OXFORD ECONOMICS
AFRICA

ENERGY TRANSITIONS IN WESTERN AND CENTRAL AFRICA

A FOCUS ON NIGERIA, GHANA, SENEGAL, EQUATORIAL GUINEA AND MAURITANIA

SEPTEMBER 2022

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ABBREVIATIONS

AG	Accelerated Growth
BAU	Business as usual
CAGR	Compound annual growth rate
CHP	Combined heat and power
CO_2	Carbon dioxide
EIA	Energy Information Administration
GDP	Gross domestic product
GHG	Greenhouse gases
GWh	Gigawatt hours
IEA	International Energy Agency
ktoe	Thousand tonnes (i.e., kilotonnes) of oil equivalent
kWh	Kilowatt hours
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MMBtu	Million British thermal units
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
PG	Policy Goals
PV	Photovoltaic
SDGs	Sustainable Development Goals
Tcf	Trillion cubic feet
toe	Tonnes of oil equivalent
TWh	Terawatt hours

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EXECUTIVE SUMMARY

Energy Inequality

The average US citizen consumes over 63 times more electricity than each person in the countries selected for this study, while the average Chinese citizen consumes over 25 times more electricity.

Energy transitions are already underway to varying degrees in the countries included in this study, namely Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. While such transitions are commonly interpreted as the sustained displacement of fossil fuels by renewable energy, it is imperative to consider these structural shifts within the distinct developmental context of each country. This report assesses the historic and future development of each country's primary energy and electricity landscapes to determine how their respective energy transitions are likely to unfold out to 2050 under two scenarios.

The **Policy Goals (PG)** scenario accounts for the stated policy ambitions and projects of the countries included in this study, while the **Accelerated Growth (AG)** scenario is extended to consider faster economic growth, the drive to achieve universal energy access, and limit carbon emissions associated with rising energy demand to fuel industrial expansion. In both scenarios, oil and natural gas fulfil important roles, particularly in primary energy supplies. Renewable energy, mainly from solar and wind, is expected to increase rapidly from a low base. Electricity production will become more diversified and progressively rely on **natural gas as a transition fuel** to accommodate and complement a rising share of variable and intermittent electricity generation from solar and wind.

Vital Resources

Oil and gas are crucial for the macro, socio-economic, and development progress of the countries, as well as energy security and self-reliance. Even so, renewable energy will grow sharply from low levels.

The proliferation of natural gas and ongoing reliance on oil can be ascribed to their developmental importance. These countries hold vast hydrocarbon resources and would continue to exploit them as long as internal and external demand for oil and natural gas exists. Both fuels are integral to the countries' energy security and independence. Although natural gas and oil are subject to price fluctuations, they generate significant fiscal revenue, strengthen trade balances, and bolster foreign reserves. Expanding the related upstream and downstream infrastructure also supports job creation and broader economic growth. **Natural gas is of particular geostrategic significance** for these countries. An escalation in geopolitical risks has underlined the need for nations to diversify their international suppliers of hydrocarbons, which bodes well for these countries to commercialise their untapped and underdeveloped hydrocarbon resources.

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These countries also have **deep socio-economic needs with a disproportionate reliance on traditional biomass**, principally the burning of firewood and charcoal in open fires or inefficient stoves. **Over 35% of their collective populations live without electricity**, while 75% do not benefit from cleaner cooking options. At the same time, energy demand is set to outstrip supply, driven by rapid population growth, industrial development, and socio-economic upliftment. Depending on the country, we forecast that total domestic **primary energy supplies will have to increase by between 1.3% and 5.3% and electricity generation by 4.6% to 7.7% on average per year out to 2050** in order to enable industrial development, improve human well-being, and reduce the use of traditional biomass.

Within this context, the relative growth of natural gas and oil in the countries' aggregate energy supplies suggests an accompanying rise in greenhouse gas (GHG) emissions, especially if they are going to meet their developmental goals and objectives. The AG scenario generally involves less oil expansion relative to natural gas, mainly as the scenario focuses on limiting carbon emissions and balancing intermittent renewable energy in the electrical power sector. While the countries' electricity systems will expand rapidly and become increasingly diversified, gas-to-power is expected to dominate their electricity industries by 2050 in both scenarios. **Oil is seen to play an increasingly negligible role in generating electricity, being displaced by natural gas and non-hydro renewables such as solar and wind**.

While carbon emissions rise over the long term in most countries, their contributions to global CO_2 emissions remain minor in both scenarios. Nigeria's share of global energy emissions rises from 0.3% in 2019 to 0.8% by 2050, while the shares for the other countries remain below 0.2%. At the same time, the dominance of traditional biomass steadily dissipates as the use of firewood and charcoal gives way to electricity and cleaner cooking alternatives. As a result, the rise in energy sector emissions would also be accompanied by fewer toxic pollutants stemming from traditional biomass.

Energy Poverty

Rapid increase in primary energy and electricity supply is needed to reduce the excessive reliance on traditional biomass, improve human wellbeing, and foster sustainable economic development.

Energy Outlook

Oil and natural gas are set to gain prominence in future energy supplies, but oil gets displaced by gas and renewables when the focus shifts toward limiting carbon emissions.

Climate Impact

CO_2 emissions are set to rise as energy supply increases to meet development needs, but the countries' contributions to global emissions will remain marginal.

Policy Objectives

Energy transition and diversification are underway, in line with climate change goals. However, these goals could be delayed due to funding shortfalls.

Drastically altering the prevailing energy trajectories of these countries, such as through aggressive strategies to phase out fossil fuels, will not only require a fundamental reset of their energy systems, but **may also have serious economic, social, and developmental repercussions**. The adoption of renewable energy and complementary technologies will nonetheless proceed, but likely at a relatively gradual and affordable pace as energy and electricity systems restructure to utilise more renewables. **The abundance of natural gas in these countries will support the adoption of renewable energy, universal access to electricity, and industrial development.** Natural gas is the least-polluting fossil fuel and its environmental drawbacks from flaring and venting can be addressed.

It is for this reason that **the countries have adopted key energy strategies and policies to promote environmentally sustainable development** in a manner that improves access to reliable, affordable, and low-carbon energy and electricity. These policy ambitions are geared to realise just energy transitions within country-specific settings to progress towards their committed climate goals. The attainment of some of these goals could, however, be delayed due to the lack of sufficient investment and support from development partners and the private sector.

This study demonstrates that the **energy transitions of Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania would likely be distinct** from those charted for other countries. This is largely due to their vast natural gas reserves which offer substantial economic, developmental, and social benefits.

1. INTRODUCTION

This study investigates the future energy trajectories in Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. To realise their policy and development goals, foster energy security, and overcome electrical and energy deficits, these countries will need to increase energy supplies significantly. This will have implications for climate change, although carbon emissions from the countries are negligible from a global perspective. Each country is already undergoing an energy transition to some extent, which affects their individual future demand and supply profiles.

While energy transitions are generally regarded as the displacement of fossil fuels by renewable energy sources, it is vital to consider such structural shifts within the distinct developmental circumstances of the countries selected for this study. Oil, and increasingly natural gas, are of geostrategic importance to these countries in a changing global energy landscape. They possess vast hydrocarbon reserves, and the commercialisation thereof can drive economic growth, create jobs, and earn substantial export and fiscal revenues.

“Energy transitions are already underway in the five countries.”

Concurrently, their populations are disproportionately reliant on traditional biomass with inadequate access to modern energy sources. While the uptake of renewable energy will continue to advance from low bases, it will likely be eclipsed by oil and natural gas. This is, however, mainly the case for primary energy supplies (i.e., the first energy form harvested directly from natural resources before transformation into other useful energy forms), whereas electricity production is more diversified. Even so, natural gas is set to fulfil an increasingly important role in the countries selected for this study as a less carbon-intensive transition fuel to the increased adoption of renewables.

While all countries other than Equatorial Guinea have started to implement modest amounts of non-hydro renewable energy, natural gas has grown in the composition of the domestic energy and electricity profiles of Equatorial Guinea, Ghana, and Nigeria. Although Senegal and Mauritania are still exceedingly reliant on imported oil, this is set to change in the near future amid the exploitation of substantial gas reserves. Moreover, Mauritania is continuing on the path of implementing relatively large capacity additions from solar technologies given its abundance of solar irradiation potential.

This report is structured into four parts. Firstly, the prevailing energy landscapes are assessed to contextualise each country’s energy and electricity supply and demand dynamics. The countries’ plans, strategies, and policies are then reviewed to appraise their respective climate goals and commitments to transition to more environmentally sustainable energy systems. This is followed by an analysis of how energy transitions may unfold within and among the group of countries based on projections of their respective volumes and compositions of primary domestic energy and electricity supplies out to 2050. The methodological description of the scenarios to inform the projections is included as an annexure. Lastly, the likely implications for climate change in terms of energy-related carbon emissions are evaluated. The study concludes with a synopsis of the key findings.

2. ENERGY STATUS QUO

This section examines the current energy landscapes of Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. An assessment of the status quo provides insight into the trends and shifts in the countries' respective energy mixes, as well as an indication of existing resource availability, production, and utilisation. These insights can inform plausible scenarios and assumptions for energy projections.

"Oil production is mostly exported, with domestic requirements also filled by imports."

"Widespread reliance on biomass shows need for faster uptake of gas and renewables."

2.1 ENERGY AND ELECTRICITY SUPPLY

2.1.1 Primary energy supply

Primary energy can be defined as the first energy form harvested directly from natural resources for supply and transformation into other useful energy forms. Total primary energy supply comprises five core activities, namely production, imports from and exports to trading partners, stock changes, and international marine and aviation bunkering. According to data from the International Energy Agency (IEA), **coal fulfilled a negligible role** in terms of primary energy supply in 2019, with only Nigeria producing a limited amount of coal and Senegal relying on imports of the commodity.

Oil fulfils a significantly more important role than coal. Nigeria, Ghana, and Equatorial Guinea all produce oil, but most of these supplies are destined for export. Conversely, Senegal and Mauritania rely exclusively on imports for primary oil supplies. **Other than Mauritania, all the countries also produce natural gas**, even though Senegal produced only marginal volumes in 2019. While Equatorial Guinea and Nigeria export natural gas, Ghana relies on additional gas imports. All of the countries besides Mauritania produced **hydro energy, which fulfils a vital role in electricity generation**, but is small from a primary energy perspective.

The use of other renewable energy sources like wind and solar remained comparatively negligible in 2019, although these non-dispatchable sources have started to grow in all countries besides Equatorial Guinea over the past decade, with Mauritania aiming to substantially expand the use of solar in its energy mix.

Biomass & waste represent a vast share of total energy supplies in all countries other than Equatorial Guinea. This primary energy source mainly involves the burning of firewood, charcoal, and other materials in open fires or inefficient cook stoves. **The incineration of traditional biomass emits toxic and harmful pollutants** that endanger human health and the environment, and suggests a severe lack of access to electricity, clean fuels, and other technologies.

Turning to domestic primary energy supply – representing the net figure after accounting for production, imports, exports, stock changes, and bunkering – oil clearly fulfils a key role in most countries, as well as biofuels & waste that largely involves traditional biomass. There are, however, stark differences among the countries' domestic energy mixes.

SNAPSHOT

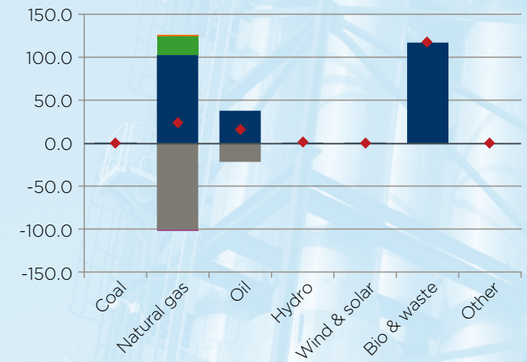
PRIMARY ENERGY SUPPLY IN 2019

Production
Imports
Exports
Stock changes
Int. bunkers
Total domestic*

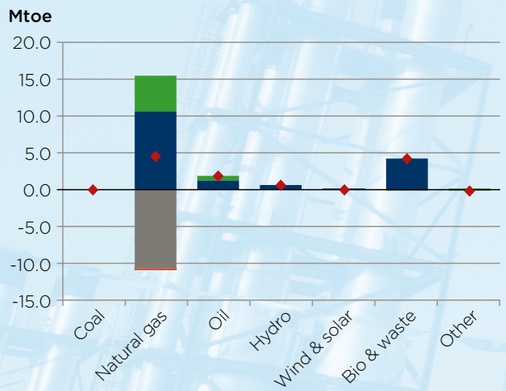
*Production and imports net of exports, international bunkers and stock changes.

