambique LNG and a floating LNG facility are fully operational only by the late-2020s, with the first LNG train in Tanzania becoming operational in the same period.

In addition, against a backdrop of high prices for imported LNG, buyers in the Asia-Pacific region are also looking for concessions on pricing from prospective LNG suppliers. Anadarko, operator of Mozambique's Area 1, has already indicated that pricing formulas for Mozambique LNG export may be indexed, in part, to gas prices at Henry Hub, as well as to oil prices. This would make the delivery price for Mozambique's LNG more sensitive to the supply-demand dynamics in gas markets (albeit those in North America) rather than to the average Japanese crude import price, which has been the preferred index for pricing LNG supplies to the Asian market in the past.

Coal

South Africa is the sixth-largest coal exporter in the world, providing (almost exclusively) steam coal to the international market. It has seen its share of international steam coal trade decrease in recent years, going from 14% in 2003 to 8% in 2012. South Africa also used to be the main supplier of coal to Europe but, over the last few years, has seen its exports flow increasingly to the Pacific basin, where demand is growing more quickly and prices are higher. South Africa benefits from a position at the low end of the global cost curve, with FOB costs broadly falling in a range of $40-70 per tonne. It also has a favourable geographical location that allows exporters to supply into both the Atlantic and Pacific basins at a reasonable freight cost. Despite these advantages, the South African coal industry is facing problems that have held back export growth. Production from the major current producing areas, in Mpumalanga province, is set to decline, necessitating a shift towards the abundant but more distant Waterberg fields, near the border with Botswana. This means major new investment in railway transportation, shortage of which is already a constraint on export: throughput capacity at Richard's Bay Coal Terminal, has been lifted to over 90 million tonnes per annum (Mtpa), but the 580 km railway line linking the main existing mining area to the port is constrained at around 72 Mtpa and other ports can handle only small quantities. Assuming that these constraints can gradually be lifted, South African coal exports increase to almost 100 Mtce in the New Policies Scenario in 2040, with the majority destined for India.

Mozambique is the second-most important player when it comes to coal in Africa. However, in contrast to South Africa, its prospects lie mainly in coking coal and therefore follow a different dynamic. For the moment, the lack of export infrastructure has impeded a rapid increase of exports. The idea of barging coal down the Zambezi River has been ruled out by the Mozambican authorities due to environmental concerns, so the main transport option to bring the coal to port is the railway. The existing 590 km Sena railway line that links the Tete coal fields with the port of Beira is currently constrained to around 6 Mtpa. To foster further increases in exports, capacity expansion and additional infrastructure is needed; the preferred route is the so-called Nacala corridor, a 900 km railway line crossing southern Malawi to link the mines with a new deepwater terminal at Nacala. In the New Policies Scenario, exports from Mozambique are projected to increase from around 3 Mtce in 2012 to around 30 Mtce in 2040, the majority being coking coal. As with South Africa, the natural destination for the coal is India, but Brazil is also expected to be a market for Mozambique's coal export.

Coal production in other Southern African countries like Botswana, Zimbabwe or Zambia is also set to increase, but exports remain small scale, mainly involving land borne trade with neighbouring countries. Due to the remoteness of the coal reserves and the land-locked geography of these countries, infrastructure requirements to provide access to the seaborne market would be huge. Madagascar is an exception, with the proposed coal mines being located only 150-200 km from the coast. However, political instability has so far prevented any export-oriented coal operation coming to fruition.

Energy and the environment

The energy projections in the New Policies Scenario have a wide range of environmental implications, both in terms of local impacts in Africa and the much broader issue of global climate change. These can include: energy-related greenhouse-gas emissions, such as from power generation and transport; local pollution, particularly in growing urban areas; indoor air pollution, as the widespread traditional use of solid biomass for cooking continues; deforestation and land degradation as the result of unsustainable practices to cater for fuelwood and charcoal consumption; other forms of environmental degradation, such as from open-cast mining or oil spills resulting from oil theft or sabotage; a range of environmental considerations linked to new hydropower projects (especially those with reservoirs); emissions from the venting or flaring of natural gas (Box 2.3); and, handling and storage of potentially harmful waste or by-products from energy-related processes, such as nuclear waste. While all of these are important factors for policymakers to monitor and tackle, and often require ongoing social engagement, this section concentrates on two, energy-related carbon dioxide (CO_2) emissions and the environmental consequences of sub-Saharan Africa's heavy reliance on solid biomass.

Box 2.3 ▷ Natural gas flaring in sub-Saharan Africa

Around 28 bcm of natural gas (primarily consisting of methane, a potent greenhouse-gas) is estimated to have been flared or vented in sub-Saharan Africa in 2012, a volume that, had it all been consumed in gas-fired (CCGT) power plants could have increased sub-Saharan electricity supply by around 35% (nearly 155 TWh).[7] Nigeria accounted for around 60% of the gas flared in 2012 (around 17 bcm), and Angola, Congo and Gabon for much of the remainder. Flaring reduction (and gas utilisation) has become a greater policy focus in several sub-Saharan countries, as they recognise its wasteful nature in the face of growing domestic energy needs, as well as its potential to generate revenue from the utilised gas and its negative environmental effects. Just one example of the positive action being taken is the membership of Nigeria, Angola, Congo, Gabon and Cameroon in the Global Gas Flaring Reduction Partnership, an initiative that supports national efforts to use currently flared gas by promoting effective regulatory frameworks and tackling the constraints on gas utilisation.

The New Policies Scenario sees volumes of flared and vented gas in sub-Saharan Africa reduce over time, reaching around 15 bcm in 2025 and less than 10 bcm by 2040, as a result of both positive policy efforts (such as pricing and regulatory reforms that incentivise marketing of the gas), declining production in some of the oil fields where flaring takes place today and greater action to avoid or minimise flaring in new fields. While actions taken in Nigeria are the most important (see Chapter 3), other countries also contribute to the declining trend. In aggregate, countries other than Nigeria are expected to reduce flaring to around 5 bcm by the early 2020s and continue to decline

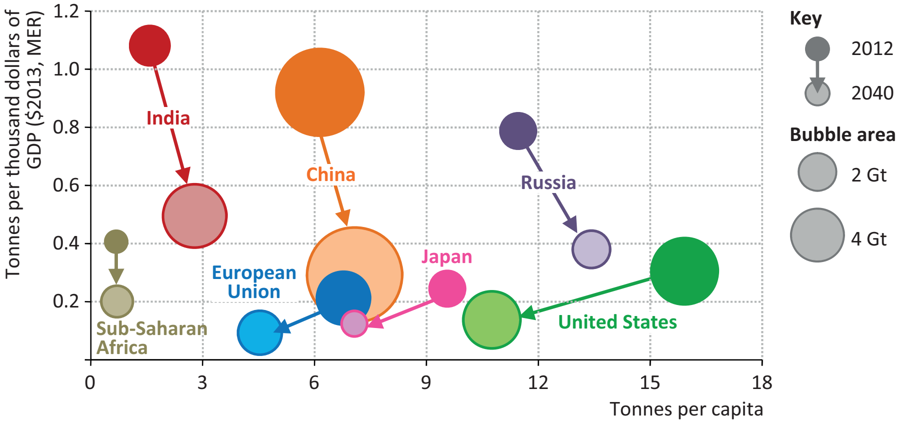
7. Assuming plant efficiency of 57%, the CCGT fleet average in sub-Saharan Africa.

gradually thereafter. Central to this trend is Angola's plan to commercialise more of its natural gas reserves through its LNG facility at Soyo (which is due to come back into operation from 2015). When the LNG plant reaches full capacity, it is designed to receive up to 10 bcm per year of mainly associated gas from offshore oil fields, contributing to a significant reduction of gas flaring in the country. Gabon has already introduced penalties to curb gas flaring but these have yet to be enforced. Following government encouragement, the country's largest operators have launched their own gas flaring reduction programmes. In Congo, the government has imposed requirements to reduce gas flaring, which have already decreased volumes by around 40% from their 2005 peak (over 2 bcm). Furthermore, gas that would previously have been flared has been used to fuel two power plants.

Energy-related CO_2 emissions

Sub-Saharan Africa accounts for only a very small share of cumulative historical energy-related CO_2 emissions: in the 1900 to 2012 period, the region was responsible for 1.8% of the global total (0.6% if South Africa is excluded). In the New Policies Scenario, energy-related CO_2 emissions double in sub-Saharan Africa, reaching 1.2 gigatonnes (Gt) in 2040. The region's share of global emissions increase from 2% to 3%, while emissions per capita barely change, remaining below 0.7 tonnes per capita in 2040, around 15% of the global average (Figure 2.25). The economies of sub-Saharan Africa in 2040 are, on average, only half as carbon intensive as they are today, as economic growth encompasses a shift towards less energy-intensive economic activity, including services. Rising levels of access to modern energy have a negligible impact on emissions, with the improvement in electricity access accounting for around 10% of the increase in sub-Saharan emissions (around 70 Mt) or just over 1% of the increase in global emissions from now to 2040.

Figure 2.25 ▷ Energy-related CO_2 emissions by selected country and region in the New Policies Scenario



Note: GDP is presented in year-2013 dollars at market exchange rates (MER).

Africa's contribution to global greenhouse-gas emissions may be relatively limited, but its involvement in the issue is pronounced. In particular, temperatures across the continent are projected to rise faster than the global average (James and Washington, 2013). The nature and scale of the challenge is subject to a broad range of uncertainty, but existing climate models suggest that, in scenarios broadly consistent with the outcomes of the New Policies Scenario, annual average temperatures across the continent will rise between 3 °C and 6 °C by 2100, compared to the 1986-2005 average (IPCC, 2014). The African continent, already prone to weather extremes, would be affected in several ways, including droughts in some areas, extreme precipitation in others and rising sea-levels affecting coastal areas (where many large populations are based and substantial components of economic output are concentrated).

One key uncertainty for Africa's power sector is the impact of climate change on hydropower capacity and potential. Climate change could increase run-off and increase output from hydropower in East Africa, but decrease water run-off in parts of West and Southern Africa (Hamududu and Killingtveit, 2012). The Zambezi River system, along which a significant share of hydropower capacity in Southern Africa is expected to be located by 2040, could be one of the worst affected in Africa, suffering reduced run-off as a result of decreased rainfall of between 10% and 15% across the basin (Beilfuss, 2012). Increased evaporation will affect the level of "stored" energy in reservoirs, while increasing temperatures can be expected to boost demand for water resources from other sectors, such as for irrigation, intensifying problems of water scarcity. Such changes emphasise the need for future energy projects, in the hydropower sector as in others, to be tested for their climate resilience as a standard element of assessing their overall feasibility and acquiring societal consent.

Deforestation and forest degradation

As discussed earlier in this chapter, sub-Saharan Africa continues to rely heavily on bioenergy in the New Policies Scenario, consuming nearly 1 100 Mt of fuelwood in 2040. The extent to which this fuelwood can be considered a renewable source of energy depends on how it is produced and consumed. Many sub-Saharan countries already face deforestation (and even desertification) and it is clear that reversing this loss depends on policies all along the value chain. One example of what can be done comes from the Bugasea region in Rwanda, which was completely stripped of available wood in the 1980s, mainly to produce charcoal for Kigali. Government efforts to support replanting and to promote efficient charcoaling techniques, supplemented by other efforts, have resulted in the area once again being covered in eucalyptus trees. Rwanda is one of the few African countries to have seen an increase in its forest area in recent years.

The need for national strategies for bioenergy is gaining recognition among several African governments, including Ethiopia, Mozambique, Liberia, Sierra Leone and others that are engaging with the EU Energy Initiative Partnership Dialogue Facility to develop their own Biomass Energy Strategy Plans. Among others, policies are needed to regulate fuelwood and charcoal markets which, despite being an important source of income and employment in sub-Saharan Africa, are at present almost entirely unregulated. For example, in Tanzania, at least 80% of charcoal is reportedly produced and traded outside the formal economy (World Bank, 2009). An estimated $1.9 billion of government revenue is lost in Africa each year as a result of unregulated charcoal trade (UNEP and INTERPOL, 2014). Furthermore, because the price of charcoal traded on the informal market does not adequately reflect the cost of reforestation, if at all, charcoal produced in a more sustainable way is often priced out of the market. On the demand side, there is a need to boost the uptake of improved biomass cookstoves. The higher efficiency of improved biomass cookstoves can decrease fuelwood consumption by half when used correctly. They can also reduce carbon monoxide and particulate matter emissions during cooking. An essential feature of successful policies in this area, as in all areas of energy production and consumption with important social and environmental implications, is serious engagement of the community in understanding the issues and contributing to their resolution.

African energy issues in focus

Five key features of the sub-Saharan energy outlook

Highlights

- Over the period to 2040, 950 million people are projected to gain access to electricity in sub-Saharan Africa. Urban populations gain access via connections to the grid; in rural areas, mini-grid and off-grid solutions, increasingly powered by renewables, play a much larger role. Against a backdrop of strong population growth, cumulative investment of more than $200 billion lowers the total without access by 15%: a major step forward, but not far enough, as it still leaves 530 million people in the region, primarily in rural communities, without electricity in 2040.
- Solid biomass, much of it used by households for cooking, accounts for 70% of final energy use in sub-Saharan Africa today, with adverse environmental consequences and health effects from household air pollution. Rising incomes over the period to 2040 produce only a gradual shift in the cooking fuels and technologies used. Policy actions and wood scarcity accelerate the switch in some regions to alternative fuels, notably to LPG and to more efficient cookstoves, but 650 million people, again mainly in rural areas, still cook with biomass in an inefficient and hazardous way in 2040.
- Angola is set to temporarily overtake Nigeria as the largest sub-Saharan Africa producer of crude oil, as regulatory uncertainty in Nigeria, militant activity and oil theft in the Niger Delta impact production there. Oil theft is estimated at 150 kb/d today, leads to oil spills and represents lost revenue of more than $5 billion per year, an amount that would be sufficient to fund universal access to electricity for all Nigerians by 2030. Reducing the risks facing investors will also be critical if Nigeria is to make productive domestic use of its abundant gas resources.
- A successful programme for grid-based renewables in South Africa is stimulating private investment and helping to diversify a power mix dominated by coal, a process to which regional hydropower projects, natural gas and, eventually, additional nuclear capacity contribute. Coal faces rising costs with a move to new production areas. Even so, it remains a low-cost option for new capacity, a competitive strength in a society concerned about the affordability of electricity.
- Expectations are high in Mozambique and Tanzania that major recent gas discoveries can spur domestic economic development. Upstream projects depend on large-scale gas export, in the form of LNG, and also produce an estimated $150 billion in fiscal revenue to 2040. But the respective governments are also determined to pursue the challenging and long-term endeavour of promoting gas use in domestic power generation and industry. Developing a local consumer base for gas requires a careful choice and location of projects to anchor the development of a gas grid, but is an appropriate way to get value from gas.

Five features of Africa's energy outlook

Africa presents a very heterogeneous energy landscape, with large country-by-country variations in resource endowments, patterns of consumption and policy challenges. But certain questions recur. In this chapter, we focus on five of them, drawing on the results of our projections in the New Policies Scenario. The aim is to illuminate features that, in our judgement, are critical to the energy future of sub-Saharan Africa:

- Limited access to electricity is a fundamental weakness in sub-Saharan Africa's energy system and a huge barrier to development: which policies, fuels and technologies can improve the situation, and how quickly is the energy access gap being closed?
- Traditional use of solid biomass for cooking accounts for the largest part of household energy consumption, but has significant health and environmental impacts: how rapidly might Africa see a transition to cleaner alternatives?
- Oil has been central to Nigeria's modern history, but for many the large revenues have not been translated into tangible socio-economic benefits: can oil still be part of the way forward for Africa's largest economy?
- South Africa is diversifying a heavily coal-dominated electricity system, with renewable energy playing a much larger role: what are the policies, costs and benefits involved?
- The major natural gas discoveries in the offshore waters of Mozambique and Tanzania are creating high expectations, but what are the avenues – and obstacles – facing these countries as they look to get the best value from natural gas?

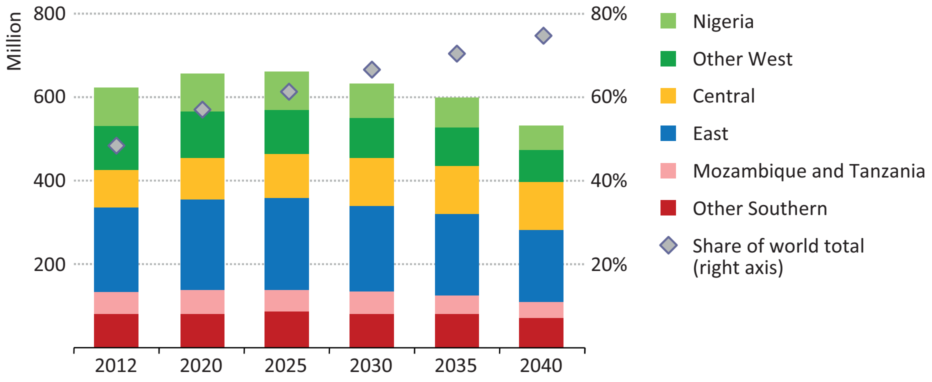
Electricity access: what is the path to power?

As highlighted in Chapter 1, lack of access to electricity is a fundamental brake on development in many parts of Africa. As of 2012, almost half of those around the world without access are on the African continent; the vast majority of these are in sub-Saharan Africa. In our projections, 1 billion people gain access to electricity in Africa by 2040, 950 million of them in sub-Saharan Africa; but population growth in sub-Saharan Africa and progress in other parts of the world means that the remaining global population without electricity access becomes increasingly concentrated in sub-Saharan Africa – this figure reaches 75% in 2040, compared with half today (Figure 3.1). This projection indicates that current efforts to tackle this problem are set to fall well short of the goal of achieving universal access by 2030, the target of the Sustainable Energy for All initiative. Instead, some 635 million people in sub-Saharan Africa are set to remain without electricity by this date, leaving a sombre gap in the global energy system.

Why do so many remain without electricity access in sub-Saharan Africa? There are a number of contributing factors, including the current state of electricity infrastructure, the nature and extent of expected flows of investment to different parts of the power sector and the huge size of many countries. Demographic trends also play an important part. Sub-Saharan Africa is distinctive in our global projections in two aspects: a significant rate of population growth, and a large increase in the rural population. By 2040, around 90% of the sub-Saharan population without access to electricity lives in rural areas (accounting for two-thirds of the global population without access), where providing electricity is that much more difficult than in urban areas.

3

Figure 3.1 ▷ Population without access to electricity by sub-region in sub-Saharan Africa in the New Policies Scenario



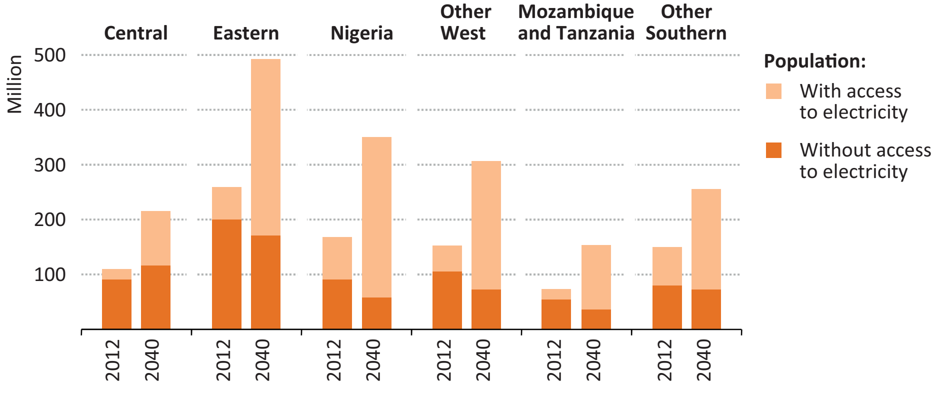
The size of the challenge that remains in our projections should not obscure the progress that is being made, aided by the numerous national and multilateral initiatives focusing on this issue. At present, population growth is outpacing efforts at electrification, but – as Figure 3.1 makes clear – this trend is reversed in the mid-2020s, as the total population without access to electricity in sub-Saharan Africa peaks and then goes into decline. Over the projection period, the number of people without access in sub-Saharan Africa declines by 15% from today's level, to around 530 million. The pace of change is fastest among the urban population, where the number of people without access is reduced by more than half.

Our projections also point to some distinctive regional developments within sub-Saharan Africa (Figure 3.2):

- Nigeria brings electricity access to more people than any other country in Africa, reducing the absolute number of those without access by around 40% by 2040. The electrification rate goes from 45% today to nearly 85% in 2040, which translates into more than 200 million people gaining access. However, as highlighted later in this section, the rural population without access sees only a small decrease in absolute terms, thereby accounting for around 80% of Nigerians without access in 2040. Other parts of West Africa see continued progress in raising electrification rates, such that, by 2040, West Africa has the highest electrification rate (80%) of all the African sub-regions. Outside Nigeria, around 85% of those remaining without access in West Africa in 2040 are in rural areas.

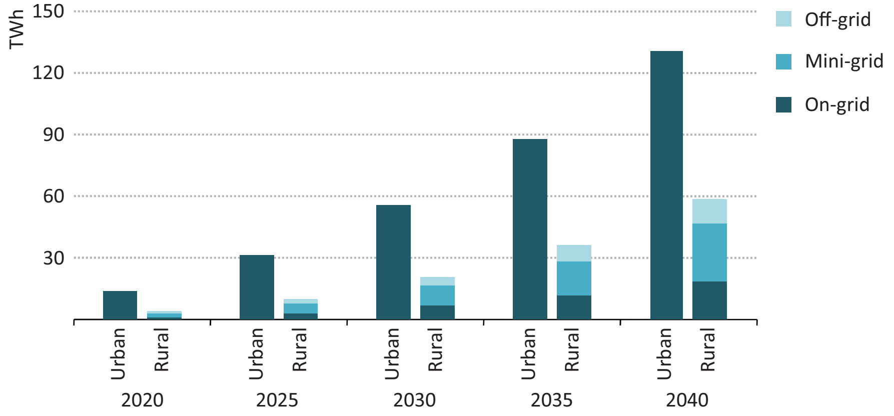
- The problem of electricity access is more persistent in Central Africa. Although some countries, like Equatorial Guinea and Gabon start from relatively high electrification rates and continue to make progress, others, like Chad and the Central African Republic, start from a very low base. More than half of the total population of this sub-region remains without access in 2040 in our projections. Countries with very low population densities, like Congo, face particularly severe challenges in bringing electricity to their rural communities.
- East Africa is the sub-region which achieves the most rapid pace of growth in providing electricity access, with Ethiopia, Kenya and Rwanda leading the way; but a large part of the rural population here, too, remains without access: one-third of the sub-Saharan African population remaining without access in 2040 consists of rural communities in East Africa. The challenge is particularly acute for Ethiopia, which currently has the world's second-largest rural population without access to electricity (almost 70 million).
- In South Africa, the government aims to reach a 97% electrification rate by 2025 through a combination of on-grid and off-grid technologies (mainly solar home systems). This target is achieved by 2030 in our projections and a 100% electrification rate is reached in the late 2030s, thanks to supportive financing schemes, such as charging poor households without access a minimal fee for the connection and providing 50 kilowatt-hours (kWh) per month free of charge. Progress with electrification in Mozambique and Tanzania is helped by an expansion of gas use in the power sector, but also by a large push for mini-grid and off-grid solutions in rural areas. In other parts of Southern Africa, good progress is made as well, notably in Botswana and Zambia.

Figure 3.2 ▷ Electricity access by region in sub-Saharan Africa in the New Policies Scenario



The impact of increased electricity access on overall power demand in sub-Saharan Africa is very limited. The population gaining access throughout the period to 2040 adds around 190 terawatt-hours (TWh) to total power consumption in 2040 (Figure 3.3). This is only around 20% of the overall increase in electricity demand over the projection period, and less than 15% of total sub-Saharan African power demand in 2040, which is projected to reach 1 300 TWh. Of the population gaining access, two-thirds live in urban areas and are connected to a main grid. In rural areas, mini- and off-grid solutions play a much more prominent role, accounting for 70% of new access-related demand over the period to 2040.

Figure 3.3 ▷ Electricity demand from the population gaining access to electricity in sub-Saharan Africa in the New Policies Scenario



The type of access that is provided is heavily contingent on a range of country-specific factors, including the nature of policies and financing for access-related projects, the current state and coverage of the transmission and distribution systems, the status of plans to extend the grid and the capacity and financing to realise these plans (Spotlight). Alongside policy-related considerations, actual costs are also strongly affected by the density of population in the area without access. For areas with significant concentrations of population, i.e. in urban areas or larger settlements, on-grid supply is typically the most cost-effective solution. Indeed, urban populations gaining access in our projections do so entirely via the grid because of the relatively low cost of additional connections and because the fixed costs of extending the grid are spread over a larger amount of electricity consumed.

On-grid connections can also be cost-effective for more dispersed populations living within a reasonable distance of transmission and distribution lines, even allowing for the additional expense of extending the service. The maximum economic distance for extending the grid tends to reduce over time, as the costs of generation in mini-grids or off-grid systems come down, but the average cost of supplying grid-based electricity remains below the cost of the alternatives in our projections. Moreover, as transmission and distribution systems expand to connect growing demand centres, new power plants and large "anchor" consumers, such as mining operations, this has the effect of bringing the grid closer to other settlements and so reducing the grid costs in comparison with other connection options.

SPOTLIGHT

With grid or without? The varied dynamics of expanding electricity access in Nigeria and Ethiopia

The most cost-effective way to expand electrification varies widely between and within countries in sub-Saharan Africa, as well as changing over time as incomes and consumption patterns change. A detailed spatial analysis for Nigeria and Ethiopia, undertaken for this report, illustrates how a range of factors – including population density, tariffs for grid-based electricity, technology costs for mini-grid and off-grid systems and the final cost of diesel at the point of consumption – affect the optimal mix of grid-connected, mini-grid and off-grid generation options.[1]

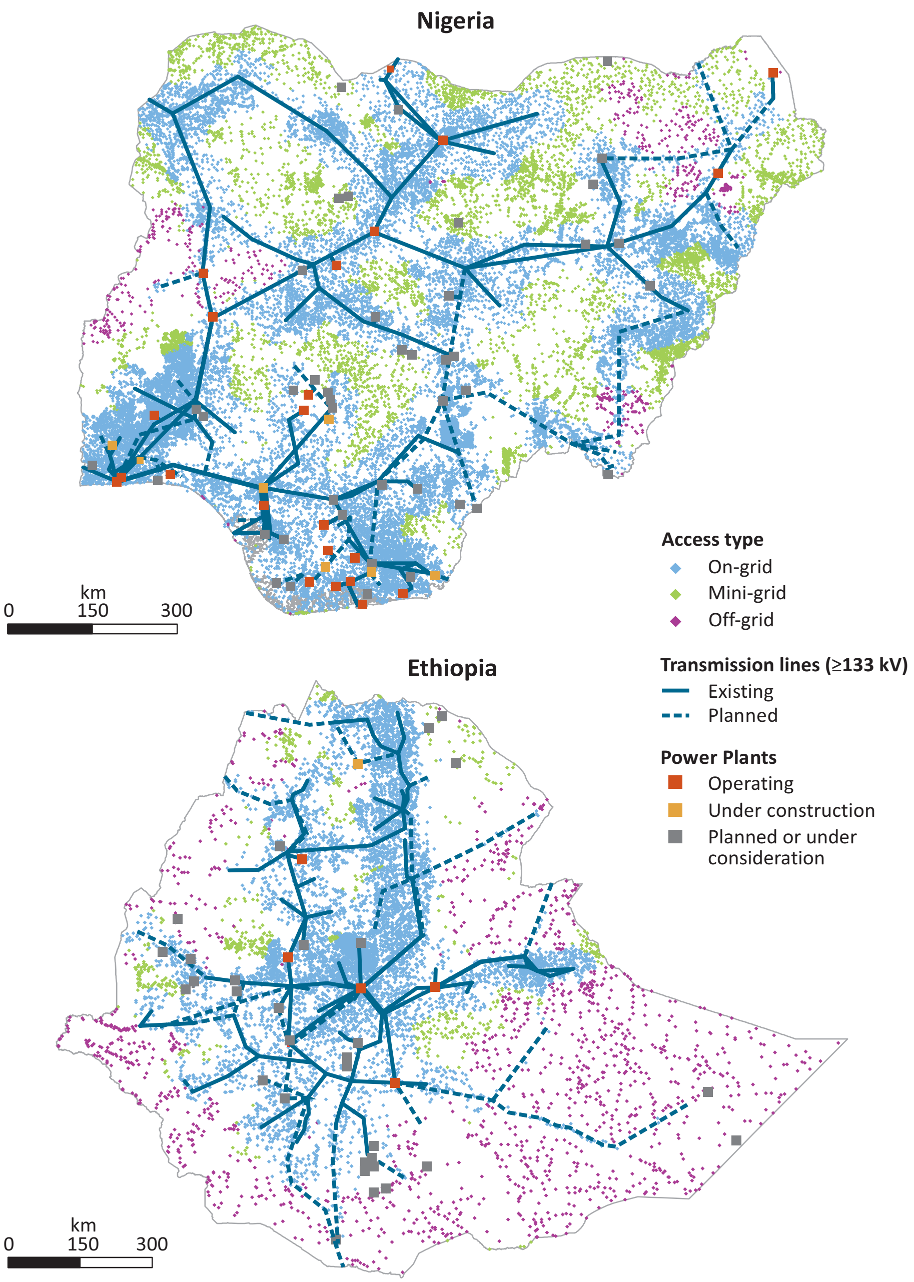
In Nigeria, higher population density and more widespread coverage by the transmission grid tends to favour on-grid supply as the most cost-effective route to electricity access (Figure 3.4). In the New Policies Scenario, this is the principal means by which the electricity rate is increased from 45% in 2012 to around 85% in 2040, providing new access to over 200 million people. In areas where grid extensions are not cost-effective, mini-grids tend to provide the preferred solution.

In Ethiopia too, a significant proportion of the population lives in areas that can be best connected through the grid. But the overall population density of Ethiopia is considerably lower – the number of people per square kilometre is half that of Nigeria – meaning that mini- and, especially, off-grid solutions play a much more prominent role. Overall, the electrification rate in Ethiopia increases from 23% in 2012 to around 60% in 2040. The 40% remaining without access to electricity in 2040 tend to be in dispersed rural communities.

The levelised cost of electricity supply for those that gain access to electricity through grid extensions is typically well below the cost of supply from mini-grids or off-grid systems. Within mini-grids and off-grid systems in both Nigeria and Ethiopia, diesel generators and solar photovoltaic provide the largest shares of electricity. Solar technologies are key to setting up a large number of off-grid systems that each supply small amounts of electricity. At higher levels of electricity consumption, there is a tendency to rely more on mini-grids powered by diesel generators and, where available, small hydropower.

1. The geographic analysis of the type of access that contributes to increased electrification rates in Nigeria and Ethiopia has been developed in collaboration with the KTH Royal Institute of Technology, division of Energy Systems Analysis (KTH-dESA).

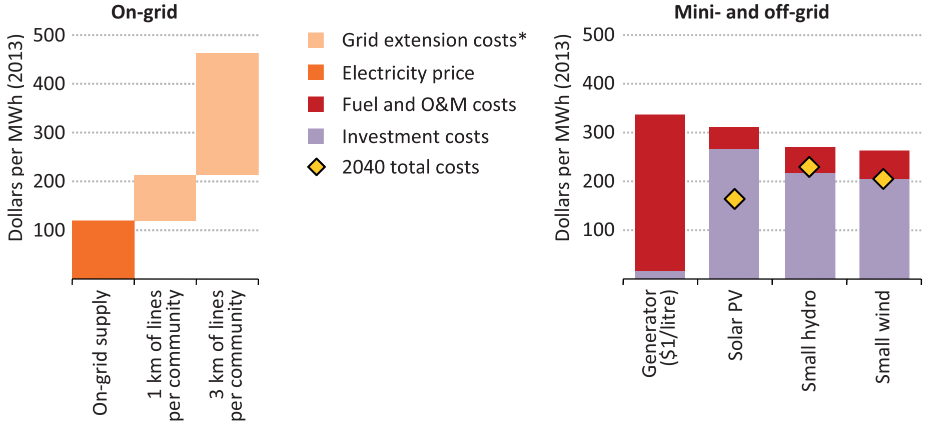
Figure 3.4 ▷ **Optimal split by grid type in Nigeria and Ethiopia, based on anticipated expansion of main transmission lines**



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.

Nonetheless, beyond a certain distance, the costs of grid extensions become prohibitive, tipping the balance in favour of mini-grids or off-grid systems (Figure 3.5). The comparison between these two options turns on the density of settlement, with higher density favouring the development of mini-grids. The main technologies available for these types of systems are diesel generators or renewable energy technologies – solar photovoltaic (PV), small hydropower and small wind systems.

Figure 3.5 ▹ Indicative levelised costs of electricity for on-grid, mini-grid and off-grid technologies in sub-Saharan Africa, 2012



*Costs of grid extension are calculated as the average cost of extending the medium-voltage grid a certain distance (e.g. 1 km) to each community on a levelised cost basis.

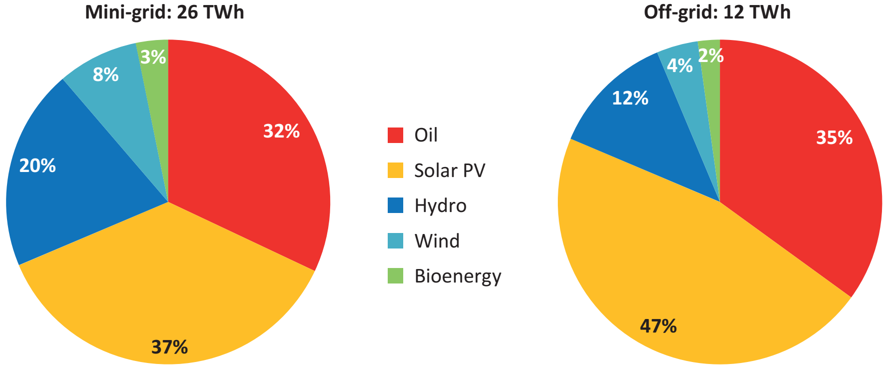
Notes: Costs are indicative and could vary significantly depending on local conditions such as electricity tariffs, population density and the delivered cost of diesel. The quality of service for the different technologies also varies: additional investment in batteries or back-up power may be needed to compensate for the variability of renewables or intermittent grid supply. O&M = operation and maintenance.

The choice of generating system for mini-grid or off-grid access depends on multiple variables. The attractiveness of renewable technologies is much higher when costs are considered on a life-cycle basis, but finance must be available to meet the relatively high upfront outlay, which – even as costs come down – remains significantly above that required for a diesel generator. Generators have the advantage of providing power when needed (if fuel is available), but also face the significant downside of ongoing fuel costs, which can vary substantially. Diesel or gasoline is subsidised in some of the major oil-producing and exporting countries, notably Nigeria, Angola and Gabon, which improves the relative attraction of oil-based electricity generation to the final consumer, albeit at a fiscal and environmental cost. But even in countries where fuels are subsidised, bringing oil products to remote communities adds quickly to the final cost of generation.

There are also potential synergies between different technologies. Hybrid systems combining fossil fuel and renewables power generation (e.g. diesel and solar PV) can bring considerable flexibility and higher reliability of supply.[2] The Government of Mali plans to increase hybridisation of its mini-grids by adding PV capacity to diesel power plants. Tanzania's Rural Electrification Agency also favours hybrid diesel-PV systems for remote areas that are expected not to be connected to the main grid before 2020. An important consideration for off-grid or mini-grid systems is the ability to scale-up supply: options that provide electricity for lighting may not be sufficient to run a refrigerator, let alone to start a business. The interactions between these different factors can be complex: some renewables off-grid options can integrate well with grid extensions, but the commercial interests of diesel suppliers are undercut. Uncertainty over the likelihood and pace of grid extensions can hold back investment in other solutions.

3

Figure 3.6 ▷ Technology mix for mini-grid and off-grid power generation in sub-Saharan Africa in the New Policies Scenario, 2040



Solar PV is expected to become increasingly competitive with diesel generation, as well as with other renewable technologies. Although solar PV has one of the highest average costs of generation today, it is still an attractive option for remote areas when the transport costs for diesel are high. The solar resource is very good across many parts of sub-Saharan Africa, providing generally reliable power during the day. Renewables options alone cost less over time, benefitting from technological advances and a larger scale of production; by 2040, the delivered cost of diesel would have to be less than $0.50 per litre to be competitive with the anticipated cost of generation from solar PV. For the poorest communities, smaller solar technologies, such as solar lamps, can provide an invaluable initial step towards electricity access. Very small-scale hydro (also known as pico hydro) can generate electricity at very low average costs, where suitable waterways are close. The attraction of small-scale wind generation also depends on local conditions, but provides limited reliability on its own. A snapshot of mini-grid and off-grid power generation in 2040 (Figure 3.6) shows that solar PV provides the largest share in both mini-grid and off-grid systems, followed by diesel generators, then small hydro and wind, with smaller amounts of bioenergy.

2. The speed at which battery technologies improve will also be an important variable in determining the reliability of systems powered solely by renewable energy; in the New Policies Scenario, we anticipate incremental technology improvements and learning, but no technology breakthroughs.