Sources: IEA, OE Africa

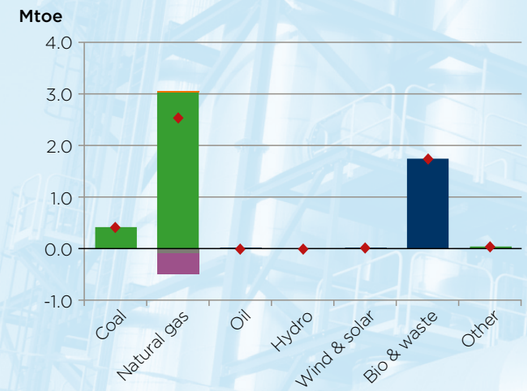
Nigeria



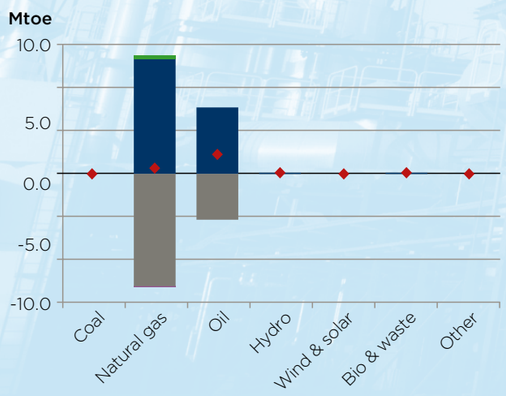
Ghana



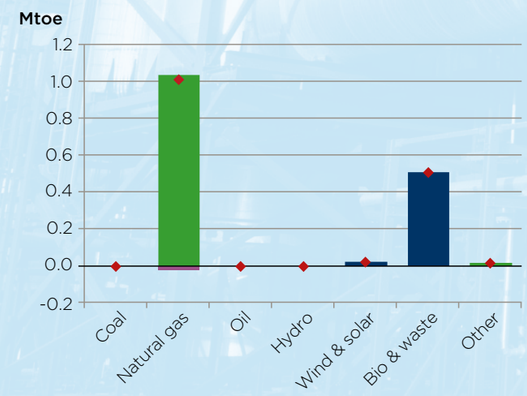
Senegal



Equatorial Guinea



Mauritania



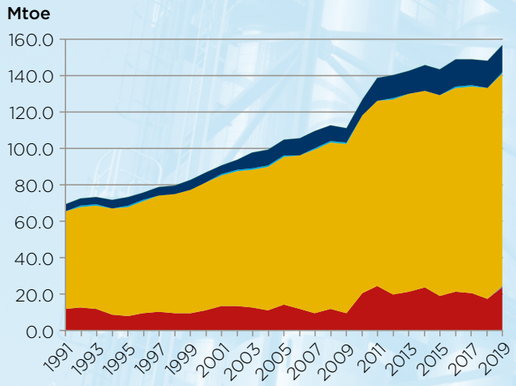
SNAPSHOT

DOMESTIC PRIMARY ENERGY SUPPLY

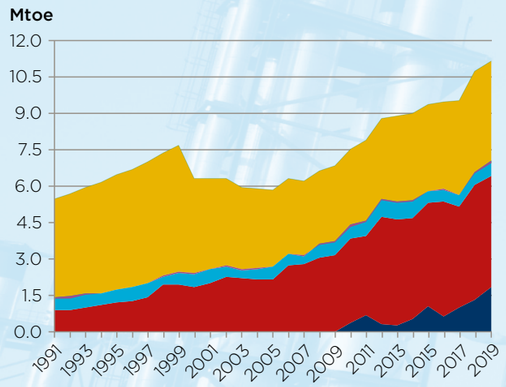
- Natural gas
- Oil
- Coal
- Other
- Solar & wind
- Hydro
- Biomass & waste

Sources: IEA, OE Africa

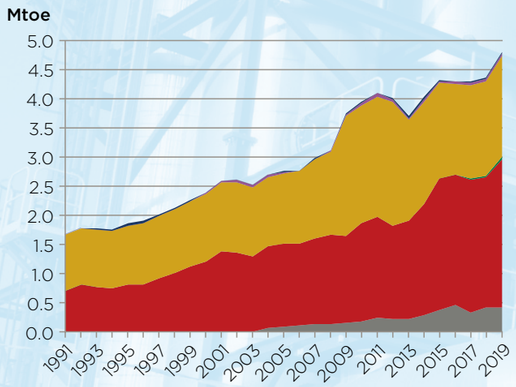
Nigeria



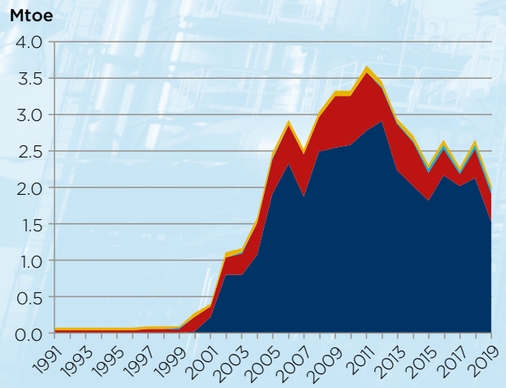
Ghana



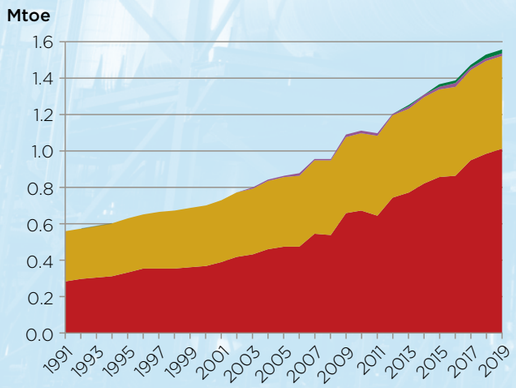
Senegal



Equatorial Guinea



Mauritania



Nigeria's domestic energy supply reached 157.5 million tonnes of oil equivalent (Mtoe) in 2019, expanding by a compound annual rate (CAGR) of 2.4% since 2010. **The country's domestic supply mix has remained quite stable over the past decade**, with (mostly traditional) biomass dominating (74.7% of the total), followed by oil (15.1%) and natural gas (9.7%). Ghana's domestic energy supply expanded at a significantly faster pace over the previous decade, growing by 4.5% p.a. to 11.2 Mtoe by 2019. Oil has gained prominence (41.0% of the total by 2019), while natural gas supplies have also expanded sharply more recently (16.6% of the total).

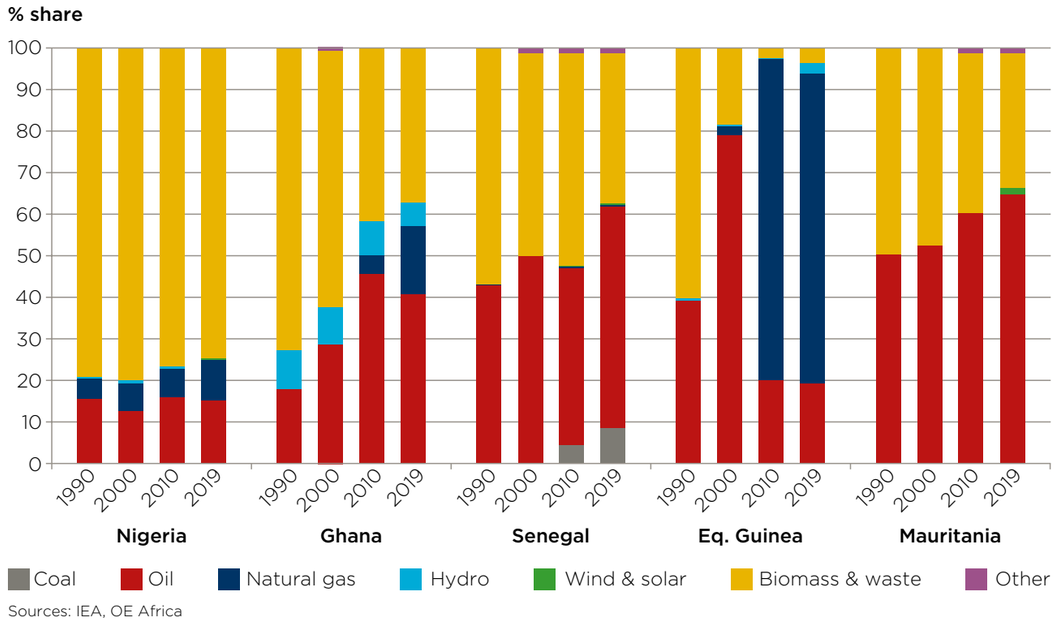
Senegal and Mauritania both exhibit fairly similar trends in their respective domestic energy supply mixes, with oil gaining ground since the 1990s. In 2019, oil accounted for more than half of the domestic energy supply in both countries (53.2% for Senegal and 65.1% for Mauritania). Senegal's domestic energy supply, amounting to 4.8 Mtoe by 2019, expanded by a CAGR of 2.2% over the 2010-19 period.

Mauritania's energy supply expanded at a faster rate of 3.8% p.a. over the same period, with the country's domestic energy availability reaching 1.6 Mtoe in 2019. Looking ahead, natural gas is set to be a game changer in both countries amid the imminent commercialisation of roughly 25 trillion cubic feet (Tcf) of reserves.

Finally, Equatorial Guinea's energy supply profile reflects a sharp deviation from the other countries examined in this study. This is ascribed to the dominance of natural gas. Of the country's total domestic energy supply amounting to roughly 2.0 Mtoe in 2019, natural gas accounted for a substantial 74.7%.

> **"Natural gas looks set to be a game changer in Mauritania and Senegal."**

Figure 1: Composition of total domestic primary energy supply



Sources: IEA, OE Africa

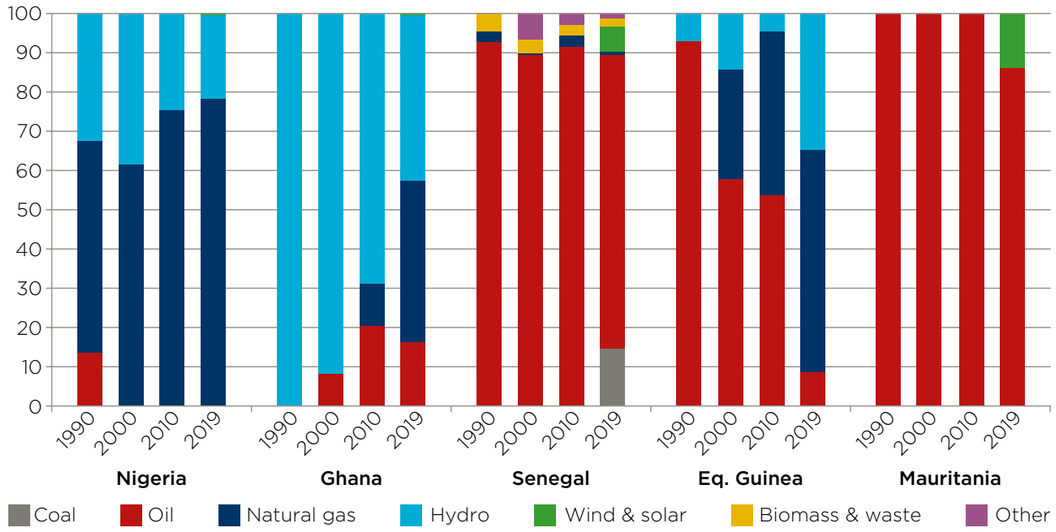
2.1.2 Electricity production

The nature of electricity production differs vastly among the countries. **Figure 2** shows the composition of each country's electricity production mix by energy source. Despite being the largest oil producer in Africa, Nigeria's electricity system has traditionally been powered by natural gas and hydroelectricity, while backup generators are frequently used to overcome blackouts. The country produced 31.4 TWh in 2019 to which natural gas contributed 78.4% and hydroelectricity 21.5%. Ghana, meanwhile, supplied 17.3 TWh from hydropower (42.0%), natural gas (41.6%), oil (16.1%), and solar plants (0.3%), which indicates a diversification away from the country's sole reliance on hydropower in the 1990s. Senegal generated 5.2 TWh, mostly from oil (74.8%), while imported coal (14.7%) has gained momentum since 2004, followed by solar and wind (6.0%), biogas (2.3%), and natural gas (1.1%). Mauritania's 1.7 TWh is nearly completely enabled by imported oil (86.3%), although the country has rapidly advanced electrical energy production from wind and solar (13.7%) since 2013. Equatorial Guinea's electricity production was also around 1.7 TWh and has progressively shifted from a reliance on oil to natural gas (56.9%), followed by hydroelectricity (34.3%) and oil (8.8%).

"Intermittent renewables and gas to continue displacing oil."

In addition to Mauritania, Nigeria, Ghana, and Senegal have gradually introduced non-hydro renewables, particularly from solar energy, over the past decade, although it still represents a negligible share in the composition of their electrical energy mixes. Regardless, **the progressive uptake of solar energy entails additional prospects for natural gas to play a larger role**, especially since the fuel provides a dispatchable alternative to complement intermittent electrical energy generation from solar and wind plants.

Figure 2: Composition of total electricity supply



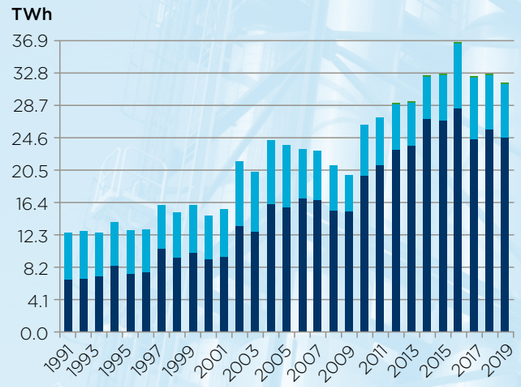
Sources: IEA, OE Africa

SNAPSHOT

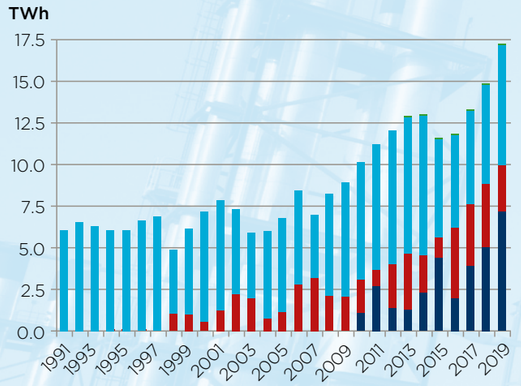
ELECTRICITY PRODUCTION MIX

Sources: IEA, OE Africa

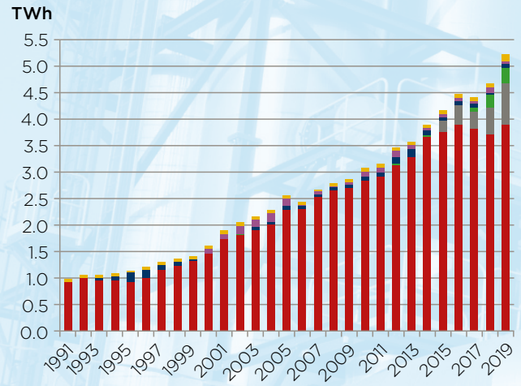
Nigeria



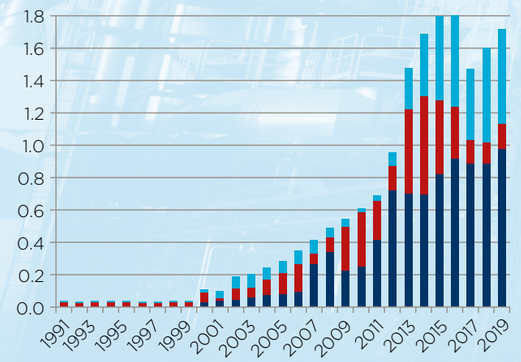
Ghana



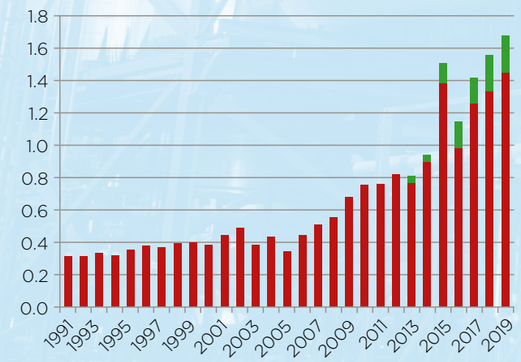
Senegal



Equatorial Guinea



Mauritania



2.2 ENERGY AND ELECTRICITY CONSUMPTION

2.2.1 Primary energy use

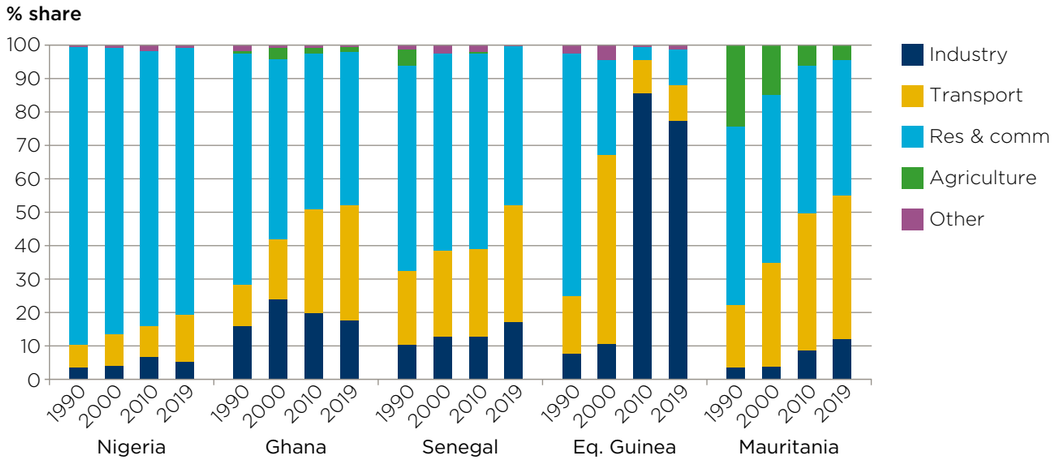
The composition of total final primary energy consumption by sector is depicted in **Figure 3**. In the majority of countries, transport's share in energy consumption has continued to increase, although residential and commercial energy use accounts for the largest share in most countries. **The bulk of this consumption, however, still embodies the burning of firewood and charcoal for cooking and heating purposes, as sufficient electricity has not reached all people.**

"Major share of residential energy use is still in the form of traditional biomass."

The outlier is Equatorial Guinea, where industry accounts for a dominant share (77.2%) of final primary energy consumption. That said, the country's total final primary energy use has declined by a CAGR of 6.3% since 2010 to 1.7 Mtoe in 2019, which can be ascribed to a slowdown in industrial activity, coupled with maturing gas fields and delayed new investments. In contrast, Ghana's energy consumption has grown by a CAGR of 4.7% since 2010 to a total of 8.3 Mtoe in 2019. Senegal's total energy consumption of 2.8 Mtoe in 2019 has grown by a CAGR of only 1.0% since 2010 to which the residential & commercial sector (47.5%) also contributed the most, followed by transport (35.0%) and industry (17.4%). Mauritania's energy use, on the other hand, has grown strongly by a CAGR of 4.0% since 2010 to 1.2 Mtoe, driven by transport (43.1%), the residential & commercial sector (40.1%), industry (12.0%), and agriculture (4.8%). Energy use in the agricultural sector has, however, been on a declining trend since the 1990s. Nigeria, meanwhile, consumed a substantial 135.5 Mtoe, increasing by a CAGR of 2.7% since 2010, which stemmed mainly from residences & commerce (79.3%), followed distantly by transport (14.0%) and industry (5.5%).

"Equatorial Guinea's primary energy use has declined in recent years."

Figure 3: Composition of total final primary energy consumption



Sources: IEA, OE Africa

2.2.2 Electricity consumption

Despite enormous grid losses, electricity consumption increased substantially over the past decade in most countries. Equatorial Guinea saw the strongest growth in electricity use, rising by a CAGR of 12.4% since 2010 to around 1.5 TWh in 2019. Mauritania experienced the second-fastest growth in electricity use with a CAGR of 8.2% since 2010 to 1.4 TWh by 2019, followed by Ghana where consumption increased by a CAGR of 7.7% to 13.5 TWh. Electricity consumption in Senegal has also grown by 6.0% p.a. between 2010 and 2019 to 4.8 TWh. Despite its much larger electricity system and absolute level of consumption, Nigeria lags the group with a CAGR of 2.1% since 2010 to 26.7 TWh.

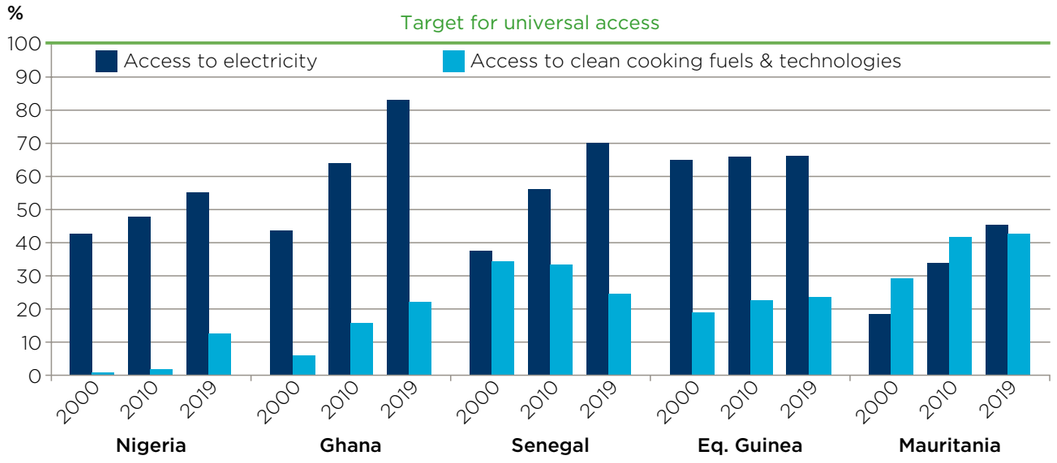
Interestingly, electricity use per capita is the highest in Equatorial Guinea, reaching 1,138 kWh in 2019. Ghana ranks a distant second, with consumption per capita at 444 kWh, followed by Mauritania with 317 kWh and Senegal with 293 kWh. **Nigeria again lags significantly behind the other countries, with electricity use per capita at a meagre 133 kWh in 2019.** Regardless, electricity use per person within the group pales in comparison to other developed and developing economies, such as the US (12,087 kWh), EU (5,788 kWh), Brazil (2,527 kWh), and China (4,793 kWh). **Figure 4** shows the progress made by the individual countries in attaining universal access to electricity and clean cooking fuels.

"On average each US citizen uses 40 times more electricity than each Senegalese or Mauritanian."

It is challenging to connect portions of the largely rural population to the electricity grid, and attracting investment into off-grid solutions can be difficult. Rural communities are geographically thinly spread and families often lack the financial means to pay for services. A large share of the population therefore lacks access to electricity, while all countries fare poorly with regard to access to clean cooking alternatives.

"Long way to go to ensure universal access to electricity."

Figure 4: Population with access to electricity and clean cooking



Sources: World Bank, OE Africa


MAERSK
SEALAND
COSCO
EVERGREEN
P&O

3. ENERGY STRATEGIES AND CLIMATE COMMITMENTS

Energy is vital for economic development and the countries have formulated strategies and policies aimed at improving access to reliable and sustainable energy. These efforts are underscored by the adoption of the UN's Sustainable Development Goals (SDGs), which explicitly call for targets for universal access to reliable, affordable, and modern energy sources. This section provides an overview of the energy strategies and policies in each country aimed at improving electrical and energy output, access, and self-sufficiency, as well as some of the countries' stated commitments to mitigate and/or adapt to climate change. Attaining energy security and independence are especially fundamental amid recent geopolitical events.

"Oil is still a big part of Nigeria's energy plans as it looks for more investment inflows."

3.1 NIGERIA

The National Energy Policy (NEP), first adopted in 2003 and revised over the years, with its related National Energy Masterplan, is the most comprehensive policy. The NEP has birthed other legislation and policies aimed at deregulating the electricity sector, improving renewable energy development, and reducing the effects of climate change. Specifically, the introduction of the Renewable Energy Masterplan (2005) and the Renewable Energy and Efficiency Policy (2015) marked a policy shift towards a more environmentally sustainable energy system.

Despite this policy shift, electricity generation from renewable energy sources other than hydropower remains marginal. The slow uptake of renewables along with the country's weak transmission network makes the latest Nationally Determined Contribution (NDC, 2021) goals of **increasing the on-grid electricity share of renewables to 30%** difficult to achieve (see **Table 1** below for other energy-related NDC targets), especially without significant investments in renewable energy plants and upgrading the transmission network.

The petroleum sector remains essential to the country's energy security, self-reliance, and economic prospects. This is articulated in the National Petroleum Policy (2017), which aims to **maximise the production and processing of hydrocarbons,** position oil as an economic growth catalyst, and create value by processing oil into lucrative end products. Key to the ongoing growth of the oil and gas industry is significant investment inflows. To attract more investment, the long-delayed Petroleum Industry Bill (PIB) was enacted in 2021, which seeks to transform the Nigerian oil and gas industry.

The PIB strikes a balance between attracting investments and developing host communities by providing governance and a regulatory and fiscal framework. Critics argue that the environmental aspects of the bill could have been stronger, and it was a missed opportunity to prepare for a zero-carbon future. Notably, the PIB includes exemptions that allow gas flaring to continue, which reduces the likelihood of the country meeting its **target of eliminating gas flaring by 2030.** This, coupled with the poor adoption of non-hydro renewable energy, could see Nigeria miss its NDC target of reducing total emissions by 20% (unconditional) and 47% (conditional) compared to the business as usual (BAU) case by 2030.

Energy transitions in Western and Central Africa
OXFORD ECONOMICS AFRICA

In 2021, Nigeria introduced its Climate Change Act, which provides a framework for coordinating the country's climate actions and is the first stand-alone comprehensive climate change legislation in West Africa. It also paves the way for the National Climate Change Action Plan to ensure that the country's emissions profile is consistent with its carbon budget goals and **prescribes measures for identifying actions for climate adaptation and mitigation.**

3.2 GHANA

As mandated by law, Ghana's Energy Commission periodically puts forward Strategic National Energy Plans (SNEPs) that, alongside the National Energy Policy, outline the policies aimed at addressing the country's energy needs amid its rapid population growth and ambitious development agenda. These policies are also aimed at regulating the petroleum industry with respect to the licensing and operation of oil and gas companies, **increasing the share of renewables in the energy mix,** and improving electricity output to achieve universal access by 2020. After missing this target in 2020, with electricity access of about 84%, Ghana has since **extended the target of achieving universal access to 2030.**

The Renewable Energy Act (2011) and the Renewable Energy Master Plan (2019) provide the legal frameworks to support the deployment of renewable energy technologies. Ghana extended its target by a decade and now **aims to increase the share of renewable energy (excluding large-scale hydro) in electricity generation to 10% by 2030.** The extension occurred due to difficulties to deliver on policy instruments in the Renewable Energy Act that could not be fully implemented owing to investment constraints. According to the country's latest NDC (2021), the implementation of low-carbon electrical capacity additions in accordance with the Renewable Energy Master Plan, among other conditional and unconditional policy actions, **could help Ghana reduce its GHG emissions by a cumulative 64 Mt CO_2e** (conditional: 24.6 Mt CO_2e; unconditional: 39.4 Mt CO_2e) by 2030 (see **Table 1** below for other energy-related NDC targets).