Bringing the electrification rate in sub-Saharan Africa up from 32% today to 70% in 2040 is estimated to cost around $205 billion in capital investment, less than one-fifth of total power sector investment in the region. Projected investment flows largely mirror the split by the type of access. Most of the investments go towards providing on-grid access, with more than half of the total required for new transmission and distribution lines. Mini-grids and off-grid solutions that are less capital-intensive and require less investment in infrastructure account for around 30% of the total. By sub-region, the largest share goes to West Africa, with $75 billion over the projection period (60% of which in Nigeria). Southern Africa follows with around $65 billion, East Africa with $50 billion and Central Africa with $15 billion.

Averaged over the projection period, this amounts to capital investment in energy access of around $7.5 billion per year, a figure not far from our current estimate of total annual power sector investment in sub-Saharan Africa (see Chapter 4). It accordingly represents a significant increase in spending for this purpose over the coming decades, reflecting declared government intentions. Achieving this level of investment will require not only steady improvements in the investment conditions for electricity access-related projects, but also rapidly improving capacity and effective co-ordination among the various actors involved. Realism, clarity and consultation over the pace of grid extension allows the stakeholders, including local communities, to make an informed assessment about the best options for expanding access, whether through co-ordinated development of the grid, mini-grids or off-grid systems. Donor programmes likewise need to be managed carefully, both to ensure that the beneficiaries are fully involved from the outset, not least to guarantee adequate and on going maintenance, and to avoid undercutting fledgling commercial energy providers.

Grid extensions are set to remain largely within the domain of the public authorities and utilities, relying on a combination of self-financing from within the power sector (if the tariff structure allows for a degree of cross-subsidisation), government budgetary allocations and funding from international donors. The spread of decentralised access also involves other public entities, such as rural electrification agencies, and a range of non-government organisations and private entities, as well as local communities. Private capital is proving to be increasingly important in rural areas: in Senegal for instance, the structuring of rural electrification concessions with private sector participation helped raise the rural electrification rate from 8% in 2000 to 26% in 2012. Small-scale options, commercialised by the private sector, may be the only way forward where there are shortcomings in public policies or institutions. New business models, often involving pre-payment or pay-as-you-go for a certain level of service, underpin some of these commercial efforts, but expensive finance, regulatory barriers in some countries and limited capacity among the poorest to pay for energy remain major constraints on scaling-up the provision of rural energy services.

Biomass: here to stay?

Solid biomass is the largest energy source in sub-Saharan Africa, accounting (in IEA data) for 70% of the region's current total final energy consumption. If South Africa is excluded, this share rises to 80%.[3] Of the estimated 280 million tonnes of oil equivalent (Mtoe) of solid biomass currently used in sub-Saharan Africa (outside South Africa), 90% is used by households, almost all being fuelwood, straw, charcoal or dried animal and human waste, mostly used as cooking fuel. Overall, cooking accounts for more than 80% of household energy usage, compared with less than 5% in Europe. Of the population of around 915 million in sub-Saharan Africa in 2012, an estimated 730 million people do not have access to clean cooking facilities (see definition in Chapter 1). Especially for those cooking indoors in poorly ventilated spaces, this means daily exposure to noxious fumes, with adverse health impacts – and the burden of collecting fuelwood – falling heavily on women and children.

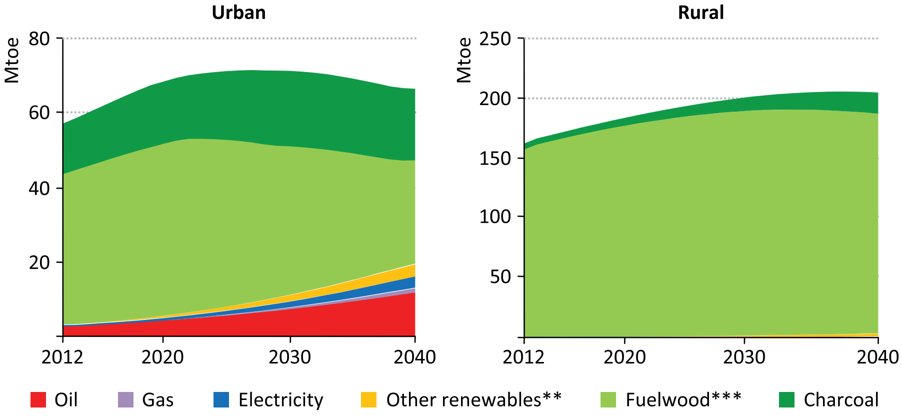
The correlation between high levels of solid biomass use for cooking and high levels of poverty in much of sub-Saharan Africa can give rise to a perception that an increase in average incomes will lead to a fall in the traditional use of solid biomass, as use of other fuels increases. However, this is not borne out by historical trends: in sub-Saharan Africa, outside South Africa, GDP per capita has increased by 3% on an annual average basis since 1995 and population by 2.7% per year, but the number of people without access to clean cooking facilities has still increased by 2.4% per year, i.e. the population relying on traditional use of solid biomass has tracked population growth fairly closely, despite increasing incomes.

In our projections to 2040, demand for energy services by households across sub-Saharan Africa continues to rise along with incomes, but the mix of fuels used is relatively slow to change. Solid biomass still accounts for half of total final consumption in sub-Saharan Africa in 2040, this figure rising to almost 60% if South Africa is excluded. Looking only at fuels used for cooking (Figure 3.7), the position of fuelwood is undercut to a degree by alternative fuels in urban areas, but hardly at all among the rural population (where consumption is much larger).[4] As explored in more detail below, the way in which preferences for cooking fuels evolve is a complex question – and certainly more complex with the idea of a fixed "energy ladder", whereby choice of fuel graduates from solid to non-solid fuels as households get richer.

3. South Africa relies less on traditional use of solid biomass than any other country in mainland sub-Saharan Africa. Only 15% of its final energy consumption comes from bioenergy, in large part because only 13% of the population still relies on solid biomass for cooking: at the other extreme, up to 93% of total final consumption in DR Congo consists of bioenergy.

4. As the efficiency of alternative cookstoves is higher compared with traditional ones – and cooking times are generally shorter – the move away from traditional cookstoves results in significantly lower energy consumption for the same service provided.

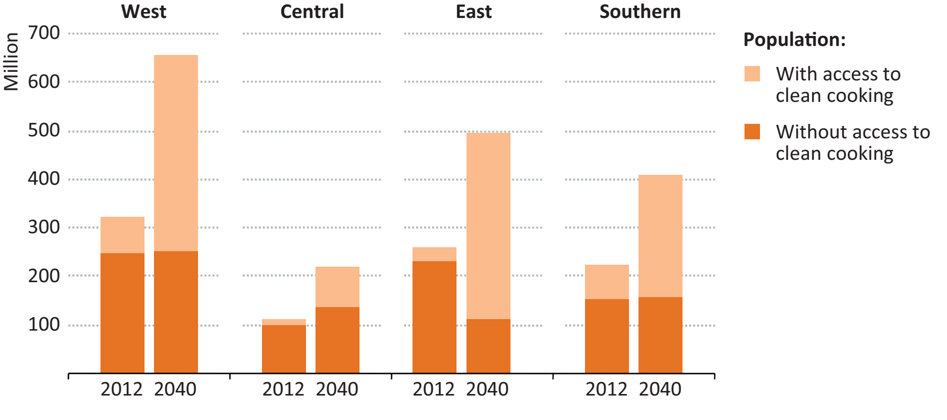
Figure 3.7 ▻ Household energy consumption for cooking by fuel in sub-Saharan Africa* in the New Policies Scenario



* Excluding South Africa. ** Other renewables include solar, biogas, biofuels and pellets.
*** Fuelwood includes agriculture and animal wastes.

One of the major changes in our projections is not captured in Figure 3.7, because it involves not a fuel switch but a change in the way that solid biomass is used. Gaining access to clean cooking facilities encompasses not only switching to alternative fuels, but also access to improved biomass cookstoves (fired with fuelwood, charcoal or pellets) that are more efficient and reduce household air pollution. Together, fuel switching and the spread of improved cookstoves lead to a decrease in the number of people in sub-Saharan Africa without access to clean cooking to 650 million in 2040 – a 10% decline in relation to the figure for 2012. Within the overall context of a rising population, this means, more positively, that around 1.1 billion people do have access to clean cooking facilities in 2040, two-thirds of them living in urban areas (Figure 3.8).

Figure 3.8 ▻ Population with and without clean cooking access in sub-Saharan Africa in the New Policies Scenario



Examining the trends by sub-region, the area in which the largest decrease in the number of people without access occurs is East Africa, where currently around 70% of the urban population and 95% of the rural population rely on solid biomass. More than 350 million people gain access to clean cooking facilities in the region. Without the shift to more efficient use of biomass, the risks to an already depleting forest biomass stock would be significantly higher in East Africa (see Chapter 2), especially around urban areas where high demand for solid biomass and lack of regulation of the charcoal industry are blamed for 10-20% of the deforestation occurring in these areas (GIZ, 2014). Another notable shift is in Nigeria, where around 230 million people gain access to clean cooking facilities over the period to 2040. By contrast, in Central Africa, where forest biomass is more plentiful (and therefore relatively cheap), the population without access actually increases by 40%.

The options for access to clean cooking facilities

If economic development and income growth do not automatically lead to a decrease in the traditional use of solid biomass, then what are the factors that can lead to an improvement in access to clean cooking facilities? In practice, there are numerous considerations, besides income, that are in play, particularly the relative prices and availability of the various alternatives and scarcity of forest biomass – felt in the availability and price of fuelwood, or the time required to collect it. In some cases, an increase in solid biomass prices makes alternative fuels competitive. This is particularly likely in urban areas, where charcoal can lose out to more accessible alternative fuels.

There is also some evidence that households attach a fairly low priority to cleaner cooking facilities when deciding how to spend incremental income (compared with other options, such as food, lighting, education or communications). Policies and programmes play a major role in changing the picture, for example, through provision of finance to cover the upfront investment costs associated with more efficient cookstoves (Table 3.1), raising public awareness of the issues involved or promotion of the distribution of an alternative fuel. Programmes aimed at promoting access to clean cooking are much less prevalent than those promoting access to electricity, but they can make a major difference – as many countries in Asia and in some parts of West Africa are demonstrating.[5]

An additional complication is that, where new sources of energy for household use are adopted, this often does not mean that the use of the older one is discarded, a phenomenon known as "fuel stacking". As explored below, choices are influenced by fluctuations in relative prices, but also by confidence in the physical availability of the alternatives to solid biomass. Until distribution networks are sufficiently well established to ensure reliable supply of alternative energy carriers at reasonably predictable prices, consumers typically (and rationally) prefer to retain the option to switch.

5. Among the regional initiatives in place, ECOWAS (the Economic Community of West Africa States) initiated a programme in 2012 called the West African Clean Cooking Alliance which aims to ensure that by 2030 the entire ECOWAS population has access to efficient, sustainable and modern cooking fuels and devices.

Table 3.1 ▷ Technology characteristics of different cooking options

	Investment cost ($)	Efficiency	Daily hours for cooking	Consumption per household (toe/year)
Traditional cookstoves				
Charcoal	3 - 6	20%	2 - 4	0.5 - 1.9
Fuelwood, straw	0 - 2	11%	2 - 4	1.0 - 3.7
Alternative cookstoves				
Kerosene	30	45%	1 - 3	0.1 - 0.2
LPG	60	55%	1 - 3	0.08 - 0.15
Electricity	300	75%	1.2 - 2.4	0.07 - 0.13
Biogas digester	600 - 1 500	65%	1 - 3	0.07 - 0.14
Improved cookstoves:				
Charcoal	14	26%	1.5 - 3	0.4 - 1.5
Fuelwood	15	25%	1.9 - 3.8	0.5 - 1.6

Note: toe = tonnes of oil equivalent.
Sources: Jeuland and Pattanaya, (2012); Department of Energy at the Politecnico di Milano; IEA analysis.

Improved biomass cookstoves

More efficient cookstoves provide a very cost-effective way to reduce household air pollution as well as the environmental and other risks associated with solid biomass use. In many rural areas, where alternative fuels are either unavailable or unaffordable, they are often the only practicable way forward. There are various models and technologies available, but common features are that they reduce the amount of smoke that is released, compared with the classic three-stone open fire, and achieve a much more complete combustion of the fuel if they are correctly used and maintained. They typically operate either with fuelwood (or with biomass that is processed into pellets) or with charcoal.

Among the factors pushing the uptake of improved cookstoves in our projections, consumer preference can be important, particularly where public information campaigns have helped to make indoor pollution or economic benefits a factor in household decision making. Economic arguments in favour of improved cookstoves are strongest in areas where wood depletion or competition for wood between household and other final uses pushes up the price of charcoal (notably for urban users) and of fuelwood.[6] This is the case in East Africa, which has the lowest forest biomass stock and, in our projections, accounts for more than half of the 390 million people taking up improved biomass cookstoves in sub-Saharan Africa over the projection period. The availability of an affordable local commercial manufacturer of cookstoves can also make a major difference, as with the Kenyan Ceramic Jiko, the first models of which came into production in the 1980s. The further penetration of cookstoves is being pushed up by government and donor programmes, such as the initiative, supported

6. Biomass is also used for other economic activities such as brick-making, fish/meat smoking, food processing and tobacco curing.

by the Swedish Energy Agency, to distribute more than half a million improved cookstoves in both urban and rural areas in sub-Saharan Africa and GIZ's Energising Development (EnDev) programme, which aims to encourage the commercial development of improved cookstoves and expand their use.

Oil products (LPG, kerosene)

The two oil products that can provide alternatives to solid biomass, liquefied petroleum gas (LPG) and kerosene present a very different balance of risks and opportunities.[7] In addition to refinery supply, LPG is also produced from natural gas liquids, a by-product of gas production, and its market price is typically well below that of kerosene, which is a premium middle distillate fuel. However, subsidising kerosene is a decades-old tradition in some African countries, creating the misleading perception that it is the lower cost fuel. LPG is not hazard-free, but using kerosene as a household fuel involves significant risks of ingestion (often by children) or fire, as well as household air pollution. Yet kerosene has a key practical advantage, in that it can be transported and delivered with relative ease.

Even though LPG does not need a pipeline or distribution grid like natural gas, it requires dedicated infrastructure. In regions where LPG is potentially available at competitive prices, overcoming the infrastructure constraints is the key to its expanded use. Due to its volatile nature, LPG has to be transported in special pressurised trucks and stored in pressurised facilities. While using LPG has health advantages in terms of indoor air pollution, it can be dangerous if safety precautions are not followed. LPG cylinders, trucks and refuelling facilities need regular check-ups and maintenance. Trust in LPG is consequently contingent on well-functioning institutions and regulation. There is anecdotal evidence that, in Nigeria, some landlords specifically ban the use of LPG on their premises for fear of the risks arising from old, uncontrolled, sometimes damaged LPG cylinders. This is an area where government financing could usefully be deployed – facilitating upfront investments in safe LPG stoves and cylinders, rather than subsidising fuel prices, although in some situations initial fuel price subsidies may also be necessary (Box 3.1).

Another requirement for wider LPG use is the development of the supply chain from the production site or import terminal to the consumer. Strained import infrastructure, bad road conditions, vehicle breakdowns, the absence of stocks in inland storage facilities and low density of retail outlets mean that sometimes even consumers who are able and willing to pay to refuel their cylinders face a long wait for supply. This can drive many back to solid biomass, with LPG used only when it is readily available. In our projections we assume that both the infrastructure and regulatory issues of LPG supply and distribution

7. Some governments are making specific policy efforts to move residential consumers away from kerosene and towards LPG. In Nigeria, around 45 million people in urban areas currently rely on kerosene as a cooking fuel, which is both hazardous for residential use and represents a significant fiscal burden because the price is subsidised. The government has a national target to help 10 million households make the switch to LPG by 2021.

are effectively addressed. With residential oil demand expected to triple by the end of the projection period, residential LPG consumption increases rapidly to 320 thousand barrels per day (kb/d), while kerosene rises more modestly to 190 kb/d.

Box 3.1 ▷ Bottled gas: half-full or half-empty?

Some countries in sub-Saharan Africa have improved their clean cooking access rates by deploying government programmes promoting LPG use by households, often with the aim of reducing fuelwood collection from the country's forests. Notable examples are Senegal, Ghana and Côte d'Ivoire: Senegal and Ghana rely almost entirely on imported LPG, while Côte d'Ivoire meets about 70% of its demand through local refinery output. In Nigeria, which is the leading LPG producer in sub-Saharan Africa with around 3 million tonnes annual output, only around 0.2 million tonnes are used locally.

However, further analysis of the countries that have been lauded for their LPG access rates shows the challenges involved in establishing and maintaining a viable LPG supply chain. Senegal started its programme in the 1970s, with the promotion of a small LPG cylinder-stove, the elimination of taxes and duties on LPG equipment and the introduction of a subsidy covering smaller-volume cylinders for household use. By the 2000s, 70% of urban households had access to LPG, (though it may not have been the only fuel used for cooking). The subsidy was removed in 2010, to alleviate the financial burden on the government. Within a year, consumption dropped significantly. The government later removed value-added tax from the LPG price, which helped to restore demand. Currently, even with the highest rates of per-capita consumption of LPG in the region, the share of this fuel in household energy consumption in Senegal is only 7%.

Electricity and natural gas

Electricity does not emerge as a major alternative cooking fuel in our projections. Despite its increasing availability (see electricity access section above), it accounts – outside South Africa – for less than 10% of cooking fuel in urban areas and less than 1% in rural areas in 2040. It is already the case globally that those with access to electricity still often use solid fuels for cooking, meaning that cooking is often not seen as a priority for incremental electricity use compared with lighting and appliances.

Natural gas contributes to access to clean cooking facilities only in countries where there is significant projected production. Even in such cases, building a residential gas distribution network is justified only where income levels and population density are sufficiently high, or there are baseload customers in the vicinity, such as power plants or large industrial facilities. In our projections, we assume that some of the largest cities in gas-rich countries, notably Lagos, Dar es Salaam, Accra and parts of Mozambique develop distribution networks, starting on a relatively small scale in the 2020s and expanding steadily thereafter. More than 40 million people rely on gas for cooking purposes by the end of the projection period in 2040.

Renewable alternatives

The main renewables-based alternatives to solid biomass for cooking are biogas and solar cookers.[8] Domestic biogas digesters enable more efficient use of animal manure and human waste, converting it into methane that can be used as a cooking fuel. The size of digesters (and their costs) can vary widely, from those used by a single household to community-based systems. The technology is mature and proven, but its broad application is held back by a number of technical and non-technical constraints, including the type and availability of feedstock to determine the optimal digester size, availability of water and of local construction and maintenance services, and access to finance to cover the relatively high upfront costs. The existence and design of state support can play a critical role: Ethiopia has had a National Biogas Programme since 2008, resulting in more than 7 000 digesters being installed by the end of 2013, primarily in rural communities; but the implementation of similar programmes in Uganda and Tanzania has been slower. In our projections, more than 6 million rural households in sub-Saharan Africa rely on biogas in 2040, more than half of which are in East Africa.

There are various technologies already available to capture the sun's heat for cooking. Given the solar resource available in many parts of sub-Saharan Africa, this is an attractive option especially for those with limited access to other options, e.g. in rural areas, especially those where biomass is scarce, or in conjunction with a biomass cookstove, to ensure reliable cooking at all times of day and evening. Take-up of solar cookers depends both on their capacity to match the performance of conventional options and the existence of sufficient distribution channels. Almost 4 million households are projected to rely in full or in part on solar for cooking by 2040.

The cost of cleaner cooking

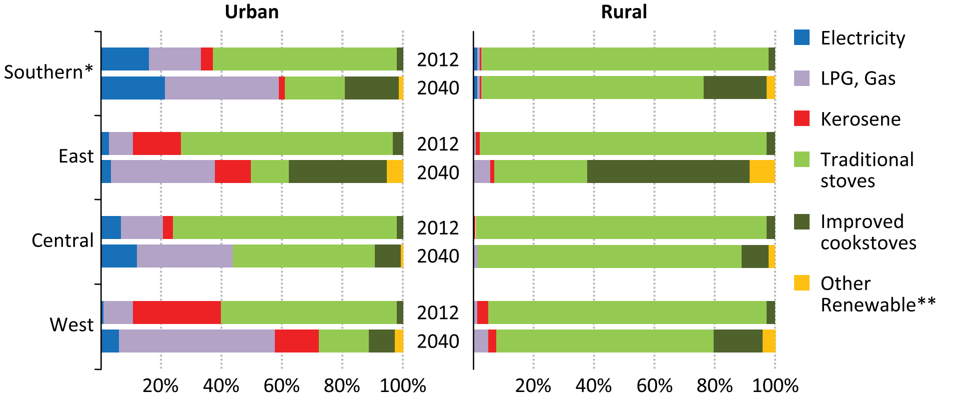
There are important distinctions between the urban and rural populations to be made in the type of access gained over the projection period, and also between different regions. Within urban areas, most of those gaining access do so by switching to other fuels, with LPG being the best placed of the alternatives. The share of urban households outside South Africa relying on traditional cookstoves decreases from 65% to 20% over the projection period. In rural areas, where household energy use continues to be dominated by solid fuels, those gaining access do so almost entirely via improved biomass cookstoves (Figure 3.9).

The investments in access to clean cooking in sub-Saharan Africa reach a cumulative $9.5 billion over the period to 2040. The main component of this sum is the cost of the improved or alternative cookstoves (the cost of infrastructure related to LPG, electricity or natural gas distribution is not included). Cookstoves require replacement, but only the cost of the first stove and half of the cost of a second stove is included, reflecting an assumed

8. There are also a number of projects, such as project Gaia in Ethiopia, that promote biofuel-based cookstoves; Ethiopia's National Biofuels Policy plan promotes ethanol both for stoves and for blending with gasoline as a transport fuel.

path towards such investment becoming self-financing.[9] Around 45% of the total is related to LPG cookstoves, 30% is for biogas digesters and 25% for solar cookers and improved biomass cookstoves.

Figure 3.9 ▷ Primary fuel/technology used by households for cooking in sub-Saharan Africa in the New Policies Scenario



* Excludes South Africa. ** Other renewables includes biogas, biofuels and solar cookers.

Is oil the way forward for Nigeria?

Oil is a major feature of the modern history of Nigeria. The start of production in the Niger Delta in the late 1950s, quickly followed by independence from the United Kingdom, brought great aspirations of economic development, which have yet to be completely fulfilled. Since 1980, oil export has brought in more than $1 trillion in cumulative revenue (in year-2013 dollars). But, even with the re-basing of the country's GDP in 2014, which made Nigeria the largest economy in sub-Saharan Africa, on a per-capita basis the country performs no better on several key human development indicators, ranging from the level of education to life expectancy, than the sub-Saharan Africa average. This reflects the failure of successive governments to translate sizeable natural resource revenues into tangible socio-economic benefits.

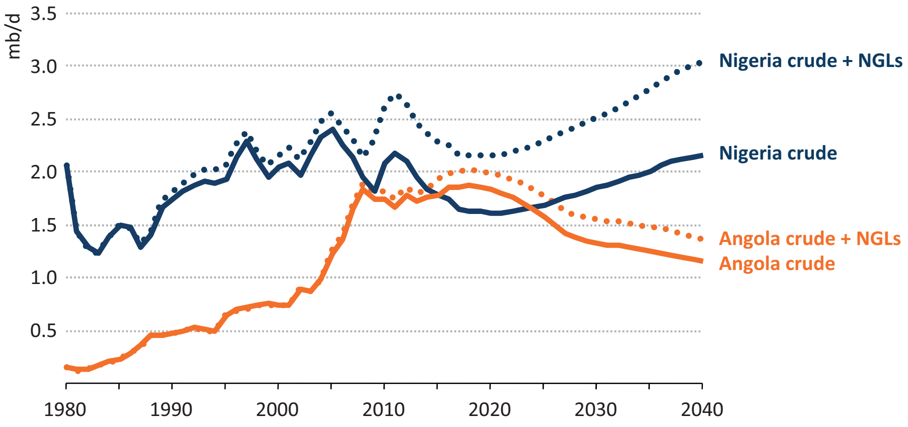
The part oil will play in Nigeria's future is less easy to discern. On one hand, the revised categorisation of GDP makes it clear that the non-oil sectors of the economy, services in particular, are in practice a greater source of dynamism and national wealth than had previously been thought. On the other, the oil sector, for the moment, remains an indispensable pillar of fiscal revenue, accounting for more than half of the anticipated total in 2014. It is arguable – and our projections tend to support this view – that, insofar as Nigeria's future depends on its resource base, natural gas is as important as oil, as a means

9. An improved biomass cookstove typically requires replacement every 2-4 years, stoves using LPG every 5-15 years, those using kerosene every 4-6 years.

of generating power and of powering industrial development. But, if gas is indeed the way forward for Nigeria, then many of the constraints affecting the oil sector will have, in any case, to be overcome.

Nigeria has, by a distance, the largest oil resource base in sub-Saharan Africa. Yet a sobering indicator of the state of the oil sector is that, from around 2016 until the early 2020s in our projections, Nigeria is overtaken as Africa's largest producer of crude oil by Angola (Figure 3.10). During this period, Angola is also likely to be Africa's largest crude oil exporter.[10] This situation is reversed later in our projection period, as Nigerian crude output edges higher to 2.2 million barrels per day (mb/d) by 2040 and total liquids production, buoyed by natural gas liquids, reaches 3 mb/d.

Figure 3.10 ▻ Nigeria and Angola conventional oil production in the New Policies Scenario (crude and natural gas liquids)



Note: NGLs = natural gas liquids.

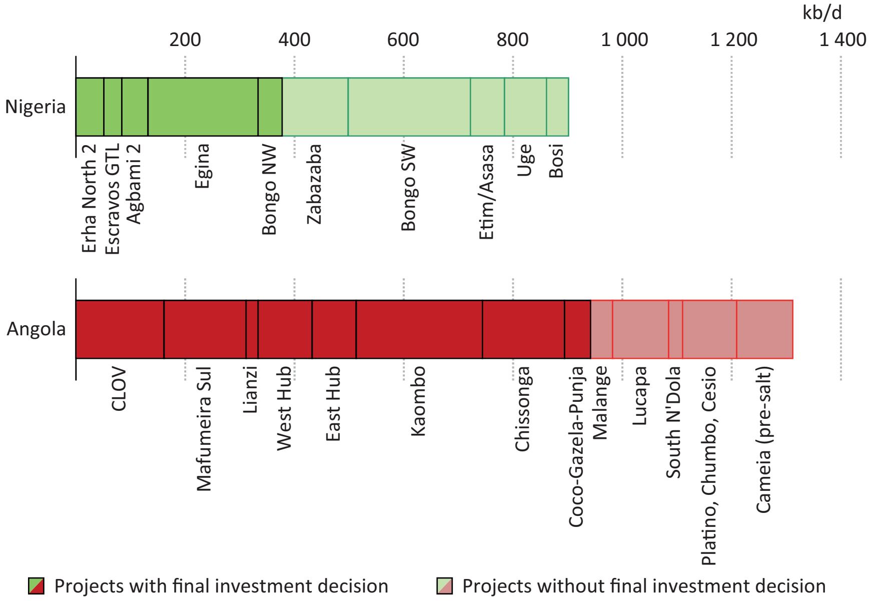
Signs of this role reversal between Nigeria and Angola have been present for a while. Upstream investments have been flowing more readily to Angola in recent years.[11] A telling comparison is between the extent of the "pipeline" of major offshore projects in the two countries (Figure 3.11). Although Angola has seen some slowing of commitments to new projects since a tightening of fiscal terms in 2006, more than 1.3 mb/d of nameplate capacity is due to come into operation between 2014 and 2020, compared with 0.9 mb/d in Nigeria. More telling still is that only 40% of the planned capacity in Nigeria has passed the final investment decision (FID), whereas 70% of the planned capacity in Angola has already passed this milestone. In the last year, only Total has taken a final investment decision in

10. Angola had a taste of this position in May 2014, when monthly exports from Nigeria dipped below those of Angola, largely due to theft and sabotage-related outages.

11. Nigeria has not held a licensing round for new exploration acreage since 2007 (a promised round of marginal fields has not materialised so far in 2014), whereas Angola has held pre-salt rounds, offshore in 2011 and onshore in 2013. In the ten years to 2013, Angola drilled 166 exploration and appraisal wells in deep water while Nigeria drilled 144.

Nigeria (Egina project). A key obstacle in Nigeria is uncertainty over regulatory provisions, with the much-delayed passage of the Petroleum Industry Bill (Box 3.2). A Nigerian Senate Committee has estimated that $28 billion of upstream investment is dependent on the passage of this legislation: until commercial decision makers are in a position to evaluate their projects against a more-or-less well-defined set of fiscal and regulatory conditions, continued project delays are inevitable.

Figure 3.11 ▷ Comparison of planned projects in Nigeria and Angola



Notes: Figure includes projects of more than 20 kb/d that are beyond the design phase and planned for delivery between end-2013 and 2020. Capacities are name-plate production capacities. Dark shading represents projects for which the final investment decision has been taken. Total's CLOV project saw first oil in June 2014.

Sources: Company reports; IEA analysis.

Box 3.2 ▷ Will Nigeria's Petroleum Industry Bill see the light of day?

The wide-ranging Petroleum Industry Bill (PIB), which was first drafted in 2008, aims to resolve two key – and intensely political – questions for the oil and gas sector:

- How the government can maximise its benefits from hydrocarbon resource development, while still encouraging efficient private investment.
- How revenue from the sector will be distributed and used among the various layers of government and administration.

It has a particular focus on measures necessary to increase domestic gas supply. All stakeholders agree that sweeping fiscal and non-fiscal reforms are sorely needed, but finding the right balance in a comprehensive and detailed piece of legislation has made its progress into law very slow and difficult. The provisions for revenue distribution between the 36 states and 774 local governments in Nigeria are particularly contentious.

From the perspective of future investment flows, two issues stand out. The first is the detailed provision on licensing, concessions, fiscal terms and cost allocation that will have a strong impact on investors' assessment of risk and return. The contractual system for deepwater projects is particularly sensitive. The deepwater production sharing contracts, which have been awarded since 1993 with a view to encourage frontier exploration, are now seen by many as too generous to the companies: technology advances have meant that the sliding-scale provision, whereby royalties decrease with increasing water depth, is more favourable than anticipated. The government would also like to gain more benefit from oil prices which are higher than were estimated in 1993, when oil was at $20/barrel. Analysis of the PIB, as currently drafted, suggests that it would increase government accruals slightly for onshore and shallow water operations (to more than 90%), but have a much more significant impact (from 50% towards 80%) on deepwater projects. Detractors argue that any revenue windfall from this will be short-lived if further investment and future production do not materialise. The PIB would also have strong implications for the institutional set-up of the oil sector, introducing both a crucial separation of duties between policymaking, regulatory compliance and commercial operations, and the unbundling of the NNPC to form a commercially viable, partially privatised entity that can be a stronger player in its own right and in dealing with international companies.[12]

There is a growing realisation that, although all stakeholders are aligned on the overall aims, the PIB may be too ambitious to survive as a single, comprehensive piece of legislation. Consultations in 2014 have suggested that it be broken into its constituent parts, which could then be considered as separate pieces of legislation – a pragmatic approach but one that could come at the cost of overall coherence and consistency. For the moment, uncertainty persists, but our projections assume that a more stable regulatory and fiscal environment, reflecting the key aims of the PIB, is achieved by 2020, providing a stimulus for upstream investment and a particular boost to the gas sector.

Oil theft and sabotage

Uncertainty over the regulatory environment is only one of the challenges facing Nigeria's oil sector. A more pressing immediate concern is the impact of unrest and militant activity in the Niger Delta region, which results both in oil theft and sabotage to the energy infrastructure. This has been a problem in Nigeria for many years, but the scale has increased. No hard numbers are available on the volume of crude that is stolen, but we estimate it to be just over 150 kb/d, when pilfering from crude trunk lines and product

12. The draft PIB, though, would give significant discretionary power to the Ministry of Petroleum, including the right to set royalty levels which are not specified in the bill.

theft have been added to theft between well-heads and the fiscal metering points in the Niger Delta (Figure 3.12). Additional losses come from deferred production due to damage to pipelines and other infrastructure. Together these losses add up to an annual average total of about 335 kb/d, or around 14% of total output. A distinction can be made between small-scale oil theft, which typically feeds local artisanal refineries that illegally supply the domestic market, and theft on an industrial scale by well-organised criminal groups using sophisticated techniques and with both the financial strength and international reach to support their operations.[13]

Oil theft brings with it a range of severe consequences. The most visible is that the environment in the Niger Delta has been severely compromised by the tapping and sabotage to pipelines that are always accompanied by some degree of oil spillage. The primitive technologies used in illegal bush refineries produce only limited amounts of refined product; it is estimated that more than 70% of crude is wasted in this type of operation. The environmental damage resulting from dumping the residues is widespread and affects agriculture, fisheries and the quality of water sources.

The way that oil theft sustains militant groups, and the concurrent weakness of administration in parts of the Delta region, also constrains adequate provision in the region of basic services, including piped water, electricity, health and education (Box 3.3). The revenues from selling 150 kb/d could amount to more than $5 billion per year, equivalent to the total sum budgeted in 2013 for federal spending on education and health together. This is also the annual amount that would be required, in our estimation, to fund universal access to electricity to all Nigerians by 2030.

The leaks in the Nigerian oil system are not confined to the upstream. Nigeria has four main refineries, two in Port Harcourt and one each in Kaduna and Warri, with a combined installed capacity of 445 kb/d. A history of poor maintenance and lack of investment in these refineries, particularly during the periods of military rule, resulted in the effective capacity in 2013 being only one-fifth of this figure. NNPC is responsible for keeping the domestic market adequately supplied with oil products; product demand is around 400 kb/d and NNPC in 2013 was allocated 435 kb/d of crude for this purpose. The nominal capacity of Nigeria's refineries is sufficient to meet this level of demand, but effective refining capacity of less than 100 kb/d means that other, often opaque arrangements are made, including sending crude to neighbouring countries to be refined, swapping crude for products through traders and selling crude to buy products.

13. It is difficult to track the destination of oil stolen in Nigeria but, given its limited refinery capacity the vast majority of this oil is thought to be exported illegally to international markets. This often involves the use of barges and small tankers that transport oil through the dense network of swamps and estuaries to larger vessels positioned offshore.

Box 3.3 ▷ Tackling oil theft

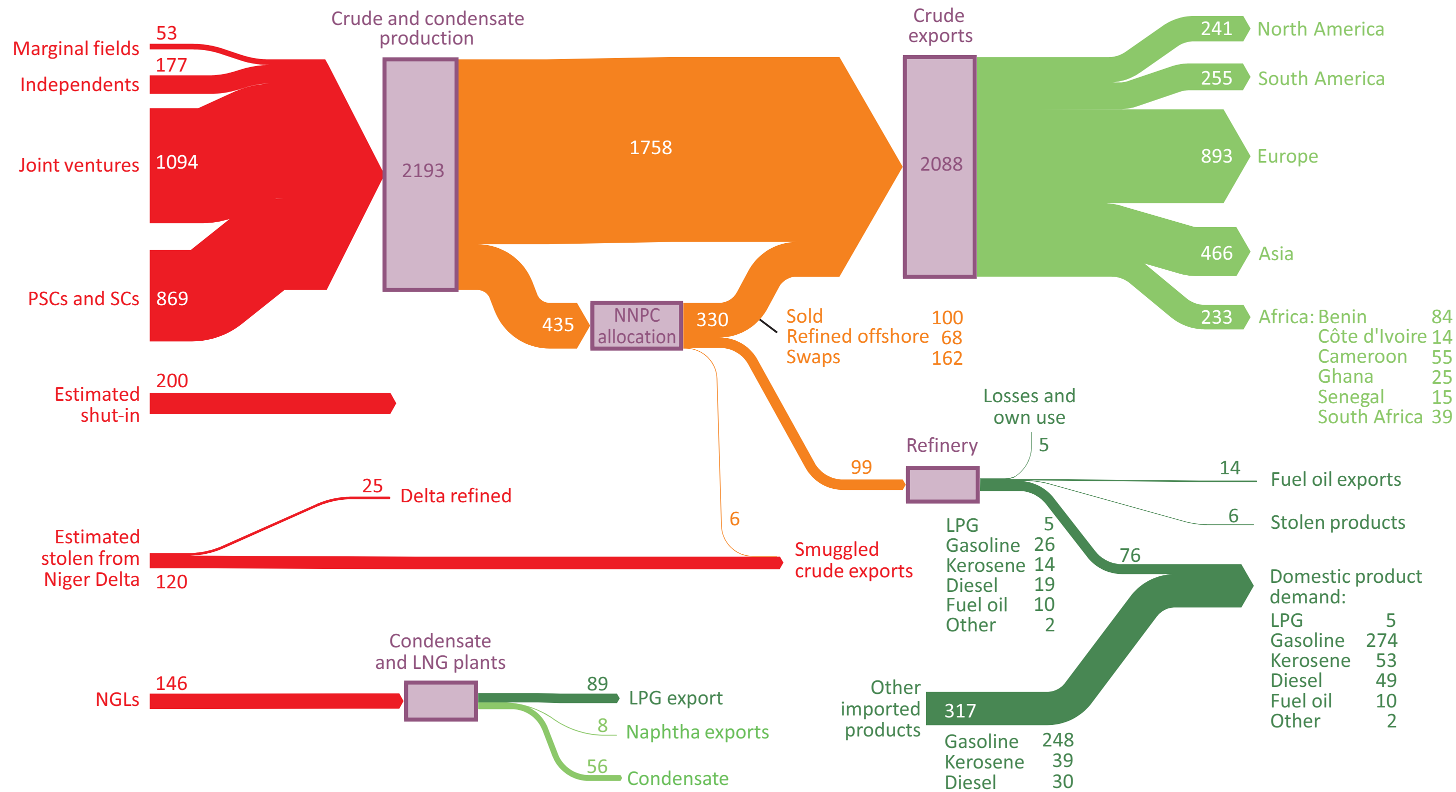
Oil theft is a multi-faceted issue, symptomatic of problems that stretch well beyond the energy sector. Potential solutions involve remedies that go well beyond the immediate issue of criminal activity. A lasting resolution must involve a consistent effort to tackle the main societal problems in the Delta region, including high unemployment, poverty and a lack of infrastructure and public services, in order to demonstrate that development of this national resource can bring tangible benefits to the local population. Weak institutions and corruption not only allow the theft to take place, but stifle efforts to address it.