Since its domestic discovery in 2007, gas has become a fundamental electricity source in Ghana and now accounts for a larger share than oil. The completion of onshore infrastructure has also seen the country's gas reach market.

The Gas Master Plan was drafted with the objective of developing a strategy that will **boost natural gas production and secure energy supply.** Ghana plans to produce and process estimated reserves of 300 million barrels of oil and gas by 2040.

"Ghana plans to raise the share of non-hydro renewables in its energy mix."

3.3 SENEGAL

The energy sector is at the heart of the country's Plan for an Emerging Senegal (PES, 2014), which forms the reference framework for its socio-economic policy over the medium term. The action plan for the energy sector to achieve PES goals is enshrined in the Letter of Policy Development of the Energy Sector (LPDSE, 2019-23). The LPDSE aims to establish the prerequisites for local oil and gas production, **provide universal and sustainable access to low-cost electricity, supply sustainable cooking energy to households**, and complete the reform of the legal and regulatory framework of the sector.

“ Gas set to grow into a key energy and electricity source for Senegal. ”

The LPDSE works in tandem with the Renewable Energy Law (2010), which regulates renewable energy in Senegal and its main goals are to **diversify the energy mix** while ensuring energy security and reducing GHG emissions. The government **aims to achieve universal electricity access by 2025**, including through a combination of on- and off-grid solutions for rural areas. In its latest NDC (2020), Senegal notes that these energy-related commitments and others will help the country to **cut its GHG emissions by 7% (unconditional) and 29.5% (conditional on support) by 2030** compared to baseline projections.

“ Equatorial Guinea’s recent regulations will boost output and returns of oil and gas projects. ”

Natural gas is growing into an important primary energy and electricity generation source for Senegal. The **production of gas is also set to increase as planned projects come online** in the coming years. Midstream and downstream gas activities - including transportation, storage, processing, and trade - are governed by the Gas Code (2020), while the Petroleum Code (2019) outlines the rules on prospecting, exploration, development, exploitation, transport, and storage of hydrocarbons, as well as the liquefaction of natural gas.

The government furthermore enacted laws and requirements to promote local content in the hydrocarbons industry, including in its supply chains, workforce, and value addition activities. Key among these is the Local Content Law (2019), which aims to advance Senegal’s industrial development. The laws also advocate for technology and skills transfer after a specified period in plant operations.

3.4 EQUATORIAL GUINEA

The country’s energy and electricity sector’s main policy framework is contained in the Hydrocarbons Law (2006), National Electricity Plan 2025, and National Renewable Energy Action Plan 2018 to 2025 (2018). The Hydrocarbons Law stipulates Equatorial Guinea’s exclusive ownership of hydrocarbon exploitation rights, as well as the operational standards for the different industries under its ambit. It is supplemented by the Petroleum Operations Regulations, which are occasional ministerial orders that provide operational guidelines for the petroleum industry. The latest regulations cover policy changes made to **increase the output and returns of petroleum projects**, extending the productive life of mature fields, monetising natural gas, and developing the petrochemicals industry.

The electricity sector is a major focus of the country’s development strategy, as improved access to reliable energy will continue to support industrial activity and help to improve both the business environment and living conditions. The country plans to increase electricity output and access by leveraging its oil and gas potential. As indicated in its latest NDC (2015), Equatorial Guinea plans to reduce GHG emissions and contribute to global climate change goals by **increasing the production of electrical energy from renewable sources, particularly hydro, wind, and solar.** These sources are envisioned to lessen the country’s emissions by up to 50% by 2050 compared to 2010 levels.

3.5 MAURITANIA

Key goals of Mauritania’s Accelerated Growth and Shared Prosperity Strategy (SCAPP) are to promote strong, sustainable, and inclusive growth, as well as to develop human capital and access to basic social services. These goals include access to reliable and sustainable electricity for both industrial and residential use. To achieve this, the government plans to **increase electrical generation capacity from natural gas** and raise **the share of renewables, mostly from solar and wind, in the energy mix.** Mauritania has set a target of **increasing the share of renewables in the electricity generation mix to 50% by 2030.**

The government has launched and committed to several climate-related strategies to curb the effects of climate change, including by diversifying its energy mix. In its latest NDC (2021), the country committed to unconditionally **reduce emissions by 11% by 2030** compared to the BAU case, which could be raised to a cumulative 92.5% of emissions reduction by 2030 should sufficient support be provided.

“ Mauritania to leverage its considerable solar and wind energy potential for electricity. ”

3.6 SUMMARY OF ENERGY-RELATED NDC TARGETS

Table 1 summarises the energy-related plans and actions of the five countries **to meet their climate goals** as per their latest NDC commitments. Most of these plans aim to increase energy security and electrical supply to ensure universal access to clean cooking technologies and electricity, as well as to diversify the energy mix to include more renewables. **Energy access and security is crucial to attain energy self-sufficiency and maintain social stability amid burgeoning populations.** Rural access is still a challenge, however, as these populations are geographically thinly spread and lack the financial means to pay for electricity, making investments in off-grid solutions commercially complex.

The **attainment of these goals requires significant investment** by the countries and their development partners to build the necessary infrastructure, including for electricity generation, transmission, and gas supply. Energy investment was below the required levels before the onset of the Covid-19 pandemic, while government responses to the pandemic have exacerbated the situation as funding had to be redirected toward curbing the spread and socio-economic effects of the virus. As a result, current economic conditions suggest that adequate funding may not be available to secure the investments needed to realise the NDCs without external support. This raises the risk that some of the climate goals may be missed.

“ Major energy investments needed for human welfare and social stability. ”

Table 1: Summary of energy-related climate change commitments and policies

NIGERIA	
National Electricity Access Target	**Government Plans & Actions**
90% access by 2030	• 48% of population using LPG and 13% using cookstoves by 2030. • Elimination of kerosene lighting by 2030. • 30% of on-grid electricity from renewables (15.5 GW hydro, 6.5 GW Solar PV, 3.2 GW wind) and 13 GW off-grid renewable energy. • Reduce grid transmission and distribution losses to 8% of final consumption of electricity in 2030. • Replace all diesel & single-cycle steam turbines with combined cycle. • Eliminate diesel & gasoline generators for electricity by 2030.
National Clean Cooking Target	
80% access by 2030	
National Renewable Energy Target	
30% renewables share of electricity generation	
National GHG Target	
Cut emissions by 20% (unconditional) and 47% (conditional) relative to BAU (453 Mt CO_2e) by 2030	

GHANA	
National Electricity Access Target	**Government Plans & Actions**
100% access by 2030	• Expand the adoption of market-based cleaner cooking solutions. • Low carbon electricity generation. • Promote sustainable charcoal production, including youth and female entrepreneurs. • Promote clean rural household lighting. • Scale-up renewable energy penetration by 10% by 2030. • Decarbonisation of oil and gas production. • Adopt alternative urban solid waste management.
National Clean Cooking Target	
50% rural and 100% urban access by 2030	
National Renewable Energy Target	
10% non-hydro renewables share of electricity	
National GHG Target	
Cut emissions by 64 Mt CO_2e (conditional: 24.6 Mt CO_2e; unconditional: 39.4 Mt CO_2e) by 2030	

SENEGAL	
National Electricity Access Target	**Government Plans & Actions**
100% access by 2025	• 392 villages to be electrified using mini-grid solar or hybrid solutions. • Add solar PV power plants with a cumulative capacity of 335 MW. • Add wind turbine power plants with a cumulative capacity of 250 MW. • Add hydraulics power plants with a cumulative capacity of 314 MW.
National Clean Cooking Target	
Rollout of 8.4 million improved cookstoves by 2030	
National Renewable Energy Target	
Capacity of 999 MW from renewable energy by 2030	
National GHG Target	
Cut emissions by 7.0% (unconditional) and 29.5% (conditional) relative to BAU (37.8 Mt CO_2e) by 2030	

EQUATORIAL GUINEA	
National Electricity Access Target	**Government Plans & Actions**
100% access by 2030	• Reforms to increase the output of petroleum projects including the extension of the productive life of mature fields, monetisation of gas and the development of the petrochemicals industry. • Strengthening existing initiatives in the electricity sector by developing the hydroelectric potential of the Wele River. • Reforming existing hydroelectric centres (Musola: 0.5 MW; Riaba: 3.8 MW) for universal electrification of Bioko Island. • Wind and solar options for electrification in remote islands.
National Clean Cooking Target	
N/A	
National Renewable Energy Target	
N/A	
National GHG Target	
Cut emissions by 20% by 2030 relative to 2010 levels (20.4 Mt CO_2e)	

MAURITANIA	
National Electricity Access Target	**Government Plans & Actions**
100% access by 2030	• 170,000 LPG stoves and 10,000 electricity-efficient stoves by 2030. • Reduction of industrial energy demand by 10% to 20% by 2030. • Replace fuel oil with natural gas in 180 MW Nouakchott plant in 2025. • 200 MW natural gas power plant in 2025. • Extend solar PV capacity to a cumulative installed 100 MW in 2030. • Installation of a new 300 MW natural gas power plant. • Implement the National Electricity Grid Development Programme which aims to connect more than 25 isolated grids to the core grid.
National Clean Cooking Target	
50% rural and 100% urban access by 2030	
National Renewable Energy Target	
50% renewables share of electricity generation	
National GHG Target	
Cut emissions by 11.0% (unconditional) and 81.5% (conditional) relative to BAU (18.8 Mt CO_2e) by 2030	

Sources: UNFCC, IRENA, AFREC, World Bank, WRI, Country Energy Ministries, IEA, OE Africa


GCB TOWER
Pedestrians Shopping Mall
tigo
Dr. Sika Asem
"Believe in Ghana

4. THE ENERGY OUTLOOK TO 2050

The status quo assessment highlighted distinguishing features that characterise the primary energy and electricity environments of Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. The differences in each country's source composition and volume of energy and electrical supply were analysed, along with the sectoral makeup of total final energy consumption. Subsequently, their climate and energy commitments, policy frameworks, and strategies were evaluated, further signalling how their energy landscapes could evolve into the future.

"Sharp increase in energy supply is required to meet policy and development goals."

A key finding that emerged is that **the countries are already undergoing internal energy transitions**. While such transitions are commonly regarded as the sustained displacement of fossil fuels by renewable energy and complementary technologies, it is imperative to consider these structural shifts within the distinct developmental contexts of each country. This entails important implications for their future demand and supply profiles.

4.1 SCENARIO DESCRIPTION

The potential sources of energy supply in each country are informed by the historic development of their respective energy systems and natural resource endowments that could be viably exploited for energy and electricity security. The degree to which these sources can be utilised is concurrently informed by the countries' developmental needs, extent of energy poverty, and aspirations for energy autonomy and industrial progress. It is within this context that the appraisal of the countries' energy status quo and policy frameworks offered valuable insights that guide the modelling approach and scenarios for projecting their primary domestic energy and electricity supply trajectories between 2020 and 2050.

The methodological approach and scenario design is described in the **annexure**. The following two scenarios were constructed to underpin the projections of how the countries' respective energy pathways may practically unfold into the future:

- **Policy Goals (PG):** This scenario accounts for the existing stated policy ambitions and projects of the countries included in this study. It considers the timing and viability associated with their likely implementation, whilst prioritising the need to retain energy security, expand access in line with commitments, and improve affordability.
- **Accelerated Growth (AG):** This scenario builds on the PG scenario and also considers accelerated industrial and economic growth, the drive to achieving full access to electricity and clean cooking alternatives, and limiting GHG emissions associated with a higher volume of energy demanded by increased economic expansion. In that regard, the AG scenario includes the faster adoption of relevant renewable energy sources and related technologies, as well as the swifter uptake of natural gas in their energy and electricity systems relative to other fossil fuels.

Due to the lack of adequate domestic production volumes and access rates, both scenarios involve a significant expansion of primary energy and electricity supplies to meet projected future demand. This may affect their ability to reduce GHG emissions in aggregate. Any projection of the future is notoriously characterised by uncertainty spanning political, economic, environmental, social, financial, and technological aspects. The outlook for energy and electricity should therefore not be construed as a prescription of how the future will unfold, but rather as likely future pathways based on the scenarios outlined above. Even so, the approach followed offers valuable insights into the future energy transition that may emerge within and among the group of countries.