In concert with a broader approach to address these points, more targeted measures in the following areas could also be effective in limiting oil theft and related activities:

- ***Enhance pipeline protection, measurement and monitoring:*** preventative measures cannot work in the absence of effective Nigerian law enforcement, but are essential to reduce access to pipelines, detect leaks and intrusions, improve response times and to pin down the nature and extent of the theft. Technology can contribute, but cannot provide a complete answer. Bringing local communities on-board is much more challenging, but essential.
- ***Prevent stolen oil from getting to market:*** a key measure to deter theft is to make stolen oil difficult to monetise. In the Delta, this includes marine patrolling of the main estuaries through which oil is transported to international waters. Other measures include improved control of documentation (bills of lading) for cargoes and increased oversight of purchases by refineries.
- ***Follow the money:*** intelligence on the financial flows associated with stolen oil is essential if those responsible beyond the immediate low-level participants are to face prosecution. This means identifying suspicious financial transactions and repositories, and cracking down on money-laundering.

The Nigerian experience underlines the problems that arise when there is little or no local gain from the development of a national resource. Early consultation and investment in local infrastructure and services is essential if public consent to resource development is to be obtained and maintained. Good measurement and transparency are essential to prevent flows of oil or money from being stolen. But perhaps the most important lesson from Nigeria is that theft must not be allowed to grow unchecked. Nigeria's difficulties at times seem intractable because the problem has been allowed to grow to a scale where the techniques can be very sophisticated, the groups involved very well-financed, and the vested interests well-entrenched.

Figure 3.12 ▷ Average daily oil production and distribution in Nigeria, 2013



Notes: Numbers shown on diagram are in kb/d. Changes in storage levels account for flow imbalances. PSC = Production-Sharing Contract; SC = Service Contract

Sources: Based on NNPC annual statistical bulletin 2013; CITAC data; company reports; IEA analysis.

The outlook for oil

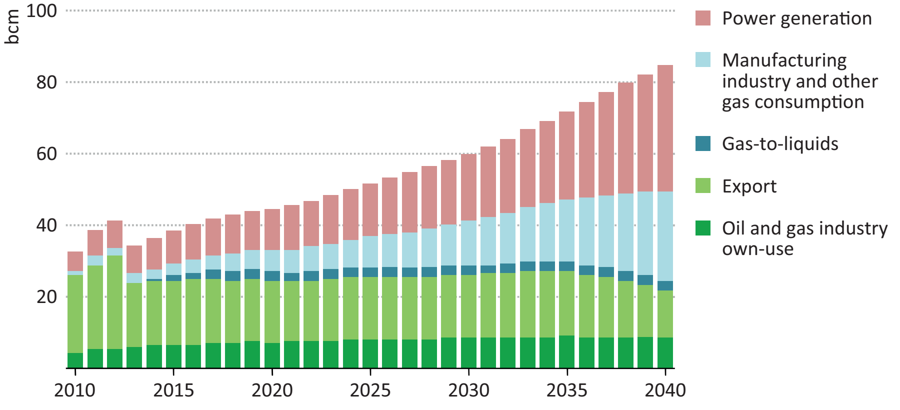
The development of the large and relatively accessible resources of the Delta region is constrained in our projections by considerations of cost. Costs are pushed higher by the existence of a large number of small oil fields and the difficulty of producing from swampy terrain. But a major additional barrier is the risk premium associated with operating in the Delta, due to security needs and expenditure on repair and maintenance of damaged infrastructure. The decision of some large international oil companies to divest their onshore Nigerian assets is symptomatic of their doubts over the outlook in this area, even though these divestitures also create opportunities for other players, typically local independent companies. Already in 2013, independent operators were producing nearly 100 kb/d, alongside a further 100 kb/d from the Nigerian Petroleum Development Company (NPDC), the operating arm of NNPC. The production outlook is heavily contingent on the evolution of the political and security situation in the Delta: in our projections, onshore production edges higher, to around 1 mb/d by 2040.

The production outlook for offshore areas, particularly in deep water, depends to a larger degree on the way that fiscal and regulatory issues evolve. As is the case with most deepwater projects, costs are relatively high and there are also particular pressures and bottlenecks in Nigeria arising from local content requirements (although investments are being made to bring local capacity up to the required levels). Our longer term outlook is predicated on the assumption of greater regulatory clarity being achieved by the end of this decade; with this in place, investments planned for the deepwater continue and additional resources are developed. By 2040, half of Nigeria's 2 mb/d of offshore output comes from deepwater projects (at a water depth greater than 400 metres).

With production of 3 mb/d in 2040, Nigeria remains a significant player in global oil markets: the second-largest OPEC producer outside the Middle East (after Venezuela), the largest African oil producer by a distance (well ahead of Libya and Algeria, and producing more than double the projected output of Angola). Cumulative estimated fiscal revenues from oil in the period to 2040 amount to more than $1.5 trillion. Yet, even if Nigeria were to be more successful in developing its huge resource base and managing its revenues, it is difficult to argue that oil will shape the way forward for the country. In many ways, Nigeria's prosperity depends on how quickly it can reduce its dependence on oil, by building up the non-oil sectors of the economy and broadening the tax base, so lessening the importance of petroleum fiscal revenue.

And yet the oil sector is nonetheless an important barometer of Nigeria's prospects. If investment in oil is not forthcoming, then investment in Nigeria's abundant gas resources is unlikely to materialise. In our projections, gas output – buoyed by a gradual reduction in the amounts that are wastefully flared – plays an increasingly important role in the domestic energy mix: gas more than doubles its share in the domestic energy mix by 2040 (from 9% to 23%), overtaking oil along the way and so playing a critical role in the country's development.[14] All incremental natural gas production post-2020 is needed to underpin domestic economic growth, with 28 billion cubic metres (bcm) of additional supply to power generation by 2040 and 16 bcm of additional supply to industry (Figure 3.13). The list of policy conditions associated with a thriving domestic gas sector is considerably longer and more challenging than those for oil: not only a supportive framework for the upstream, but a host of pricing and regulatory reforms to govern its transportation and use on the Nigerian market.[15] Managing oil wealth has proved a stern test for Nigeria: successfully creating and nurturing a vibrant natural gas industry will be an even more imposing task.

Figure 3.13 ▷ Gas production in Nigeria in the New Policies Scenario



Notes: The drop in 2013 gas production was caused by an industrial dispute that interrupted operation of the LNG export terminal and also by the need during the year to repair theft-related damage to pipelines. It also reflects in part an underlying shortage of recent investment in gas field developments.

South Africa: will energy diversity deliver?

Coal is the mainstay of the South African energy system, meeting around 70% of primary energy demand and accounting for more than 90% of domestic electricity output, but its position in the energy mix is not quite as secure as such a dominant position might suggest. Most South African coal comes from the mature Witbank coal fields in the north-eastern Mpumalanga province, where coal has been produced for many decades and as a result,

14. Nigeria's efforts to reduce gas flaring have met with some success, but an estimated 17 bcm was still flared in 2012, the second-largest volume globally after Russia. Our assumption of further reductions in gas flaring over the projection period is underpinned by several factors, including: the completion of new gas gathering projects now underway (by Shell, Total, Eni and others); the declining share of production from oil fields not equipped with the appropriate infrastructure (new fields should by law be zero-flaring); and greater incentives to market the gas because of pricing and other regulatory reforms. The increased availability of gas previously flared accounts for almost half of incremental gas supply in the period to 2025.

15. The Nigerian Gas Master Plan, published in 2011, identifies policy actions for the sector and provides a blueprint for gas infrastructure development. Producers are required to sell gas to the Gas Aggregation Company of Nigeria at a wholesale price which is set by the government. The government has been taking steps to increase this price as part of measures to ensure the availability of gas to power plants.

coal qualities and geological conditions are deteriorating; expanding coal supply from the more distant deposits, such as the Waterberg, located near the border with Botswana, brings a requirement for new infrastructure and the likelihood of upward pressure on costs. Other clouds on the horizon arise from a broader debate around the future of the South African power system. Low fuel input costs and ample reserve margins (resulting from over-building of capacity in the 1970s and 1980s) mean that South Africa's electricity prices have been among the lowest in the world. But the balance has tightened dramatically over the last ten years. Delays in bringing on new generation capacity – including two huge 4.8 gigawatts (GW) coal-fired plants at Medupi and Kusile being built by the state-owned utility Eskom – mean that the system is now supply constrained, causing load-shedding. The average price of Eskom electricity has tripled in real terms since 2005. Expensive oil-fired peaking plants are being called upon on a regular basis to meet demand, setting an implicit benchmark against which almost all alternative sources of power provide good value. And these alternatives are starting to appear, notably a well-designed programme to support renewable power projects, which has held three bidding rounds since 2011. These three rounds resulted in commitments from private investors to almost 4 GW of grid-connected renewables capacity: the first projects started operation in late 2013.

This new context for South African energy policy is reflected in a late 2013 update to the Integrated Resource Plan (IRP) for Electricity, the main long-term planning document for generation capacity. The existing IRP, promulgated in 2011, set out a vision of long-term diversification of the power mix and moves towards lightening the carbon footprint of the sector.[16] The update responds to a new set of circumstances and uncertainties; the likely pace of demand growth, falling technology costs for renewables, the costs of nuclear and of future coal supply, the possible rise of shale gas (a resource that South Africa is estimated to have in abundance) and natural gas discoveries in Mozambique and Tanzania. The 2013 IRP provides a starting point for our assessment of the prospective diversity of the South African power sector, how the fuel mix and costs of generation play out in the future, the questions that remain and the potential implications for the affordability of power and the environmental performance of the South African power sector.

What can displace coal?

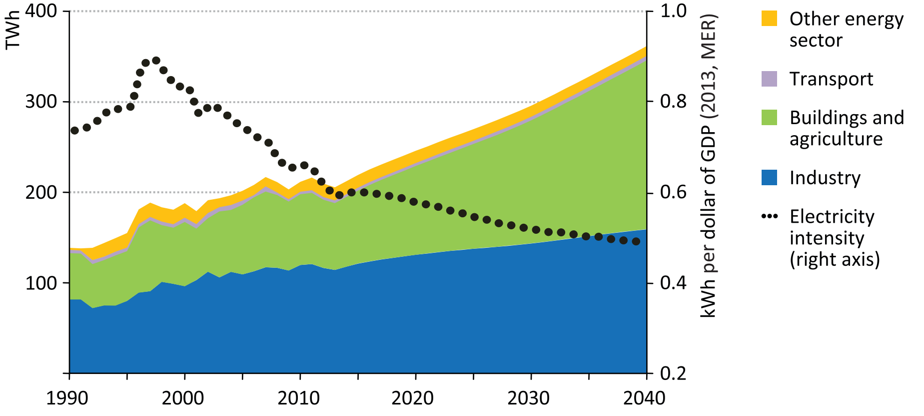
Electricity demand in South Africa in 2012 was 212 TWh, the same level as in 2006, even though the economy had expanded by almost 3% per year in the meantime.[17] Recent circumstances in the power sector are quite atypical, including not only load-shedding but also a power buy-back programme, instigated by Eskom in late 2012, in which large industrial consumers were paid to switch off production capacity, thereby avoiding broader shortages. Nonetheless, the flattening of power consumption in recent years is symptomatic

16. South Africa's president pledged at the Copenhagen climate meeting in 2009 that the country would reduce its carbon-dioxide emissions 34% below a business-as-usual case by 2020 and 42% below by 2025, provided the international community supported South Africa with financial aid and appropriate technology.

17. Net of own-use in power generation and transmission and distribution losses.

of broader questions that arise over the trajectory of future demand. As the economy shifts away from an energy-intensive phase of development, growth in GDP should de-link from growth in power consumption. A further dampening effect on demand comes from the rapid rise in end-user prices, which have created powerful incentives for efficiency improvements, spurred on by new efficiency programmes from the national government and municipalities. Our projections of demand growth (Figure 3.14) come in at the bottom end of the range foreseen in the updated IRP.[18]

Figure 3.14 ▷ Electricity demand growth by sector in South Africa in the New Policies Scenario



Policymakers, concerned about over-building generation capacity, have changed the emphasis of power sector development planning. Whereas the previous approach prized large-scale capital-intensive projects (including new nuclear plants) to meet high expectations of consumption growth, the updated IRP is wary of the risks of locking in capital and technology in a fast-changing energy environment. While large-scale regional projects are still part of the picture, a more flexible approach is advocated towards the domestic market, aimed to bring production closer to demand and to reduce transmission and integration costs.[19]

The implications of this strategy are poor for nuclear power; and additional nuclear capacity is postponed in our projections until the latter part of the 2020s. They are, though, positive for non-hydro renewables, which by their nature are smaller scale and can often be situated closer to demand centres. In our projections, the share of renewables in the

18. Electricity demand for 2030 in the 2013 IRP is projected to be in the range of 345-416 TWh (this definition of demand includes own-use in the power sector and transmission and distribution losses). This already represents a lowering of the demand outlook, compared with the original IRP. The equivalent demand figure for 2030 in the *WEO* New Policies Scenario is 347 TWh. GDP growth assumptions in the New Policies Scenario are lower than those in South Africa's National Development Plan, upon which the IRP is based.

19. The current South African power system relies on a series of large power stations clustered inland near the country's mining and industrial heartland, with long transmission lines to the coast.

power mix rises from 1% today to 22% in 2040, with solar power (PV and concentrating solar power [CSP]) making up more than half of this expansion (Table 3.2). By 2040, the share of CSP in the South African generation mix is among the highest in the world. One important implication is a significant drop in the carbon dioxide (CO_2) emissions intensity of the power sector, as average emissions per kWh (which are currently among the highest in the world) are reduced by around half in 2040.

Table 3.2 ▻ Electricity balance for South Africa in the New Policies Scenario (TWh)

	2000	2012	2020	2030	2040
Coal	193	239	257	247	243
Oil	-	0.2	0.2	0.2	0.2
Gas	-	-	4	12	22
Hydro	1	2	4	4	4
Nuclear	13	13	13	25	47
Other renewables	0.3	0.4	16	51	84
Wind	-	0.1	5	11	17
Solar PV	-	0.1	5	17	27
CSP	-	-	2	11	20
Total generation	**208**	**255**	**293**	**339**	**401**
(+) Net imports	12	-5	-2	8	20
(-) Distribution losses and own-use	30	38	43	49	58
Total demand	**190**	**212**	**248**	**298**	**364**

The envisaged expansion in renewables is delivered mainly through continued bidding rounds for renewables capacity, of the sort currently undertaken by the Renewable Energy Independent Power Producer Procurement Programme. This programme, which has attracted a range of domestic and international project developers, sponsors and equity shareholders, has so far accounted for the lion's share of private capital attracted to the power sector, not just in South Africa but in sub-Saharan Africa as a whole.[20] As with Brazil's pioneering auction system for new capacity, it uses competitive bidding to establish the price at which participants are ready to supply power to the market; this bid price then underpins a long-term power purchase agreement. The three bidding rounds thus far have delivered a large reduction in average prices for the various renewable technologies, mainly because of increased competitive pressure as more companies became interested in participation (the total amount of power to be procured was also restricted after Round 1, with this in mind), but also because of declining unit costs. As well as large scale renewable projects, the government also plans to encourage distributed generation, predominantly rooftop solar PV.

20. Of the 22 power sector projects in sub-Saharan Africa registered in the World Bank's Private Infrastructure Projects database as reaching financial closure in 2012, 18 of them are renewables-based projects in South Africa.

The scale of the South African market also makes it a major player in all discussions about regional renewable energy projects. South Africa is already a major customer for the Cahora Bassa hydropower facility in Mozambique and there are other projects being considered with the South African market in mind, including an expansion of Cahora Bassa and the new Mphanda Nkuwa project in Mozambique, as well as the huge Grand Inga project in DR Congo (see Chapter 2).

Another diversification option for South Africa is natural gas. The country is a minor producer from maturing offshore fields in the south, which feed the 45 kb/d gas-to-liquids plant in Mossel Bay, but a larger importer by pipeline from Sasol-operated fields in Mozambique (see next section), used primarily by industrial consumers. The new discoveries in the north of Mozambique have stimulated interest in the expansion of regional gas trade but, given the distances involved, this is more likely to be in the form of liquefied natural gas (LNG). The main potential for increasing the role of natural gas in the South African energy mix comes from indigenous shale gas (Box 3.4).

Box 3.4 ▹ Karoo Basin shale – a domestic gas source for South Africa?

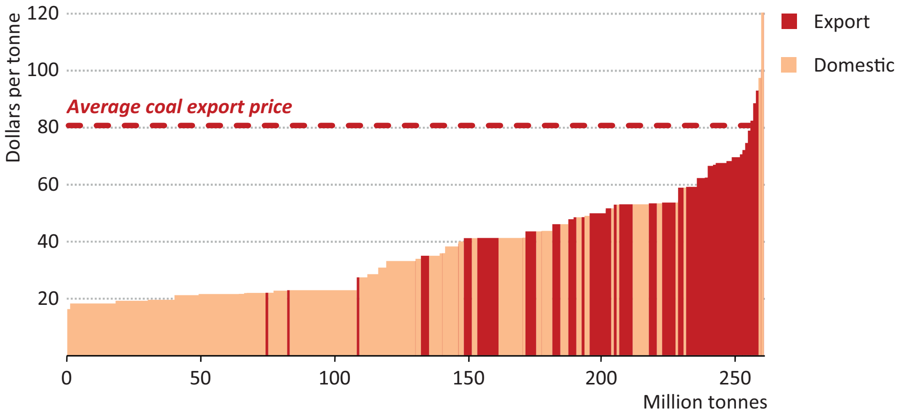
The large Karoo Basin in central South Africa holds significant shale gas resources, estimated at 11 trillion cubic metres (tcm) (US EIA, 2013). However, while discussion of exploiting the shale gas resource started at least six years ago, no exploration drilling or even modern seismic surveying has occurred, so figures for resources and development costs remain provisional.

Shell, Australian-based Challenger Energy and a number of other companies have been awarded exploration licenses. But in 2011 the government imposed a moratorium on hydraulic fracturing, effectively stopping activity, citing the need to develop an appropriate regulatory framework. The Karoo Basin is arid, and although sparsely populated, many communities rely on groundwater supplies. As elsewhere, concern over the possible impact of hydraulic fracturing on scarce water supplies dominates environmental concerns. Although the moratorium was lifted late in 2012, environmental opposition continues to be strong, focusing not only on water impacts, but also vehicle movements and other aspects of unconventional gas production.

The government is taking a supportive but measured approach to the development of its nascent gas industry, with significant work still to be done on the regulatory framework before any commercial shale gas activity begins in earnest. In our projections, development of shale gas in South Africa is assumed to start in the 2020s, with output rising steadily to reach 11 bcm by 2040. The absence of gas distribution infrastructure is expected to slow the uptake, so that over the projection period, South African gas use expands only slightly, from the current 3% in the primary energy mix (more than half of which is used for transformation into liquid fuels) to around 5% by 2040. The contribution to power generation rises to around 20 TWh, or 6% of total power output.

But coal remains at the centre of South Africa's energy outlook, and a critical question for the sector in a new competitive landscape is the extent of prospective upward pressures on coal costs and domestic prices. Eskom accounts for over 60% of coal consumption and is by far the main buyer of domestic coal. As things stand, most of Eskom's coal-fired generating stations are grouped around the mines in the Mpumalanga region, with relatively short transport distances. The utility procures most of its coal needs through long-term contracts that are typically priced at production cost, plus a rate of return. The main alternative market for coal producers is export: the coal fields in Mpumalanga are connected by railway to Richard's Bay Coal Terminal – the country's main export hub.[21] Coal mines that produce export-quality coal have an incentive to export any surplus that is not contracted domestically (moreover, the export options have broadened with Indian power companies willing to buy coal with high-ash content). The cost-plus coal prices paid by Eskom are typically much lower than the international coal price at Richard's Bay, even if theoretical transport cost to the export terminal plus washing and handling cost ($20-28 per tonne) are included (Figure 3.15).

Figure 3.15 ▹ South Africa mine-by-mine coal supply curve and the average coal export price, 2013



Notes: The graph shows the cash costs of South African coal mines at the point of sale. For domestic mines the point of sale is typically the mine-mouth while export mines sell on a free-on-board (ocean-going vessel) basis.

Sources: IEA analysis; Wood Mackenzie databases.

Many of the mines supplying power plants in Mpumalanga and providing exports are nearing exhaustion. New mines and expansion of existing capacity in Mpumalanga will only partially compensate for the long-term decline in production from this region. To increase

21. While throughput capacity at Richard's Bay Coal Terminal has been lifted to over 90 million tonnes per annum (Mtpa), the 580 km-railway line linking the mines to the port is currently constrained to around 72 Mtpa and other ports can handle only small quantities. Thus infrastructure bottlenecks are essentially impeding growth in South African coal exports.

production from today's 210 million tonnes of coal equivalent (Mtce) to 240 Mtce by 2040, as projected in the New Policies Scenario, South African coal producers have to move further north to greenfield projects in the Waterberg fields in Limpopo province. However, these coal fields are far from the export terminals, the existing coal-fired generation fleet and the electricity load centres.[22] The distance from the Waterberg to the coal plants in Mpumalanga is about 700 km and the distance to Richard's Bay is around 1 300 km.

Although Eskom has secured most of its coal needs for the coming years through long-term contracts, it will occasionally need to buy additional quantities on a spot basis, and then re-negotiate supply contracts over the medium term as they expire. This will take place against a backdrop of the gradual move to new coal production areas, an expansion of transport capacity to Richard's Bay, and increasing demand for lower quality coal from the international market. We assume that these pressures will bring domestic prices for coal in South Africa closer to export prices, at least for the share of the production that is of export quality.[23]

This shift in prices has an impact on our calculation of the costs of coal-fired power relative to other fuels (Figure 3.16). Yet, due to the relatively low transport distances to power stations and the high share of low quality material, coal is expected to remain on average significantly cheaper in South Africa than in most other countries.[24] Another factor affecting coal's competitive position is an envisaged gradual increase in the efficiency of coal-fired power plants. All coal-fired plants currently in operation are using subcritical technology and are hence operating at relatively low efficiencies of around 34% on average. With over 75% of current installed coal capacity built before 1990, and a typical technical lifetime of 50 years, many existing plants will need to be replaced before the end of the projection period. In our outlook, the first supercritical coal plants (the huge Medupi and Kusile plants) enter service by the end of this decade. After 2020, additional supercritical and, later, also ultra-supercritical plants are added, which push the average efficiency of the coal fleet close to 40% by 2040.[25]

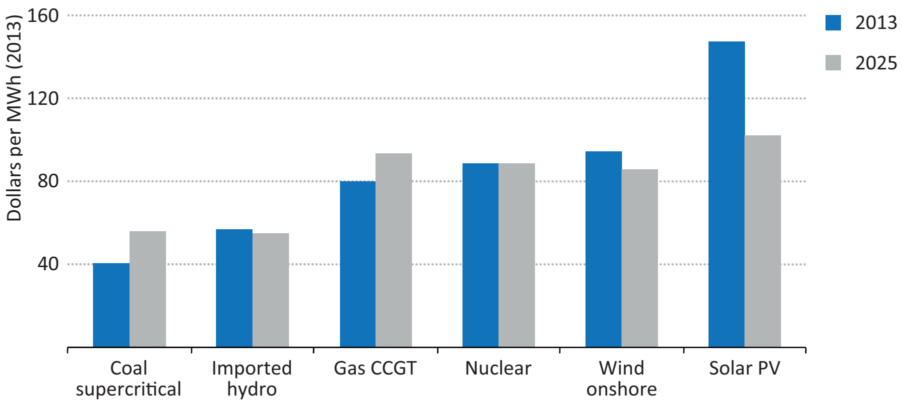
22. New coal-fired power plants are also planned in the Waterberg region to reduce coal transportation requirements in the longer term. Since the power demand hubs in Gauteng and along the east coast are located far away from these plants, this would require an expansion of long-distance transmission lines.

23. This confluence of circumstances has nourished fears that Eskom might not be able to secure sufficient amounts of low-cost coal to satisfy power demand. This has led to a debate on whether partial nationalisation of the coal industry or the introduction of a domestic supply obligation could increase national welfare. Were this to happen, it would affect the domestic price outlook but also the likelihood of investment in new mines and transport capacity.

24. The government proposal to introduce a modest CO_2 price, envisaged for 2016, would not make a material difference to the relative costs shown in Figure 3.16. However, stricter environmental standards on other emissions could have more far-reaching implications for both coal power generation and coal-to-liquids production.

25. Part of the new fleet will be designed to use high-ash coal and discard material from coal washing combining fluidised-bed combustion with latest steam-cycle technology.

Figure 3.16 ▷ Levelised costs of power generation by fuel and technology in South Africa



Note: Levelised costs are calculated based on an assumed weighted average cost of capital of 7%, though this may vary under certain market conditions.

The net result is that, even though rising coal prices narrow the gap between the cost of advanced coal-fired plants and alternative sources of power generation, coal remains a low-cost option for South Africa, with only imported hydro offering comparable value (demonstrating how regional integration can reduce the cost of energy). Renewables, in our estimates, become increasingly competitive and the bid system is well placed to track and take advantage of any reductions in unit costs. But the analysis suggests that commercial considerations alone will not deliver diversification of the power mix. Other considerations, such as local air pollution, reduction of CO_2 emissions, the lead times to build new capacity, and locational and grid issues need to be taken into account.

While the options appear diverse, the affordability of electricity supply looms as a key concern and, potentially, a constraint on the diversification agenda. The structure of consumption and of spending on electricity is skewed towards higher income groups, with the richest 20% of the population accounting for more than half of the total. In recent polling conducted by the Department of Energy, three-quarters of South Africans stated that the priority for government energy policy should be to keep electricity prices low: economic considerations outweighed other priorities by a considerable margin (Department of Energy, 2013). Regarding the future fuel mix, nearly a third of respondents agreed with the statement: "it does not matter which source, as long as it is the cheapest". But a quarter of respondents explicitly supported renewable energy sources, with a further 14% placing emphasis on sources that are not damaging to the environment. As elsewhere, the government will face complex choices as it pursues its energy policy objectives and needs to pursue an active policy of public engagement in the debate. But South Africa's combination of integrated policymaking, strong regulation, well-designed incentives for low carbon investment (including private investment), greater efficiency and regional integration gives it enviable strength for the task.

Mozambique and Tanzania: how to get best value from gas?

Major offshore gas discoveries in Mozambique and Tanzania (Figure 3.17) have created high expectations, both within the countries concerned and internationally, about the opportunities that might open up both for the domestic economy and for supply to more distant markets. In our projections, Mozambique and Tanzania are among the main sources of sub-Saharan gas supply growth, contributing 44% of the 170 bcm increase in the region's gas output. But, even as the extent of East Africa's energy resource wealth becomes clearer, so the focus shifts to questions above the ground: how can gas, considered a premium fuel in many parts of the world, foster local industrial and economic development in fast-growing but still very poor countries? And what are the options and risks facing national policymakers as they attempt to maximise the value of their gas resources?

Gas is more challenging to develop than other fossil fuels. In particular, its low energy density means that the end-product is more difficult and costly to transport. With oil discoveries, project developers can proceed safe in the knowledge that they can expect readily to find a buyer. By contrast, in the absence of a large and proximate market, gas tends to stay in the ground until there are clear and specific commitments as to its use, as well as clarity on how it will reach the relevant end-user. Achieving these is a delicate and complicated process, requiring co-ordination along the value chain, anchor volumes of demand at sufficient scale and adequate regulation of markets and networks.

Developing gas resources is also a hugely capital-intensive process, with cost estimates for the first phase of upstream and LNG development in Mozambique being well above the country's entire annual GDP. In addition, the gas resource is very dry, i.e. with a very low share of the natural gas liquids that can often considerably boost project economics. Although favourably located in international terms, in relative proximity to the fast-growing markets of Asia, local gas consumption and infrastructure – particularly in Mozambique – are at a very early stage of development.

Options for gas utilisation

Appraisal of the gas discoveries made since 2010 off the coast of northern Mozambique and southern Tanzania is still underway but, based on the information available, the amount of gas recoverable from the new discoveries could be in excess of 5 trillion cubic metres (tcm), most of which is in Mozambique. Both countries only used a combined 1 bcm in 2012 in their domestic markets (0.02% of the estimated resource), most of this in Tanzania. Against this backdrop, it is clear that the main market for gas is export, bringing revenues to the national budget which can be used to fund domestic infrastructure and other spending priorities.

Figure 3.17 ▷ Main gas fields and infrastructure in Mozambique and Tanzania

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.

In our projections, LNG facilities start operating in Mozambique in the early 2020s, with four LNG trains and a floating LNG (FLNG) facility on stream by the latter part of the decade. By 2040, further expansion brings total projected gross export capacity in Mozambique to 60 bcm per year (43 million tonnes of LNG). LNG export from Tanzania is anticipated on a smaller scale and to start somewhat later than in its southern neighbour, with one train fully operational in the 2020s and a second following in the 2030s. These expectations for the timing of the start of new LNG facilities are later than those envisaged by the companies involved. The reason is not related to the size or quality of the resource base, but rather to multiple factors that could contribute to delays in project implementation. The region in which the LNG facilities are planned – particularly on the Mozambique side – is remote with very limited infrastructure, complicating all aspects of the construction phase.[26] There are arguments in favour of co-operation between different consortia on either side of the border: in Mozambique to develop the parts of the Prosperidade and Mamba prospects that straddle Areas 1 and 4, and in Tanzania to combine the resource bases of smaller fields in different license areas (Table 3.3). But resolving whether and how this co-operation might work in practice is likely to be a complex and lengthy business. There is also residual uncertainty over the legal and regulatory frameworks, notably in Tanzania, where a constitutional review is underway that could affect natural resource ownership. Last but not least, there are questions about the marketing of the LNG to prospective buyers, given that strong competition between suppliers is expected in the early 2020s.

Table 3.3 ▷ Main new upstream gas projects in Mozambique and Tanzania

Block / main fields	Partners	Status
Mozambique		
Area 1: Golfinho, Tubarao, Prosperidade	***Anadarko*** (26.5%), Mitsui (20%), ONGC (16%), ENH (15%), Bharat (10%), PTT (8.5%), Oil India (4%)	Area 1 is closest to the Mozambique coastline. Discoveries in 2010-2012; part of the Mamba field (Area 4) straddles the border with Area 1
Area 4: Coral, Mamba	***Eni*** (50%), CNPC (20%), Galp Energia (10%), KOGAS (10%), ENH (10%)	Discoveries in 2011-2013, part of the Prosperidade field (Area 1) straddles the border with Area 4
Tanzania		
Blocks 1,3,4: Chaza, Jodari, Mzia, Papa, Chewa	***BG*** (60%), Ophir (20%) Pavilion (20%)	Nine discoveries in total in 2010-2014, although considerably smaller than those in Mozambique
Block 2: Lavani, Tangawizi, Piri,	***Statoil*** (65%), ExxonMobil (35%)	Six discoveries in 2012-2014

Notes: Existing production in Mozambique comes from the Sasol-operated Pande and Temane fields (connected by pipeline with South Africa) and in Tanzania mainly from the Songo Songo field. These were discovered in the 1960-1970s, but only started operation in the 2000s. No final investment decision has yet been taken on any of the projects in the table above.

New gas developments are a major potential source of fiscal revenue to the host governments. Our projections envisage a cumulative $115 billion over the period to 2040 in Mozambique and about $35 billion in Tanzania. This income flow provides an opportunity to step up the pace of investment in power generation, water supply and sanitation, transport, education and health. Prudent borrowing against future income would allow

26. Construction risk and onshore environmental impacts are limited with floating LNG facilities, which can be manufactured at a distance and towed into place; but the downside is the absence of economies of scale if facilities need to be expanded. There are also fewer benefits in terms of onshore development, which can be a barrier for acceptance by host governments.

this investment to start well in advance of first gas being produced.[27] However, LNG projects and their associated revenue streams do not satisfy the desire of the countries concerned to see gas become a direct driver for national development, whereas there is a widely shared determination among governments – and a strong expectation from the public – that the benefits of these gas developments should be felt more directly. Two issues dominate this debate: that there should be the maximum amount of local sourcing during the construction phase of the upstream and LNG projects, i.e. requirements for local content; and that every effort should be made to build up domestic gas- consuming sectors.

The issue of local content is rising in prominence in both countries. Tanzania is in the process of adopting legislation providing that training and procurement opportunities open up for local firms. Mozambique is not far behind, although on this issue as on others, they may take a less prescriptive stance. In both countries there is an acute shortage of capacity to provide goods and services for the gas industry and, for now, this limits the potential impact in terms of employment and value added. Capacity will take time to develop, and will tend to start in areas such as logistics and catering, before progressing to more skilled areas like equipment maintenance, welding, fabrication and component manufacturing. Local content provisions that run too far ahead of capacity can quickly lead to bottlenecks in the supply chain.

Domestic gas-consuming sectors also have to be built from a very low base (Figure 3.18), although, in Tanzania, gas from the Songo Songo field already feeds power stations and provides process heat to local industrial facilities. Compressed natural gas (CNG) is also used as a transport fuel in Dar es Salaam. The ambition to expand domestic consumption is clearly expressed in Tanzania's Natural Gas Policy, adopted in 2013, which states that the government shall "ensure that the domestic market is given first priority over the export market in gas supply" and this is reflected in an obligation on gas producers to sell a portion of their output to the domestic market. Larger resources and anticipated production volumes means that a greater share of Mozambique's gas is destined for export as LNG, but here too – as expressed in a Gas Master Plan and a new Petroleum Law adopted in 2014 – Mozambique is determined to create new outlets for domestic gas supply. [28]

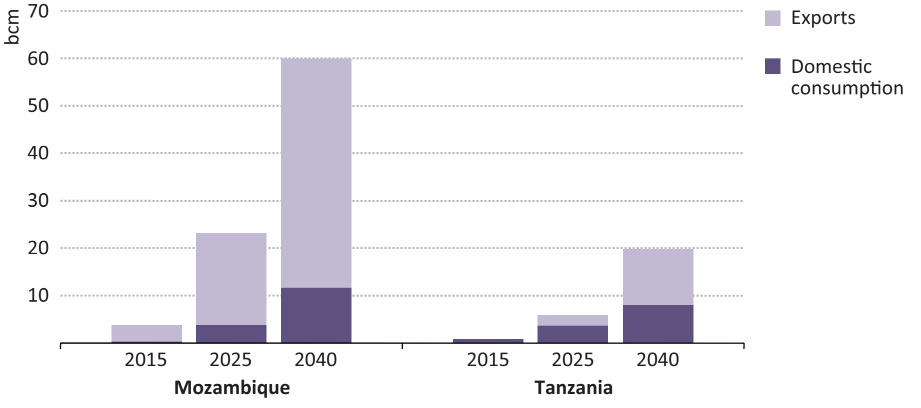
The dilemma facing both countries, and particularly Mozambique, is that building up a sizeable domestic gas-consuming sector is a challenging and expensive undertaking. Tanzania is in a slightly easier position, because of the relative proximity of the gas discoveries to the major consumption centre of Dar es Salaam: there is already a pipeline link from Songo Songo and a major Chinese-built coastal pipeline, with 8 bcm/year capacity,

27. In the case of Mozambique (and many other African jurisdictions), capital gains tax applied to the sales of stakes in the various blocks – irrespective of the locations of the companies concerned – has already been a major source of early income from the gas discoveries.

28. Of the total gas currently produced and exported to South Africa from the Sasol-operated Pande and Temane fields, around 5% is consumed in Mozambique in industry, transport (as CNG) and the residential sector.

is due to start operation in 2015 (well in advance of the start of production from the major offshore discoveries). In Mozambique, by contrast, the gas discoveries are more than 2 000 km from the capital, Maputo, and there is very limited access to major population or industrial centres. International experience offers little guidance for countries seeking to expand gas consumption from this starting position (Box 3.5).

Figure 3.18 ▷ Gas consumption and export in Mozambique and Tanzania in the New Policies Scenario



Notes: Mozambique exports in 2015 are from the Pande and Temane fields to South Africa. Domestic consumption includes the gas used in the liquefaction process for LNG.

Both Tanzania and Mozambique are looking for sizeable projects (so-called mega-projects) that can buttress the development of the domestic gas sector. The power sector seems an obvious place to start. A high share of the population in both countries is without access to electricity. This is combined with an urgent need in Tanzania to reduce its use of high cost emergency power plants that burn oil products. But putting in place sizeable power projects requires a high degree of assurance about the adequacy of future revenue streams, both for power generators and gas suppliers. The record here has been mixed in Tanzania, with Tanesco, the state power utility, running up large debts to the operators of the Songo Songo field.