4.2 PRIMARY DOMESTIC ENERGY SUPPLY

Before considering the energy market outlook for each country individually, four salient features arise for the collective group. Firstly, the dominance of traditional **biomass gradually dissipates over time** as the residential use of firewood and charcoal gives way to electricity and cleaner cooking fuels, thereby also abating pollutants that are toxic to human health and the environment. The proportional decline in biomass is faster under the AG scenario than in the PG scenario.

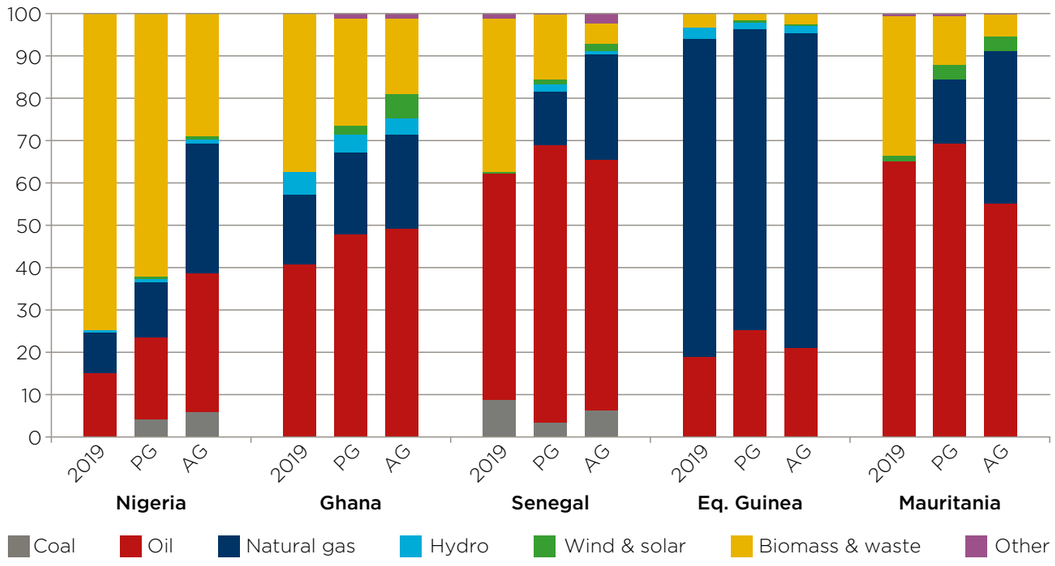
Secondly, while total domestic primary energy supply is lower in Nigeria and Senegal in the AG scenario than in the PG scenario, the AG scenario involves a **larger volume of energy in all five countries** when traditional biomass is excluded. This is largely a function of faster economic growth and development under the AG scenario, which in turn necessitates the accelerated uptake of other forms of energy to fuel industrial expansion, transport, and universal electrification.

Thirdly, in both scenarios, coal and renewable energy are expected to play much smaller roles in the future energy mixes of the countries relative to natural gas and oil. This can be ascribed to the sheer volume of hydrocarbon deposits that the countries possess and would still exploit, not only to fuel their domestic economies amid rising demand, but also to earn much-needed foreign exchange and fiscal revenues through exports.

"Primary energy demand will continue to rise, largely fuelled by natural gas."

Figure 5: Composition of domestic primary energy supply by 2050

% share



Sources: IEA, OE Africa

Existing and expanding upstream and downstream infrastructure further support the creation of indispensable jobs and drive economic expansion. Although the decarbonisation of global energy systems will continue to gain pace, the five countries would concurrently aim to benefit from their fossil fuel reserves as long as demand for it exists to strengthen external trade balances and bolster foreign reserves. These fuels are also integral to energy security and independence.

“Energy security and self-reliance are crucial to counter geopolitical disruptions.”

The recent escalation in geopolitical risks emphasised the challenges countries face when they are overly reliant on single suppliers of hydrocarbons and the impact of such tensions on commodity prices.

This has highlighted the need for countries to diversify their international suppliers of, and markets for, hydrocarbons, which would further encourage the countries to attract foreign investment and commercialise their untapped and underdeveloped hydrocarbon resources.

That said, the ongoing uptake of renewable energy, particularly solar and wind, is anticipated to endure in the five countries, which would also be accompanied by the adoption of natural gas.

Fourthly, viewed against their historical energy profiles, **oil and natural gas continue to gain prominence in the group’s aggregate supply under both scenarios**. The degree, however, to which natural gas grows relative to oil, or vice versa, differs among the group, as well as within each country over time.

Except for Nigeria and Ghana, the AG scenario generally involves less oil expansion relative to natural gas in comparison to the PG scenario, while the uptake of gas is also greater in volume under the AG scenario.

This could mainly be attributed to the AG scenario’s larger need to limit carbon emissions, balance intermittent renewable energy in the electrical power sector, and reduce the prevalent use of traditional biomass, whilst still supporting accelerated economic growth and development.

Additionally, each country’s energy trajectory differs in scope, volume, and composition.

NIGERIA

In the **PG scenario**, primary domestic energy supply grows by a CAGR of 1.3%, from 157.5 Mtoe in 2019 to 180 Mtoe in 2030 and 237 Mtoe in 2050.

Biofuels & waste account for most of the supply, mainly in the form of traditional biomass, followed by oil and natural gas. Oil production remains constrained in the medium term due to the slow implementation of reforms and growing foreign competition, while domestic industry and electrical power plants still drive gas demand.

Coal production also grows, but remains small as a share of total supply, while hydro, wind, and solar energy similarly rises, but remain small as a share of total primary energy. In the next decade, 212.6 Mtoe from prospective oil projects and 290.8 Mtoe from natural gas projects are likely to enter commercial operations for domestic use and export.

In the **AG scenario**, total primary energy supply declines to 111.5 Mtoe in 2030 before returning to 2019 levels in the 2040s and a total of 176.3 Mtoe by 2050.

The use of traditional biomass drops sharply as the energy sector diversifies and more people gain access to electricity and cleaner cooking fuels through urban gas networks and liquefied petroleum gas (LPG).

Oil dominates the energy mix by 2030, whereafter natural gas progressively grows, supported by the execution of reforms related to the PIB that aims to significantly expand the country’s gas market. Nigeria continues to be the group’s largest economy and industrial base, whilst chemicals production and the vehicles fleet grow significantly, driving the country’s demand for natural gas and oil.

GHANA

In the **PG scenario**, total domestic energy supply grows by a CAGR of 2.3%, from 11.3 Mtoe in 2019 to 14.7 Mtoe in 2030 and 22.6 Mtoe in 2050.

Both oil and gas supplies continue to increase over the forecast horizon, although oil maintains the largest share of total domestic energy, which is mainly consumed by transport. By 2027, around 54.1 Mtoe from prospective oil projects and 2.5 Mtoe from natural gas projects are likely to enter commercial operations. The uptake of renewable energy increases significantly from a low base in the 2030s, but remains a minor portion of total domestic energy supply to 2050.

In the **AG scenario**, primary domestic energy supply grows by a CAGR of 3.7% to 16.1 Mtoe in 2030 and 34.9 Mtoe in 2050.

This scenario is similar to the PG scenario, although oil and natural gas supplies increase at a faster pace, while renewable energy also rises to represent a larger share of total domestic energy. Ghana remains a large steel and aluminium producer, while growth in primary energy is contained by the realisation of energy efficiency standards.

SENEGAL

In the **PG scenario**, Senegal’s domestic energy supply grows by a CAGR of 4.4%, from 4.8 Mtoe in 2019 to 8.9 Mtoe in 2030 and 18.3 Mtoe in 2050.

While the share of oil, all of which is currently imported, is projected to rise, natural gas grows into a key source to fuel rising electrical, industrial, and export demand. This will also reduce the use of traditional biomass.

Senegal is an emerging gas market, boosted by recent oil and gas discoveries. By 2025, 32.9 Mtoe from prospective oil projects and 32.1 Mtoe from natural gas projects are set to enter commercial operations. The latter includes the country’s Yakaar-Teranga gas field with approximately 25 Tcf of gas reserves, but excludes around 279.8 Mtoe from the Greater Tortue Ahmeyim floating liquefied natural gas (LNG) project that is being jointly implemented with Mauritania. Senegal and Mauritania each own 50% of the total discovered gas reserves of the Greater Tortue Ahmeyim hub, which is estimated to be 25 Tcf. The first phase of the Greater Tortue Ahmeyim LNG project is expected to be completed by end-2023 and will produce 2.5 Mtoe per year.

In the **AG scenario**, primary domestic energy supply also grows by a CAGR of 4.4% to 7.9 Mtoe in 2030 and 18.2 Mtoe in 2050.

Growth in energy demand relative to the PG scenario is contained through the commercialisation of recent natural gas discoveries, which partly offsets primary oil supply and is accompanied by a rising share of renewable energy.

As a result, natural gas supply expands at a faster pace and in larger volumes to supply swelling industrial undertakings. Moreover, the traditional use of biomass declines significantly in rural areas through improved access to electricity and cleaner cooking fuels, enabled through the enhanced availability of natural gas and complemented by renewable energy.

The rise of natural gas in the energy mix is, however, contingent on the country’s development of natural gas strategies that encompass the entire gas value chain.

EQUATORIAL GUINEA

In the **PG scenario**, the country's domestic energy supply grows by a CAGR of 5.1%, from 2 Mtoe in 2019 to 4.1 Mtoe in 2030 and 9.5 Mtoe in 2050.

Although the small country's primary energy supply has dwindled over the past decade in sync with lower industrial demand, oil and natural gas supply is anticipated to expand as industrial and electrical power demand is reinvigorated, coupled with government investments in pipelines.

While crude oil output would continue to diminish from mature fields and absent of new discoveries, the country's natural gas supply is projected to rise sharply given reserves of around 1.3 Tcf. Most of the natural gas output will, however, be destined for export markets amid the relatively modest size of its domestic industry and transport sectors.

Among others, around 36.5 Mtoe from a natural gas project is set to enter commercial operations in 2025.

In the **AG scenario**, primary domestic energy supply grows by a CAGR of 5.3% to 4.7 Mtoe in 2030 and 10 Mtoe in 2050. This scenario is very similar to the PG scenario with the main difference being a faster phasing out of oil and a slightly larger uptake of gas and renewable energy.

The country also delivers on its gas master plan and establishes itself as a regional gas hub and processing centre.

MAURITANIA

In the **PG scenario**, Mauritania's domestic energy supply grows by a CAGR of 3.5%, from 1.6 Mtoe in 2019 to 2.6 Mtoe in 2030 and 4.5 Mtoe in 2050.

The country still relies on imported oil to fuel industry, transport, and agriculture. Even so, vast gas discoveries between 2015 and 2017 sees natural gas rising from 2023 to denote around 15.2% of domestic supplies by 2050 to fuel sectoral growth and power plants.

Around 279.8 Mtoe of natural gas projects could be operational by 2027, which comprises 72.3 Mtoe from the Greater Tortue Ahmeyim floating LNG project (start-up anticipated at the end of 2023) and 207.5 Mtoe from the related gas hub (2025) that is being developed on the country's maritime border with Senegal. The Greater Tortue Ahmeyim gas hub comprises around 25 Tcf of natural gas, half of which belongs to Mauritania, while the other 50% is owned by Senegal. The BirAllah gas field is further poised for development in Mauritania, which is estimated to comprise a total of 50 Tcf of recoverable gas reserves. The total reserves of the BirAllah hub includes both the Marsouin and Orca discoveries.

Due to the difficulty of, and costs associated with, extending the electric grid and clean fuels to remote areas, a large segment of the population continues to rely on traditional biomass.

In the **AG scenario**, primary domestic energy supply grows by a CAGR of 3.7% to 2.4 Mtoe in 2030 and 4.8 Mtoe in 2050.

Natural gas rises more prominently in the energy mix once the country's gas masterplan is finalised and the LNG hub becomes operational to represent 23.6% of total domestic supplies by 2030 and 36.1% by 2050, while the use of traditional biomass is also lower. In both scenarios, solar energy experiences ongoing growth, but remains small in relation to oil and natural gas.

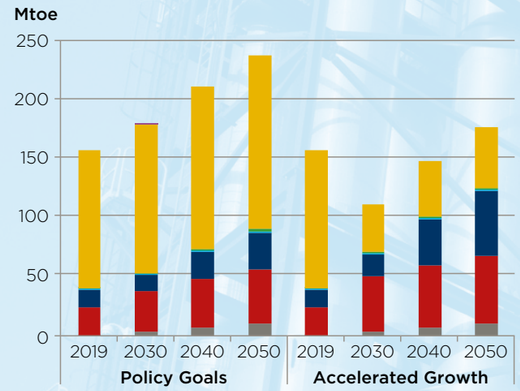
SNAPSHOT

DOMESTIC PRIMARY ENERGY OUTLOOK

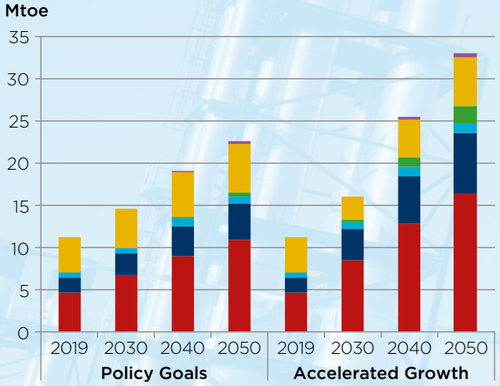
Natural gas
Oil
Coal
Other
Solar & wind
Hydro
Biomass & waste

Sources: IEA, OE Africa

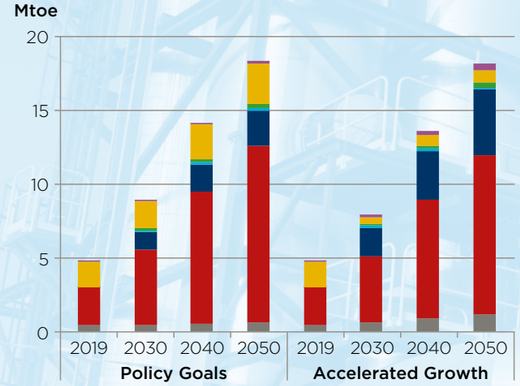
Nigeria



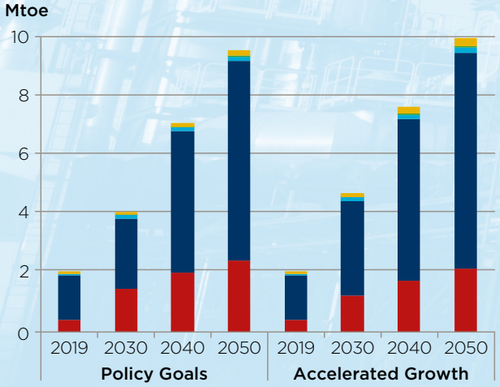
Ghana



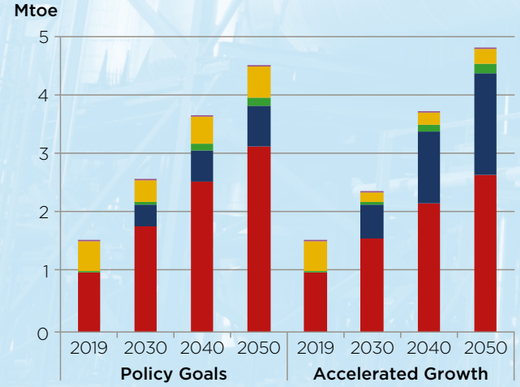
Senegal



Equatorial Guinea



Mauritania



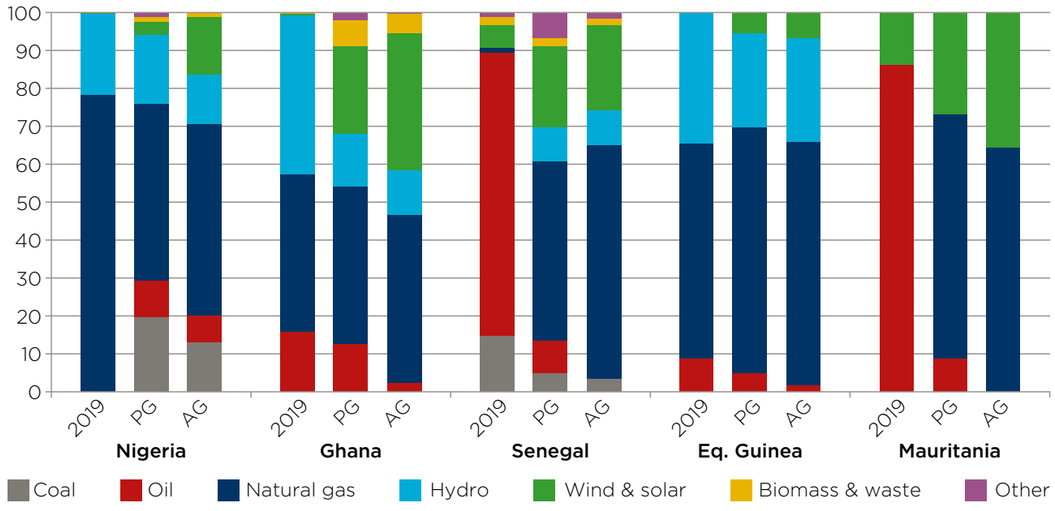
4.3 ELECTRICITY PRODUCTION

In addition to the observations outlined for the group's projected domestic primary energy supply profiles, further salient features arise concerning their collective electricity production outlooks. **The electricity systems within the group will continue to expand rapidly and diversify.** This is especially evident in the AG scenario as more electricity is required to power greater economic and industrial development, as well as to broaden electricity access to the average of 35.7% of the countries' collective populations who are still without it. Similarly, **the AG scenario sees a larger interplay between natural gas, hydro, and non-hydro renewable electrical generation options to lower carbon emissions in pursuit of the SDGs.**

"Electricity supply rises sharply and is progressively diversified, driven by natural gas and renewables."

Principally, gas-to-power is expected to dominate the countries' electricity industries and expands at a faster pace than oil-based electrical power generation, including in Senegal and Mauritania where oil has to date accounted for over three quarters of electricity production. This is the case under both scenarios, although gas-based electricity generation is significantly larger in the AG scenario. Oil's share in total electricity production subsequently declines in both scenarios as electrical capacity additions from gas, hydro, solar, and wind plants lead the energy transition within the group. This is primarily due to the size of exploitable reserves and the growing importance of natural gas in the energy landscapes and economies of these countries, including for energy security, self-reliance, and to reduce the relative carbon intensity of their electrical power industries in parallel with renewable energy options.

Figure 6: Composition of total electricity supply by 2050



Sources: IEA, OE Africa

The implementation of gas-to-power also accelerates as renewable energy increasingly penetrates electric grids over the forecast horizon. This is due to the operational capability of gas-fired power plants to be flexibly dispatched to overcome bouts of intermittent electrical production from solar and wind plants, as well as to supply electricity during peak demand periods. The AG scenario therefore involves significantly more electricity supplied by non-hydro renewable energy plants.

Hydropower production continues to play an essential role in all countries other than Mauritania, which imports hydroelectricity from neighbouring countries via the Senegal River Basin Development Authority framework but has little domestic hydro energy potential, and remains fairly constant in both the PG and AG scenarios. **The relative share of hydroelectricity generation, however, gradually declines over the forecast horizon as the group reduces their reliance on hydropower amid increasing intervals of drought and the adverse impact it can have on national electricity supplies and energy security.**

As is the case with primary energy, each country's future electricity production mix differs in size, volume, and composition.

NIGERIA

In the **PG scenario**, electricity production rises by a CAGR of 5.9%, from 31.4 TWh in 2019 to 90 TWh in 2030 and 184.1 TWh by 2050. Nigeria's electricity system remains the largest in the group by far and becomes increasingly diversified over time from its current reliance on natural gas and hydroelectricity. Even so, both sources remain an integral part of the country's electrical power supply, while the coal-fired power plants are also anticipated to start contributing before 2030, despite current projects having been stalled. Backup generators, however, remain widely used to overcome frequent and long periods of electrical power outages.

Under the **AG scenario,** the country's electricity production increases by a CAGR of 7.7% to 142 TWh in 2030 and 317.5 TWh in 2050. Natural gas increases to a further extent, benefiting from political commitment regarding it as a key component in Nigeria's transition to a less carbon-intensive energy system, as well as from the execution of reforms associated with the country's gas masterplan. This also enables the implementation of solar and wind plants as the country begins to take advantage of its renewable energy potential outside of hydropower. In addition to increased electricity supply, outages and losses are kept to a minimum through improved power system operations, grid management, and congestion relief, which reduces the use of backup generators and stimulates industrial development. Moreover, along with grid extension and expansion, the country invests in off-grid solutions to provide full access to electricity in remote areas.

GHANA

In the **PG scenario**, Ghana's electricity production grows by a CAGR of 3.7%, from 17.3 TWh in 2019 to 28.1 TWh in 2030 and 53.4 TWh in 2050. This is largely driven by natural gas and hydroelectricity, while the country also implements larger shares of solar and wind-based electrical generation options.

In the **AG scenario**, total electricity generation grows by a CAGR of 5.4% to 39.1 TWh in 2030 and 89.3 TWh in 2050. This scenario builds on the PG scenario, with a larger penetration of renewable energy, including from biogas and hydro, while the use of backup generation also declines substantially. Higher domestic demand requires additional natural gas imports and gradually displaces the use of oil in the electrical power and industrial sectors. While electricity demand in the AG scenario is contained through energy efficiency measures, additional demand relative to the PG scenario

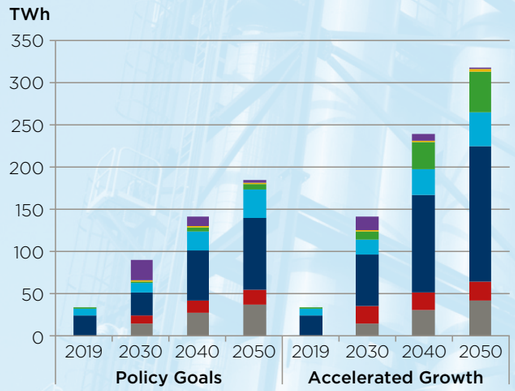
SNAPSHOT

ELECTRICITY PRODUCTION MIX OUTLOOK

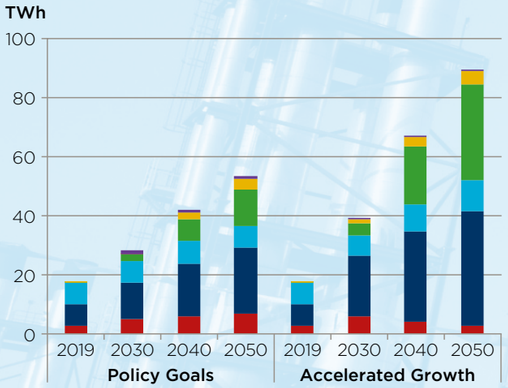
- Natural gas
- Oil
- Coal
- Other
- Solar & wind
- Hydro
- Biomass & waste

Sources: IEA, OE Africa

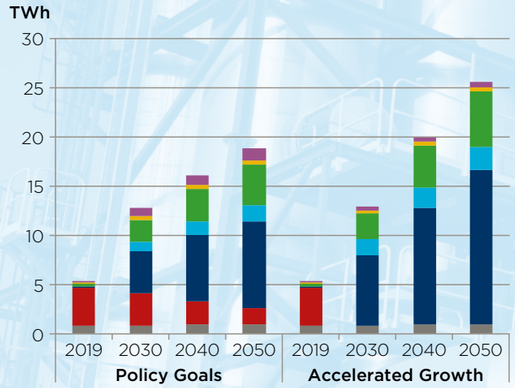
Nigeria



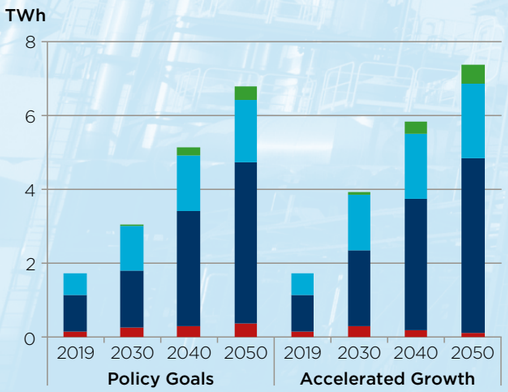
Ghana



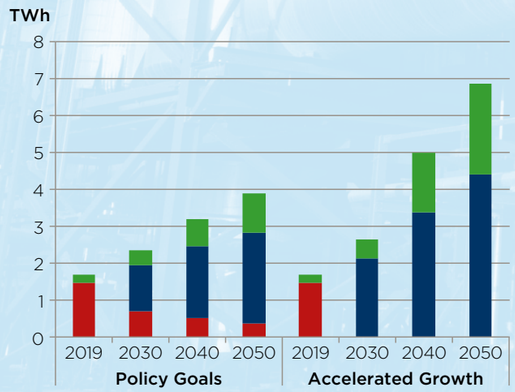
Senegal



Equatorial Guinea



Mauritania



emanates from the residential and commercial sector, as well as an expansion of bauxite mining, steel, and aluminium industries. Moreover, the remaining 16.5% of people without access to electricity gains access through grid strengthening and off-grid solutions, while access to clean cooking fuels is also stimulated through LPG, biogas, and improved cookstoves.

SENEGAL

In the **PG scenario**, Senegal's electricity production grows by a CAGR of 4.2%, from 5.2 TWh in 2019 to 12.8 TWh in 2030 and 18.8 TWh in 2050. In contrast to primary energy supply, the use of heavy fuel oil in the electrical power sector declines as a share of total electricity production and is displaced by natural gas-fired power plants, which are set to account for the majority share of electricity production from 2029 onwards. Senegal's emerging gas market is complemented by an ambitious renewable energy plan, which sees solar, wind, and hydropower representing a larger share in the electricity production mix than oil from 2031 onwards as the uptake of solar and wind plants are enabled by dispatchable gas-fired turbines. The country's first utility-scale wind farm entered commercial operations in 2021 and is likely to be extended from 158.7 MW to 258 MW, which would represent around 15.0% of total electricity supply. Additionally, while the country has to date failed to generate hydroelectricity, a 128 MW plant is expected to commence construction this year and enter commercial operations in 2026. Coal power stations continue to play a role, but supply remains stable from current levels, while its share in the electricity mix declines.