In Mozambique, the nearest existing consumption centres to the gas discoveries are the port cities of Pemba and Nacala, but these are not now major industrial centres. Moreover, the further south that gas penetrates into Mozambique, the higher the infrastructure cost and the greater the challenge of competition from other indigenous energy sources (coal, large hydro and other renewables), a consideration that holds back the growth of gas-fired power in our projections. In the New Policies Scenario, gas use for power generation in Mozambique and Tanzania rises from 0.8 bcm in 2012 to 3 bcm in 2025 and 9 bcm in 2040, with Tanzania accounting for 40% of the eventual total. By 2040, gas provides more than one-third of combined electricity production from the two countries.

Box 3.5 ▷ Building up a customer base for natural gas

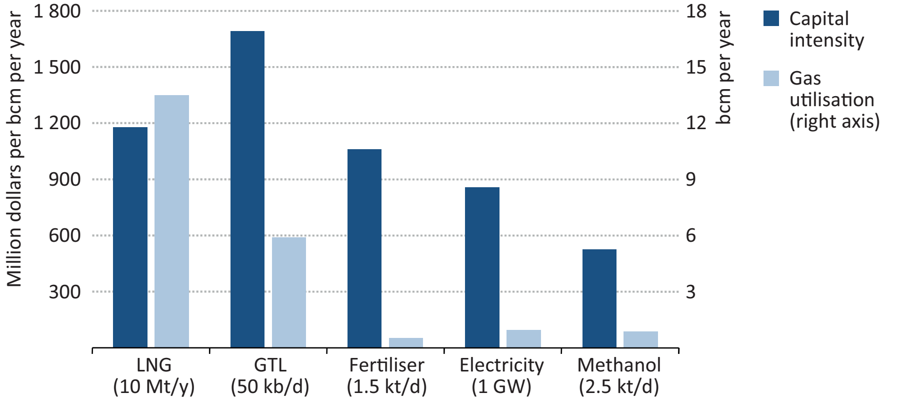
Historical data for natural gas use suggest that a rapid expansion in domestic gas use has, by and large, occurred only in countries which already have a large and diversified base of power generation and industrial assets, parts of which can switch to gas and other parts of which can use gas to fuel their expansion. With investment in distribution systems, gas can also make quick in-roads as a fuel for residential use where population density is high. A notable example was in West Germany in the 1970s, following the start of large-scale gas imports from the Soviet Union: domestic gas use increased by almost 50 bcm in the space of ten years. The United Kingdom and the Netherlands also achieved large increases in domestic demand to accommodate the rise in their gas production.

For countries without a large existing base of potential consumers, the speed at which gas consumption can be developed is much more constrained. Large "anchor" projects are essential to underpin the economics of pipelines and other gas infrastructure, with investment co-ordinated with the upstream to ensure that gas output finds a ready market. These projects come in two categories: those using process heat from gas combustion (mainly gas-for-power, but also industrial plants for steel or cement manufacture, or refineries) and those using gas primarily as a feedstock (as for gas-to-liquids technology, or the production or ammonia, urea and methanol).

Trinidad and Tobago provides an interesting case of a gas-producing country that, with limited potential for growth in gas demand from the residential and power sectors, chose to stimulate gas demand in domestic industry. With ample and relatively cheap gas supply, the country became the world's largest exporter of ammonia and the second-largest exporter of methanol. However, these are both capital-intensive export-oriented sectors, that have generated revenue but have had only a relatively limited impact on domestic employment. Other initiatives in Trinidad and Tobago have been less successful: a gas-to-liquids plant approved in 2005 was never finished and was eventually dismantled and sold for scrap. Much depends on the availability of markets, Trinidad and Tobago is fortunate because of its proximity to the large North American market. Landlocked Turkmenistan, by contrast, has many fewer options to monetise its gas which is why petrochemical and other initiatives to use the gas domestically (outside the power sector) have enjoyed only limited success.

Outside the power sector, the most promising avenues for industrial gas consumption, apart from the LNG facilities themselves, would be the manufacture of various chemicals, notably fertilisers (ammonia, urea) and methanol, as well as gas-to-liquids projects. All of these are under consideration and involve different degrees of capital intensity and commercial risk (Figure 3.19). The chemicals projects would rely to varying degrees on exports: local and regional demand for fertiliser is higher than for methanol, but a reasonable-sized plant of either type would need to target international markets. While capturing additional value, compared with gas export, and diversifying commodity price risk away from gas, these projects would still be subject to significant hazards from fluctuating international prices. A gas-to-liquids project would use a much larger volume of gas, with the attractions related more to import substitution and the possibility of selling a gas-based product into a market that has different dynamics; but this option has the highest (and least certain) capital costs.

Figure 3.19 ▷ Indicative capital intensity and gas utilisation for different large-scale uses of gas



The relative virtues of the various mega-project proposals will require careful and transparent assessment by the respective national authorities, based on a clear vision of how gas will be priced on the domestic market. What is already evident though, is that such mega-projects are unlikely to spread the benefits of gas more widely through society by themselves. They are highly capital-intensive, with low direct impacts in terms of employment.[29] To ensure a broader impact, these projects need to act as catalysts for developing pipelines and other infrastructure, facilitating gas distribution to smaller commercial and residential consumers along the way. This effect is already visible in Dar es Salaam, where the delivery of piped gas to the Ubungo power plant on the outskirts of the city has allowed businesses, ranging from bottling plants and food processing to textile and glass manufacturers, to tap into this source of gas supply, some switching from more expensive oil products. While typically accounting for a relatively small share of pipeline throughput, these end-users can play a much larger role in job creation. Distributing fiscal revenues from exports to the community is a relatively simple task: reaching them with reliable gas supply is much more difficult, but potentially represents a much longer-lasting source of value to the economy.

29. These characteristics are shared with some of the main mega-projects implemented thus far in Mozambique. Mozal (a major aluminium plant) and the Cahorra Bassa hydropower plant were multi-billion dollar capital investments; (they account for around 10% of GDP and 60-70% of Mozambique's exports by value), but employ less than 0.05% of the labour force (IMF, 2014).

Building a path to prosperity

How can sub-Saharan Africa make the most of energy?

Highlights

- Securing a more prosperous future for sub-Saharan Africa depends on progress in three areas of energy policy: increased investment in supply, in particular of electricity, to meet the region's growing energy needs; improved management of natural resources and associated revenues; and deeper regional co-operation. The pace of change will be set by the quality and integrity of the public institutions concerned, as well as the transparency and accountability of their operations.

- Since 2000, two out of every three dollars invested in sub-Saharan energy has gone to produce energy for export. Some of the policy and regulatory constraints holding back a much-needed expansion in domestic power supply are eased in the New Policies Scenario, bringing in a new cast of investors including more private companies. Over the period to 2040, two-thirds of investment in the energy sector goes towards providing energy to be consumed within sub-Saharan Africa itself.

- Projected oil and gas output to 2040 generates more than $3.5 trillion in cumulative fiscal revenues, an amount higher than the $3 trillion invested in the sub-Saharan energy sector over the same period. These revenues are though concentrated in a much smaller group of countries, first among them Nigeria followed by Angola, that face a stern challenge to manage them efficiently. Despite the large anticipated increase in gas output, around 90% of hydrocarbon fiscal revenues come from oil.

- Regional co-operation is a major element of Africa's vision for its future, providing a cost-effective way to increase the availability and security of energy supply. Energy trade rises, but some major projects, notably for hydropower, still face technical, political and social hurdles that increase reliance on expensive alternatives.

- The New Policies Scenario sets a demanding agenda for Africa's policymakers, but hardly reflects the full potential of energy to act as an engine for prosperity. Opportunities are missed, or not captured in full. Power supply remains unreliable and more than half a billion are left without access to electricity and clean cooking facilities. In an African Century Case, more rapid energy development, set against a backdrop of improved governance, gives a 30% boost to GDP by 2040.

- An extra $450 billion in power sector investment in the African Century Case, accompanied by deeper regional integration, accelerates progress with energy access, especially in rural areas. More reliable and affordable power supply removes a major obstacle to business development: every $1 invested in power supply generates more than $15 in incremental GDP. Oil and gas production is higher and a larger share of the resulting revenue is invested productively in reversing deficiencies in essential infrastructure.

Towards a better-functioning sub-Saharan energy sector

The two faces of energy, its positive and negative aspects, are more clearly visible in sub-Saharan Africa than in any other part of the world. As underlined in earlier chapters, energy is a critically important enabler of social and economic development and a source of revenue for much-needed investment in infrastructure and other purposes. But – particularly where electricity is lacking or resources are poorly managed – it can also become a source of division, conflict, environmental degradation, poverty and under-performance.

What conditions will need to be met for the positive contribution of energy to predominate? In this chapter, we focus on three areas that are critical, in our judgement, to a better-performing sub-Saharan African energy sector.

- **A step-change in investment in domestic energy supply:** since 2000, we estimate that two out of every three dollars invested in sub-Saharan Africa went to produce energy for exports, with only one dollar in three going towards providing energy to be consumed within the region. Increasing investment in the sub-Saharan power sector is essential to bring this equation into line with the region's energy needs.
- **Better management of the region's resources:** sub-Saharan Africa has ample energy resources, both fossil fuel and renewable, but the opportunities that these offer to support sustained economic growth are often missed. A glaring example is the way that deficiencies in essential infrastructure in many countries are perpetuated by ineffective or corrupt misuse of revenues from fossil fuel extraction.
- **Deeper regional energy co-operation:** expanding cross-border trade can be a very cost-effective way to increase the reliability and affordability of energy supply, but this is often hindered in practice by a range of technical and political barriers. The lack of regional scale is a particular obstacle for the development of sub-Saharan Africa's large remaining hydropower potential.

These conditions are inter-linked, not least because their achievement depends in large part on the broader standards of governance that countries succeed in maintaining, both inside and outside the energy sector.[1] Governance indicators are generally weak in sub-Saharan Africa, compared with other parts of the world (although stronger in some southern parts of the region, notably Botswana, Namibia and South Africa), implying substantial risks arising from policy and regulatory uncertainty, inadequate protection of contracts and property rights, poor-quality administration and the actions of governments that are only weakly accountable to their citizens. Tackling these weaknesses will require

1. Governance is defined as "the traditions and institutions by which authority in a country is exercised" and encompasses such factors as the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them (Worldwide Governance Indicators Project, 2014).

actions across a broad front; particularly important elements from an energy perspective are investment in the skills and knowledge required for a modernising energy economy and the transparency and consultation on energy policies that is essential to winning public consent.

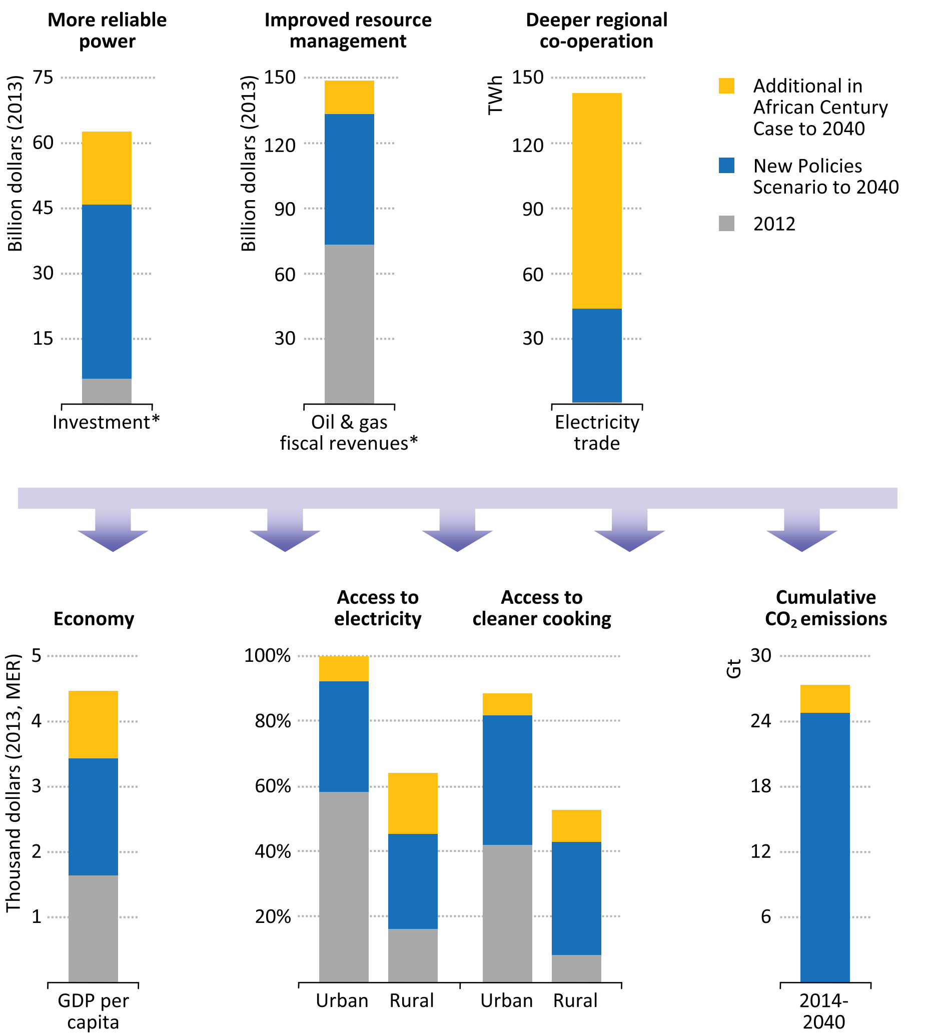
In this chapter, the discussion is viewed initially through the lens of the projections in the New Policies Scenario. This scenario sets a demanding agenda by taking into account the energy policy ambitions and targets of African countries, but accompanied by a careful assessment of the prospects for realising them in full, bearing in mind the difficulties that often arise with securing the necessary budgetary and financial support and, crucially, in ensuring adequate performance of the relevant institutions and administrative mechanisms that formulate and implement policies. This means that official targets are often not met in our projections, or their achievement is postponed.

The energy path outlined in the New Policies Scenario therefore represents a realistic, but not a fully satisfactory outcome for sub-Saharan Africa. This scenario does not reflect the full potential of the energy sector to act as an engine for economic transformation and growth. Some opportunities are missed, or not captured in full. Progress remains uneven and constrained. Constraints on the availability or reliability of energy supply continue to act as a brake on economic activity and welfare. Power generation steps up, but the problem of unreliable supply could be expected to persist in many countries; moreover, over half a billion people are left in 2040 without access to electricity.

Much more could be done. What might be achievable in sub-Saharan Africa is illustrated in an African Century Case, in which more rapid development of the energy sector, set against a broader backdrop of improved governance, plays a significant part in bringing about a faster improvement in living conditions and prospects (Figure 4.1). Although still not achieving universal access to modern energy for all of Africa's citizens by 2040, this outlook is one in which uninterrupted and reliable energy supply increasingly becomes the rule, rather than the exception, thereby reducing the economic losses and inconveniences to businesses and households caused by brown-outs and disruptions.

The actions that underpin the African Century Case (described in more detail later in this chapter) target the same three critical areas identified above, but go beyond what is achieved in the New Policies Scenario: an additional $450 billion in power sector investment; higher revenue from the oil and gas sectors, a larger share of which is invested in improving infrastructure; and deeper regional co-operation, which allows for more efficient use of the continent's resources. These actions take time to feed back into greater economic activity, but we estimate that, by 2040, they generate a very substantial return, sufficient to boost the combined GDP (at market exchange rates) of sub-Saharan Africa by 30% above the levels anticipated in the New Policies Scenario, an increase in regional output of almost $2 trillion. Over the projection period as a whole, the annual average growth rate for sub-Saharan Africa is raised by one percentage point, from 5.1% to 6.1%. The level of per-capita income reached in 2040 ($4 500 per capita, calculated at market exchange rates) would be reached only after 2050 in the New Policies Scenario, suggesting that the impact of the African Century Case is to generate an additional decade's worth of growth.

Figure 4.1 ▻ Policy actions and outcomes in the African Century Case



*Data are annual averages. Historical annual average data are shown for the period 2000-2013. Projections show the additional annual average for the period 2014-2040.

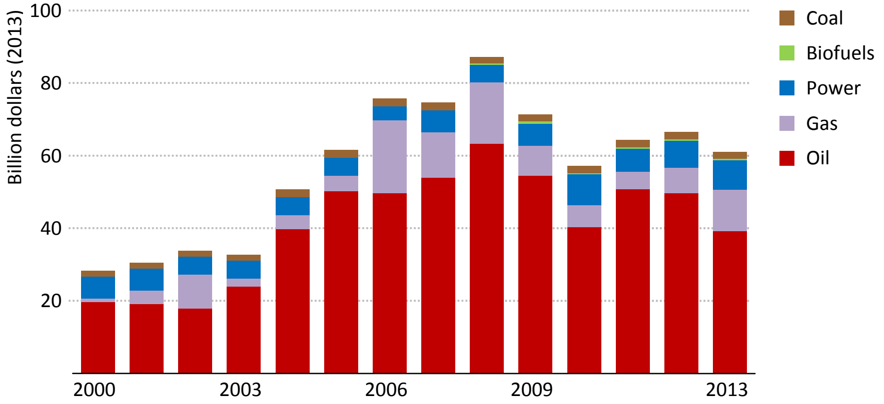
Note: MER = market exchange rate.

Three keys to Africa's energy future

Investment in the region's energy supply

An improved energy outlook for sub-Saharan Africa will require sustained investment, at higher levels than have been seen in the past, as well as a significant re-balancing of overall investment flows towards the provision of energy to domestic consumers within Africa. We estimate that, since 2000, investment in sub-Saharan African energy supply has more than doubled in real terms, from around $30 billion per year in the early 2000s to an annual average of around $65 billion since 2006 (Figure 4.2). Africa is a growing destination for international investment flows, from both developed and emerging economies. However, the bulk of this increase is attributable to a rise in spending on projects in the oil sector, which reached an average of $50 billion, almost 15% of total oil investment outside the OECD. For the period 2000-2013 as a whole, oil accounted for almost three-quarters of total investment in sub-Saharan African energy supply, a higher percentage even than in the Middle East (where oil spending accounted for around 60% of total energy supply investment) and a much higher share than in the rest of the world (where oil made up around one-third of the total).

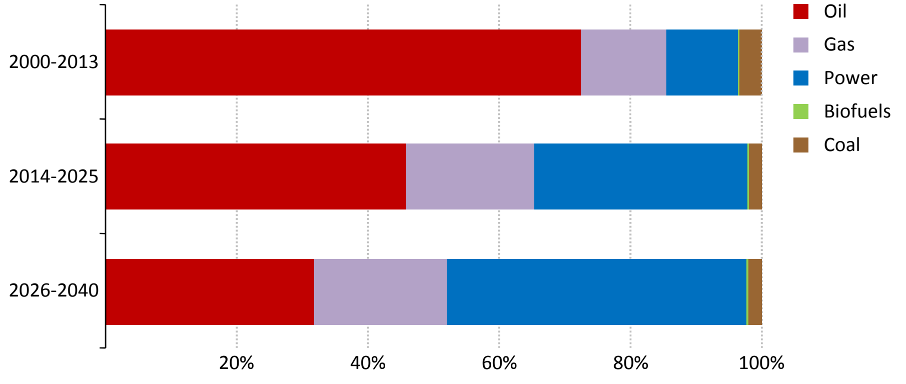
Figure 4.2 ▻ **Investment in energy supply in sub-Saharan Africa**



The mismatch between the direction of current investment flows and the continent's energy needs becomes even clearer when looking at the power sector. Although spending has increased over the last decade, annual investment in the sub-Saharan African power system is currently estimated at around $8 billion per year, or 0.5% of GDP. This compares very unfavourably with the non-OECD average of 1.3% of GDP invested in the power sector, and remains well below what is needed to improve the reliability and coverage of the electricity system. This has led to the present situation – as detailed in Chapter 1 – where the power sector more often limits economic growth rather than boosting it. To accelerate capital flows to projects in electricity generation, transmission and distribution is a critical challenge – recognised both in Africa's own policy ambitions and in international efforts, such as the Sustainable Energy for All and US Power Africa initiatives.[2]

In the New Policies Scenario, investment in all areas of the sub-Saharan energy sector increases substantially, averaging more than $110 billion per year, with a steadily growing share of this investment directed towards meeting the region's own energy demand. Over the period 2000-2013, two-thirds of the total invested in sub-Saharan Africa went to produce energy for exports, with only one-third going towards providing energy to be consumed within the region. In the New Policies Scenario, this situation is gradually reversed, so that two-thirds of energy investment in sub-Saharan Africa to 2040 goes towards meeting the region's own energy needs. This is reflected in the large increase in the share of the power sector in total energy investment (Figure 4.3).

Figure 4.3 ▷ Shares of investment by sector in sub-Saharan Africa in the New Policies Scenario



Over the period to 2040, there remains a steady stream of investment aimed in full or in part at bringing sub-Saharan energy resources to international markets. Indeed, this remains the driver for many upstream oil and gas projects, as well as for some Southern African coal investments (see section on international energy trade in Chapter 2). Such projects produce an invaluable flow of national income for application to other projects commanding national priority. However, this changing balance of investment in the energy sector does imply a large increase, to an average of $75 billion per year, in the amount invested in projects supplying sub-Saharan African consumers with fuels and electricity.

2. For consistency with our projections of future trends, our historical investment numbers reflect "overnight investment", i.e. the capital spent is assigned to the year that production is started, rather than to the year when it was actually incurred. In the case of the African power sector, the figures for current investment do not therefore include the significant number of projects in which capital investment is ongoing, but which have not yet started operation.

A necessary condition for achieving this step-change in capital flows is government action to create sufficient opportunities for investment. This challenge extends well beyond the energy sector, involving a reduction of the risks arising from macroeconomic or political instability and from weak protection of contract and property rights (Spotlight). But it also means consistent attention to reform of the way the power sector operates, in order to realise the policy ambitions of governments across sub-Saharan Africa to improve the reliability and coverage of their electricity systems. Reform programmes, including plans for electrification, have been put in place in countries including Nigeria, Angola, Uganda, Rwanda, Ethiopia, Ghana, Mozambique, Tanzania, the Democratic Republic of Congo (DR Congo) and Benin. Some early movers, such as Kenya, have implemented measures that increase access to electricity and reduce electricity losses, while maintaining affordable tariffs. As discussed in Chapter 3, South Africa has put in place a model for procurement of low-carbon generation in the power sector that could find much broader application. In our projections, these and related initiatives provide the foundation for a large increase in annual average investment in the power sector of sub-Saharan Africa, where spending is projected to rise over the next ten years to more than $30 billion per year and increase again to more than $60 billion per year in the 2030s (Table 4.1).

Table 4.1 ▷ Investment in energy supply in sub-Saharan Africa in the New Policies Scenario, 2014-2040 ($2013 billion)

	Sub-Saharan Africa (excluding South Africa)		South Africa	
	Cumulative	Annual average	Cumulative	Annual average
Oil	**1 119**	**41**	**26**	**1**
Upstream	1 038	38	16	1
Transport	32	1	4	0.1
Refining	50	2	6	0.2
Gas	**544**	**20**	**21**	**1**
Upstream	394	15	17	1
Transport	150	6	4	0.1
Coal	**17**	**0.6**	**49**	**2**
Mining	9	0.3	46	2
Transport	9	0.3	2	0.1
Power generation	**415**	**15**	**193**	**7**
Oil	9	0.3	0.2	0.0
Coal	42	2	81	3
Gas	51	2	6	0.2
Nuclear	-	-	27	1
Hydro	172	6	3	0.1
Other renewables	143	5	76	3
Power transmission & distribution	**549**	**20**	**92**	**3**
Total energy supply*	**2 644**	**98**	**380**	**14**

* Includes biofuels.

SPOTLIGHT

The nexus of governance and energy sector reforms: a key to poverty reduction and economic growth?

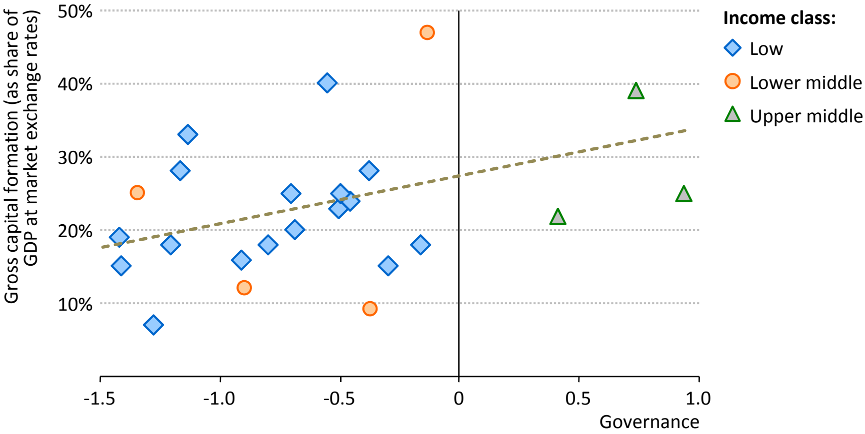
Not all of the factors holding back the expansion of energy provision in sub-Saharan African are to be found within the energy sector itself. Comparing the shares of investment in GDP in different sub-Saharan countries with a composite indicator for standards of governance, there is a clear coincidence in many countries between low levels of capital formation, i.e. low investment, and weak governance (Figure 4.4).[3] Very few sub-Saharan countries have shares of investment in GDP comparable to those seen in some major emerging economies: in India and Indonesia, this figure is around 35%, in China close to 50%. The capital stock created in this way provides the means – together with labour – to expand future output of goods and services.

Improvements in the indicators for governance have tended to be correlated with increased levels of investment, a relationship that is backed up by studies looking specifically at flows of foreign direct investment to sub-Saharan Africa (Wernick, Haar and Sharma, 2014) (Naudé and Krugell, 2007). A cautionary note is that this link is weaker or absent in countries that possess abundant oil and gas, where the pull of natural resources is sufficiently strong that substantial foreign investment is forthcoming even without efforts to improve the quality of institutions. However, in the absence of attention to this issue, these resource-rich countries risk losing out on investment in the non-resource sectors of the economy, including the power sector.

Improvements in governance also show a strong association with the reliability of electricity supply, implying that a reduction in political risk plays through into a higher level of power sector investment (Figure 4.5). Beyond this, there are strong signs that reliable electricity supply is among the most important factors underpinning economic development and poverty reduction. International Monetary Fund (IMF) analysis shows how poverty levels in sub-Saharan Africa are higher in countries with low quality electricity infrastructure; the correlation is higher than for other types of infrastructure or for general structural variables, such as levels of health or education (IMF, 2014a). Poor electricity infrastructure and unreliable supply is also widely understood as a key factor holding back business development. World Bank Enterprise Survey data shows that African enterprises identified problems with power supply as the most pressing obstacle to the growth of their business, ahead of access to finance, red tape and corruption (AfDB, OECD, UNDP, ECA, 2012). This nexus of power sector and governance indicators suggests high priority should be given to strengthening the capacity and accountability of institutions in and around the energy sector, as well as the quality of regulation, as a means to reduce poverty and stimulate economic growth.

3. Gross capital formation refers to the net additions to a country's capital stock in a given year, e.g. investment in new equipment, buildings and other intermediate goods.

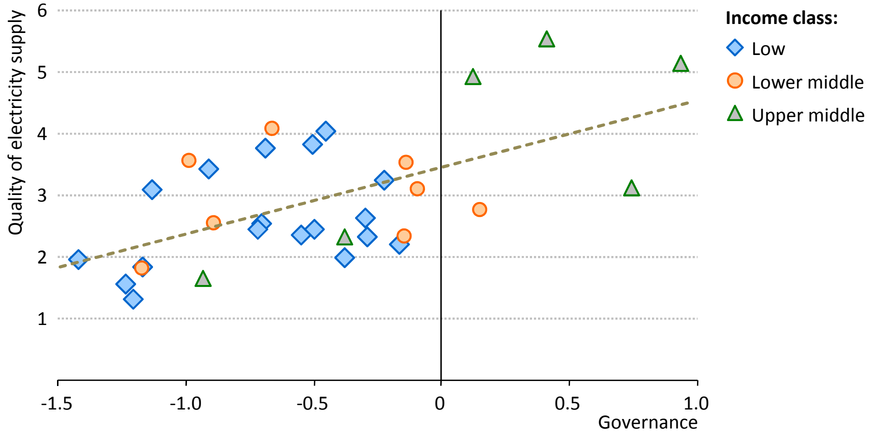
Figure 4.4 ▷ Relationship between indicators for governance and for gross capital formation in sub-Saharan Africa



Notes: The score for governance is an average of six indicators (with possible scores from a low of -2.5 to a high of +2.5) prepared by the Worldwide Governance Indicators project, which combines the views of a large number of enterprise, citizen and expert survey respondents on country performance in the following areas: voice and accountability; political stability and absence of violence; government effectiveness; regulatory quality; the rule of law; and control of corruption.

Sources: (for governance) Worldwide Governance Indicators, *www.govindicators.org*; (for investment) World Bank World Development Indicators, *http://wdi.worldbank.org/tables*. Country income classifications are from the World Bank.

Figure 4.5 ▷ Relationship between indicators for governance and for quality of electricity supply in sub-Saharan Africa

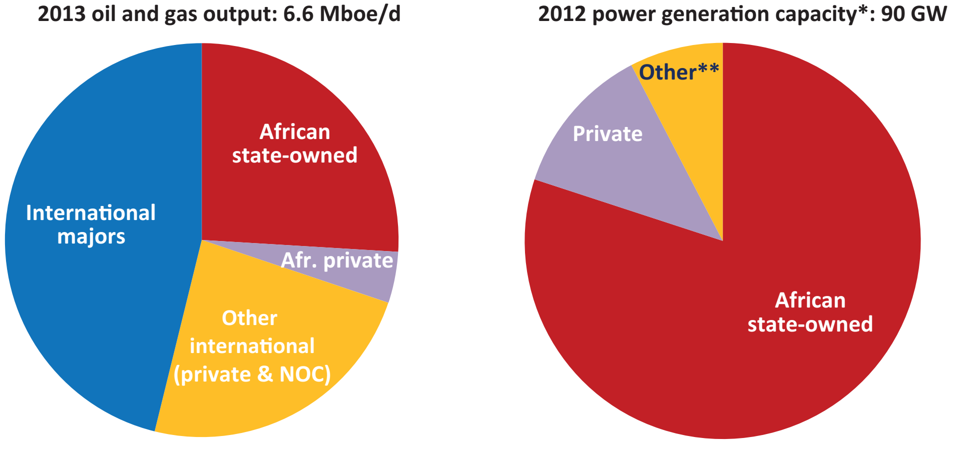


Notes: The scores and sources for governance indicators are above in Figure 4.4. The indicator for quality of power supply is based on survey responses to the question: "In your country, how would you assess the reliability of the electricity supply (lack of interruptions and lack of voltage fluctuations) on a scale from 1 (not reliable at all) to 7 (extremely reliable)".

Source: World Economic Forum, Global Competitiveness Report 2013-2014 *www.weforum.org/reports/global-competitiveness-report-2013-2014* (for quality of electricity supply).

Successful power sector reform will require a sustained effort to harness and develop the expertise required to formulate and implement energy policies, to plan the development of the sector (i.e. identify the least-cost options to meet anticipated demand) and to manage and operate the power system efficiently. Capacity in many of these areas has been understandably weak, given the stage of development of many countries. An improvement in power supply will also require an expanded cast of investors. Up until now, investment by private companies and international players has been heavily concentrated in the oil and gas sectors (Figure 4.6) and investment in these areas is likely to continue to have a strong private and international appeal, albeit with increasing involvement of African independents (a process that has already started in Nigeria) and more internationally-minded national oil companies (NOCs), particularly from Asian importing nations. The power sector is a different case. Ownership of today's generation fleet is dominated by state-owned utilities. It is difficult to see how the rise in power sector investment foreseen in the New Policies Scenario – much less, investment beyond that – can fully be achieved without serious efforts to improve the commercial discipline and circumstances of these utilities, along with a concerted attempt to harness the capital and expertise of the private sector.[4]

Figure 4.6 ▹ Ownership structure of oil and gas output, and power generation capacity in sub-Saharan Africa



* Includes only grid-based power generation capacity. ** Other includes auto-producers, i.e. an industrial plant that has generating capacity that primarily serves its own needs (but is also grid-connected).

Notes: Mboe/d = million barrels of oil equivalent per day. NOC is national oil company. The seven international majors are BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Shell and Total.

4. Private sector investment in the power sector, while small in relation to sub-Saharan Africa's needs, nonetheless already represents a significant share of the estimated investment actually going into the sector. According to the World Bank Private Participation in Infrastructure database, 22 new energy projects with private participation reached financial closure in 2012; these represent some $5 billion in investment (*www.ppi.worldbank.org*).

There is no uniform set of conditions in the power sector that can accelerate capital flows and bring new private investors on board: there are, however, some recurring policy and regulatory themes that need to be addressed:

- **Integrated and realistic strategic planning:** well-designed, comprehensive strategies covering efficient generation capacity, grid expansion and access are essential to avoid generation projects being held back by a lack of transmission capacity, or off-grid initiatives being deterred by the promise of a grid extension that never arrives. With Africa's large and growing rural population, governments need to lay out clear plans as to how electricity is to get to populations that will be hard-to-reach with the grid, albeit with scope for pragmatic and flexible variations to the details. There are also major gains to be had from regional co-operation and co-ordination, without which large-scale generation projects, notably for hydropower, struggle to make headway (see section on regional co-operation below).
- **Project development, procurement and contracting:** amid a host of more general concerns about governance, a key issue is the ability to get projects off the ground with integrity, using a transparent set of procedures and approvals, extending to social and environmental aspects. South Africa's Renewable Energy Independent Power Producer Procurement Programme (described in Chapter 3) provides a good example of what can be achieved in a well-run process, attracting $14 billion of investment commitments, from a wide range of international project developers, sponsors and equity shareholders, within three years of inception. Much investment is required in human capacity building within public institutions, to assist in distinguishing between legitimate demands from a potential investor and unwarranted demands for guarantees, government undertakings and so on.
- **Risk of non-payment:** private investment in power generation in sub-Saharan Africa typically takes place on the basis of power purchase agreements with a national utility, which then distributes and sells the power to customers: a major concern for investors is non-payment for the electricity produced. A tariff structure that secures overall cost recovery is vital to the financial health of the counterparty transaction and the security of the investor, though other financial mechanisms can be put in place to enhance the creditworthiness of the institutional buyer. An example comes from Nigeria, where the World Bank is providing credit enhancement and debt mobilisation guarantees to the Nigeria Bulk Electricity Trading company to facilitate private investment in Nigeria's reforming power sector.
- **Gas pricing and allocation:** in our projections, the share of natural gas in sub-Saharan Africa's power mix rises from less than 10% today to one-quarter in 2040, meaning that, from around 10 billion cubic metres (bcm), the amount of gas used in power generation exceeds 70 bcm by the end of the period. This will not happen without a sophisticated regulatory framework for gas transmission and distribution infrastructure, as well as contracting and pricing arrangements that guarantee both reliable supply and a reasonably predictable return to those producing the gas.

- **Pricing and tariff structures:** getting these right is clearly challenging where there is limited ability to pay and consumers have low expectations of the quality of service. Nonetheless, subsidised tariff structures that consistently fail to reach cost-recovery levels are a recipe for low investment (Box 4.1).

The development of large-scale power projects, in hydro as elsewhere, will continue to be heavily contingent on governments and international financing. The ambition to bring in new private investors, by contrast, implies a different (parallel) path towards the transformation of the power sector, involving multiple, smaller scale projects rather than a limited number of high-impact initiatives. Although this might grow over time, the typical power generation project attracting the attention of private investors (even in South Africa) is small-to-medium size with capacity of around 10 megawatts (MW) to 100 MW, i.e. a scale at which commitments of capital and risks by private investors are deemed manageable. These are largely grid-based projects, although there is growing awareness of the potential for private initiatives to contribute to improving access to electricity.[5] Bringing a sufficient quantity of these ideas to fruition requires a serious effort to reduce transaction costs and ensure adequate access to finance, but more projects, greater project diversity and more private sector participation can be instrumental in meeting African consumers' needs for reliable power – as well as to help bridge the energy access gap.

Financing energy projects

If improvements in the energy policy and regulatory framework are successful in generating a steady stream of bankable projects, the next hurdle relates to sources of capital: will financing be available to cover the envisaged scale of investment in sub-Saharan Africa? Capital comes to the energy sector from a variety of sources, as self-financing (via the revenue from existing operations), through an allocation from the state budget or from external financing (via lending institutions or capital markets). Access to capital is easiest for international companies, especially those with significant revenue streams from existing assets. The situation can be very different for African state-owned companies, which, whether involved in the extractive sector or in power supply, are often drained of resources because of subsidised fuel prices and competition from other spending priorities, as in Nigeria, or which, as in Mozambique, face the challenge of financial participation in huge capital-intensive projects.[6] For power utilities, the extent to which they generate any revenue in excess of costs depends on the way that tariffs (and subsidies) are structured in relation to the income levels of their customers (Box 4.1).

5. Electrification programmes are largely supported by public and donor funds, but the money already spent by those without access on poor-quality energy supply (kerosene lamps, candles, batteries) can also open up some commercial opportunities for provision of household-level devices such as solar lamps and improved biomass cookstoves as well as for some community-level mini-grids (IFC, 2012).

6. Nigeria's NNPC is a good example: it does not have control over the revenue that it generates but passes it on to the government, which in turn allocates an annual budget to the organisation. In recent years, the NNPC budget allocation has been in the region of $10 billion, meant to cover capital and operating costs for all of its joint projects with international companies. However, high operating costs in Nigeria have meant that very little budget is left for capital investments.

Box 4.1 ▻ Power tariffs: trapped between affordability and cost recovery?

End-user electricity tariffs are subject to two primary, and typically competing, considerations: the importance of recovering the costs of supply, as a step towards earning the necessary return on investment and to fund future capital spending; and the social imperative to keep prices at levels that allow consumers to benefit from affordable energy services. In many parts of sub-Saharan Africa, utilities can appear trapped between these two objectives: tariffs are either too high for consumers, or too low in relation to the costs of supplying them with power.[7] The risk is that this locks the power sector into a cycle of low revenues, high debts, inadequate maintenance, under-investment and poor quality of service.

There are ways out. Although there are options to improve tariff design, the amounts charged for electricity in many parts of sub-Saharan Africa are already high – as noted in Chapter 1, residential tariffs are among the highest in the world. The underlying problem is rather the elevated costs of generation, caused by reliance on expensive oil products rather than deployment of cheaper fuels and technologies. Reducing the share of oil-based generation plants in the power mix is a sure way to bring down the average cost of generation, often entailing readiness to challenge the vested interests that profit from expensive diesel supply. An important route to least-cost generation planning for many countries can be regional interconnections and cross-border electricity trade. In the New Policies Scenario, the expansion of lower cost sources of power supply is the main factor easing the burden of energy costs on household budgets: even as consumption rises, household energy expenditure as a share of household disposable income declines in this scenario, from 3.8% today down towards 3% by 2040.

A second priority is to reduce losses and improve efficiency. This applies both to the operation of the utility itself and the way that electricity is used (e.g. through the introduction of efficiency standards for lighting and appliances), but in particular to the transmission and distribution infrastructure. We estimate that, on average, around 18% of grid-based electricity generated in sub-Saharan Africa (outside South Africa, where losses are lower) is lost in transmission and distribution, a very high figure by international standards. These losses are reduced to 14% by 2040 in the New Policies Scenario, thanks to investment in upgrading the grid and improving its maintenance and operation. If losses were to remain at today's levels, more than 40 terawatt-hours (TWh) of additional electricity output would be needed in 2040, requiring around 10 gigawatts (GW) of generation capacity, which would cost in the order of $7 billion.

7. Research for the World Bank shows how tariffs in countries such as Chad, Mozambique, Rwanda and Uganda have fared well for cost recovery, but poorly for affordability: whereas in South Africa, DR Congo, Tanzania and Zambia tariffs are more affordable relative to incomes, but are well below the average costs of supply (Briceño-Garmendia and Shkataran, 2011).

In addition, there are the measures that utilities can take to optimise their tariff structures. In an environment where a large share of the population remains without access to electricity, any subsidy on the electricity tariff reaches only a small group, typically those with higher incomes. In Rwanda, for example, where the electrification rate is under 20%, we estimate that more than 90% of household electricity is consumed by those in the top 20% income bracket. Under these circumstances, it can make more sense for governments to direct their support to the cost of new connections, rather than lowering tariffs that are paid by relatively few. In any case, as the electrification rate rises and incomes increase, a typical tariff structure would see consumers facing higher unit prices as their consumption goes up, with lifeline tariffs or other schemes protecting, where possible, the poorest consumers.[8]

A major constraint in many parts of sub-Saharan African is a lack of domestic sources of capital, due to low savings rates and an undeveloped financial sector. Improving access to basic financial services is a key way to encourage domestic savings and to channel them efficiently into investment. There are some signs of improvement: the number of people with a commercial bank account has risen sharply in recent years, from 70 per 1 000 adults in 2004 to 295 per 1 000 adults in 2012 (IMF, 2014b), and this may understate actual levels because of the rise of mobile phone-based accounts. However, this is still well below the levels reached in other parts of the world, and the positive signs are very unevenly distributed. Local financing is starting to play a role in the larger economies, notably in Nigeria as a source of support for the emerging independent oil and power producers. There are also growing pension fund resources seeking productive long-term investment. But it remains the case that, in most countries, financing from local institutions is either unavailable or prohibitively expensive.

Most capital flows come, instead, from abroad, through foreign direct investment and multilateral and bilateral development assistance, with a small but growing share of international bank lending. As we have seen, much of the foreign direct investment has been directed to the hydrocarbons sector, driven in part by rising consumption in the emerging economies of Asia, matched by rising outward investment from these countries, notably China. Chinese companies and development banks are also becoming active investors in infrastructure projects. Cross-border bank lending to sub-Saharan Africa dropped during the financial crisis of 2008-2009, but has since shown some signs of a rebound: banks from South Africa are also increasingly active across other parts of sub-Saharan Africa.

8. Effective tariff design and implementation requires progress with metering as well as data on consumption patterns, typically obtained via household surveys. Rwanda is distinctive in this respect because of its regular surveys of household living conditions, which are a key source of data for government and for development policies.

For the moment, the bottlenecks holding back an increase in investment appear to arise more from considerations of policy and project preparation, rather than financing. But if policy and capacity constraints are eased and investment projects are proposed at the rate projected in the New Policies Scenario, then the limitations of the region's financial systems may become much more pertinent. The way that capital has been mobilised quickly and at scale for South African renewables projects since 2011 indicates what is possible; but domestic financial intermediation will take time to mature in other parts of sub-Saharan Africa, particularly for large-scale projects. More restrictive capital adequacy requirements, the focus of the Basel III Accord reached in the aftermath of the financial crisis, may also take their toll on the availability and cost of long-term funding from commercial banks. In practice, there is likely to be a heavy dependence on development bank funding, perhaps with a greater emphasis on enabling private sector investment through guarantee schemes, complemented by emerging south-south financial flows from China, India and Brazil, before more sustainable private and/or indigenous sources of financing are ready to take on a larger share of the burden.

Making the most of Africa's resources

A second critical variable that will shape the energy outlook for sub-Saharan Africa is the way that its resource wealth is managed. Considerations vary widely, depending on the type of resource: the extractive energy industries – oil, gas and coal – present a very different set of challenges and opportunities compared with renewable resources and, among the latter, the challenge of developing a large hydro project is quite distinct from that of a smaller scale wind or solar project. But a common thread is that the realisation of social and economic benefits is dependent on high quality and integrity in the public institutions concerned.

For renewable resources, a principal need is for effective policies for land use, forest management and sustainable wood production and measures to bring markets for charcoal and fuelwood into the formal economy. A sound policy and regulatory environment is also essential to foster the large-scale development of other modern renewable resources, particularly in the electricity sector where the projected share of power produced from renewables rises from 23% today (the overwhelming share of which is from large hydro) to more than 40% by 2040, with solar, wind and geothermal accounting for one-third of the growth. Among the investments in renewable energy, the challenge of large hydropower developments stands out because of the range of environmental and social impacts involved and the need, in an African context, for interconnected markets, involving regional accords. The attraction of other, non-hydro developments increases steadily over time, as technologies become more widely and cheaply available.[9]

9. Grid-connected renewable projects require a more robust governance framework to succeed, but some smaller-scale and off-grid projects have greater potential to sidestep institutional weaknesses (though other hurdles can include poor access to finance and to replacement / maintenance services).

Adequate investment in extractive industries is likewise dependent on a clear policy framework and high-quality regulation, but the hazards are different – notably that projects move ahead without producing tangible benefits to society. The deterministic view that resource development is necessarily detrimental to the chances for prosperity no longer prevails, but governments and societies face a difficult task to ensure that the systems governing the exploitation of natural resources maximise the chances of sustained economic benefits.[10] If not, then the example of Nigeria examined in Chapter 3 is illustrative of the perils.

Three main avenues exist for a state to secure a positive return on natural resource development: tax revenue, use of the commodity produced, and participation by local companies in the investment and supply chain. Using these channels productively requires comprehensive, long-term strategies and a coherent set of rules, along with competent institutions to design, administer and enforce them. Participation from civil society in the formulation of these resource strategies – and an ability to hold governments to account for their implementation – is instrumental to their chances of success.

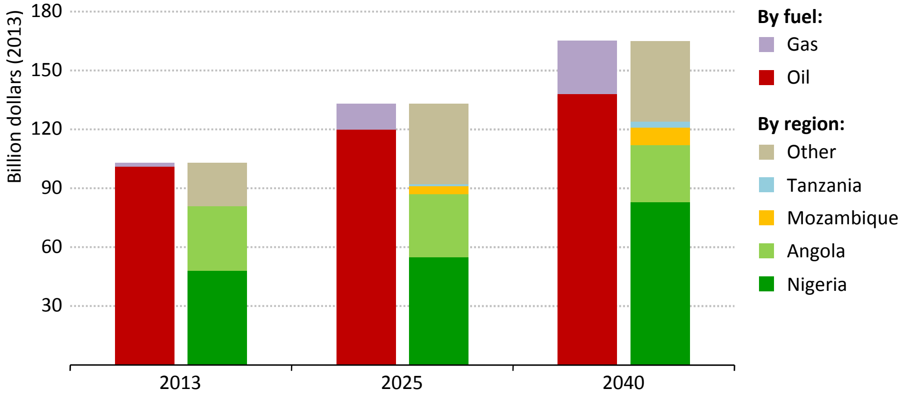
In industries such as oil and gas, where foreign investment is high and much equipment and labour is necessarily foreign-sourced (especially for offshore developments), the task of maximising local benefits falls heavily on the tax regime. The way that tax regimes and contractual terms evolve is particularly relevant to our *Outlook,* because so many of the major resource-holding countries are in the process of revising or rewriting legislation in these areas (a process which, as in Nigeria, is itself holding companies back from committing capital). In the New Policies Scenario to 2040, we estimate that hydrocarbon extraction generates more than $3.5 trillion in cumulative fiscal revenue for resource-owning governments across sub-Saharan Africa (Figure 4.7). The overwhelming majority of this revenue comes from oil, only 11% from gas. Revenues are concentrated in a few countries, first among them Nigeria, followed by Angola, Ghana, Mozambique and Congo.

Generating these revenues requires a well-designed fiscal system, combining some standard elements with some that are adapted to the specific circumstances of extractive industries. Among the standard features, simplicity and transparency are especially valuable where tax assessment and collection capabilities are poorly developed; the stability of the tax regime is likewise important, especially for highly capital-intensive industries. But, precisely because of this capital intensity, there needs to be a balanced trade-off between the government's desire for early revenue and the need for companies to recover large upfront costs as quickly as possible. Crucially, the system needs to provide for variations in commodity prices; capturing a fair share of these resource rents is not only desirable, but essential if public support for extractive investment by non-national companies is to be earned or maintained. While any tax system needs to be tailored to a country's circumstances and the nature of its resources, a combination of a royalty system

10. The Natural Resource Charter is a global initiative that provides useful guidance, in the form of twelve principles, on how to manage opportunities created by natural resources (*www.resourcegovernance.org*).

(normally at a modest level, but at least ensuring a revenue flow as soon as production starts), a normal corporate income tax (to ensure neutrality versus other sectors of the economy) and a resource rent tax (to capture economic rents) is a typical way to balance the various objectives. The levels at which these taxes are set is critical, as the state risks either losing out on revenue or losing out on investment if it misjudges this part of the equation.

Figure 4.7 ▹ Estimated fiscal revenue from hydrocarbon extraction in sub-Saharan Africa in the New Policies Scenario



For the countries concerned, deciding how to allocate revenues of the magnitude shown in Figure 4.7 is not a simple process: there are urgent requirements for present-day spending, but also a strong case that revenues should be invested (or saved) in a way that benefits future generations. For many countries in sub-Saharan Africa, spending heavily on reversing deficiencies in essential infrastructure would seem to be an obvious solution: by funding power generation needs, investing in education and health, and building water and sanitation systems and transport infrastructure. Set against this, however, are questions over the administrative capacity to select projects well and to spend funds efficiently, and doubts in many countries over whether the domestic economy can absorb large increases in public spending. Strong oversight and public, multi-year spending plans, and disclosure of realised mineral revenues, costs incurred, and taxes actually paid (as advocated by the Extractive Industries Transparency Initiative) all have a major role to play. The creation of mechanisms to smooth revenue flows and expenditure – normally stand-alone funds, insulated from political interference – help to avoid macroeconomic pitfalls and inefficient spending.

The task of securing a positive return on natural resource development is made harder if a country is reliant on a single extractive industry or commodity; this increases the likelihood that revenues are strongly affected by fluctuations in commodity prices, exacerbating the risk of an (inefficient) expansion of spending in boom times and sharp contractions when prices fall. The risk of macroeconomic instability is particularly important in many African countries, where resource-related revenues account for high shares of total government revenue: in Nigeria and Angola, petroleum revenues accounted for some 75% of total government revenues on average over the period 2001-2010; the figure was even higher, almost 90%, in Equatorial Guinea and above 50% in both Chad and Sudan (IMF, 2012). At the same time, the example of Botswana suggests that the risks associated with high dependence on a single resource can be mitigated (Box 4.2).

Box 4.2 ▷ Botswana – a model for resource governance?

Since gaining independence in 1966, when it was classified among the world's ten poorest countries, Botswana has become an upper-middle income country, its per-capita income increasing 100-fold to reach $7 300 in 2013, the sixth-highest in Africa. Much of this growth is attributed to the development of the diamond extraction industry, and the successful management of the revenue that this has brought in.[11] Over the last two decades, the number of Batswana living below the poverty line has fallen from a third to under a fifth; the proportion of households with access to electricity has increased from 13% to over 65%; and literacy rates have increased from under 70% to more than 85%.

Botswana's success rests on several interwoven factors: the country has maintained a multi-party democratic political system since independence, with an established culture of accountability and transparency that is anchored in the Tswana traditions of consultation, participation and consensus. It has consistently been rated among the least corrupt African countries for over a decade. Public spending is planned over multi-year cycles to iron out the effect of the boom years that are a feature of commodity cycles. The accumulation of international reserves has allowed the government to manage the exchange rate in a way that stopped the currency from appreciating, facilitating the government's drive for development of the non-mineral sectors of the economy. Apart from monetary and fiscal prudence, the care with which Botswana's domestic infrastructure investments was handled has also proven to be high: public projects need to be ratified by parliament, while the government takes into careful consideration the absorptive capacity of the domestic economy to guard against investments that generate poor returns.

Fiscal considerations are part of a broader calculation of risk and reward affecting the prospects for investment. As argued in the Spotlight in Chapter 2, the political, economic

11. In Botswana, revenues from mining accounted for more than 40% of total government revenue on average over the period 2001-2010. Royalties are levied at between 3 and 10% of the gross market value at the mine gate of the mineral concerned, the high rate being for precious stones, the lower rate for other minerals. For the last 15 years, the mining tax has been levied at a variable rate, whichever is the greater of the normal corporate tax rate of 22% or that determined by a formula based on the ratio between net and gross income (a proxy of the existence of super-profits). The tax formula includes the three elements discussed in the text: royalty system, corporate income tax and resource rent tax.

and institutional context, outside the energy sector, has a direct impact on the risk calculation for prospective upstream investors, discouraging – or encouraging – investment in marginal projects (a factor that underpins higher production in the African Century Case). The broader context also determines the extent of spin-offs from extractive projects to other sectors and their contribution to industrialisation, employment and welfare. These co-benefits can be realised via end-users which use the commodity produced, e.g. power plants or gas-related industrial projects. Potentially larger gains, in terms of value added, employment and skills, typically come from domestic sourcing of the goods and services used by major extractive projects. This can be a boon for firms in areas such as construction, machine maintenance and repair, and services such as catering and industrial clothing, but over time also in the supply of equipment and more specialised engineering, technical and advisory services. Governments tend to reach quickly for local content provisions in an attempt to realise these benefits, but often then fail to provide sufficient investments in training and capacity or a supportive and low-risk environment for local business development.

In addition, the need of major extractive projects for infrastructure can also be a source of value. Coal extraction creates demand for new railways: upstream and mining operations all need large amounts of electricity. Investing companies often, in practice, build their own facilities (because of the unreliability or scarcity of local supply), but this can have knock-on effects, particularly if there are incentives to "over-build" generation capacity and become power suppliers to the grid. Alternatively, such companies can act as anchor customers that ensure the viability of other generation or transmission projects. There are opportunities, in any case, for the co-ordinated growth of project infrastructure through national or regional plans, for example, building gas transmission pipelines along routes that encourage other smaller consumers to take advantage of gas availability.

Regional energy co-operation and integration

Regional co-operation is a major component of Africa's vision for its future. A number of initiatives are underway, with the most comprehensive being the Programme for Infrastructure Development in Africa (PIDA), launched in 2010 and led by the African Union, the New Partnership for Africa's Development and the African Development Bank. PIDA defines a series of goals to be achieved by 2020, 2030 and 2040, focusing on transport, energy and information and telecommunications technologies. If implemented as planned, this would be a major step towards relieving some of the trans-border constraints on energy sector development and facilitate a major expansion of energy trade.

Yet, as in many parts of the world, there is in practice a large and persistent gap between the potential gains from regional co-operation in sub-Saharan Africa and the actual record of achievement. Examples of successful cross-border co-operation and cross-border infrastructure are relatively few and far between. The regional power pools are something of an exception (see Chapter 2), but they are still often poorly interconnected in practice, with most cross-border flows regulated by long-term bilateral agreements: they do not yet operate as integrated regional power markets. Of the two cross-border gas pipelines, one has functioned as intended (from Mozambique to South Africa); the other, the West Africa Gas Pipeline (WAGP), stands as an example of the pitfalls as well as the potential for such projects (Box 4.3).

Box 4.3 ▷ The West Africa Gas Pipeline: partial delivery of its promise

The West Africa Gas Pipeline was first proposed in 1982 as a way to enhance regional economic growth, linking resource-rich regions in western Nigeria to centres of potentially burgeoning demand in Benin, Togo and Ghana. The pipeline, which stretches 680 km and has a capacity of around 5 bcm/year, was seen as a way to monetise a portion of the gas flared in Nigeria (over 20 bcm/year at the time), enabling the region to expand electricity supply and reduce its reliance on expensive liquid fuels for power generation. A final investment decision on the WAGP was taken 23 years later, in 2005, delayed by the complexity of reaching agreement among multiple countries and companies[12], the challenge of securing adequate financing and loan guarantees, and opposition from local communities troubled by the social and environmental footprint of the project. The project itself was also delayed in the construction phase, with first gas reaching Ghana only at the end of 2008.

Since the pipeline became operational, supply has been intermittent, halted at times by acts of vandalism in the Niger Delta, damage in offshore Togo and, most seriously, by an incident in 2012 during the re-commissioning of the Takoradi metering station in Ghana. When it has been in operation, the pipeline has supplied far less than envisaged, due to a shortage of gas that has been exacerbated by increasing consumption in Lagos (situated on the pipeline route and which itself has an economy of comparable size to that of Ghana). Some benefits of cross-border flows have, nonetheless, been realised. By end-2013, even the limited gas supplied through WAGP has been estimated to bring down the weighted average generation cost of electricity in Ghana by more than 10%, reflecting the cheaper cost of gas-fired generation compared to the oil-fired alternative. But the lack of reliable supply has also forced Ghana to ration its power, and to explore options for liquefied natural gas (LNG) imports. The prospect of Nigerian domestic gas demand and LNG plants absorbing much of any gas surplus and Ghana's access to new supply sources along the coast, notably the Jubilee development, diminishes further the prospects of the WAGP achieving the lofty ambitions initially set out for it.

Lack of infrastructure is one of the main barriers to regional energy co-operation, but far from the only one. The dominant position of state utilities in most countries means that national investment plans tend to take priority and are often not aligned with regional initiatives. At the root of the problem is that, while many countries and dominant state utility companies are happy to see themselves in the role of energy exporter, few are ready

12. The consortium includes Chevron as operator as well as NNPC, Shell, GhanaNPC, Societe Beninoise de Gaz S.A. and Societe Togolaise de Gaz S.A.

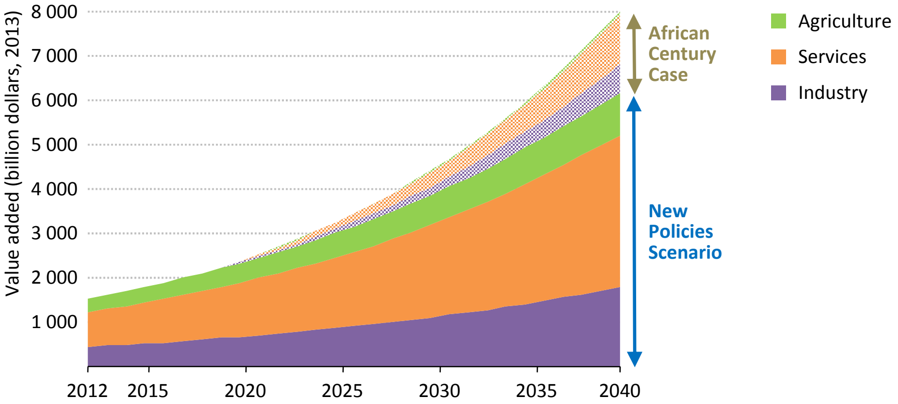
to rely on imports for more than a small share of their domestic needs, because of doubts about the reliability of supply or the political consequences of import dependence. Given the patchy record of implementing regional projects in practice, we envisage partial, but not full implementation of PIDA projects in the New Policies Scenario. The lack of regional scale is a particular constraint on the development of Africa's hydropower: the domestic markets of the countries with large hydropower potential (DR Congo, Ethiopia, Ghana, Guinea, Cameroon) are not of sufficient size to justify major project development. Without the regional market dimension, countries can be locked into less efficient – and more expensive – generation options.

Low levels of cross-border co-operation do not afflict only the power sector or trade in fossil fuels. They are also a vexed question for companies operating in different parts of the energy sector that may be looking to expand beyond their home markets. Barriers to trade include weak transport links, a variety of technical and non-technical barriers to trade and rules on local content, and mean that it is very difficult to move skilled labour, parts and supplies across borders from one African country to another. The difficulty of optimising supply chains on a regional basis pushes up costs for many energy projects.

An African Century Case

By easing some of the key constraints that hold back the development of the energy sector in the New Policies Scenario, the African Century Case offers a brighter vision of how energy can contribute to inclusive economic growth in sub-Saharan Africa. In this case, three targeted actions in the energy sector, set against a backdrop of improved standards of governance, deliver a major boost to economic activity. The sub-Saharan African economy in 2040 is 30% larger in the African Century Case than in the New Policies Scenario, an increase larger than the current GDP of sub-Saharan Africa today (Figure 4.8).

Figure 4.8 ▷ GDP growth in sub-Saharan Africa in the African Century Case and the New Policies Scenario



Note: Measured at market exchange rates (MER) in year-2013 dollars.

The actions that underpin the African Century Case are:

- An additional $450 billion in power sector investment, compared with the New Policies Scenario, with a consequent improvement in the reliability of electricity supply, reducing the incidence of power outages by half, and in access to electricity.
- A larger share of the revenue from the oil and gas sectors reinvested in infrastructure, accompanied by a rise in oil and gas production to keep pace with higher demand.
- Increased regional co-operation and integration, facilitating new large-scale generation and infrastructure projects, faster development of the regional power pools and the interconnections between them.

A $450 billion boost to power sector investment

Although the New Policies Scenario sees a large step up in power sector investment compared with current trends, the investment level runs at an average of only around 1.3% of GDP over the projection period. By way of comparison, China has invested the equivalent of around 1.9% of GDP in its power sector since 2000 and India 2.6%. The persistently high number living without access to electricity in the New Policies Scenario provides additional evidence of a continued shortfall in power sector investment relative to sub-Saharan Africa's needs.

The increase in power sector investment in the African Century Case, by more than one-third relative to the New Policies Scenario, brings annual average spending up to 1.5% of GDP. Of these additional investments, 30% are directed at providing access to electricity. This means that, by the end of our projection period, full access is achieved in urban areas in all countries of sub-Saharan Africa and the proportion of the rural population with access rises to two-thirds. Of the additional 230 million that gain access to electricity in the African Century Case, more than 70% are in rural areas, the growth in supply coming predominantly from mini-grid or off-grid solutions. By 2040, around 300 million people remain without access to electricity in sub-Saharan Africa. This figure is still very high; but it is a reduction of more than 40% compared with the New Policies Scenario. An additional 150 million people also gain access to cleaner cooking facilities in the African Century Case, again with the majority being in rural areas. The implication is that this Case contributes significantly to a closing of the rural / urban divide and a reduction in extreme rural poverty in many countries.

The African Century Case is accompanied by improved maintenance and management of the power system, reducing the incidence of assumed power outages by half.[13] Total electricity consumption increases by more than 30%, compared with the New Policies Scenario, reaching 1 700 TWh by 2040. The contribution of expanded electricity access to this increase is modest, at only 110 TWh, representing about one-quarter of the total

13. Our modelling of the relationship between the energy sector and GDP in sub-Saharan Africa includes a constraint representing the impact of unreliable power supply on economic activity. This constraint is cut in half in the African Century Case.

incremental electricity consumption; the remainder is a product of higher household consumption, driven by rising incomes, and increased demand from the industrial and service sectors. The improved reliability of power supply has the effect of raising the productivity of African companies, i.e. the efficiency with which they are able to turn inputs of capital and labour into outputs, providing a significant boost to the economy. Every additional $1 invested in the power sector in the African Century Case generates more than $15 in incremental GDP.

A larger share of (higher) petroleum revenue invested in infrastructure

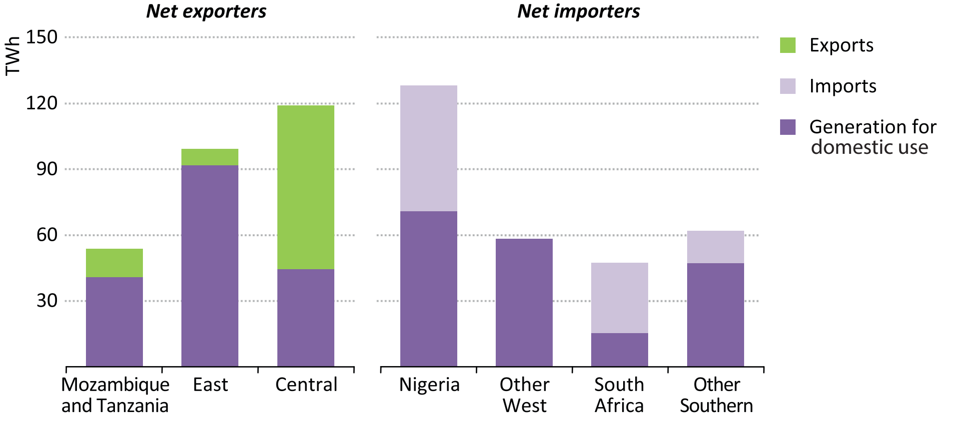
Higher economic growth pushes up domestic demand for all energy carriers, although the traditional use of solid biomass is replaced more rapidly by modern fuels, compared with the New Policies Scenario, relieving to an extent the pressure on the forestry biomass stock. The incremental demand for fossil fuels is largely met by increased production from within sub-Saharan Africa. Improved governance and transparency in the management of the oil and gas sectors reduce the risks facing investors, making African oil and gas developments more competitive with production from other sources. This facilitates higher investment (also in exploration) that allows production to edge higher from the 2020s onwards. Fiscal revenues reach $200 billion by 2040, 20% higher than the figure in the New Policies Scenario. The additional funds available to governments (a cumulative $410 billion over the projection period) are assumed to finance a faster pace of infrastructure investment, making an additional contribution to overall economic growth.

Oil production is 1.2 mb/d higher in 2040, with the additional output coming in part from Nigeria, but also from faster growth of oil production in East Africa and from investment that allows other mature producers in Central Africa, such as Cameroon and Congo, to slow the pace at which their oil production declines. Contributions to incremental output also come from the new frontiers where today's estimates of resources are high, such as Madagascar and deep offshore resources in Angola, Congo and Gabon. In the case of natural gas, production of which rises to 270 bcm in 2040 (17% higher than in New Policies Scenario), major contributions to the increase in output come from Nigeria, largely in the form of associated gas, and also from Mozambique and Tanzania, where the resource base is sufficient to support higher levels of production. Higher levels of oil and gas production are a consequence of a system in which risks to economic activity and investment are reduced. The larger narrative though lies outside the extractive industries, in the opportunities for human development and prosperity that a well-functioning energy system can create across sub-Saharan Africa.

Deeper regional co-operation

In the African Century Case, improved regional energy co-operation allows countries to take better advantage of opportunities for trade within and between their respective power systems, moving towards a more integrated African power grid, based on the existing power pools. It also means that some large regional projects, notably the expansion of hydropower capacity from the Grand Inga project in the DR Congo, move ahead more quickly. Even with the increase in electricity demand, this brings the average cost of Africa's power generation down to levels slightly below those seen in the New Policies Scenario. The share of hydropower, a relatively cheap source of power, rises in the overall electricity mix to 31% in 2040 (from 22% today), five percentage points higher than in the New Policies Scenario, with the effect of displacing more expensive power generation options, notably oil-fired generation. Even though electricity use is higher in the African Century Case, the share of energy in household expenditures is slightly lower.

Figure 4.9 ▷ Increase in regional electricity generation and trade in sub-Saharan Africa in the African Century Case versus the New Policies Scenario, 2040



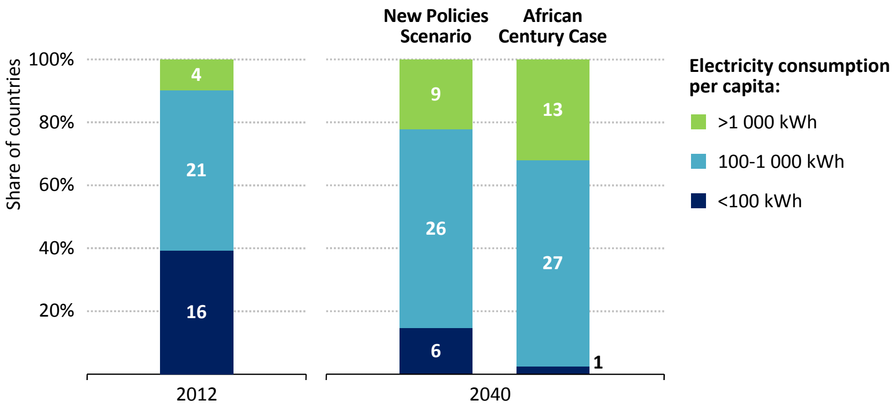
Enhanced power connections across Central Africa are a main differentiating feature of the African Century Case (Figure 4.9). On the back of an extra $130 billion of investment (30% of the total additional power sector investment in the African Century Case), Central Africa becomes a hub for regional energy trade by harnessing 25 GW of additional hydropower capacity, in effect more than doubling its hydro capacity compared with the New Policies Scenario. Similar dynamics are at play in East Africa, mostly in Ethiopia, and Mozambique, where a proliferation of hydropower projects is made financially viable by the prospect of increased trade. The African Century Case sees a much greater expansion of trade than suggested by the sum of import or export numbers. Kenya, for example, simultaneously imports electricity from Ethiopia in the north and exports to Tanzania in the south.

Africa's energy choices in a global context

The choices facing sub-Saharan Africa's policymakers cannot be seen outside the context of international prices and patterns of energy trade, global competition for investment capital, and shifts in the efficiency and cost of the competing energy technologies available on the African and international markets. The interactions extend also to the environmental sphere. Although the South African energy economy is relatively carbon-intensive, sub-Saharan Africa as a whole continues to contribute very little to energy-related carbon dioxide (CO_2) emissions (even in the African Century Case, sub-Saharan Africa's share in global emissions in 2040 rises to 4%, compared with 3% in the New Policies Scenario). It is, though, in the front line among the regions most likely to face impacts from a changing global climate.[14]

Overall, our projections suggest a significant improvement in the energy situation of many people in sub-Saharan Africa, but also that the difficulty of providing energy services to a rapidly growing population will leave a significant gap in 2040 in most countries, relative to global average levels of energy use. Taking electricity as an example, there are 16 countries in sub-Saharan Africa where average per-capita electricity consumption in 2012 was below 100 kilowatt-hours (kWh), compared with a global per-capita average in 2012 of close to 2 800 kWh. This number of countries falls to six in the New Policies Scenario – and only one in the African Century Case (Figure 4.10). There is likewise an increase in the number of countries where average per-capita consumption levels rise above 1 000 kWh by 2040, with a larger number passing this threshold in the African Century Case. But, even in this more optimistic outlook, in only three sub-Saharan African countries (South Africa, Botswana and Namibia) does this indicator surpass the projected 2040 global average of 3 900 kWh per capita. Increasing the provision of energy services in large urban and peri-urban areas is eased by high population density, but our *Outlook* points to some persistent and formidable challenges in extending this coverage to all rural communities.

Figure 4.10 ▷ Country-by-country growth in electricity consumption per capita in sub-Saharan Africa by scenario



Source: IEA analysis in collaboration with KTH Royal Institute of Technology.

A projected oil price that rises to more than $130 per barrel in real terms by 2040 affects the outlook in numerous ways. It means high import bills for many countries that lack indigenous resources as well as the possibility of oil shocks in case of volatile price

14. The improvement in energy access in both scenarios has only negligible implications for energy-related CO_2 emissions and no discernible impact on the price or availability of fuels on the world market.

movements, with land-locked importers particularly vulnerable to the risk of interruptions to physical supply. It means a continued windfall for resource-owners, amplifying the potential benefits from improvements in infrastructure, as well as the risks associated with resource and revenue mismanagement. It also increases pressure for change: the opportunity cost, and, in some cases, the actual fiscal cost, of subsidising oil products is unsustainably high, as is the cost of generating electricity from oil products. This means rising momentum, already visible in some countries, behind a shift towards cheaper and often cleaner alternative fuels and technologies for all stationary uses. Natural gas answers this call in some countries in our projections, but economic drivers and falling costs for some technologies create widespread opportunities for modern renewable energy to play a much larger role in Africa's energy future.

How far these opportunities are taken up will depend on the policies adopted by sub-Saharan Africa's governments. The solutions to their energy dilemmas vary widely across the region: in some areas, the most effective actions are local and small scale; in others, national or regional initiatives are essential. But an increasing number of governments are seriously tackling the barriers that have held back investment, both domestic and foreign, from meeting African consumers' needs: if these constraints are effectively tackled, Africa's energy and economic future can look very different from its past.

Tables for Scenario Projections

General note to the tables

The tables in this Annex detail projections to 2040 in the New Policies Scenario (NPS) and the African Century Case (ACC) by geographic area for: Africa, sub-Saharan Africa, West Africa, Nigeria, Central Africa, East Africa, Southern Africa and South Africa. These tables are in five categories, including:

- Annex A1: Fossil-fuel production
- Annex A2: Energy demand, gross electricity generation and trade, gross electrical capacity and carbon-dioxide (CO_2) emissions from fossil-fuel combustion
- Annex A3: Access to electricity and clean cooking facilities and related investments
- Annex A4: Investments in the power sector
- Annex A5: Investments in fossil-fuel supply

Data for fossil-fuel production, energy demand, gross electricity generation and CO_2 emissions from fossil-fuel combustion up to 2012 are based on IEA statistics, published in *Energy Balances of non-OECD Countries*, *CO_2 Emissions from Fuel Combustion* and the *IEA Monthly Oil Data Service*. Historical oil demand data have been complemented from CITAC Africa Ltd. Historical data for gross electrical capacity are drawn from the Platts World Electric Power Plants Database (December 2013 version), and the International Atomic Energy Agency PRIS database. Both in the text 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 (CAAGR) and are marked "n.a." when the base year is zero or the value exceeds 200%. Nil values are marked "-".

Definitional note to the tables

Total primary energy demand (TPED) is broken down into power generation, other energy sector and total final consumption (TFC). TPED does not include ambient heat from heat pumps or electricity trade. Oil demand for power generation includes fuel consumption from back-up power generators. Power generation and capacity include on-grid plants, mini-grid and off-grid systems and back-up generators. TFC sectors are: residential, transport and productive uses (industry, services, agriculture and non-energy use). Projected electrical capacity is the net result of existing capacity plus additions, less retirements. Total CO_2 includes emissions from other energy sector in addition to the power generation and TFC sectors shown in the tables. CO_2 emissions do not include emissions from industrial waste and non-renewable municipal waste.

Definitions for regions, fuels, sectors, access and investments are in Annex B.