In the **AG scenario**, total electricity generation grows by a CAGR of 5.3% to 12.8 TWh in 2030 and 25.5 TWh in 2050. Electricity supply expands significantly from 2030 onwards relative to the PG scenario as natural gas completely displaces oil in electrical power generation to accommodate a mounting share of intermittent renewables. The displacement of heavy fuel oil generators, however, depends on the timely execution of the country's gas-to-power plans. In this scenario, Senegal achieves universal electricity access by 2025, mainly by extending the grid to rural areas, while remote communities benefit from off-grid solutions.

EQUATORIAL GUINEA

In the **PG scenario**, electricity production grows by a CAGR of 4.5%, from 1.7 TWh in 2019 to 3.1 TWh in 2030 and 6.8 TWh in 2050. Gas-to-power is expected to steadily displace heavy fuel oil through new investments and the conversion of turbines to be gas-fired. In that regard, natural gas development benefits from private sector participation and conducive policies, while it maintains the majority share in the electricity mix, followed by hydropower. While hydropower potential has been estimated at 2,600 MW, only half of this is viable for exploitation. Non-hydro renewables also start playing a role from 2025 onwards but represent only a 5.6% share by 2050. The country's large forest and biomass coverage suggests that solar irradiation is too low for utility-scale investments, while wind farms also offer limited opportunities. That said, underdeveloped grid infrastructure could hamper investments in the electricity sector despite growing demand.

In the **AG scenario**, total electricity generation grows by a marginally higher CAGR of 4.8% to 3.9 TWh in 2030 and 7.4 TWh in 2050. The same rationale applies as in the PG scenario, although with a slightly higher uptake of hydroelectricity and other renewables. While the country aims to become a regional gas-to-power supplier, this does not materially alter the projected electricity output. Even so, the adoption of natural gas accelerates as the government implements its gas strategy, while raising electrification rates and pursuing decarbonisation objectives.

MAURITANIA

In the **PG scenario**, Mauritania's electricity production grows by a CAGR of 2.7%, from 1.7 TWh in 2019 to 2.3 TWh in 2030 and 3.9 TWh in 2050. Gas-fired power plants still displace heavy fuel oil due to the Greater Tortue Ahmeyim LNG project. Mauritania also progressively implements large volumes of renewables, notably from solar technologies, complemented by natural gas as a transitory fuel. The country's solar irradiation potential is estimated to be 4 TWh and electrical energy derived from solar plays a key part in its electricity plans, as well as through the Desert-to-Power initiative. While the country has insufficient domestic hydropower potential, it imports approximately 129.5 MW via the Senegal River Basin Development Authority framework, which is set to grow to 217.3 MW by 2025.

In the **AG scenario**, total electricity generation grows by a CAGR of 5.1% to 2.6 TWh in 2030 and 7.8 TWh in 2050. Electricity demand rises strongly from 2030 onwards, which is entirely met by a more rapid uptake of gas-fired turbines, solar plants, and wind farms. In this scenario, the country stops relying on imported oil for electricity generation by 2030 as it successfully transitions to renewable energy where natural gas is used to supply electricity to meet baseload and peak demand, as well as during periods of renewable resource intermittency. For this goal to be realised, though, the country needs to invest in improved system operations and significant grid strengthening. Moreover, the government recently entered an agreement with the private sector to investigate the feasibility of a 10 GW 'green' hydrogen project, which could eventually raise the outlook for renewables and include hydrogen in the country's energy mix if the project is realised.

5. IMPLICATIONS FOR CARBON EMISSIONS

Having assessed the energy and electricity supply outlooks for Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania, the focus shifts to the implications thereof for carbon emissions. Specifically, the primary domestic energy supply pathways intended for use in all economic sectors are converted into the related carbon dioxide (CO_2) emissions for each country based on the relative carbon intensity of each fuel source. The methodological approach followed to determine the energy-related CO_2 emissions is described in the annexure.

“ Africa’s share of global emissions is small, yet the continent is vulnerable to climate change. ”

“ Sharp rise in energy supply needed to meet development goals, driving emissions higher. ”

5.1 OUTLOOK FOR CARBON DIOXIDE EMISSIONS

Africa accounts for a small share of global CO_2 emissions. The IEA estimates that Africa’s share of global energy-related CO_2 emissions amounted to a mere 3.3% by 2010, with this figure rising slightly to 3.8% in 2022. The continent has the lowest carbon emission per capita in the world. **Despite this negligible share, Africa is among the regions most exposed to the adverse effects of climate change**. Another notable fact is that African countries, and also specifically those covered in this study, are still faced with substantial development challenges and needs. Energy supplies will need to rise significantly to meet growing demand stemming from burgeoning populations and economic and industrial development, in addition to important considerations such as attaining energy security, energy autonomy, and ensuring universal access to electricity and clean cooking fuels.

The proportion of the population with access to electricity is exceptionally low in Mauritania (45.8%) and Nigeria (55.4%), with Senegal (70.4%) and Equatorial Guinea (66.6%) faring slightly better. Ghana records the highest access among the sample of countries with around 83.5% of its population connected to the electric grid. This suggests that meeting development objectives requires a significant expansion in energy supplies.

In turn, GHG emissions are likely to rise in the future amid the hydrocarbon reserves that the countries possess, which are also used to foster energy security and earn much-needed foreign exchange. This is confirmed in this study when the direct domestic energy-related CO_2 emissions are forecast for each of the five countries out to 2050 under both the **PG and AG scenarios. In most country cases, the rise in emissions is driven by increased domestic oil and natural gas supplies, with the mix often influencing the extent to which CO_2 emissions intensify over the long term.**

Due to the relative size of its economy, industrial base, and population, Nigeria produces the most emissions. Under the PG scenario, energy-related CO_2 emissions surge from 99.8 million tonnes (Mt) of CO_2 in 2019 to 233.3 Mt CO_2 by 2050. This swell is mainly ascribed to the increased utilisation of coal, oil, and natural gas as part of the domestic energy supply mix, with the latter fulfilling the dominant role in the electricity mix. Energy emissions leap to an even higher level of 316.9 Mt CO_2 by 2050 under the AG scenario, despite overall domestic primary energy supply being lower. However, the use of traditional biomass declines sharply, thereby avoiding harmful pollutants, with the gap being filled by higher oil and natural gas supplies that significantly raises carbon emissions.

Ghana’s energy emissions are forecast to rise from 16.9 Mt CO_2 in 2019 to 39.7 Mt CO_2 by 2050 under the PG case as more oil and gas supplies come online. Emissions are even higher under the AG case at 61.2 Mt CO_2 by 2050 as domestic oil supply increases. Natural gas supply rises to a lesser extent, but it fulfils an important role in the electricity mix.

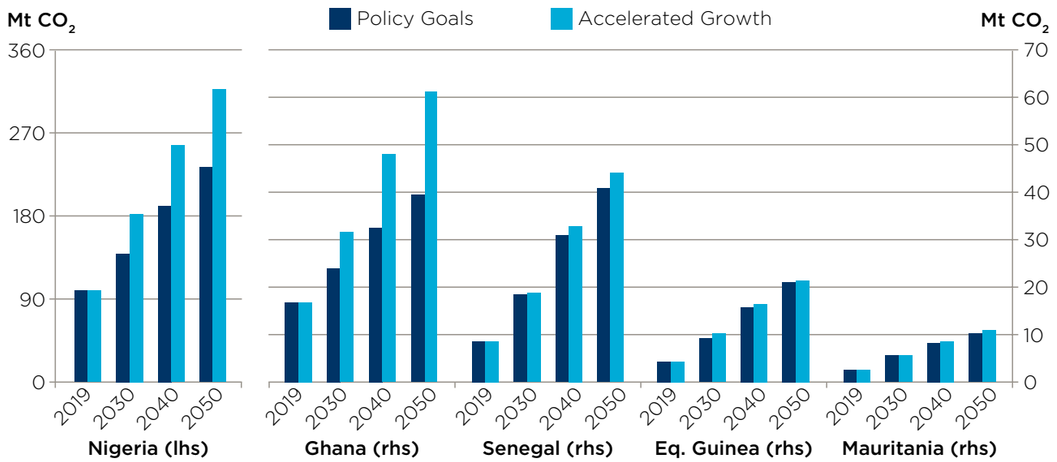
Senegal’s energy emissions are forecast to leap from 8.8 Mt CO_2 in 2019 to 41.0 Mt CO_2 under the PG case and to 44.2 Mt CO_2 under the AG case. Oil and natural gas supplies are assumed to ramp up sharply, but a comparatively stronger increase in natural gas limits the increase in emissions under the AG scenario, which sees natural gas accounting for 61.5% of the electricity mix by 2050.

Equatorial Guinea’s energy emissions rise from 4.3 Mt CO_2 in 2019 to 21.2 Mt CO_2 by 2050 under the PG case and to 21.7 Mt CO_2 under the AG case, with domestic natural gas supply rising significantly over the forecast period. Similar to Senegal, natural gas displacing some of the rise in oil under the AG scenario counteracts the rise in emissions.

In Mauritania, energy emissions increase from 2.8 Mt CO_2 in 2019 to 10.3 Mt CO_2 by 2050 under the PG case and to 11.1 Mt CO_2 under the AG case. Despite a higher level of total domestic energy supplies, the sharp escalation in natural gas negates the rise in emissions under the AG scenario.

“ Rise in emissions mainly due to sharp increase in oil and natural gas supplies. ”

Figure 7: Energy-related carbon dioxide emissions



Source: OE Africa

“ While emissions rise over time, the countries’ shares of global emissions remain marginal. ”

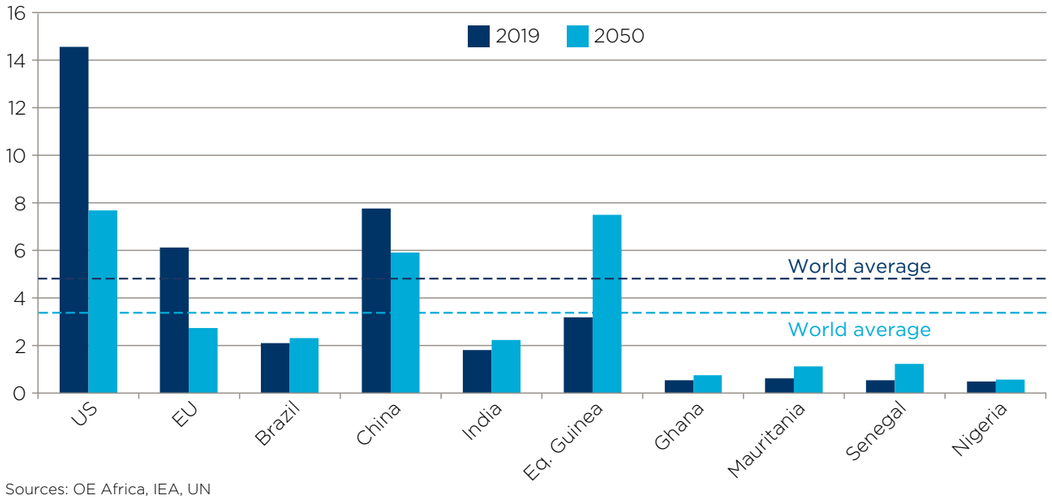
While emissions increase over the long term in most countries, their respective and combined contributions to global emissions remain minor. Nigeria’s share of global emissions rises from 0.3% in 2019 to 0.8% by 2050, while the combined shares for the other countries increase from 0.1% to 0.3% over the same period. The collective emissions from all five countries still represent only 65% of Brazil’s emissions by 2050, and this figure declines to just 21% if Nigeria is excluded.

On a per capita basis, most of the countries covered in this study are expected to experience growing CO_2 emissions trajectories, mainly as they start from a very low base and aim to expand supplies significantly to meet policy and development objectives, such as improving access to electricity.

Despite this, CO_2 emissions remain low for most of the countries. In fact, the amount of CO_2 emissions is close to or even below one tonne per person in Nigeria, Ghana, Senegal, and Mauritania. **This is still broadly two to three times lower than per capita emissions in the EU, Brazil, and India by 2050.**

The only exception is Equatorial Guinea, where CO_2 emissions per capita already stood at 3.2 tonnes in 2019. Due to the anticipated increase in oil and natural gas supplies in line with expanding industrial activity, government investments, and rising electricity demand, CO_2 emissions per capita are seen rising to 7.5 tonnes by 2050. However, these figures need to be viewed against the fact that Equatorial Guinea’s CO_2 emissions remain marginal in general, and the country’s tiny population serves to inflate emissions on a per capita basis. With focused attention on responsible operations in its oil and gas sector, Equatorial Guinea’s per capita emissions intensity could be reduced.