New Policies Scenario

	Oil production (mb/d)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Africa	**7.8**	**9.8**	**9.2**	**9.5**	**9.4**	**9.5**	**9.8**	**100**	**100**	**-0.0**
Conventional crude oil	6.7	8.3	7.6	7.6	7.2	7.0	6.9	84	71	-0.6
Natural gas liquids	0.9	1.4	1.5	1.7	1.9	2.1	2.5	14	25	2.0
Unconventional oil	0.2	0.1	0.2	0.3	0.3	0.4	0.4	1	4	4.7
Sub-Saharan Africa	**4.1**	**5.9**	**6.2**	**5.9**	**5.5**	**5.4**	**5.3**	**60**	**54**	**-0.4**
West Africa	2.2	2.8	2.6	2.7	2.8	3.0	3.2	29	33	0.5
Nigeria	2.2	2.7	2.2	2.3	2.5	2.8	3.1	27	31	0.5
Central Africa	0.8	1.0	1.0	0.7	0.5	0.4	0.3	11	3	-4.5
East Africa	0.2	0.1	0.5	0.5	0.4	0.3	0.2	1	2	1.9
Southern Africa	0.9	2.0	2.1	2.0	1.8	1.7	1.6	20	17	-0.7
Angola	0.7	1.9	2.0	1.8	1.6	1.5	1.4	19	14	-1.1
South Africa	0.2	0.1	0.1	0.1	0.2	0.2	0.2	1	2	2.6

	Natural gas production (bcm)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Africa	**124**	**213**	**235**	**295**	**347**	**405**	**469**	**100**	**100**	**2.9**
Conventional gas	122	212	231	281	319	370	427	99	91	2.5
Unconventional gas	2	1	4	14	27	35	42	1	9	13.7
Sub-Saharan Africa	**16**	**58**	**78**	**127**	**161**	**198**	**230**	**27**	**49**	**5.0**
West Africa	14	43	48	58	69	84	98	20	21	3.0
Nigeria	12	41	45	52	60	72	85	19	18	2.6
Central Africa	0	8	9	10	13	15	16	4	3	2.5
East Africa	-	0	0	1	1	1	1	0	0	5.3
Southern Africa	2	7	21	57	78	98	114	3	24	10.6
Angola	1	1	16	20	22	22	21	0	5	12.6
Mozambique	0	4	3	23	36	50	60	2	13	10.3
South Africa	2	1	1	7	9	10	12	1	3	8.6

	Coal production (Mtce)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Africa	**187**	**218**	**241**	**262**	**280**	**301**	**326**	**100**	**100**	**1.4**
Steam coal	183	213	234	250	265	282	305	98	93	1.3
Coking coal	4	5	7	11	15	19	22	2	7	5.6
Sub-Saharan Africa	**187**	**218**	**241**	**262**	**280**	**301**	**326**	**100**	**100**	**1.4**
Mozambique	0	4	9	16	22	28	34	2	10	7.7
South Africa	181	209	222	230	234	238	241	96	74	0.5

African Century Case

	Oil production (mb/d)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Africa	**9.3**	**10.0**	**10.0**	**10.4**	**11.0**	**0.6**	**1.2**	**100**	**0.4**
Conventional crude oil	7.7	8.0	7.7	7.8	8.0	0.5	1.1	73	-0.1
Natural gas liquids	1.5	1.7	2.0	2.2	2.6	0.1	0.1	23	2.1
Unconventional oil	0.2	0.3	0.3	0.4	0.4	-0.0	0.0	4	4.9
Sub-Saharan Africa	**6.2**	**6.4**	**6.1**	**6.3**	**6.5**	**0.6**	**1.2**	**59**	**0.3**
West Africa	2.7	2.9	3.1	3.3	3.4	0.2	0.2	31	0.7
Nigeria	2.2	2.5	2.7	3.0	3.2	0.2	0.2	29	0.7
Central Africa	1.0	0.7	0.6	0.5	0.4	0.1	0.2	4	-3.0
East Africa	0.5	0.7	0.7	0.6	0.5	0.3	0.3	5	5.6
Southern Africa	2.1	2.0	1.9	2.0	2.1	0.1	0.5	19	0.3
Angola	2.0	1.8	1.6	1.6	1.5	0.1	0.2	14	-0.7
South Africa	0.1	0.1	0.2	0.2	0.2	-0.0	-0.0	2	2.6

	Natural gas production (bcm)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Africa	**235**	**296**	**352**	**417**	**509**	**5**	**39**	**100**	**3.2**
Conventional gas	231	284	327	384	469	8	41	92	2.9
Unconventional gas	4	13	25	33	40	-2	-2	8	13.5
Sub-Saharan Africa	**78**	**128**	**166**	**209**	**268**	**5**	**38**	**53**	**5.6**
West Africa	49	60	74	90	106	5	8	21	3.3
Nigeria	46	55	67	81	95	7	10	19	3.0
Central Africa	8	9	12	14	16	-1	-0	3	2.4
East Africa	0	2	1	1	1	0	0	0	6.4
Southern Africa	20	57	79	105	144	1	30	28	11.5
Angola	16	19	21	23	23	-1	2	5	13.0
Mozambique	3	25	38	55	81	3	21	16	11.5
South Africa	1	5	7	7	10	-2	-2	2	7.8

	Coal production (Mtce)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Africa	**240**	**264**	**288**	**315**	**353**	**8**	**27**	**100**	**1.7**
Steam coal	233	252	272	296	330	8	26	94	1.6
Coking coal	7	11	15	19	23	0	1	6	5.7
Sub-Saharan Africa	**240**	**264**	**288**	**315**	**353**	**8**	**27**	**100**	**1.7**
Mozambique	9	16	23	31	39	0	6	11	8.3
South Africa	220	231	237	243	249	3	7	71	0.6

Africa: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**498**	**739**	**897**	**994**	**1 095**	**1 203**	**1 322**	**100**	**100**	**2.1**
Coal	90	105	117	128	138	150	164	14	12	1.6
Oil	100	168	203	218	234	255	278	23	21	1.8
Gas	47	100	129	153	178	207	243	14	18	3.2
Nuclear	3	3	3	3	6	10	12	0	1	4.7
Hydro	6	10	16	20	26	32	38	1	3	5.0
Bioenergy	250	352	417	449	475	489	496	48	38	1.2
Other renewables	0	2	11	21	38	61	91	0	7	15.2
Power generation	**98**	**156**	**199**	**234**	**278**	**340**	**413**	**100**	**100**	**3.5**
Coal	52	65	73	80	84	93	103	42	25	1.7
Oil	13	24	25	23	21	21	22	15	5	-0.3
Gas	22	51	68	81	96	113	136	33	33	3.6
Nuclear	3	3	3	3	6	10	12	2	3	4.7
Hydro	6	10	16	20	26	32	38	6	9	5.0
Bioenergy	1	1	3	6	9	12	15	1	4	10.4
Other renewables	0	2	11	20	36	59	87	1	21	15.3
Other energy sector	**69**	**110**	**137**	**157**	**175**	**186**	**191**	**100**	**100**	**2.0**
Electricity	*8*	*12*	*16*	*19*	*22*	*27*	*31*	*11*	*16*	*3.4*
TFC	**370**	**538**	**649**	**709**	**771**	**836**	**909**	**100**	**100**	**1.9**
Coal	19	20	22	24	25	27	29	4	3	1.5
Oil	88	144	178	196	215	236	260	27	29	2.1
Gas	14	29	36	42	49	58	69	5	8	3.2
Electricity	32	52	72	88	107	131	159	10	18	4.1
Bioenergy	217	294	340	358	372	380	387	55	43	1.0
Other renewables	0	0	1	1	2	3	4	0	0	13.4
Residential	**222**	**307**	**356**	**381**	**401**	**418**	**435**	**100**	**100**	**1.3**
Coal	1	3	3	3	3	2	2	1	0	-1.8
Oil	13	17	21	24	28	32	36	6	8	2.8
Gas	2	7	8	9	11	12	14	2	3	2.5
Electricity	9	16	24	31	40	51	64	5	15	5.0
Bioenergy	197	263	300	313	320	319	317	86	73	0.7
Other renewables	0	0	0	1	1	1	2	0	0	14.8
Transport	**52**	**90**	**111**	**123**	**134**	**147**	**161**	**100**	**100**	**2.1**
Coal	0	0	0	0	0	0	0	0	0	-0.4
Oil	51	88	108	120	131	143	157	98	97	2.1
Gas	1	1	1	2	2	2	3	1	2	2.4
Electricity	1	0	1	1	1	1	1	1	1	2.7
Biofuels	-	0	1	1	1	1	1	0	1	23.6
Productive uses	**96**	**142**	**182**	**206**	**235**	**271**	**313**	**100**	**100**	**2.9**
Coal	18	16	19	21	23	25	27	11	9	1.9
Oil	24	39	49	53	57	62	68	27	22	2.0
Gas	11	20	27	31	37	44	52	14	17	3.4
Electricity	23	35	47	56	66	79	94	25	30	3.6
Bioenergy	21	31	39	44	51	60	69	22	22	2.9
Other renewables	0	0	0	1	1	1	2	0	1	12.7

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	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**893**	**992**	**1 100**	**1 240**	**1 411**	**5**	**89**	**100**	**2.3**
Coal	116	131	145	162	184	7	20	13	2.0
Oil	208	229	253	285	326	19	48	23	2.4
Gas	131	160	188	227	284	11	41	20	3.8
Nuclear	3	3	6	10	14	-	2	1	5.2
Hydro	17	23	32	43	56	6	18	4	6.5
Bioenergy	406	424	436	446	445	- 39	- 51	32	0.8
Other renewables	12	22	40	66	102	2	11	7	15.7
Power generation	**202**	**244**	**299**	**379**	**481**	**21**	**68**	**100**	**4.1**
Coal	74	83	91	103	116	7	13	24	2.1
Oil	24	22	20	21	24	- 0	3	5	0.1
Gas	70	86	103	126	158	7	22	33	4.1
Nuclear	3	3	6	10	14	-	2	3	5.2
Hydro	17	23	32	43	56	6	18	12	6.5
Bioenergy	3	6	9	12	15	0	0	3	10.5
Other renewables	11	21	38	63	98	2	11	20	15.8
Other energy sector	**136**	**159**	**175**	**186**	**198**	**0**	**7**	**100**	**2.1**
Electricity	*17*	*20*	*24*	*30*	*37*	*2*	*6*	*19*	*4.0*
TFC	**646**	**702**	**768**	**856**	**963**	**- 2**	**54**	**100**	**2.1**
Coal	23	25	28	31	37	2	7	4	2.3
Oil	182	206	233	265	306	17	46	32	2.8
Gas	38	46	56	69	88	6	19	9	4.1
Electricity	74	94	118	152	194	11	35	20	4.8
Bioenergy	329	331	332	336	334	- 40	- 53	35	0.5
Other renewables	1	1	2	3	4	0	0	0	13.9
Residential	**346**	**355**	**366**	**383**	**399**	**- 35**	**- 36**	**100**	**0.9**
Coal	3	3	3	2	2	- 0	- 0	1	-1.8
Oil	22	25	29	34	39	2	3	10	3.1
Gas	8	10	11	13	14	0	0	4	2.6
Electricity	25	33	45	60	81	5	17	20	5.9
Bioenergy	288	283	277	272	261	- 43	- 56	65	-0.0
Other renewables	0	1	1	2	2	0	0	1	15.7
Transport	**113**	**128**	**145**	**165**	**191**	**10**	**30**	**100**	**2.7**
Coal	0	0	0	0	0	0	0	0	-0.2
Oil	110	125	141	161	187	10	30	97	2.7
Gas	1	2	2	2	3	0	0	1	2.4
Electricity	1	1	1	1	1	0	0	1	2.8
Biofuels	1	1	1	1	1	0	0	1	23.9
Productive uses	**187**	**219**	**258**	**309**	**372**	**23**	**59**	**100**	**3.5**
Coal	20	22	25	29	35	2	7	9	2.8
Oil	50	56	62	70	80	5	13	22	2.7
Gas	28	35	43	54	71	6	19	19	4.6
Electricity	49	59	73	90	112	6	18	30	4.2
Bioenergy	40	47	54	63	72	3	3	19	3.0
Other renewables	0	1	1	2	2	0	0	1	12.8

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	Electricity generation (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**449**	**741**	**1 023**	**1 241**	**1 504**	**1 835**	**2 217**	**100**	**100**	**4.0**
Coal	209	259	303	336	361	402	451	35	20	2.0
Oil	59	89	93	88	81	83	85	12	4	-0.1
Gas	92	262	383	472	573	694	853	35	38	4.3
Nuclear	13	13	13	13	25	37	47	2	2	4.7
Hydro	75	112	182	235	300	372	442	15	20	5.0
Bioenergy	1	2	11	21	31	42	53	0	2	12.9
Solar PV	0	0	11	24	42	61	83	0	4	22.1
Other renewables	1	4	27	52	91	143	202	1	9	15.1

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**165**	**253**	**313**	**384**	**469**	**558**	**100**	**100**	**4.5**
Coal	42	56	65	72	80	90	26	16	2.7
Oil	34	36	36	36	37	38	20	7	0.4
Gas	60	100	122	146	174	207	37	37	4.5
Nuclear	2	2	2	4	5	7	1	1	4.5
Hydro	25	41	54	70	87	104	15	19	5.3
Bioenergy	0	2	4	6	8	11	0	2	15.5
Solar PV	0	7	15	25	36	48	0	9	26.0
Other renewables	1	9	16	27	40	54	1	10	14.1

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**690**	**1 052**	**1 260**	**1 388**	**1 504**	**1 660**	**1 844**	**100**	**100**	**2.0**
Coal	277	331	374	404	420	453	491	32	27	1.4
Oil	309	502	604	651	698	758	826	48	45	1.8
Gas	103	218	283	332	385	448	527	21	29	3.2
Power generation	**296**	**447**	**520**	**570**	**608**	**676**	**760**	**100**	**100**	**1.9**
Coal	202	252	283	308	319	344	373	57	49	1.4
Oil	42	75	77	72	66	67	68	17	9	-0.3
Gas	51	120	159	190	224	265	318	27	42	3.6
TFC	**354**	**556**	**677**	**746**	**819**	**903**	**1 001**	**100**	**100**	**2.1**
Coal	75	79	91	96	101	108	117	14	12	1.4
Oil	249	409	509	561	614	673	741	74	74	2.1
Transport	*151*	*261*	*321*	*356*	*389*	*425*	*465*	*47*	*46*	*2.1*
Gas	29	68	78	89	104	121	143	12	14	2.7

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	Electricity generation (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**1 050**	**1 317**	**1 653**	**2 110**	**2 681**	**150**	**465**	**100**	**4.7**
Coal	307	351	388	441	504	27	53	19	2.4
Oil	89	86	80	84	93	- 1	8	3	0.2
Gas	397	502	621	783	1 001	48	148	37	4.9
Nuclear	13	13	25	40	54	-	7	2	5.2
Hydro	192	265	368	499	654	68	212	24	6.5
Bioenergy	11	21	31	42	54	0	1	2	13.0
Solar PV	12	26	46	71	104	4	20	4	23.0
Other renewables	28	54	94	150	218	3	16	8	15.4

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**259**	**331**	**421**	**537**	**674**	**37**	**116**	**100**	**5.2**
Coal	57	67	77	87	99	5	9	15	3.1
Oil	36	35	35	37	40	- 0	2	6	0.6
Gas	103	129	158	197	242	13	35	36	5.1
Nuclear	2	2	4	6	7	-	1	1	4.9
Hydro	43	61	86	117	153	16	50	23	6.7
Bioenergy	2	4	6	9	11	0	0	2	15.6
Solar PV	7	16	28	42	63	3	14	9	27.1
Other renewables	9	17	27	42	59	1	5	9	14.4

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**1 281**	**1 448**	**1 606**	**1 833**	**2 140**	**102**	**295**	**100**	**2.6**
Coal	380	423	450	497	556	30	65	26	1.9
Oil	611	677	746	841	965	48	139	45	2.4
Gas	289	348	410	495	619	25	92	29	3.8
Power generation	**526**	**593**	**644**	**735**	**856**	**36**	**96**	**100**	**2.3**
Coal	287	322	339	373	411	20	37	48	1.8
Oil	74	70	65	67	76	- 1	8	9	0.1
Gas	165	201	240	295	369	16	51	43	4.1
TFC	**693**	**786**	**891**	**1 024**	**1 198**	**72**	**198**	**100**	**2.8**
Coal	93	101	111	124	145	9	27	12	2.2
Oil	520	588	663	755	871	49	131	73	2.7
Transport	*328*	*372*	*419*	*478*	*554*	*30*	*89*	*46*	*2.7*
Gas	80	97	117	144	182	14	40	15	3.6

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	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**396**	**570**	**694**	**773**	**855**	**941**	**1 039**	**100**	**100**	**2.2**
Coal	86	101	111	122	130	141	154	18	15	1.5
Oil	45	85	107	121	136	155	180	15	17	2.7
Gas	9	22	38	50	64	83	110	4	11	5.9
Nuclear	3	3	3	3	6	10	12	1	1	4.7
Hydro	5	8	14	18	23	29	35	1	3	5.3
Bioenergy	247	348	412	443	469	482	488	61	47	1.2
Other renewables	0	1	9	16	27	41	60	0	6	14.1
Power generation	**69**	**96**	**124**	**150**	**184**	**230**	**289**	**100**	**100**	**4.0**
Coal	50	62	68	74	78	85	94	65	33	1.5
Oil	6	11	11	11	12	14	16	11	6	1.4
Gas	4	9	16	22	30	41	59	9	20	6.9
Nuclear	3	3	3	3	6	10	12	4	4	4.7
Hydro	5	8	14	18	23	29	35	9	12	5.3
Bioenergy	1	1	3	6	9	12	14	1	5	10.2
Other renewables	0	1	8	15	26	40	57	1	20	14.1
Other energy sector	**55**	**90**	**114**	**133**	**149**	**157**	**160**	**100**	**100**	**2.1**
Electricity	*6*	*8*	*10*	*12*	*15*	*18*	*22*	*9*	*14*	*3.7*
TFC	**299**	**422**	**508**	**557**	**606**	**659**	**722**	**100**	**100**	**1.9**
Coal	18	19	22	23	24	26	28	5	4	1.4
Oil	44	75	97	112	127	146	168	18	23	2.9
Gas	2	7	11	14	18	24	32	2	4	5.8
Electricity	22	30	43	54	69	87	111	7	15	4.7
Bioenergy	214	290	335	353	366	374	380	69	53	1.0
Other renewables	0	0	0	1	1	2	2	0	0	13.1
Residential	**205**	**280**	**324**	**345**	**361**	**372**	**384**	**100**	**100**	**1.1**
Coal	1	3	3	3	3	2	2	1	1	-1.8
Oil	5	7	10	12	14	17	21	3	5	3.7
Gas	-	0	0	0	1	1	2	0	0	41.9
Electricity	4	8	13	18	25	34	45	3	12	6.2
Bioenergy	195	261	297	310	317	316	313	93	82	0.7
Other renewables	0	0	0	0	1	1	1	0	0	40.6
Transport	**29**	**48**	**62**	**72**	**82**	**94**	**109**	**100**	**100**	**3.0**
Coal	0	0	0	0	0	0	0	0	0	-0.4
Oil	28	47	60	71	81	92	107	99	98	2.9
Gas	-	0	0	0	0	0	0	0	0	7.2
Electricity	0	0	0	0	0	1	1	1	1	2.1
Biofuels	-	0	1	1	1	1	1	0	1	23.6
Productive uses	**65**	**94**	**122**	**140**	**163**	**193**	**230**	**100**	**100**	**3.2**
Coal	17	16	19	20	22	24	26	17	11	1.8
Oil	11	20	26	29	32	36	41	22	18	2.5
Gas	2	7	10	13	17	23	30	7	13	5.5
Electricity	17	22	29	35	43	53	65	23	28	4.0
Bioenergy	19	30	37	42	48	56	66	31	29	2.9
Other renewables	0	0	0	0	1	1	1	0	0	9.9

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	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**690**	**771**	**861**	**978**	**1 127**	**5**	**89**	**100**	**2.5**
Coal	110	124	137	152	174	7	20	15	1.9
Oil	112	132	155	186	228	19	48	20	3.6
Gas	40	57	75	104	151	11	41	13	7.1
Nuclear	3	3	6	10	14	-	2	1	5.2
Hydro	15	20	29	40	53	6	18	5	6.9
Bioenergy	401	418	430	439	437	- 39	- 51	39	0.8
Other renewables	9	17	29	46	71	2	11	6	14.8
Power generation	**128**	**161**	**205**	**269**	**357**	**21**	**68**	**100**	**4.8**
Coal	69	78	84	95	107	7	13	30	2.0
Oil	10	11	12	14	19	- 0	3	5	2.0
Gas	19	27	37	54	81	7	22	23	8.1
Nuclear	3	3	6	10	14	-	2	4	5.2
Hydro	15	20	29	40	53	6	18	15	6.9
Bioenergy	3	6	9	12	15	0	0	4	10.3
Other renewables	8	16	27	44	68	2	11	19	14.8
Other energy sector	**113**	**134**	**149**	**158**	**167**	**0**	**7**	**100**	**2.2**
Electricity	*11*	*13*	*17*	*21*	*27*	*2*	*6*	*16*	*4.6*
TFC	**505**	**549**	**604**	**680**	**776**	**- 2**	**54**	**100**	**2.2**
Coal	22	24	27	30	36	2	7	5	2.2
Oil	101	121	144	175	214	17	46	28	3.8
Gas	12	17	24	35	51	6	19	7	7.6
Electricity	45	60	80	108	145	11	35	19	5.8
Bioenergy	324	326	327	330	327	- 40	- 53	42	0.4
Other renewables	1	1	1	2	3	0	0	0	13.7
Residential	**314**	**319**	**326**	**338**	**348**	**- 35**	**- 36**	**100**	**0.8**
Coal	3	3	3	2	2	- 0	- 0	1	-1.8
Oil	11	13	16	20	24	2	3	7	4.2
Gas	0	1	1	2	2	0	0	1	42.9
Electricity	14	21	30	44	61	5	17	18	7.4
Bioenergy	285	280	274	269	257	- 43	- 56	74	-0.0
Other renewables	0	1	1	1	2	0	0	1	n.a.
Transport	**64**	**78**	**92**	**112**	**139**	**10**	**30**	**100**	**3.9**
Coal	0	0	0	0	0	0	0	0	-0.2
Oil	63	76	91	110	137	10	30	99	3.9
Gas	0	0	0	0	0	0	0	0	7.7
Electricity	0	0	0	1	1	0	0	0	2.3
Biofuels	1	1	1	1	1	0	0	1	23.9
Productive uses	**127**	**153**	**186**	**230**	**289**	**23**	**59**	**100**	**4.1**
Coal	19	22	24	28	34	2	7	12	2.7
Oil	27	32	37	44	54	5	13	19	3.6
Gas	12	17	23	33	49	6	19	17	7.4
Electricity	30	39	49	64	83	6	18	29	4.9
Bioenergy	38	44	51	60	68	3	3	24	3.0
Other renewables	0	0	1	1	1	0	0	0	10.1

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	Electricity generation (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**307**	**440**	**621**	**777**	**974**	**1 228**	**1 541**	**100**	**100**	**4.6**
Coal	200	247	283	312	332	368	412	56	27	1.8
Oil	19	40	41	42	45	52	63	9	4	1.7
Gas	12	40	87	130	186	263	385	9	25	8.4
Nuclear	13	13	13	13	25	37	47	3	3	4.7
Hydro	60	96	159	207	269	339	408	22	26	5.3
Bioenergy	1	2	11	20	30	40	50	0	3	12.7
Solar PV	0	0	9	19	31	44	58	0	4	27.1
Other renewables	0	2	17	33	56	85	117	0	8	16.1

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**97**	**154**	**198**	**251**	**315**	**385**	**100**	**100**	**5.0**
Coal	41	53	61	67	75	84	42	22	2.6
Oil	22	24	25	26	29	31	23	8	1.2
Gas	13	28	39	52	70	94	13	24	7.4
Nuclear	2	2	2	4	5	7	2	2	4.5
Hydro	20	34	46	60	77	93	20	24	5.7
Bioenergy	0	2	4	6	8	10	0	3	15.2
Solar PV	0	6	11	19	26	34	0	9	27.1
Other renewables	0	5	10	16	24	32	0	8	19.5

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**437**	**619**	**753**	**853**	**943**	**1 071**	**1 238**	**100**	**100**	**2.5**
Coal	263	315	352	379	390	418	452	51	37	1.3
Oil	156	262	322	366	414	472	546	42	44	2.7
Gas	18	42	79	108	139	181	241	7	19	6.4
Power generation	**220**	**296**	**338**	**375**	**402**	**454**	**529**	**100**	**100**	**2.1**
Coal	194	241	265	287	293	315	340	81	64	1.2
Oil	17	34	35	35	37	43	51	11	10	1.5
Gas	9	21	38	52	71	97	138	7	26	7.0
TFC	**202**	**305**	**388**	**442**	**501**	**573**	**663**	**100**	**100**	**2.8**
Coal	69	75	87	92	97	103	112	24	17	1.5
Oil	128	216	278	320	365	419	483	71	73	2.9
Transport	*84*	*140*	*179*	*209*	*239*	*274*	*316*	*46*	*48*	*2.9*
Gas	5	14	23	30	39	51	68	5	10	5.8

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	Electricity generation (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**647**	**853**	**1 124**	**1 503**	**2 006**	**150**	**465**	**100**	**5.6**
Coal	288	327	359	407	464	27	53	23	2.3
Oil	38	40	44	52	71	- 1	8	4	2.1
Gas	101	160	233	352	534	48	148	27	9.7
Nuclear	13	13	25	40	54	-	7	3	5.2
Hydro	169	237	337	466	620	68	212	31	6.9
Bioenergy	11	20	30	40	51	0	1	3	12.7
Solar PV	10	21	35	53	79	4	20	4	28.5
Other renewables	18	35	59	92	133	3	16	7	16.6

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**161**	**216**	**288**	**383**	**501**	**37**	**116**	**100**	**6.0**
Coal	54	64	72	82	93	5	9	19	3.0
Oil	24	24	26	29	33	- 0	2	7	1.5
Gas	31	46	65	93	129	13	35	26	8.6
Nuclear	2	2	4	6	7	-	1	1	4.9
Hydro	36	52	76	107	143	16	50	29	7.3
Bioenergy	2	4	6	8	11	0	0	2	15.4
Solar PV	6	13	21	32	48	3	14	10	28.7
Other renewables	5	11	17	26	37	1	5	7	20.0

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**774**	**913**	**1 045**	**1 245**	**1 533**	**102**	**295**	**100**	**3.3**
Coal	358	398	420	462	517	30	65	34	1.8
Oil	330	392	461	555	684	48	139	45	3.5
Gas	85	123	164	228	333	25	92	22	7.6
Power generation	**344**	**397**	**437**	**512**	**625**	**36**	**96**	**100**	**2.7**
Coal	269	301	314	343	377	20	37	60	1.6
Oil	32	33	36	43	59	- 1	8	9	2.0
Gas	43	63	87	127	189	16	51	30	8.2
TFC	**404**	**482**	**572**	**694**	**861**	**72**	**198**	**100**	**3.8**
Coal	89	97	106	119	139	9	27	16	2.3
Oil	289	348	414	501	614	49	131	71	3.8
Transport	*185*	*225*	*269*	*327*	*404*	*30*	*89*	*47*	*3.9*
Gas	26	37	52	74	107	14	40	12	7.5

West Africa: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**127**	**197**	**241**	**263**	**288**	**317**	**355**	**100**	**100**	**2.1**
Coal	0	0	2	5	8	12	15	0	4	13.9
Oil	20	33	42	48	55	64	76	17	21	3.0
Gas	7	14	25	31	40	51	69	7	19	5.7
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	1	3	4	5	7	9	1	2	6.5
Bioenergy	98	147	168	174	178	178	180	75	51	0.7
Other renewables	0	0	0	1	2	4	6	0	2	39.9
Power generation	**8**	**15**	**23**	**31**	**41**	**56**	**75**	**100**	**100**	**5.8**
Coal	0	0	1	4	7	10	13	1	18	17.4
Oil	3	6	6	5	5	5	5	39	7	-0.4
Gas	4	8	12	16	20	27	39	50	52	5.9
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	1	3	4	5	7	9	9	11	6.5
Bioenergy	0	0	1	1	2	3	3	1	5	14.0
Other renewables	0	0	0	1	2	4	6	0	8	39.5
Other energy sector	**13**	**27**	**31**	**32**	**35**	**37**	**36**	**100**	**100**	**1.1**
Electricity	*1*	*1*	*2*	*3*	*4*	*5*	*6*	*5*	*18*	*5.7*
TFC	**109**	**161**	**198**	**215**	**234**	**255**	**286**	**100**	**100**	**2.1**
Coal	0	0	1	1	1	2	2	0	1	7.9
Oil	15	25	35	41	48	57	68	15	24	3.6
Gas	1	3	6	8	11	15	21	2	7	6.8
Electricity	2	5	9	13	19	26	36	3	13	7.1
Bioenergy	90	128	147	153	156	156	159	79	56	0.8
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Residential	**88**	**120**	**138**	**145**	**148**	**149**	**152**	**100**	**100**	**0.8**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	2	4	5	6	8	9	11	3	7	4.0
Gas	-	-	0	0	0	1	1	-	1	n.a.
Electricity	1	2	4	6	8	12	16	2	10	7.4
Bioenergy	85	114	129	133	132	127	124	95	81	0.3
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Transport	**8**	**16**	**20**	**24**	**28**	**33**	**40**	**100**	**100**	**3.4**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	8	16	20	24	28	33	40	100	100	3.4
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	0	0	0	0	0	0	0	0	0	0.9
Biofuels	-	-	-	-	-	-	-	-	-	n.a.
Productive uses	**12**	**26**	**39**	**47**	**58**	**73**	**93**	**100**	**100**	**4.7**
Coal	0	0	1	1	1	2	2	1	2	7.9
Oil	4	6	10	11	12	14	17	22	18	4.0
Gas	1	3	6	8	10	14	19	13	21	6.6
Electricity	2	3	5	7	10	14	20	12	22	6.9
Bioenergy	5	13	18	20	24	29	35	52	37	3.5
Other renewables	-	-	-	-	-	-	-	-	-	n.a.

West Africa: African Century Case

	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**238**	**260**	**288**	**335**	**394**	**- 0**	**39**	**100**	**2.5**
Coal	2	6	9	14	19	1	4	5	14.8
Oil	44	53	63	77	96	8	21	24	3.9
Gas	27	37	49	66	94	9	25	24	6.9
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	6	8	10	1	1	2	7.0
Bioenergy	162	159	158	165	168	- 20	- 13	43	0.5
Other renewables	1	1	3	5	7	0	1	2	40.9
Power generation	**24**	**35**	**48**	**68**	**94**	**7**	**19**	**100**	**6.7**
Coal	2	5	8	12	16	1	3	17	18.1
Oil	5	4	4	5	6	- 0	1	6	0.1
Gas	14	19	26	36	52	5	13	55	7.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	6	8	10	1	1	10	7.0
Bioenergy	1	1	2	3	4	0	0	4	14.1
Other renewables	0	1	2	4	7	0	1	7	40.6
Other energy sector	**32**	**37**	**40**	**41**	**42**	**5**	**6**	**100**	**1.7**
Electricity	*2*	*3*	*5*	*6*	*8*	*1*	*2*	*20*	*6.7*
TFC	**195**	**207**	**228**	**267**	**316**	**- 6**	**30**	**100**	**2.4**
Coal	1	1	1	2	3	0	1	1	9.6
Oil	37	46	56	70	88	9	20	28	4.6
Gas	7	11	16	23	34	5	14	11	8.8
Electricity	10	16	23	35	50	5	14	16	8.4
Bioenergy	140	133	131	137	140	- 25	- 19	44	0.3
Other renewables	0	0	0	0	1	0	0	0	n.a.
Residential	**132**	**126**	**125**	**134**	**141**	**- 23**	**- 11**	**100**	**0.6**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	5	7	9	10	12	1	1	9	4.4
Gas	0	0	1	1	1	0	0	1	n.a.
Electricity	4	7	11	16	22	2	6	16	8.7
Bioenergy	122	112	105	106	105	- 27	- 19	74	-0.3
Other renewables	0	0	0	0	1	0	0	0	n.a.
Transport	**22**	**27**	**33**	**41**	**53**	**5**	**13**	**100**	**4.5**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	22	27	33	41	53	5	13	100	4.5
Gas	-	-	-	-	-	-	-	-	n.a.
Electricity	0	0	0	0	0	-	- 0	0	0.7
Biofuels	0	-	-	-	-	-	-	-	n.a.
Productive uses	**42**	**54**	**70**	**92**	**121**	**12**	**28**	**100**	**5.7**
Coal	1	1	1	2	3	0	1	3	9.6
Oil	10	13	15	18	23	3	6	19	5.1
Gas	7	10	15	22	33	4	14	27	8.7
Electricity	6	9	13	19	27	3	7	23	8.1
Bioenergy	18	22	26	30	35	2	0	29	3.5
Other renewables	-	-	-	-	-	-	-	-	n.a.

West Africa: New Policies Scenario

	Electricity generation and trade (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**38**	**74**	**128**	**180**	**252**	**350**	**474**	**100**	**100**	**6.8**
Coal	0	1	6	17	27	42	54	1	11	17.3
Oil	10	22	21	18	17	18	20	29	4	-0.3
Gas	12	35	63	88	123	169	249	47	53	7.3
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	15	17	33	45	63	85	100	23	21	6.5
Bioenergy	0	0	2	4	7	9	12	0	3	18.1
Solar PV	0	0	2	5	8	12	17	0	4	34.9
Other renewables	0	0	1	3	8	14	21	0	4	39.2
Net imports	**0**	**2**	**3**	**5**	**7**	**10**	**17**	**n.a.**	**n.a.**	**8.0**

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**25**	**40**	**52**	**67**	**89**	**113**	**100**	**100**	**5.5**
Coal	0	1	3	5	7	9	0	8	18.9
Oil	11	11	10	10	10	11	43	10	0.0
Gas	11	18	23	29	38	50	42	44	5.7
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	4	8	11	15	20	24	16	21	6.7
Bioenergy	-	0	1	1	2	2	-	2	n.a.
Solar PV	-	1	3	5	7	10	-	9	n.a.
Other renewables	-	0	1	3	5	7	-	6	n.a.

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**75**	**130**	**185**	**227**	**277**	**345**	**434**	**100**	**100**	**4.4**
Coal	0	2	8	21	32	48	63	1	14	14.1
Oil	58	97	121	136	156	183	217	75	50	2.9
Gas	17	31	56	70	90	114	155	24	36	5.9
Power generation	**18**	**37**	**52**	**69**	**89**	**119**	**161**	**100**	**100**	**5.4**
Coal	0	1	6	17	27	42	54	2	34	17.6
Oil	10	18	18	15	14	15	17	50	10	-0.4
Gas	8	18	29	36	48	63	90	49	56	5.9
TFC	**46**	**81**	**114**	**136**	**164**	**200**	**247**	**100**	**100**	**4.1**
Coal	0	1	2	3	4	6	8	1	3	7.9
Oil	43	73	99	115	136	162	195	91	79	3.5
Transport	*25*	*46*	*60*	*70*	*83*	*98*	*119*	*57*	*48*	*3.4*
Gas	3	7	13	17	24	33	45	8	18	7.0

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	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**138**	**208**	**304**	**437**	**604**	**52**	**129**	**100**	**7.8**
Coal	6	19	32	49	64	5	10	11	18.1
Oil	17	17	16	18	22	- 1	2	4	0.1
Gas	75	112	161	236	340	39	91	56	8.5
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	33	47	70	93	114	7	14	19	7.0
Bioenergy	2	4	7	9	13	0	0	2	18.2
Solar PV	3	6	10	16	26	2	8	4	36.7
Other renewables	1	3	8	16	25	1	4	4	40.1
Net imports	**6**	**11**	**19**	**37**	**71**	**13**	**54**	**n.a.**	**13.6**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**43**	**57**	**78**	**107**	**142**	**11**	**29**	**100**	**6.3**
Coal	1	3	5	8	10	1	2	7	19.7
Oil	10	10	10	10	11	- 0	0	8	0.1
Gas	21	28	36	50	66	8	16	47	6.8
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	8	11	17	23	28	2	3	20	7.2
Bioenergy	0	1	1	2	2	0	0	2	n.a.
Solar PV	2	4	6	10	16	1	5	11	n.a.
Other renewables	0	1	3	5	8	0	2	6	n.a.