Figure 8: CO_2 emissions per capita



Sources: OE Africa, IEA, UN

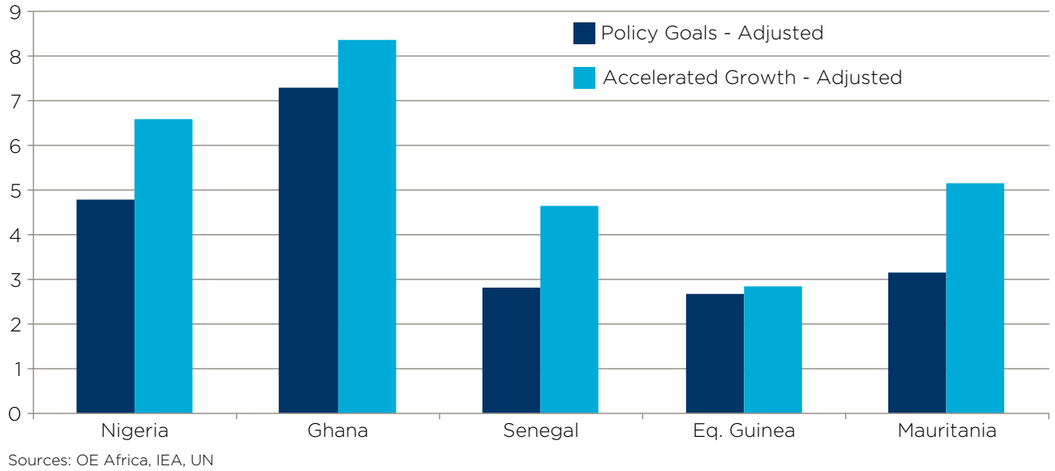
5.2 SIGNIFICANCE OF NATURAL GAS TO LIMIT CO_2 EMISSIONS

As indicated in this study, the increase in domestic primary oil and natural gas supplies is central to the countries reaching their development goals, energy security, and self-sufficiency in a changing global landscape. While oil and natural gas represent the main drivers of rising CO_2 emissions, different trajectories in terms of their uptake hold significant implications for carbon emissions. **In all cases, natural gas fulfils the dominant role in electricity supply by 2050. But what if this was not the case? Delving into this trade-off, the focus is hypothetically shifted to a future** in which natural gas plays less of a transitory role. To achieve this, the two scenarios are adjusted so that the amount of electricity produced from natural gas is reduced by 50% in each country and fictitiously replaced by oil. This shift affects both the electricity and primary energy supply mixes. The CO_2 emissions from these new scenarios, named ‘PG - Adjusted’ and ‘AG - Adjusted’, are compared with their respective counterparts to examine the differences.

If oil presumably had to displace 50% of electricity produced from natural gas, energy-related CO_2 emissions would be between 2.7% and 7.3% higher compared with the PG case, depending on the country under consideration, and between 2.9% and 8.4% higher compared with the AG case. Put differently, **the faster uptake of natural gas at the expense of oil in electrical power generation would reduce carbon emissions by an average of 4.2% or 72.3 Mt CO_2 under the adjusted PG scenario and by an average of 5.5% or 96.9 Mt CO_2 under the adjusted AG scenario.** The respective differences are driven by various factors, including the size of the electrical power sector (small electricity sectors relative to overall primary energy supplies also negate the impact) and the importance of each resource in the electricity and domestic primary energy supply mixes.

“ Displacing oil with natural gas in electricity will limit carbon emissions over the long term. ”

Figure 9: Percentage difference in CO_2 emissions when oil displaces gas



Sources: OE Africa, IEA, UN

6. CONCLUSION

This study assessed the future energy landscapes of Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. In doing so, the past development of their energy and electricity profiles was analysed, complemented with a review of their existing energy sector strategies and climate commitments.

"Economic fundamentals and development needs inform the nature of energy transitions."

The energy status quo and policy evaluation established the countries' supply and demand dynamics, as well as the extent of their current ambitions to transition to more environmentally sustainable energy systems. It also contextualised their energy frameworks and informed the methodological inputs, assumptions, and scenario design for modelling the primary domestic energy and electricity supply trajectories between 2020 and 2050.

"Large increase in energy and electricity supply is needed to reduce energy poverty."

Two scenarios were constructed to underpin projections of how the countries' respective energy transition pathways may practically unfold into the future. The **PG scenario** accounts for the stated policies and projects of each country, while the **AG scenario** further considers faster economic growth, eradicating energy poverty, and limiting emissions associated with a higher volume of energy demanded to fuel accelerated industrial development. The methodology was subsequently used to forecast the volume and composition of the countries' individual primary energy and electricity outlooks to 2050, as well as the likely implications for climate change.

While the energy transition encompasses a structural shift from fossil fuel-based systems to renewable energy-based systems, often with gas utilised as a transition fuel, it is important to consider such transitions within individual country circumstances and development needs. It is in this spirit that transitioning to environmentally sustainable, low-carbon energy systems need to be socially inclusive and just. In that regard, the specific economic and development settings and requirements of the countries appraised in this study demonstrated that their **energy transitions will likely be distinct.**

The populations of these countries face stark energy poverty and are excessively reliant on the harmful incineration of traditional biomass, such as firewood, charcoal, or other materials. Only 64.3% of their collective populations have access to electricity, while a mere 25.4% benefit from cleaner cooking fuels and technologies. At the same time, energy demand is set to continue outstripping supply, driven by rapid population growth, industrial development, and socio-economic upliftment. Starting in 2020 and depending on the country, it is forecast that total domestic **primary energy supplies will have to increase by between 1.3% and 5.3% and electricity generation by 4.6% to 7.7% on average per year out to 2050.**

A key finding from this study is that energy transitions are already underway in the countries selected for the analysis. Oil and natural gas will, however, continue to grow in the countries' primary energy systems, while natural gas will **generally complement rising shares of renewables in electricity production.** These hydrocarbons are not only essential to their fiscal, economic, social, and developmental outlooks, but are also of geostrategic significance in a changing global energy landscape. Even so, renewable energy and complementary technologies will concurrently continue to gain in prominence, although from very low bases at present.

The AG scenario generally involves less oil expansion relative to natural gas, mainly as the scenario focuses on limiting carbon emissions and balancing larger volumes of variable and intermittent electrical energy output from renewables. In terms of electrical power generation, the countries' electricity systems will still expand rapidly and become increasingly diversified. **Gas-to-power is expected to dominate the countries' electricity industries by 2050 in most cases.** Oil is seen to play a progressively negligible role to generate electricity, being displaced by natural gas and non-hydro renewables such as wind and solar.

Due to the lack of adequate domestic production volumes and access rates, both scenarios involve a significant expansion of primary energy and electricity supplies to meet projected future demand. The need to substantially increase their absolute volumes of energy and electricity supplies suggests an accompanying rise in carbon emissions if these countries are going to meet their developmental goals and objectives. As a result, carbon neutrality is not achieved over the forecast horizon given the countries' existing reliance on fossil fuels, although the AG scenario contains the relative growth in emissions through the deployment of more renewable energy and natural gas technologies than would otherwise be the case. **While carbon emissions increase over the long term in most countries, their contributions to global emissions remain marginal** in both scenarios. Nigeria's share of global energy emissions rises from 0.3% in 2019 to 0.8% by 2050, while the shares for the other countries remain below a mere 0.2%.

Concurrently, the historical dominance of traditional biomass dissipates over time as the residential use of firewood and charcoal gives way to electricity and cleaner cooking alternatives. As a result, the rise in energy sector emissions would also be accompanied by fewer toxic pollutants stemming from traditional biomass.

Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania will persist in their pursuit of just energy transitions within their individual development circumstances and needs. Oil and natural gas are central to the countries' macroeconomic and socio-economic progress, complemented by the growing geostrategic importance of natural gas globally. The hydrocarbons that these countries possess further support their drive to energy security and self-sufficiency.

"Natural gas to fulfil a prominent role in countries' future energy transitions."

As a result, sudden disruptive changes to the energy trajectory in these countries, such as through the aggressive phasing out of fossil fuels, will not only jeopardise their energy systems, but may also have serious economic, social, and developmental repercussions. It is within this context that the energy transition in the countries selected for this study will be challenging and differ from the approach followed by other countries.

"Emissions rise as increased energy supply supports economic development, but remain marginal."

"Restricting hydrocarbons in these countries will have serious developmental consequences."

Energy transitions in Western and Central Africa
OXFORD ECONOMICS AFRICA

SOURCES

Africa Energy Commission
Equatorial Guinea: Ministry of Mines, Industry, and Energy
Equatorial Guinea: Ministry of Fishing and Environment
Ghana: Energy Commission
Ghana: Ministry of Energy
Ghana: Ministry of Lands and Natural Resources
International Energy Agency
International Renewable Energy Agency
Mauritania: Ministry of Petroleum, Energy and Mines
Mauritania: Ministry of Environment and Sustainable Development
Nigeria: Federal Ministry of Environment
Nigeria: Federal Ministry of Power
Nigeria: Ministry of Petroleum Resources
Nigeria: Energy Commission of Nigeria
Senegal: Ministry of Energy, Industry and Mines
Senegal: Ministry of the Environment and Sustainable Development
United States Energy Information Administration
World Bank
World Resources Institute (WRI)

METHODOLOGY

DERIVING ESTIMATES OF FUTURE ENERGY LANDSCAPES

This study provides forecasts for primary domestic energy and electricity supplies by source. These forecasts extend out to 2050 for each of the countries covered in the assessment, namely Nigeria, Ghana, Senegal, Equatorial Guinea, and Mauritania. The methodology followed to inform forecasts of primary domestic energy supplies, electricity demand, and the composition of energy and electrical supply by source broadly entailed the following initial steps:

- **Status quo assessment:** This affords insight into recent trends and shifts in the countries' energy mixes and also provides an indication of existing resource availability, production, and utilisation.
- **Policies, plans, and commitments:** An analysis of the countries' plans, strategies, and energy commitments (including NDCs) in terms of energy transitions provides important information on their strategic goals (quantitative targets or more qualitative statements) for the future.
- **Literature review:** A review of credible sources pertaining to developments in the countries' energy and electrical power sectors, including large projects in the pipeline, which informs the practicality of the stated policies and plans, the related inputs and assumptions, and the feasibility of projections.

The findings from the assessments above subsequently informed the assumptions underpinning the eventual forecasts. A scenario-based approach was also deemed most appropriate, as it ensures a more holistic view of possible energy transition trajectories. The 'Stated Policies' and 'Africa Case' scenarios employed by the IEA have become authoritative sources in the literature. According to the IEA, the Stated Policies case reflects a measured assessment of countries' policy frameworks and plans, also bearing in mind the institutional, regulatory, infrastructure, and financial considerations which may affect implementation prospects. The Africa Case, meanwhile, is based on the goals outlined by the African Union's Agenda 2063. It assumes faster economic expansion and industrial development across the continent to reach the Agenda 2063 objectives, while also assuming the full achievement of key SDGs by 2030, such as 100% access to electricity and clean cooking fuels by 2030.

A similar approach was followed in this study, but the underlying assumptions were adapted based on adjusted policy objectives and other changes related to the energy landscapes of each country specifically or economic and institutional changes more broadly. In summary, the forecasts are underpinned by two scenarios as follows:

- **Policy Goals (PG):** Accounts for the existing stated policy ambitions and projects of the countries included in this study, as well as the timing associated with their likely implementation as a means to realise the future pathway of viable energy and electricity sources, whilst prioritising the need to retain energy security, expand access in line with commitments, and improve affordability.
- **Accelerated Growth (AG):** Builds on the PG scenario and also considers accelerated industrial and economic growth, the drive to achieving full access to electricity and clean cooking alternatives, and limiting GHG emissions associated with a higher volume of energy demanded by increased economic expansion. Regarding the latter, the AG scenario includes the faster adoption of relevant renewable energy sources, related technologies, and swifter uptake of natural gas in energy and electricity systems relative to other fossil fuels.

ESTIMATES OF CARBON DIOXIDE EMISSIONS

In this study, direct domestic energy-related CO_2 emissions are forecast for each of the five countries out to 2050 under each of the two scenarios: the PG and AG scenarios. The estimates and forecasts of primary domestic energy supplies are translated into carbon and carbon dioxide emissions for each country based on the relative carbon intensity of each fuel source. The carbon dioxide intensity of each fuel was sourced from the US Energy Information Administration and converted into carbon intensity, broadly using the conversion factors below:

	Kg CO_2/MMBtu	Kg Carbon/MMBtu
Coal	93.35	25.5
Oil	76.50	19.3
Natural gas	53.07	14.7

Note: 39,680,000 MMBtu = 1 Mtoe and 1 g carbon = 3.664 g CO_2

The study also investigates the implications of a hypothetical future energy transition where oil fulfils a more prominent role. To achieve this, the two scenarios are adjusted based on the following assumption: for each country and under each scenario, the amount of electricity produced in TWh from natural gas is reduced by 50%, with this gap being filled by oil (total electricity output in TWh is kept unchanged). Subsequently, the following conversion factor is used: 1 TWh = 0.086 Mtoe.

Furthermore, assumptions are needed in relation to power generation efficiencies. These efficiency factors provide an indication of the efficiency of power plants to convert primary energy into electrical power. Various factors, aside from the type of fuel used, play a role in this regard. Losses occur as a result of the energy transformation process, while the type of plant (older plants are generally less efficient) and the technologies used are also factored in. Based on a review of the data and literature, we opted for conservative efficiency factors, ranging from 35% to 45%. Natural gas is assumed to have a higher efficiency factor compared with oil. In both cases, efficiency gains are assumed over the forecast period to account for new plants being commissioned and technological advancements.

After the changes to the electricity supply mix, the above assumptions are used to derive the domestic primary energy supply changes required for oil and natural gas. This then allows for computing the energy-related CO_2 emissions for the adjusted scenarios and to compare this with the PG and AG scenarios, respectively.

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