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**195**	**256**	**326**	**425**	**564**	**49**	**130**	**100**	**5.4**
Coal	9	23	37	57	77	6	14	14	15.0
Oil	125	150	179	219	276	23	59	49	3.8
Gas	61	83	109	149	211	20	56	37	7.1
Power generation	**54**	**78**	**106**	**148**	**204**	**16**	**43**	**100**	**6.3**
Coal	6	19	32	49	65	4	10	32	18.3
Oil	15	14	14	14	19	- 1	2	9	0.1
Gas	33	45	60	84	121	13	31	59	7.0
TFC	**123**	**157**	**199**	**256**	**337**	**35**	**90**	**100**	**5.2**
Coal	3	4	6	8	12	1	4	4	9.6
Oil	105	130	160	198	251	24	56	75	4.5
Transport	*64*	*79*	*97*	*121*	*156*	*14*	*38*	*46*	*4.5*
Gas	15	23	34	50	74	10	29	22	8.9

Nigeria: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**88**	**141**	**173**	**188**	**205**	**224**	**251**	**100**	**100**	**2.1**
Coal	0	0	1	3	5	9	12	0	5	23.9
Oil	12	20	25	29	33	39	46	14	18	3.1
Gas	6	13	22	28	35	44	58	9	23	5.6
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	0	0	1	2	3	5	5	0	2	8.8
Bioenergy	70	108	123	125	127	125	124	77	50	0.5
Other renewables	-	-	0	1	2	3	5	-	2	n.a.
Power generation	**5**	**10**	**15**	**21**	**28**	**39**	**53**	**100**	**100**	**6.2**
Coal	-	-	1	3	5	9	12	-	22	n.a.
Oil	2	3	3	2	2	2	2	33	4	-1.5
Gas	3	6	10	12	15	20	29	62	54	5.7
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	0	0	1	2	3	5	5	5	10	8.8
Bioenergy	-	-	0	0	1	1	1	-	2	n.a.
Other renewables	-	-	0	1	2	3	4	-	8	n.a.
Other energy sector	**6**	**14**	**19**	**21**	**25**	**28**	**29**	**100**	**100**	**2.5**
Electricity	*1*	*1*	*1*	*2*	*2*	*3*	*4*	*5*	*15*	*6.4*
TFC	**78**	**121**	**146**	**156**	**167**	**178**	**198**	**100**	**100**	**1.8**
Coal	0	0	0	0	0	0	0	0	0	8.9
Oil	9	15	22	25	30	35	43	12	22	3.8
Gas	1	3	6	8	11	15	20	3	10	6.9
Electricity	1	3	6	9	13	18	25	3	13	7.7
Bioenergy	67	99	113	115	114	110	110	82	55	0.4
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Residential	**66**	**93**	**105**	**107**	**106**	**101**	**99**	**100**	**100**	**0.2**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	2	3	4	4	5	6	7	3	7	3.7
Gas	-	-	0	0	0	1	1	-	1	n.a.
Electricity	0	1	3	4	6	8	10	1	11	7.5
Bioenergy	64	89	99	98	94	86	80	96	81	-0.4
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Transport	**5**	**10**	**12**	**14**	**17**	**21**	**26**	**100**	**100**	**3.7**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	5	10	12	14	17	21	26	100	100	3.7
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	-	-	-	-	-	-	-	-	-	n.a.
Biofuels	-	-	-	-	-	-	-	-	-	n.a.
Productive uses	**7**	**18**	**29**	**35**	**44**	**57**	**73**	**100**	**100**	**5.1**
Coal	0	0	0	0	0	0	0	0	0	8.9
Oil	2	3	6	6	7	8	9	16	13	4.4
Gas	1	3	6	7	10	14	19	17	26	6.7
Electricity	1	2	3	5	7	10	15	10	20	7.8
Bioenergy	3	10	14	16	20	24	30	57	41	3.8
Other renewables	-	-	-	-	-	-	-	-	-	n.a.

Nigeria: African Century Case

	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**170**	**183**	**201**	**236**	**281**	**- 4**	**30**	**100**	**2.5**
Coal	1	3	5	9	12	0	0	4	24.0
Oil	27	33	39	48	61	6	14	22	4.1
Gas	24	32	42	56	79	7	21	28	6.8
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	1	2	4	5	5	0	0	2	8.9
Bioenergy	116	111	109	115	118	- 18	- 6	42	0.3
Other renewables	0	1	2	4	5	0	1	2	n.a.
Power generation	**16**	**23**	**33**	**46**	**64**	**4**	**10**	**100**	**6.9**
Coal	1	3	5	9	12	-	-	18	n.a.
Oil	2	2	2	2	2	- 0	0	4	-1.1
Gas	11	15	19	27	38	4	9	60	6.7
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	1	2	4	5	5	0	0	8	8.9
Bioenergy	0	0	1	1	1	0	0	2	n.a.
Other renewables	0	1	2	3	5	0	1	8	n.a.
Other energy sector	**18**	**23**	**26**	**28**	**30**	**1**	**1**	**100**	**2.6**
Electricity	*1*	*2*	*3*	*4*	*5*	*0*	*1*	*18*	*7.2*
TFC	**144**	**149**	**162**	**190**	**228**	**- 5**	**30**	**100**	**2.3**
Coal	0	0	0	0	1	0	0	0	11.1
Oil	23	29	36	44	57	6	14	25	4.9
Gas	7	10	15	23	33	5	13	15	8.9
Electricity	7	11	16	24	35	4	10	15	9.0
Bioenergy	107	98	94	99	102	- 20	- 8	45	0.1
Other renewables	0	0	0	0	0	0	0	0	n.a.
Residential	**99**	**91**	**86**	**91**	**96**	**- 19**	**- 3**	**100**	**0.1**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	4	5	6	7	8	1	1	8	4.1
Gas	0	0	1	1	1	0	0	1	n.a.
Electricity	3	5	7	10	15	2	4	15	8.8
Bioenergy	92	80	72	73	72	- 22	- 8	75	-0.7
Other renewables	0	0	0	0	0	0	0	0	n.a.
Transport	**13**	**17**	**21**	**27**	**36**	**4**	**10**	**100**	**4.9**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	13	17	21	27	36	4	10	100	4.9
Gas	-	-	-	-	-	-	-	-	n.a.
Electricity	-	-	-	-	-	-	-	-	n.a.
Biofuels	-	-	-	-	-	-	-	-	n.a.
Productive uses	**31**	**41**	**54**	**72**	**95**	**10**	**23**	**100**	**6.1**
Coal	0	0	0	0	1	0	0	1	11.1
Oil	6	8	9	11	13	2	3	13	5.5
Gas	7	10	14	22	32	4	13	34	8.7
Electricity	4	6	9	14	20	2	6	21	9.1
Bioenergy	15	18	22	26	30	2	0	31	3.8
Other renewables	-	-	-	-	-	-	-	-	n.a.

Nigeria: New Policies Scenario

	Electricity generation and trade (TWh)							**Shares** (%)		**CAAGR** (%)
	2000	**2012**	**2020**	**2025**	**2030**	**2035**	**2040**	**2012**	**2040**	**2012-40**
Total generation	**21**	**46**	**82**	**119**	**171**	**242**	**330**	**100**	**100**	**7.3**
Coal	-	-	3	12	21	34	47	-	14	n.a.
Oil	6	11	10	8	7	6	7	25	2	-1.6
Gas	9	29	50	66	91	125	184	63	56	6.9
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	6	6	16	25	38	53	60	12	18	8.8
Bioenergy	-	-	1	1	2	3	5	-	1	n.a.
Solar PV	-	-	2	3	6	9	13	-	4	n.a.
Other renewables	-	-	0	2	6	11	15	-	4	n.a.
Net imports	**-**	**-**	**1**	**1**	**3**	**6**	**11**	**n.a.**	**n.a.**	**n.a.**

	Electrical capacity (GW)						**Shares** (%)		**CAAGR** (%)
	2012	**2020**	**2025**	**2030**	**2035**	**2040**	**2012**	**2040**	**2012-40**
Total capacity	**18**	**28**	**36**	**46**	**62**	**77**	**100**	**100**	**5.3**
Coal	-	1	2	4	6	8	-	10	n.a.
Oil	7	6	6	5	5	5	36	6	-1.1
Gas	9	15	18	22	29	37	53	48	5.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	2	4	6	10	13	15	11	19	7.4
Bioenergy	-	0	0	0	1	1	-	1	n.a.
Solar PV	-	1	2	4	5	7	-	9	n.a.
Other renewables	-	0	1	2	3	5	-	6	n.a.

	CO_2 emissions (Mt)							**Shares** (%)		**CAAGR** (%)
	2000	**2012**	**2020**	**2025**	**2030**	**2035**	**2040**	**2012**	**2040**	**2012-40**
Total CO_2	**49**	**84**	**124**	**155**	**192**	**244**	**312**	**100**	**100**	**4.8**
Coal	0	0	4	13	22	36	49	0	16	24.1
Oil	35	58	71	80	92	110	133	68	42	3.0
Gas	14	27	50	62	77	98	131	32	42	5.8
Power generation	**12**	**24**	**35**	**49**	**64**	**88**	**122**	**100**	**100**	**5.9**
Coal	-	-	4	13	22	35	48	-	39	n.a.
Oil	5	10	9	8	6	6	7	42	5	-1.5
Gas	7	14	22	28	36	47	68	58	56	5.8
TFC	**29**	**50**	**72**	**87**	**106**	**132**	**167**	**100**	**100**	**4.4**
Coal	0	0	0	0	1	1	1	0	1	8.9
Oil	26	44	59	69	83	100	122	87	73	3.7
Transport	*15*	*28*	*37*	*43*	*51*	*62*	*77*	*56*	*46*	*3.7*
Gas	2	6	12	17	23	32	43	13	26	7.1

Nigeria: African Century Case

	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**90**	**139**	**205**	**295**	**401**	**34**	**71**	**100**	**8.1**
Coal	3	12	21	34	47	-	-	12	n.a.
Oil	8	7	7	6	8	- 0	1	2	-1.2
Gas	58	85	119	172	246	28	62	61	8.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	17	27	43	56	62	5	1	15	8.9
Bioenergy	1	1	2	4	5	0	0	1	n.a.
Solar PV	2	4	7	11	17	1	5	4	n.a.
Other renewables	0	2	6	12	17	0	2	4	n.a.
Net imports	**3**	**8**	**17**	**34**	**68**	**14**	**57**	**n.a.**	**n.a.**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**30**	**40**	**53**	**72**	**91**	**7**	**14**	**100**	**6.0**
Coal	1	2	4	6	8	-	-	8	n.a.
Oil	6	5	5	4	5	- 0	- 0	5	-1.3
Gas	17	22	28	37	48	5	10	52	5.9
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	5	7	11	14	15	1	0	17	7.5
Bioenergy	0	0	0	1	1	0	0	1	n.a.
Solar PV	1	2	4	7	10	1	3	11	n.a.
Other renewables	0	1	2	4	5	- 0	1	6	n.a.

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**132**	**177**	**226**	**297**	**400**	**34**	**88**	**100**	**5.7**
Coal	4	13	23	37	50	0	1	12	24.2
Oil	74	91	110	136	174	18	41	43	4.0
Gas	53	72	93	125	176	16	46	44	7.0
Power generation	**37**	**54**	**73**	**103**	**144**	**9**	**22**	**100**	**6.6**
Coal	4	13	22	35	48	-	-	33	n.a.
Oil	8	7	6	6	8	- 0	1	5	-1.0
Gas	25	35	45	62	89	9	21	62	6.8
TFC	**79**	**104**	**134**	**175**	**236**	**28**	**69**	**100**	**5.7**
Coal	0	1	1	1	2	0	1	1	11.2
Oil	64	81	100	125	162	17	40	69	4.8
Transport	*40*	*50*	*62*	*80*	*107*	*11*	*30*	*45*	*4.9*
Gas	15	23	33	49	71	10	28	30	9.0

Central Africa: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**26**	**37**	**48**	**55**	**63**	**72**	**81**	**100**	**100**	**2.8**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	2	5	6	7	8	9	10	13	13	2.8
Gas	0	2	4	4	5	6	7	5	9	4.5
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	1	2	3	4	6	8	3	9	6.7
Bioenergy	23	29	36	41	46	51	55	78	68	2.3
Other renewables	-	-	0	0	0	0	1	-	1	n.a.
Power generation	**1**	**3**	**5**	**6**	**7**	**10**	**12**	**100**	**100**	**5.7**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	0	1	1	1	1	1	1	29	8	1.2
Gas	0	1	1	1	2	2	3	22	22	5.8
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	1	2	3	4	6	8	49	63	6.7
Bioenergy	0	0	0	0	0	0	0	1	3	10.0
Other renewables	-	-	0	0	0	0	1	-	4	n.a.
Other energy sector	**1**	**3**	**5**	**7**	**8**	**9**	**10**	**100**	**100**	**4.1**
Electricity	*0*	*0*	*0*	*1*	*1*	*1*	*1*	*10*	*12*	*4.8*
TFC	**24**	**33**	**41**	**47**	**53**	**59**	**67**	**100**	**100**	**2.5**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	2	4	5	5	6	7	9	11	13	3.2
Gas	0	1	1	2	2	3	3	3	5	4.8
Electricity	1	1	2	3	4	5	6	4	10	5.7
Bioenergy	22	27	33	37	40	44	48	82	72	2.0
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Residential	**19**	**24**	**29**	**33**	**36**	**40**	**43**	**100**	**100**	**2.2**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	0	0	1	1	1	1	1	2	2	3.1
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	0	0	1	1	1	2	2	2	6	6.4
Bioenergy	18	23	28	31	34	37	40	96	92	2.0
Other renewables	-	-	0	0	0	0	0	-	0	n.a.
Transport	**1**	**3**	**3**	**4**	**4**	**5**	**6**	**100**	**100**	**3.1**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	1	3	3	4	4	5	6	100	100	3.1
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	0	0	0	0	0	0	0	0	0	0.6
Biofuels	-	-	-	-	-	-	-	-	-	n.a.
Productive uses	**4**	**7**	**9**	**10**	**12**	**14**	**17**	**100**	**100**	**3.3**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	0	1	1	1	1	1	2	10	10	3.3
Gas	0	1	1	2	2	3	3	13	19	4.8
Electricity	1	1	2	2	2	3	4	13	23	5.4
Bioenergy	3	4	5	6	6	7	8	64	48	2.3
Other renewables	-	-	-	-	-	-	-	-	-	n.a.

Central Africa: African Century Case

	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**49**	**58**	**68**	**79**	**94**	**5**	**13**	**100**	**3.4**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	6	7	9	11	14	1	4	15	4.0
Gas	4	5	5	7	10	0	3	11	5.9
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	7	11	17	3	10	18	9.9
Bioenergy	37	41	46	49	52	- 0	- 4	55	2.1
Other renewables	0	0	0	1	1	0	0	1	n.a.
Power generation	**5**	**7**	**10**	**15**	**23**	**3**	**11**	**100**	**8.2**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	1	1	1	1	1	- 0	0	6	2.1
Gas	2	2	2	2	4	0	1	16	7.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	7	11	17	3	10	74	9.9
Bioenergy	0	0	0	0	0	0	0	2	10.7
Other renewables	0	0	0	0	1	0	0	3	n.a.
Other energy sector	**5**	**7**	**8**	**8**	**9**	**0**	**- 1**	**100**	**3.9**
Electricity	*1*	*1*	*1*	*1*	*2*	*0*	*0*	*19*	*6.2*
TFC	**42**	**48**	**55**	**64**	**73**	**3**	**7**	**100**	**2.9**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	5	6	8	10	12	1	4	17	4.4
Gas	1	2	3	4	6	1	3	8	6.9
Electricity	2	4	5	7	10	1	3	13	7.3
Bioenergy	33	37	40	43	45	- 0	- 3	62	1.8
Other renewables	0	0	0	0	0	0	0	0	n.a.
Residential	**29**	**32**	**36**	**38**	**41**	**- 1**	**- 3**	**100**	**1.9**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	1	1	1	1	1	0	0	3	3.2
Gas	-	-	0	0	0	0	0	0	n.a.
Electricity	1	1	2	3	4	0	2	10	8.4
Bioenergy	28	30	33	35	35	- 1	- 5	87	1.5
Other renewables	0	0	0	0	0	0	0	0	n.a.
Transport	**3**	**4**	**5**	**7**	**9**	**1**	**2**	**100**	**4.4**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	3	4	5	7	9	1	2	100	4.4
Gas	-	-	-	-	-	-	-	-	n.a.
Electricity	0	0	0	0	0	-	-	0	0.6
Biofuels	-	-	-	-	-	-	-	-	n.a.
Productive uses	**10**	**12**	**15**	**19**	**24**	**3**	**7**	**100**	**4.6**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	1	1	2	2	3	0	1	12	5.3
Gas	1	2	3	4	6	1	2	24	6.9
Electricity	2	2	3	4	6	1	2	23	6.7
Bioenergy	6	6	7	8	10	1	2	41	2.9
Other renewables	-	-	-	-	-	-	-	-	n.a.

Central Africa: New Policies Scenario

	Electricity generation and trade (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**12**	**19**	**39**	**51**	**67**	**88**	**114**	**100**	**100**	**6.6**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	1	3	3	3	3	3	3	14	3	1.1
Gas	0	2	7	9	11	14	17	11	15	7.8
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	11	14	27	37	50	67	88	75	77	6.7
Bioenergy	0	0	0	1	1	1	1	0	1	10.2
Solar PV	-	-	0	0	0	1	1	-	1	n.a.
Other renewables	-	-	1	2	2	3	4	-	3	n.a.
Net imports	**- 1**	**0**	**- 7**	**- 10**	**- 14**	**- 19**	**- 27**	**n.a.**	**n.a.**	**n.a.**

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**4**	**10**	**15**	**20**	**27**	**36**	**100**	**100**	**7.8**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	1	1	1	2	2	2	27	6	1.9
Gas	1	3	5	7	9	12	13	32	11.3
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	6	8	11	15	20	60	56	7.6
Bioenergy	-	0	0	0	0	0	-	1	n.a.
Solar PV	-	0	0	0	0	0	-	1	n.a.
Other renewables	-	0	1	1	1	2	-	4	n.a.

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**6**	**18**	**24**	**28**	**32**	**37**	**43**	**100**	**100**	**3.2**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	6	14	17	20	22	25	30	78	69	2.7
Gas	0	4	7	9	10	12	13	22	31	4.5
Power generation	**1**	**4**	**5**	**6**	**7**	**8**	**10**	**100**	**100**	**3.6**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	1	2	2	2	3	3	3	63	34	1.3
Gas	0	1	3	3	4	5	6	37	66	5.8
TFC	**5**	**12**	**16**	**18**	**21**	**25**	**30**	**100**	**100**	**3.3**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	5	11	14	16	18	21	25	88	83	3.1
Transport	*3*	*8*	*10*	*11*	*13*	*15*	*18*	*62*	*60*	*3.1*
Gas	0	1	2	3	3	4	5	12	17	4.6

Central Africa: African Century Case

	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**45**	**67**	**100**	**152**	**233**	**33**	**119**	**100**	**9.4**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	2	2	3	3	4	- 0	1	2	1.8
Gas	10	10	11	13	23	- 0	6	10	9.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	31	52	83	131	200	33	111	86	9.9
Bioenergy	0	0	1	1	1	0	0	1	10.9
Solar PV	0	0	1	1	1	0	0	1	n.a.
Other renewables	1	2	2	3	4	0	0	2	n.a.
Net imports	**- 10**	**- 18**	**- 32**	**- 57**	**- 102**	**- 18**	**- 75**	**n.a.**	**n.a.**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**12**	**19**	**30**	**46**	**69**	**9**	**34**	**100**	**10.4**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	1	1	2	2	2	0	0	3	2.4
Gas	3	6	8	12	18	2	7	26	13.1
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	7	11	18	30	46	8	26	66	10.8
Bioenergy	0	0	0	0	0	0	0	0	n.a.
Solar PV	0	0	0	1	1	0	0	1	n.a.
Other renewables	0	1	1	1	2	0	0	3	n.a.

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**26**	**31**	**36**	**45**	**60**	**4**	**17**	**100**	**4.4**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	18	22	26	32	41	4	11	69	3.9
Gas	8	9	10	12	19	0	5	31	5.8
Power generation	**6**	**6**	**7**	**9**	**13**	**0**	**3**	**100**	**4.7**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	2	2	3	3	4	- 0	1	32	2.2
Gas	4	4	4	5	9	0	2	68	7.0
TFC	**17**	**21**	**26**	**34**	**44**	**5**	**14**	**100**	**4.7**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	15	18	22	28	35	4	10	80	4.3
Transport	*10*	*12*	*16*	*20*	*25*	*3*	*7*	*57*	*4.4*
Gas	2	3	4	6	9	1	4	20	6.8

East Africa: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**76**	**112**	**146**	**170**	**192**	**213**	**232**	**100**	**100**	**2.6**
Coal	0	0	2	4	6	9	11	0	5	12.4
Oil	6	13	17	21	25	30	37	12	16	3.8
Gas	0	0	0	1	1	2	3	0	1	36.6
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	2	3	4	5	6	8	1	3	5.7
Bioenergy	68	95	118	130	137	138	131	85	56	1.2
Other renewables	0	1	6	11	18	28	42	1	18	12.9
Power generation	**2**	**5**	**13**	**21**	**32**	**48**	**67**	**100**	**100**	**9.6**
Coal	-	-	1	2	4	6	7	-	11	n.a.
Oil	1	2	2	3	3	4	5	39	8	3.7
Gas	-	-	0	1	1	2	3	-	5	n.a.
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	1	2	3	4	5	6	8	32	11	5.7
Bioenergy	0	0	1	1	2	2	3	2	4	12.9
Other renewables	0	1	6	10	17	28	41	27	61	12.8
Other energy sector	**14**	**22**	**35**	**44**	**52**	**54**	**52**	**100**	**100**	**3.2**
Electricity	*0*	*1*	*1*	*1*	*2*	*3*	*4*	*2*	*7*	*6.9*
TFC	**61**	**88**	**103**	**111**	**119**	**126**	**132**	**100**	**100**	**1.5**
Coal	0	0	1	2	2	3	4	0	3	8.3
Oil	5	11	15	18	22	26	32	12	24	4.1
Gas	0	0	0	0	0	0	0	0	0	5.8
Electricity	1	2	4	6	8	11	15	2	11	7.6
Bioenergy	55	75	83	85	86	85	80	85	61	0.3
Other renewables	-	-	0	0	0	0	1	-	0	n.a.
Residential	**52**	**74**	**84**	**87**	**90**	**91**	**90**	**100**	**100**	**0.7**
Coal	0	0	0	0	0	0	0	0	0	2.3
Oil	1	1	2	3	3	4	5	2	6	4.6
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	0	1	2	2	4	5	8	1	9	8.5
Bioenergy	51	72	80	82	83	81	76	97	85	0.2
Other renewables	-	-	0	0	0	0	1	-	1	n.a.
Transport	**3**	**6**	**8**	**10**	**13**	**16**	**19**	**100**	**100**	**4.3**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	3	6	8	10	13	16	19	100	100	4.3
Gas	-	-	-	-	-	-	-	-	-	n.a.
Electricity	-	-	-	-	-	-	-	-	-	n.a.
Biofuels	-	0	0	0	0	0	0	0	0	5.7
Productive uses	**6**	**8**	**11**	**13**	**16**	**19**	**23**	**100**	**100**	**4.1**
Coal	0	0	1	2	2	3	4	6	17	8.3
Oil	1	3	4	5	6	7	8	41	33	3.3
Gas	0	0	0	0	0	0	0	0	0	5.8
Electricity	1	1	2	3	4	6	8	15	33	6.9
Bioenergy	4	3	3	3	3	4	4	38	17	1.0
Other renewables	-	-	-	-	-	-	-	-	-	n.a.

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	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**144**	**165**	**186**	**208**	**237**	**- 6**	**5**	**100**	**2.7**
Coal	2	4	7	10	13	1	2	6	13.1
Oil	18	23	29	39	52	4	15	22	5.1
Gas	1	1	2	3	6	1	3	2	39.7
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	7	10	13	2	5	5	7.7
Bioenergy	114	121	123	115	103	- 14	- 28	43	0.3
Other renewables	6	11	19	31	50	1	9	21	13.7
Power generation	**13**	**23**	**36**	**55**	**85**	**3**	**17**	**100**	**10.6**
Coal	1	2	4	6	7	0	0	9	n.a.
Oil	2	2	3	4	6	- 0	1	7	4.2
Gas	1	1	2	3	6	1	3	7	n.a.
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	3	4	7	10	13	2	5	15	7.7
Bioenergy	1	1	2	2	3	- 0	0	3	12.9
Other renewables	6	11	19	31	50	1	8	58	13.6
Other energy sector	**34**	**42**	**47**	**48**	**46**	**- 5**	**- 5**	**100**	**2.8**
Electricity	*1*	*2*	*2*	*3*	*5*	*0*	*1*	*10*	*8.1*
TFC	**102**	**109**	**116**	**123**	**133**	**- 3**	**1**	**100**	**1.5**
Coal	1	2	3	4	6	1	2	5	10.0
Oil	16	20	26	35	46	4	14	34	5.4
Gas	0	0	0	0	0	0	0	0	7.3
Electricity	4	6	10	15	22	2	7	16	9.0
Bioenergy	81	80	77	69	59	- 9	- 22	44	-0.9
Other renewables	0	0	0	1	1	0	0	1	n.a.
Residential	**82**	**83**	**82**	**78**	**73**	**- 8**	**- 16**	**100**	**-0.0**
Coal	0	0	0	-	-	- 0	- 0	-	n.a.
Oil	2	3	4	5	7	1	2	9	5.7
Gas	-	-	-	-	-	-	-	-	n.a.
Electricity	2	3	4	7	11	1	3	15	9.9
Bioenergy	78	77	73	65	55	- 9	- 22	75	-1.0
Other renewables	0	0	0	1	1	0	0	1	n.a.
Transport	**9**	**12**	**15**	**21**	**28**	**2**	**9**	**100**	**5.7**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	9	11	15	21	28	2	9	100	5.7
Gas	-	-	-	-	-	-	-	-	n.a.
Electricity	-	-	-	-	-	-	-	-	n.a.
Biofuels	0	0	0	0	0	0	0	0	6.5
Productive uses	**11**	**15**	**18**	**24**	**31**	**2**	**8**	**100**	**5.2**
Coal	1	2	3	4	6	1	2	19	10.0
Oil	5	6	7	9	11	1	3	35	4.6
Gas	0	0	0	0	0	0	0	0	7.3
Electricity	2	4	5	8	11	1	3	34	8.3
Bioenergy	3	3	3	4	4	- 0	- 0	12	0.9
Other renewables	-	-	-	-	-	-	-	-	n.a.

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	Electricity generation and trade (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**11**	**29**	**57**	**89**	**125**	**171**	**229**	**100**	**100**	**7.6**
Coal	-	-	3	9	16	22	29	-	13	n.a.
Oil	4	8	8	10	12	16	22	27	9	3.6
Gas	-	-	3	7	9	14	22	-	10	n.a.
Nuclear	-	-	-	-	-	-	-	-	-	n.a.
Hydro	6	19	32	44	58	73	90	66	39	5.7
Bioenergy	0	0	2	4	6	8	10	1	4	13.0
Solar PV	0	0	0	1	3	4	7	0	3	31.6
Other renewables	0	2	8	13	22	34	50	6	22	12.9
Net imports	**0**	**- 0**	**- 1**	**- 5**	**- 7**	**- 9**	**- 11**	**n.a.**	**n.a.**	**14.5**

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**8**	**16**	**24**	**33**	**43**	**55**	**100**	**100**	**6.9**
Coal	-	1	2	4	5	7	-	12	n.a.
Oil	4	5	5	6	7	7	45	13	2.4
Gas	0	1	2	3	4	6	1	11	17.0
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	4	7	10	13	17	20	52	37	5.7
Bioenergy	-	0	1	1	1	2	-	3	n.a.
Solar PV	-	0	1	2	3	4	-	7	n.a.
Other renewables	0	2	3	4	6	9	3	16	14.4

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**19**	**40**	**59**	**79**	**101**	**128**	**161**	**100**	**100**	**5.1**
Coal	0	2	8	16	25	34	45	4	28	12.5
Oil	19	38	50	61	73	89	109	96	68	3.8
Gas	0	0	1	2	3	5	7	0	5	36.1
Power generation	**4**	**6**	**10**	**19**	**29**	**39**	**53**	**100**	**100**	**8.0**
Coal	-	-	3	9	16	23	30	-	56	n.a.
Oil	4	6	6	8	9	12	16	100	31	3.6
Gas	-	-	1	2	3	5	7	-	14	n.a.
TFC	**14**	**33**	**49**	**60**	**72**	**88**	**108**	**100**	**100**	**4.4**
Coal	0	2	5	7	9	12	15	5	14	8.3
Oil	14	31	44	53	64	77	93	95	86	4.0
Transport	*8*	*18*	*25*	*31*	*38*	*47*	*57*	*54*	*52*	*4.3*
Gas	0	0	0	0	0	0	0	0	0	5.4

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	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**60**	**100**	**150**	**223**	**327**	**25**	**99**	**100**	**9.0**
Coal	3	10	16	23	29	1	1	9	n.a.
Oil	9	10	12	15	25	- 1	3	8	4.1
Gas	4	9	13	23	41	4	19	13	n.a.
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	35	52	77	111	151	19	61	46	7.7
Bioenergy	2	4	6	8	10	- 0	0	3	13.0
Solar PV	1	1	3	6	12	0	5	4	34.4
Other renewables	8	14	23	38	60	2	10	18	13.7
Net imports	**- 1**	**- 6**	**- 8**	**- 12**	**- 18**	**- 2**	**- 7**	**n.a.**	**0.0**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**17**	**27**	**39**	**58**	**83**	**7**	**27**	**100**	**8.5**
Coal	1	2	4	5	7	0	0	8	n.a.
Oil	5	5	6	7	9	0	1	10	3.0
Gas	1	3	5	8	12	2	6	14	19.7
Nuclear	-	-	-	-	-	-	-	-	n.a.
Hydro	8	12	17	25	35	4	14	42	7.7
Bioenergy	0	1	1	1	2	- 0	0	2	n.a.
Solar PV	0	1	2	4	8	0	4	10	n.a.
Other renewables	2	3	4	7	11	0	2	13	15.1

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**62**	**87**	**117**	**159**	**218**	**16**	**57**	**100**	**6.2**
Coal	9	18	28	39	54	3	9	25	13.2
Oil	52	66	85	113	151	12	42	69	5.0
Gas	1	3	5	8	14	1	6	6	39.2
Power generation	**11**	**20**	**30**	**43**	**63**	**1**	**10**	**100**	**8.7**
Coal	3	10	17	23	30	1	1	48	n.a.
Oil	6	7	9	12	19	- 0	3	30	4.1
Gas	1	3	5	8	14	1	6	22	n.a.
TFC	**52**	**67**	**87**	**117**	**156**	**15**	**48**	**100**	**5.7**
Coal	5	8	11	16	24	2	8	15	10.0
Oil	46	59	76	101	132	13	40	85	5.3
Transport	*26*	*34*	*45*	*61*	*83*	*7*	*26*	*53*	*5.7*
Gas	0	0	0	0	0	0	0	0	6.9

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	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**168**	**223**	**258**	**285**	**311**	**340**	**371**	**100**	**100**	**1.8**
Coal	86	101	107	113	116	120	127	45	34	0.8
Oil	17	34	42	45	48	52	56	15	15	1.8
Gas	2	6	8	14	18	24	31	2	8	6.3
Nuclear	3	3	3	3	6	10	12	2	3	4.7
Hydro	2	4	6	7	8	10	11	2	3	3.8
Bioenergy	57	76	90	99	108	115	121	34	33	1.7
Other renewables	0	0	2	4	6	9	11	0	3	18.6
Power generation	**57**	**73**	**84**	**92**	**103**	**117**	**134**	**100**	**100**	**2.2**
Coal	50	62	66	68	67	69	74	85	55	0.6
Oil	1	2	3	3	3	4	5	3	3	2.5
Gas	0	1	2	4	7	10	15	1	11	11.5
Nuclear	3	3	3	3	6	10	12	5	9	4.7
Hydro	2	4	6	7	8	10	11	5	8	3.8
Bioenergy	0	1	2	3	5	6	8	1	6	8.8
Other renewables	-	0	2	4	6	8	10	0	7	25.8
Other energy sector	**27**	**38**	**43**	**49**	**54**	**58**	**62**	**100**	**100**	**1.7**
Electricity	*4*	*6*	*6*	*7*	*8*	*9*	*11*	*15*	*17*	*2.3*
TFC	**106**	**139**	**165**	**183**	**200**	**219**	**238**	**100**	**100**	**1.9**
Coal	18	19	20	21	21	22	22	13	9	0.7
Oil	23	36	42	47	51	55	60	26	25	1.8
Gas	0	3	3	4	5	6	8	2	3	4.2
Electricity	18	22	28	33	38	45	53	16	22	3.2
Bioenergy	47	60	72	78	84	89	93	43	39	1.6
Other renewables	0	0	0	0	1	1	1	0	1	10.9
Residential	**46**	**62**	**73**	**80**	**86**	**93**	**99**	**100**	**100**	**1.7**
Coal	1	3	3	3	3	2	2	6	2	-1.8
Oil	2	2	2	3	3	3	4	3	4	2.4
Gas	-	0	0	0	0	0	1	0	1	36.8
Electricity	3	5	7	9	12	15	19	8	19	4.9
Bioenergy	39	51	60	65	69	72	73	83	74	1.3
Other renewables	0	0	0	0	0	0	0	0	0	33.5
Transport	**17**	**24**	**29**	**34**	**37**	**40**	**43**	**100**	**100**	**2.2**
Coal	0	0	0	0	0	0	0	0	0	-0.4
Oil	16	23	28	33	36	38	41	99	96	2.1
Gas	-	0	0	0	0	0	0	0	0	7.2
Electricity	0	0	0	0	0	1	1	1	1	2.1
Biofuels	-	0	1	1	1	1	1	0	3	39.8
Productive uses	**44**	**54**	**63**	**70**	**77**	**86**	**96**	**100**	**100**	**2.1**
Coal	17	15	17	18	18	19	20	28	21	1.0
Oil	5	11	11	12	13	14	15	20	15	1.0
Gas	0	3	3	4	5	6	7	5	8	3.9
Electricity	14	17	20	23	26	30	34	31	35	2.6
Bioenergy	7	9	11	13	15	17	19	16	19	2.7
Other renewables	0	0	0	0	1	1	1	0	1	9.9

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	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**258**	**288**	**318**	**355**	**402**	**7**	**31**	**100**	**2.1**
Coal	105	114	120	128	141	4	14	35	1.2
Oil	44	49	53	59	65	5	9	16	2.4
Gas	8	14	19	27	41	1	10	10	7.4
Nuclear	3	3	6	10	14	-	2	4	5.2
Hydro	6	7	9	11	13	1	2	3	4.4
Bioenergy	89	97	103	109	115	- 4	- 6	29	1.5
Other renewables	2	4	7	9	12	0	1	3	18.9
Power generation	**85**	**96**	**110**	**130**	**155**	**7**	**20**	**100**	**2.7**
Coal	67	70	72	77	84	5	10	54	1.1
Oil	3	3	4	4	5	0	1	3	3.0
Gas	2	5	8	13	20	1	5	13	12.7
Nuclear	3	3	6	10	14	-	2	9	5.2
Hydro	6	7	9	11	13	1	2	9	4.4
Bioenergy	2	3	5	6	8	0	0	5	8.8
Other renewables	2	4	6	8	11	0	1	7	26.1
Other energy sector	**42**	**49**	**54**	**61**	**69**	**0**	**7**	**100**	**2.1**
Electricity	*7*	*8*	*9*	*10*	*13*	*1*	*2*	*18*	*2.9*
TFC	**166**	**185**	**204**	**227**	**254**	**4**	**17**	**100**	**2.2**
Coal	20	21	23	24	26	2	4	10	1.2
Oil	42	49	54	61	68	3	9	27	2.3
Gas	4	5	6	8	11	1	3	4	5.4
Electricity	29	35	42	52	64	4	11	25	3.9
Bioenergy	71	76	79	81	83	- 5	- 10	33	1.2
Other renewables	0	0	1	1	2	0	0	1	11.2
Residential	**72**	**77**	**83**	**87**	**93**	**- 4**	**- 6**	**100**	**1.5**
Coal	3	3	3	2	2	- 0	- 0	2	-1.8
Oil	2	3	3	3	4	0	0	4	2.4
Gas	0	0	0	1	1	0	0	1	37.7
Electricity	8	10	14	18	24	2	5	25	5.8
Bioenergy	59	61	63	62	62	- 6	- 11	67	0.7
Other renewables	0	0	0	0	0	0	0	0	n.a.
Transport	**30**	**35**	**39**	**44**	**49**	**2**	**6**	**100**	**2.7**
Coal	0	0	0	0	0	0	0	0	-0.2
Oil	29	34	38	42	47	2	6	96	2.6
Gas	0	0	0	0	0	0	0	0	7.7
Electricity	0	0	0	1	1	0	0	1	2.3
Biofuels	1	1	1	1	1	0	0	3	40.2
Productive uses	**64**	**73**	**83**	**96**	**112**	**6**	**16**	**100**	**2.7**
Coal	17	19	20	22	24	2	4	22	1.7
Oil	11	12	13	15	17	1	2	15	1.8
Gas	4	4	6	7	10	1	3	9	5.1
Electricity	21	24	28	33	40	2	6	35	3.2
Bioenergy	11	13	15	18	20	0	1	18	2.9
Other renewables	0	0	1	1	1	0	0	1	10.1

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	Electricity generation and trade (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**246**	**317**	**398**	**458**	**529**	**619**	**724**	**100**	**100**	**3.0**
Coal	200	246	275	286	289	304	329	78	45	1.0
Oil	4	7	9	11	13	15	18	2	2	3.2
Gas	0	3	13	27	43	66	97	1	13	13.3
Nuclear	13	13	13	13	25	37	47	4	7	4.7
Hydro	29	46	67	82	98	114	130	14	18	3.8
Bioenergy	1	1	6	11	17	22	27	0	4	11.5
Solar PV	-	0	6	13	20	27	34	0	5	25.1
Other renewables	-	0	8	16	25	34	42	0	6	23.1
Net imports	**12**	**0**	**1**	**5**	**8**	**12**	**16**	**n.a.**	**n.a.**	**13.4**

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**59**	**88**	**108**	**131**	**155**	**181**	**100**	**100**	**4.1**
Coal	40	51	56	59	63	69	68	38	1.9
Oil	6	7	8	9	10	11	11	6	1.9
Gas	1	5	9	14	20	26	2	14	11.1
Nuclear	2	2	2	4	5	7	3	4	4.5
Hydro	9	14	18	21	25	29	15	16	4.3
Bioenergy	0	1	2	4	5	6	0	3	13.0
Solar PV	0	4	7	12	16	19	0	11	24.6
Other renewables	0	3	6	9	12	15	0	8	29.7

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**337**	**432**	**485**	**518**	**533**	**562**	**600**	**100**	**100**	**1.2**
Coal	262	312	336	342	333	336	344	72	57	0.4
Oil	73	112	134	150	162	176	190	26	32	1.9
Gas	1	8	14	26	37	50	66	2	11	8.0
Power generation	**197**	**249**	**271**	**280**	**277**	**287**	**305**	**100**	**100**	**0.7**
Coal	194	240	256	260	250	250	256	96	84	0.2
Oil	3	7	9	10	11	13	15	3	5	2.7
Gas	0	2	6	10	16	24	34	1	11	11.6
TFC	**137**	**179**	**209**	**228**	**243**	**259**	**278**	**100**	**100**	**1.6**
Coal	68	72	80	82	84	86	88	40	32	0.7
Oil	67	101	121	136	148	159	171	57	62	1.9
Transport	*48*	*69*	*84*	*96*	*105*	*114*	*122*	*38*	*44*	*2.1*
Gas	1	6	8	10	12	15	18	3	7	4.1

Southern Africa: African Century Case

	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**404**	**479**	**570**	**691**	**841**	**40**	**117**	**100**	**3.5**
Coal	278	299	311	336	371	22	42	44	1.5
Oil	10	11	13	16	20	0	2	2	3.6
Gas	13	30	48	81	130	5	33	15	14.5
Nuclear	13	13	25	40	54	-	7	6	5.2
Hydro	70	86	108	131	155	10	26	18	4.4
Bioenergy	6	11	17	22	27	0	0	3	11.6
Solar PV	6	13	22	30	40	2	7	5	25.9
Other renewables	8	16	25	35	44	1	2	5	23.3
Net imports	**6**	**12**	**21**	**33**	**49**	**13**	**33**	**n.a.**	**18.0**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**89**	**113**	**140**	**172**	**207**	**10**	**26**	**100**	**4.6**
Coal	52	58	63	69	76	4	8	37	2.3
Oil	7	8	9	10	11	0	1	5	2.1
Gas	5	10	16	23	32	2	6	16	12.0
Nuclear	2	2	4	6	7	-	1	4	4.9
Hydro	14	19	24	29	35	2	6	17	5.0
Bioenergy	1	2	4	5	6	0	0	3	13.1
Solar PV	4	8	13	18	23	1	4	11	25.4
Other renewables	3	6	9	12	16	0	1	7	30.0

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**491**	**539**	**566**	**616**	**691**	**33**	**92**	**100**	**1.7**
Coal	341	357	355	366	386	21	42	56	0.8
Oil	135	154	171	191	216	8	26	31	2.4
Gas	15	28	40	59	90	3	24	13	9.2
Power generation	**274**	**293**	**295**	**313**	**345**	**18**	**40**	**100**	**1.2**
Coal	259	272	265	271	282	15	27	82	0.6
Oil	9	10	11	14	17	0	2	5	3.2
Gas	6	11	18	29	46	2	11	13	12.7
TFC	**213**	**237**	**260**	**287**	**324**	**17**	**46**	**100**	**2.1**
Coal	82	85	90	95	104	6	15	32	1.3
Oil	123	141	156	174	195	9	24	60	2.4
Transport	*85*	*100*	*111*	*125*	*140*	*6*	*18*	*43*	*2.6*
Gas	9	11	14	18	25	2	7	8	5.2

South Africa: New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
TPED	**108**	**141**	**153**	**161**	**169**	**178**	**186**	**100**	**100**	**1.0**
Coal	82	97	100	102	102	102	101	69	55	0.2
Oil	9	21	25	26	26	27	27	15	14	0.9
Gas	1	4	5	6	7	8	9	3	5	3.1
Nuclear	3	3	3	3	6	10	12	2	7	4.7
Hydro	0	0	0	0	0	0	0	0	0	2.8
Bioenergy	13	15	18	20	22	24	26	11	14	1.9
Other renewables	-	0	2	3	5	8	10	0	5	18.2
Power generation	**51**	**64**	**68**	**71**	**74**	**79**	**83**	**100**	**100**	**1.0**
Coal	48	60	62	61	57	55	53	94	64	-0.4
Oil	-	0	0	0	0	0	0	0	0	-0.3
Gas	-	-	1	1	2	3	4	-	4	n.a.
Nuclear	3	3	3	3	6	10	12	5	15	4.7
Hydro	0	0	0	0	0	0	0	0	0	2.8
Bioenergy	0	0	1	2	3	4	5	0	6	15.0
Other renewables	-	0	1	3	5	7	8	0	10	26.0
Other energy sector	**19**	**26**	**29**	**31**	**34**	**35**	**37**	**100**	**100**	**1.2**
Electricity	*4*	*5*	*5*	*5*	*5*	*6*	*6*	*17*	*16*	*0.9*
TFC	**56**	**72**	**81**	**87**	**92**	**97**	**102**	**100**	**100**	**1.2**
Coal	16	17	17	17	17	17	17	23	17	0.0
Oil	16	25	28	31	33	34	35	35	34	1.1
Gas	-	2	2	2	3	3	3	2	3	2.3
Electricity	15	17	20	22	25	27	30	23	30	2.1
Bioenergy	9	11	13	13	14	14	15	15	15	1.2
Other renewables	-	0	0	0	1	1	1	0	1	10.4
Residential	**12**	**17**	**18**	**19**	**21**	**23**	**25**	**100**	**100**	**1.4**
Coal	1	3	3	3	3	2	2	21	8	-1.8
Oil	1	1	1	1	1	1	1	4	2	-0.9
Gas	-	-	0	0	0	0	0	-	1	n.a.
Electricity	2	3	5	6	7	8	10	20	41	4.1
Bioenergy	8	9	10	10	11	11	11	55	46	0.8
Other renewables	-	-	0	0	0	0	0	-	1	n.a.
Transport	**12**	**17**	**20**	**23**	**25**	**26**	**28**	**100**	**100**	**1.8**
Coal	-	-	-	-	-	-	-	-	-	n.a.
Oil	12	16	19	22	24	25	26	98	94	1.7
Gas	-	0	0	0	0	0	0	0	0	15.0
Electricity	0	0	0	0	0	1	1	2	2	2.1
Biofuels	-	-	1	1	1	1	1	-	4	n.a.
Productive uses	**32**	**39**	**42**	**44**	**46**	**48**	**50**	**100**	**100**	**0.9**
Coal	15	14	14	15	15	15	15	35	30	0.3
Oil	3	8	8	8	8	8	8	22	17	-0.0
Gas	-	2	2	2	2	3	3	4	6	2.0
Electricity	12	13	15	16	17	18	20	34	40	1.4
Bioenergy	2	2	2	2	2	2	3	5	5	1.1
Other renewables	-	0	0	0	0	1	1	0	2	9.9

South Africa: African Century Case

	Energy demand (Mtoe)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
TPED	**152**	**163**	**172**	**182**	**191**	**3**	**5**	**100**	**1.1**
Coal	98	102	103	103	103	1	2	54	0.2
Oil	27	28	29	30	30	3	3	15	1.2
Gas	5	5	7	8	9	- 0	0	5	3.1
Nuclear	3	3	6	10	14	-	2	7	5.2
Hydro	0	0	0	0	0	0	0	0	3.2
Bioenergy	18	20	21	23	24	- 1	- 2	13	1.7
Other renewables	2	3	6	8	10	0	0	5	18.3
Power generation	**69**	**72**	**77**	**83**	**87**	**3**	**4**	**100**	**1.1**
Coal	62	62	60	57	55	3	1	63	-0.3
Oil	0	0	0	0	0	0	0	0	-0.2
Gas	1	1	2	3	4	0	0	5	n.a.
Nuclear	3	3	6	10	14	-	2	16	5.2
Hydro	0	0	0	0	0	0	0	0	3.2
Bioenergy	1	2	3	4	5	-	-	6	15.0
Other renewables	1	3	5	7	9	0	0	10	26.2
Other energy sector	**28**	**31**	**33**	**34**	**37**	**- 1**	**0**	**100**	**1.1**
Electricity	*5*	*5*	*6*	*6*	*6*	*0*	*1*	*17*	*1.2*
TFC	**81**	**88**	**94**	**101**	**107**	**3**	**5**	**100**	**1.5**
Coal	18	18	18	18	18	1	1	17	0.2
Oil	28	31	33	35	37	1	2	34	1.4
Gas	2	2	3	3	3	0	0	3	2.6
Electricity	21	23	26	30	34	2	4	32	2.5
Bioenergy	13	13	13	14	14	- 0	- 1	13	0.9
Other renewables	0	0	1	1	1	0	0	1	10.6
Residential	**18**	**20**	**21**	**23**	**25**	**0**	**1**	**100**	**1.5**
Coal	3	3	3	2	2	- 0	- 0	8	-1.8
Oil	1	1	1	1	1	0	0	2	-0.6
Gas	0	0	0	0	0	0	0	1	n.a.
Electricity	5	6	8	10	12	1	2	48	4.8
Bioenergy	10	10	10	10	10	- 1	- 1	39	0.3
Other renewables	0	0	0	0	0	0	0	1	n.a.
Transport	**21**	**24**	**26**	**28**	**30**	**1**	**2**	**100**	**2.1**
Coal	-	-	-	-	-	-	-	-	n.a.
Oil	19	23	24	26	28	1	2	94	1.9
Gas	0	0	0	0	0	-	0	0	15.0
Electricity	0	0	0	1	1	0	0	2	2.3
Biofuels	1	1	1	1	1	0	0	4	n.a.
Productive uses	**42**	**45**	**47**	**50**	**52**	**1**	**3**	**100**	**1.1**
Coal	15	15	15	16	16	1	1	30	0.6
Oil	8	8	8	8	8	- 0	- 0	16	0.2
Gas	2	2	3	3	3	0	0	6	2.2
Electricity	15	17	18	19	21	1	1	40	1.6
Bioenergy	2	2	2	3	3	0	0	5	1.3
Other renewables	0	0	1	1	1	0	0	2	10.1

South Africa: New Policies Scenario

	Electricity generation and trade (TWh)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total generation	**208**	**255**	**293**	**315**	**339**	**370**	**401**	**100**	**100**	**1.6**
Coal	193	239	257	257	247	244	243	94	61	0.1
Oil	-	0	0	0	0	0	0	0	0	-0.1
Gas	-	-	4	8	12	17	22	-	6	n.a.
Nuclear	13	13	13	13	25	37	47	5	12	4.7
Hydro	1	2	4	4	4	4	4	1	1	2.8
Bioenergy	0	0	4	8	12	15	19	0	5	16.0
Solar PV	-	0	5	11	17	22	27	0	7	25.2
Other renewables	-	0	7	14	22	30	38	0	9	23.5
Net imports	**12**	**- 5**	**- 2**	**4**	**8**	**13**	**20**	**n.a.**	**n.a.**	**n.a.**

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total capacity	**46**	**65**	**75**	**87**	**98**	**108**	**100**	**100**	**3.1**
Coal	38	47	49	50	51	53	83	49	1.1
Oil	3	3	3	3	3	3	6	2	-0.4
Gas	0	3	4	6	8	10	1	9	12.0
Nuclear	2	2	2	4	5	7	4	6	4.5
Hydro	2	3	4	4	4	4	5	3	1.8
Bioenergy	0	1	2	3	4	5	0	4	12.0
Solar PV	0	3	6	10	13	15	0	14	23.5
Other renewables	0	3	5	8	10	13	0	12	29.2

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2012	2020	2025	2030	2035	2040	2012	2040	2012-40
Total CO_2	**297**	**376**	**400**	**404**	**387**	**376**	**363**	**100**	**100**	**-0.1**
Coal	248	298	309	303	280	262	243	79	67	-0.7
Oil	50	74	84	93	97	101	104	20	29	1.2
Gas	-	4	6	8	11	14	16	1	4	5.2
Power generation	**186**	**233**	**241**	**235**	**215**	**200**	**185**	**100**	**100**	**-0.8**
Coal	186	233	239	232	210	193	176	100	95	-1.0
Oil	-	0	0	0	0	0	0	0	0	-0.3
Gas	-	-	1	3	5	7	9	-	5	n.a.
TFC	**109**	**140**	**155**	**165**	**169**	**173**	**176**	**100**	**100**	**0.8**
Coal	62	66	70	70	70	69	68	47	38	0.1
Oil	47	70	80	89	94	97	101	50	57	1.3
Transport	*35*	*48*	*56*	*65*	*70*	*74*	*77*	*35*	*44*	*1.7*
Gas	-	4	5	6	6	7	8	3	4	2.3

South Africa: African Century Case

	Electricity generation and trade (TWh)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total generation	**296**	**323**	**353**	**387**	**417**	**14**	**16**	**100**	**1.8**
Coal	259	265	258	254	247	11	3	59	0.1
Oil	0	0	0	0	0	0	0	0	0.1
Gas	4	8	13	18	24	1	1	6	n.a.
Nuclear	13	13	25	40	54	-	7	13	5.2
Hydro	3	4	4	4	5	0	0	1	3.2
Bioenergy	4	8	12	15	19	-	-	4	16.0
Solar PV	5	12	18	25	31	1	4	7	25.8
Other renewables	7	14	22	31	38	0	0	9	23.5
Net imports	**2**	**10**	**17**	**30**	**52**	**9**	**32**	**n.a.**	**n.a.**

	Electrical capacity (GW)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total capacity	**65**	**77**	**90**	**102**	**113**	**3**	**5**	**100**	**3.2**
Coal	47	51	52	53	54	2	1	48	1.2
Oil	3	3	3	3	3	0	0	2	-0.4
Gas	3	5	6	8	10	0	0	9	12.1
Nuclear	2	2	4	6	7	-	1	7	4.9
Hydro	3	4	4	4	4	- 0	0	3	1.9
Bioenergy	1	2	3	4	5	-	-	4	12.0
Solar PV	3	7	10	14	17	1	2	15	24.1
Other renewables	3	5	8	11	13	0	0	12	29.2

	CO_2 emissions (Mt)					Difference (ACC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2012-40
Total CO_2	**402**	**413**	**397**	**384**	**364**	**9**	**1**	**100**	**-0.1**
Coal	312	311	286	265	238	7	- 6	65	-0.8
Oil	83	93	99	104	109	2	5	30	1.4
Gas	7	9	12	15	18	1	1	5	5.4
Power generation	**243**	**242**	**220**	**201**	**176**	**5**	**- 9**	**100**	**-1.0**
Coal	241	239	214	193	166	4	- 10	95	-1.2
Oil	0	0	0	0	0	0	0	0	-0.2
Gas	1	3	5	8	9	1	1	5	n.a.
TFC	**156**	**167**	**174**	**180**	**185**	**5**	**10**	**100**	**1.0**
Coal	71	71	72	72	71	2	4	38	0.3
Oil	80	90	96	101	106	2	5	57	1.5
Transport	*57*	*67*	*72*	*77*	*82*	*3*	*5*	*44*	*1.9*
Gas	5	6	6	7	8	0	0	4	2.6

New Policies Scenario

	Energy access						Share of population (%)	
	2012	2020	2025	2030	2035	2040	2012	2040
Population without access to electricity (million)								
Africa	**622**	**657**	**662**	**635**	**601**	**530**	**57**	**27**
Sub-Saharan Africa	621	657	662	635	601	530	68	30
West Africa	198	200	197	181	163	130	61	20
Nigeria	93	92	90	84	75	58	55	17
Central Africa	90	100	107	112	116	118	81	54
East Africa	202	218	219	206	196	173	79	35
Southern Africa	131	139	140	135	126	109	59	27
South Africa	8	4	3	2	0	-	15	-
Population without access to clean cooking facilities (million)								
Africa	**728**	**788**	**785**	**763**	**717**	**653**	**67**	**33**
Sub-Saharan Africa	727	788	785	763	717	653	80	37
West Africa	248	273	274	270	259	249	77	38
Nigeria	115	116	108	96	78	65	68	19
Central Africa	97	114	122	128	133	136	88	63
East Africa	230	236	222	199	164	113	89	23
Southern Africa	145	165	167	167	162	155	65	38
South Africa	7	7	6	6	6	6	13	10

	Average annual investments for energy access					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Total investments (billion, year-2013 US dollars)							
Africa	**2.6**	**5.4**	**8.2**	**11.1**	**14.5**	**86.0**	**128.2**
Sub-Saharan Africa	2.6	5.4	8.1	11.0	14.5	85.4	127.7
West Africa	0.9	1.9	2.9	4.2	5.2	30.3	47.4
Nigeria	0.5	1.1	1.8	2.7	3.2	18.4	29.3
Central Africa	0.2	0.4	0.5	0.8	1.1	6.2	9.2
East Africa	0.6	1.3	2.0	2.7	3.8	20.6	32.3
Southern Africa	0.8	1.8	2.7	3.3	4.4	28.2	38.9
South Africa	0.2	0.5	0.8	0.8	0.9	8.2	8.3
of which: Investments for access to electricity *(billion, year-2013 US dollars)*							
Africa	**2.4**	**5.1**	**7.8**	**10.6**	**14.0**	**81.6**	**123.0**
Sub-Saharan Africa	2.4	5.1	7.8	10.6	13.9	81.0	122.6
West Africa	0.9	1.8	2.8	4.1	5.1	29.0	45.8
Nigeria	0.5	1.1	1.7	2.6	3.1	17.5	28.3
Central Africa	0.2	0.4	0.5	0.7	1.0	5.9	8.9
East Africa	0.5	1.2	1.8	2.5	3.5	18.5	29.8
Southern Africa	0.8	1.8	2.6	3.3	4.3	27.5	38.0
South Africa	0.2	0.5	0.8	0.8	0.9	8.2	8.3
of which: Investments for access to clean cooking facilities *(million, year-2013 US dollars)*							
Africa	**169**	**276**	**364**	**466**	**567**	**4 381**	**5 168**
Sub-Saharan Africa	169	276	364	466	567	4 381	5 168
West Africa	49	84	112	144	164	1 320	1 538
Nigeria	34	58	76	96	102	911	990
Central Africa	11	18	25	32	42	292	372
East Africa	84	130	168	214	271	2 078	2 426
Southern Africa	25	44	59	76	90	690	832
South Africa	0	0	0	1	1	4	6

African Century Case

	Energy access					Difference (ACC minus NPS)		Share of population (%)
	2020	2025	2030	2035	2040	2030	2040	2040
Population without access to electricity (million)								
Africa	**652**	**644**	**595**	**488**	**303**	**- 40**	**-228**	**15**
Sub-Saharan Africa	652	644	595	488	303	- 40	-227	17
West Africa	199	192	171	130	64	- 11	-66	10
Nigeria	91	86	75	55	24	- 9	-34	7
Central Africa	98	100	95	82	56	- 17	-62	26
East Africa	218	218	205	174	118	- 1	-55	24
Southern Africa	136	134	124	102	64	- 11	-45	16
South Africa	3	2	1	-	-	- 1	-	-
Population without access to clean cooking facilities (million)								
Africa	**758**	**724**	**672**	**599**	**504**	**- 91**	**-148**	**25**
Sub-Saharan Africa	758	724	672	599	504	- 91	-148	28
West Africa	258	240	224	215	197	- 45	-53	30
Nigeria	107	84	68	63	56	- 28	-9	16
Central Africa	113	118	121	119	114	- 7	-22	53
East Africa	231	212	181	130	69	- 18	-44	14
Southern Africa	155	153	145	135	125	- 21	-30	31
South Africa	5	4	4	4	4	- 2	-2	6

	Average annual investments for energy access					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Total investments (billion, year-2013 US dollars)							
Africa	**3.0**	**7.0**	**11.3**	**18.3**	**29.8**	**112.6**	**240.3**
Sub-Saharan Africa	3.0	6.9	11.3	18.2	29.8	112.0	239.9
West Africa	1.0	2.3	3.8	6.1	9.5	38.0	77.6
Nigeria	0.6	1.4	2.4	3.5	4.9	23.2	42.1
Central Africa	0.4	0.8	1.5	2.7	4.8	14.1	37.7
East Africa	0.7	1.6	2.6	4.7	8.1	25.9	63.7
Southern Africa	0.9	2.2	3.3	4.8	7.4	33.9	60.8
South Africa	0.2	0.5	0.8	0.8	0.9	8.2	8.2
of which: Investments for access to electricity *(billion, year-2013 US dollars)*							
Africa	**2.8**	**6.5**	**10.8**	**17.6**	**29.0**	**106.0**	**233.0**
Sub-Saharan Africa	2.7	6.5	10.8	17.6	29.0	105.3	232.6
West Africa	0.9	2.2	3.7	5.9	9.3	35.8	75.7
Nigeria	0.5	1.3	2.3	3.4	4.8	21.6	41.0
Central Africa	0.4	0.8	1.5	2.7	4.8	13.7	37.1
East Africa	0.6	1.4	2.4	4.4	7.7	23.1	60.2
Southern Africa	0.9	2.1	3.2	4.7	7.2	32.8	59.5
South Africa	0.2	0.5	0.8	0.8	0.9	8.2	8.2
of which: Investments for access to clean cooking facilities *(million, year-2013 US dollars)*							
Africa	**253**	**427**	**549**	**669**	**798**	**6 653**	**7 337**
Sub-Saharan Africa	253	427	549	669	798	6 653	7 337
West Africa	81	152	179	180	211	2 222	1 954
Nigeria	59	111	123	101	102	1 582	1 019
Central Africa	16	25	36	52	68	417	602
East Africa	111	178	236	314	382	2 847	3 483
Southern Africa	44	73	98	123	137	1 167	1 299
South Africa	2	3	3	3	3	46	28

New Policies Scenario

	Average annual investments in the power sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Total investments							
Africa	**40.7**	**48.4**	**60.1**	**73.0**	**86.3**	**827.5**	**796.7**
Sub-Saharan Africa	**28.7**	**36.2**	**46.6**	**56.9**	**70.1**	**614.9**	**634.8**
West Africa	7.7	10.7	14.7	19.5	22.7	181.0	210.8
Nigeria	5.1	7.5	10.4	13.9	15.4	125.2	146.1
Central Africa	2.8	2.8	3.5	4.6	5.8	51.1	52.1
East Africa	4.2	6.5	7.8	9.7	12.2	100.6	109.3
Southern Africa	14.0	16.3	20.6	23.1	29.4	282.2	262.5
South Africa	8.0	8.2	11.1	11.5	15.1	152.4	133.0
Investments in power plants							
Africa	**18.8**	**22.6**	**29.6**	**35.1**	**41.6**	**392.4**	**383.4**
Sub-Saharan Africa	**14.2**	**17.5**	**23.2**	**27.3**	**33.7**	**303.1**	**305.0**
West Africa	3.3	4.6	6.3	8.4	8.7	77.2	85.4
Nigeria	2.1	3.2	4.4	5.9	5.4	52.9	56.5
Central Africa	1.2	1.3	1.7	2.2	2.8	23.0	25.0
East Africa	1.8	2.7	3.6	4.6	5.9	44.6	52.3
Southern Africa	8.0	8.9	11.6	12.2	16.3	158.3	142.4
South Africa	5.5	5.6	7.6	7.4	10.4	104.2	88.7
of which: Investments in hydropower plants							
Africa	**5.1**	**5.8**	**7.2**	**8.7**	**8.7**	**100.3**	**87.2**
Sub-Saharan Africa	**4.4**	**5.1**	**6.7**	**8.4**	**8.5**	**90.3**	**84.7**
West Africa	1.2	1.4	2.1	3.0	2.3	26.2	26.3
Nigeria	0.8	1.0	1.5	2.1	1.2	18.3	16.5
Central Africa	0.8	0.9	1.3	1.7	2.3	16.5	19.7
East Africa	0.7	1.1	1.4	1.7	2.0	17.9	18.6
Southern Africa	1.6	1.7	1.9	2.0	2.0	29.7	20.1
South Africa	0.3	0.1	0.0	0.0	0.0	3.2	0.0
of which: Investments in fossil-fuelled plants							
Africa	**7.8**	**7.7**	**9.0**	**10.3**	**12.7**	**138.2**	**115.0**
Sub-Saharan Africa	**5.2**	**5.6**	**6.6**	**7.7**	**10.5**	**97.0**	**91.0**
West Africa	0.9	1.4	1.5	2.1	2.5	20.6	23.1
Nigeria	0.6	1.0	1.1	1.6	1.9	15.0	17.4
Central Africa	0.2	0.2	0.2	0.3	0.3	3.6	2.9
East Africa	0.3	0.6	0.6	0.7	0.8	8.0	7.4
Southern Africa	3.8	3.4	4.3	4.6	6.9	64.7	57.6
South Africa	3.1	2.4	3.0	3.0	4.7	48.6	38.4
Investments in transmission and distribution lines							
Africa	**21.9**	**25.8**	**30.5**	**37.9**	**44.7**	**435.1**	**413.3**
Sub-Saharan Africa	**14.4**	**18.8**	**23.4**	**29.6**	**36.4**	**311.8**	**329.7**
West Africa	4.4	6.1	8.4	11.1	14.0	103.8	125.5
Nigeria	3.0	4.3	6.0	8.0	9.9	72.3	89.6
Central Africa	1.6	1.5	1.9	2.4	3.0	28.1	27.1
East Africa	2.4	3.8	4.1	5.1	6.3	56.0	57.0
Southern Africa	6.0	7.4	8.9	10.9	13.1	123.9	120.2
South Africa	2.5	2.7	3.4	4.1	4.7	48.2	44.3

African Century Case

	Average annual investments in the power sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Total investments							
Africa	44.0	56.9	74.4	97.8	126.1	964.6	1 119.7
Sub-Saharan Africa	**32.0**	**44.8**	**60.8**	**81.7**	**109.9**	**752.1**	**957.8**
West Africa	9.0	13.4	18.8	25.3	30.9	224.3	281.1
Nigeria	5.9	9.3	13.0	17.0	18.5	153.1	177.5
Central Africa	3.6	4.8	7.3	11.6	18.4	85.5	150.1
East Africa	4.7	7.9	10.6	15.6	22.4	125.7	190.1
Southern Africa	14.7	18.6	24.2	29.1	38.2	316.6	336.5
South Africa	8.1	9.0	12.1	12.6	15.4	162.1	139.9
Investments in power plants							
Africa	20.0	26.0	35.9	46.5	62.2	449.5	543.5
Sub-Saharan Africa	**15.5**	**20.8**	**29.5**	**38.7**	**54.3**	**360.2**	**465.1**
West Africa	3.8	5.3	7.7	10.3	13.0	91.3	116.4
Nigeria	2.4	3.7	5.4	6.8	6.9	62.1	68.3
Central Africa	1.5	2.2	3.5	5.7	9.3	38.9	74.9
East Africa	2.0	3.4	4.9	7.7	11.8	55.7	97.3
Southern Africa	8.2	9.9	13.4	15.0	20.2	174.4	176.4
South Africa	5.5	6.0	8.4	8.3	10.7	110.3	94.8
of which: Investments in hydropower plants							
Africa	5.6	7.5	10.9	14.7	19.0	131.1	168.9
Sub-Saharan Africa	**5.0**	**6.9**	**10.4**	**14.4**	**18.9**	**121.0**	**166.4**
West Africa	1.3	1.6	2.6	3.1	2.8	29.9	29.6
Nigeria	0.9	1.1	1.9	2.0	0.9	21.2	14.6
Central Africa	1.0	1.8	2.9	4.9	8.0	30.9	64.2
East Africa	0.9	1.6	2.4	3.7	5.0	26.3	43.3
Southern Africa	1.7	1.9	2.4	2.8	3.1	34.0	29.3
South Africa	0.3	0.2	0.1	0.0	0.0	3.2	0.2
of which: Investments in fossil-fuelled plants							
Africa	8.3	8.8	10.7	12.4	15.7	155.5	140.4
Sub-Saharan Africa	**5.6**	**6.7**	**8.3**	**9.8**	**13.5**	**114.2**	**116.4**
West Africa	1.1	1.8	2.0	2.9	3.3	26.8	30.9
Nigeria	0.8	1.3	1.4	2.0	2.2	18.9	21.0
Central Africa	0.3	0.3	0.3	0.5	0.8	4.8	6.6
East Africa	0.3	0.7	0.7	0.9	1.2	9.3	10.7
Southern Africa	3.9	4.0	5.2	5.5	8.2	73.3	68.3
South Africa	3.1	2.7	3.6	3.1	4.8	53.3	39.8
Investments in transmission and distribution lines							
Africa	24.0	31.0	38.5	51.3	63.9	515.1	576.2
Sub-Saharan Africa	**16.5**	**24.0**	**31.3**	**43.0**	**55.6**	**391.8**	**492.7**
West Africa	5.3	8.1	11.1	15.0	18.0	133.0	164.7
Nigeria	3.6	5.6	7.6	10.2	11.7	91.0	109.2
Central Africa	2.1	2.5	3.8	6.0	9.1	46.6	75.1
East Africa	2.7	4.6	5.7	7.9	10.6	70.0	92.8
Southern Africa	6.4	8.7	10.7	14.1	17.9	142.2	160.1
South Africa	2.6	3.0	3.7	4.3	4.7	51.8	45.0

New Policies Scenario

	Average annual investments in the oil sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**56.5**	**74.7**	**69.4**	**70.3**	**68.7**	**1 116.5**	**694.6**
Upstream	52.8	67.5	60.3	64.8	63.7	1 009.1	642.4
Transport	1.9	3.2	2.3	2.6	3.6	40.9	31.1
Refining	1.8	4.0	6.8	2.9	1.4	66.5	21.1
of which: Investments in the upstream oil sector							
Sub-Saharan Africa	**41.5**	**40.7**	**33.1**	**39.0**	**39.8**	**659.6**	**393.8**
West Africa	14.3	18.0	19.6	21.1	21.7	288.4	214.3
Nigeria	8.1	14.1	18.4	20.6	20.5	219.4	205.3
Central Africa	9.2	3.1	1.5	2.5	2.4	87.7	24.1
East Africa	2.7	6.3	2.6	1.8	1.2	63.9	14.8
Southern Africa	15.2	13.2	9.4	13.6	14.5	219.6	140.7
Angola	15.2	11.8	7.9	12.9	13.7	205.3	132.8
South Africa	0.0	1.1	1.0	0.5	0.6	10.5	5.3

	Average annual investments in the natural gas sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**25.8**	**33.3**	**37.9**	**42.7**	**48.4**	**536.6**	**455.5**
Upstream	13.8	23.9	28.9	34.4	42.5	361.0	384.5
Transport	11.9	9.4	9.0	8.3	5.9	175.6	71.1
of which: Investments in the upstream natural gas sector							
Sub-Saharan Africa	**6.4**	**13.6**	**16.3**	**19.7**	**23.6**	**194.5**	**216.4**
West Africa	3.5	5.2	6.7	8.6	10.6	83.6	96.0
Nigeria	3.2	4.4	5.6	7.4	9.5	72.7	84.8
Central Africa	0.4	0.8	1.1	1.4	1.5	12.3	14.6
East Africa	0.1	0.2	0.1	0.0	0.1	1.9	0.5
Southern Africa	2.6	7.4	8.4	9.7	11.3	96.6	105.2
Angola	2.2	2.6	2.3	2.2	2.4	39.5	23.4
Mozambique	0.3	3.1	4.0	5.1	5.8	37.4	54.1
South Africa	0.1	0.7	0.8	0.8	0.9	8.2	8.6

	Average annual investments in the coal sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**1.9**	**2.3**	**2.6**	**2.9**	**2.9**	**37.8**	**29.1**
Mining	1.5	1.9	2.1	2.4	2.3	30.8	23.9
Transport	0.4	0.4	0.5	0.5	0.5	7.0	5.2
Sub-Saharan Africa	**1.9**	**2.3**	**2.5**	**2.9**	**2.8**	**37.2**	**28.7**
Mozambique	0.2	0.2	0.3	0.3	0.4	4.0	3.7
South Africa	1.5	1.8	1.9	2.1	1.8	29.0	19.7

African Century Case

	Average annual investments in the oil sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**58.1**	**85.8**	**77.2**	**82.5**	**85.8**	**1 240.3**	**841.2**
Upstream	54.2	76.1	67.5	75.1	78.9	1 097.2	770.0
Transport	1.9	3.2	2.3	2.7	3.6	40.8	31.3
Refining	2.1	6.5	7.4	4.7	3.3	102.4	39.8
of which: Investments in the upstream oil sector							
Sub-Saharan Africa	**42.5**	**49.5**	**40.6**	**49.5**	**55.0**	**747.9**	**522.8**
West Africa	15.1	21.2	21.6	22.8	22.7	319.3	227.3
Nigeria	8.3	17.1	20.4	21.6	20.6	245.4	210.9
Central Africa	9.3	3.5	2.3	4.1	4.1	94.0	40.9
East Africa	2.8	10.6	6.8	4.0	5.0	106.2	45.1
Southern Africa	15.3	14.3	9.9	18.7	23.2	228.3	209.5
Angola	15.3	12.6	8.4	15.5	16.5	212.1	160.3
South Africa	0.0	1.1	1.0	0.5	0.6	10.5	5.3

	Average annual investments in the natural gas sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**26.4**	**34.1**	**39.4**	**45.6**	**58.2**	**553.0**	**518.6**
Upstream	13.9	24.2	29.8	36.4	51.0	367.2	437.3
Transport	12.6	10.0	9.6	9.2	7.1	185.8	81.3
of which: Investments in the upstream natural gas sector							
Sub-Saharan Africa	**6.4**	**13.8**	**17.1**	**21.7**	**32.0**	**199.9**	**268.5**
West Africa	3.5	5.6	7.4	9.6	12.2	89.6	108.7
Nigeria	3.3	5.0	6.6	8.7	11.1	81.1	99.4
Central Africa	0.4	0.7	1.0	1.2	1.6	11.0	13.9
East Africa	0.1	0.2	0.1	0.1	0.1	2.0	0.9
Southern Africa	2.5	7.3	8.6	10.9	18.1	97.3	145.0
Angola	2.2	2.3	2.2	2.6	2.9	37.5	27.6
Mozambique	0.3	3.3	4.3	5.7	10.1	40.1	78.8
South Africa	0.1	0.6	0.6	0.6	0.8	6.3	6.9

	Average annual investments in the coal sector (billion, year-2013 US dollars)					Cumulative investments	
	2014-20	2021-25	2026-30	2031-35	2036-40	2014-30	2031-40
Africa	**1.8**	**2.4**	**2.8**	**3.2**	**3.3**	**38.8**	**32.5**
Mining	1.5	1.9	2.2	2.6	2.5	31.2	25.5
Transport	0.3	0.5	0.6	0.6	0.8	7.7	6.9
Sub-Saharan Africa	**1.8**	**2.4**	**2.7**	**3.2**	**3.2**	**38.2**	**32.1**
Mozambique	0.2	0.2	0.3	0.4	0.5	4.0	4.4
South Africa	1.5	1.8	2.0	2.2	1.9	29.3	20.5

Definitions

This annex provides general information on terminology used throughout the report including: units, general conversion factors, definitions and regional groupings.

Units

Coal	Mtce	million tonnes of coal equivalent (1 Mtce = 0.7 Mtoe)
Energy	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	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
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
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})

Energy conversions

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

Currency conversions

Exchange rates (2013)	1 US Dollar equals:
Congolese Franc	919.50
Ethiopian Birr	18.54
Mozambican Metical	30.08
Nigerian Naira	155.25
South African Rand	9.65
Tanzanian Shilling	1 597.58

Definitions

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 from as little as a few kilowatts. Such capacity is distinct from mini- and off-grid systems that are not connected to the main power grid.

Bioenergy

Refers to the energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid biomass, biofuels and biogas.

Biofuels

Biofuels are 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.

Biogas

A mixture of methane and carbon dioxide produced by bacterial degradation of organic matter and used as a fuel.

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.

Investment

All investment data and projections reflect "overnight investment", i.e. the capital spent is generally assigned to the year production (or trade) is started, rather than the year when it actually incurs. Investments for oil, gas, and coal include production, transformation and transportation; those for the power sector include refurbishments, up-rates, 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. Investment data are presented in real terms in year-2013 US dollars.

Investment for access to electricity

Investment for access to electricity includes finance for new transmission and distribution lines, new power generation capacity in mini- and off-grid systems, as well as the share of capacity additions connected to the main grid needed to meet access-related electricity demand.

Investment for access to clean cooking facilities

Investment for access to clean cooking facilities includes financing for improved biomass cookstoves and in stoves using cleaner fuels such as liquefied petroleum gas, biogas and solar stoves.

Mini-grids

Small grid systems linking a number of households and other consumers.

Modern energy access

Access to modern energy services 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 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.

Off-grid systems

Stand-alone systems for individual households or groups of consumers.

Productive uses

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 also be considered as productive, but is treated separately.

Solid biomass

Solid biomass includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid wastes.

Traditional use of solid biomass

The 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.

Regional groupings

Central Africa

Cameroon, Central African Republic (CAR), Chad, Congo, Democratic Republic of Congo (DR Congo), Equatorial Guinea and Gabon.

East Africa

Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan and Uganda.

North Africa

Algeria, Egypt, Libya, Morocco, Tunisia, and Western Sahara (under UN mandate).

Southern Africa

Angola, Botswana, Comoros, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe.

West Africa

Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone and Togo.

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- Highlights key actions in the energy sector that can unleash more rapid economic and social development in sub-Saharan Africa.
- Evaluates the role of renewables in the region's energy future, and how important mini- and off-grid solutions can be in providing access to electricity.
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