Nigeria Energy

In collaboration with

Energy & Utilities

Renewable Energy Roadmap Nigeria

Summary of key recommendations and findings

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Credits to:

IRENA
International Renewable Energy Agency

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Foreword

"Nigeria has therefore reached a vital juncture at which it must decide whether to maintain its reliance on fossil fuels – accepting the inevitable environmental and economic risks that path entails – or capitalise on its ample indigenous renewable energy resources to drive economic development, decrease energy costs and significantly reduce its greenhouse gas emissions.

This renewable energy roadmap for Nigeria was developed in collaboration with the Energy Commission of Nigeria and offers a long-term perspective to 2050 guided by The International Renewable Energy Agency's (IRENA) World energy transitions outlook.

As Nigeria commits to ever more ambitious climate targets, including net-zero commitments, planning must begin now in earnest. Nigeria has a unique opportunity to develop a sustainable energy system based on renewable energy resources that can support socio-economic recovery and development while addressing climate change mitigation and adaptation strategies and accomplishing energy security, universalisation and affordability goals."

Francesco La Camera
Director-General
International Renewable Energy Agency

"Sustainable energy is the driver of modern development. The availability of adequate, reliable, sustainable and cost-effective energy is important for the socio-economic development of any nation. Given Nigeria's progress in this regard, it is necessary to continue identifying options for scaling up sustainable energy supply to achieve Sustainable Development Goals (SDGs) in the country.

IRENA has developed this Renewable Energy Roadmap (REMap) for Nigeria through the Energy Commission of Nigeria and in collaboration with energy professionals and relevant Ministries, Departments and Agencies in the country. By providing this thorough assessment, it is hoped that individuals, firms and governments can be encouraged to embrace renewable energy to benefit the national economy and the lives of the Nigerian people."

Senator (Dr) Adeleke Olorunimbe Mamora
Honourable Minister
Federal Ministry of Science, Technology & Innovation
Federal Republic of Nigeria

Introduction

The Federal Republic of Nigeria is the most populous country and largest economy on the African continent. It is home to one of the fastest-growing populations globally, which has led to a rapidly increasing demand for energy services that will be key to unlocking economic development. This presents a substantial opportunity to develop the country's rich natural renewable energy resources and unlock low-carbon growth.

Nigeria has sizeable renewable potential and has already made some promising strides towards increasing the domestic deployment of renewable energy. As a result, Nigeria has the potential to play an important role in the global energy transformation. IRENA and the Nigerian Energy Commission collaborated on this Renewable Energy Roadmap project, also referred to as REmap Nigeria, to explore how best to unlock the country's renewable energy potential while ensuring tremendous sustainable growth.

This study analyses the additional renewable energy deployment potentials out to the year 2050 in close consultation with key stakeholders, with an additional 2030 focus to aid shorter-term policy development, across the Nigerian energy system and, as a result, provide additional context for energy policy discussions of how increased ambition in terms of renewable energy, beyond the current government policy and targets, can be realised.

The country analyses follow the approach of:

- Building the Planned Energy Scenario (PES); this represents the baseline for energy demand and fuel mix out to 2030 based on current policies and strategies at the country level, including targets for renewables.
- Determining technology options based on renewable potential (based on theoretical overall resource potentials and technical and economic factors that constrain deployment) is realisable in 2030. These are called REmap Options and serve to substitute for conventional technologies that are considered in the PES.
- Assessing REmap Options for electricity and heat production, energy end use in industry and buildings (i.e., residential, commercial, public), and for the transport sector. The sum of the options results in a new energy mix called the Transforming Energy Scenario (TES).

Scenario Definitions for Nigeria

Planned Energy Scenario (PES)

The PES is essentially the primary reference case for this study, providing a perspective on energy system developments based on current national energy plans and other planned targets and policies, including Nigeria's NDC under the Paris Agreement. The PES is based on existing policies and plans, with no other substantial measures. Energy and environmental policies influence future energy demand and supply trends. The Nigerian government has a long history of developing sound policies but has faced challenges establishing implementation mechanisms. Over the years, several policies and programmes have been developed for the energy sector. Here, it was assumed that the various programmes outlined in the Nigerian energy/climate policies will be realised.

Hydroelectric Power

The TES describes an ambitious, yet realistic, energy transformation pathway based largely on renewable energy sources and steadily improved energy efficiency (though not limited exclusively to these technologies). This could set the energy system on the path needed to keep the rise in global temperatures to well below 2°C and towards 1.5°C during this century. The TES proposed by this study is aimed at expanding the current scope of renewable energy development in the country well beyond the stated capacities outlined in the national energy policy frameworks.

While an understanding of current national plans and recent national developments was derived in the PES, an understanding was also gained as to how renewables can play a more significant role than envisaged in these plans, which still feature significant levels of fossil fuel reliance. This scenario serves to maximise the use of renewable energy technologies across the energy system in a transformative and cost-effective manner with many benefits that extend well beyond the energy sector. Furthermore, in the TES, assumptions are made on the end-use technologies in terms of new technologies penetration as well as improvements in the efficiency of the existing stock.

The PES and TES are very different scenarios; the TES seeks to provide a realistic assessment of how renewable energy can be increased beyond current plans with many secondary benefits. The TES does not intend to replace the PES; rather, it seeks to provide an alternative development pathway strongly based on renewable energy technologies and can serve as context to further inform existing or planned energy policies.

Nigeria's Renewable Energy Resources

Nigeria has vast natural renewable energy resources which will be essential for the sustainable development of the country; however, at present these resources are very much underexploited.

Solar

Nigeria has high solar resource potential characterised by an average annual global horizontal irradiation ranging between 1 600 kilowatt hours per square metre (kWh/m2) and 2 200 kWh/m2 with the highest values (greater than 2 000 kWh/m2) located in the northern part of the country. IRENA estimates the technical potential for solar photovoltaic (PV) in the country at 210 gigawatts (GW) considering only 1% of the suitable land can be utilised for project development (IRENA and AfDB, 2022). The potential for concentrated solar power (CSP) is also very significant with a potential of approximately 88.7 GW and is mostly located in northern Nigeria, where the direct normal irradiance is highest (Ogunmodimu, 2013).

Wind

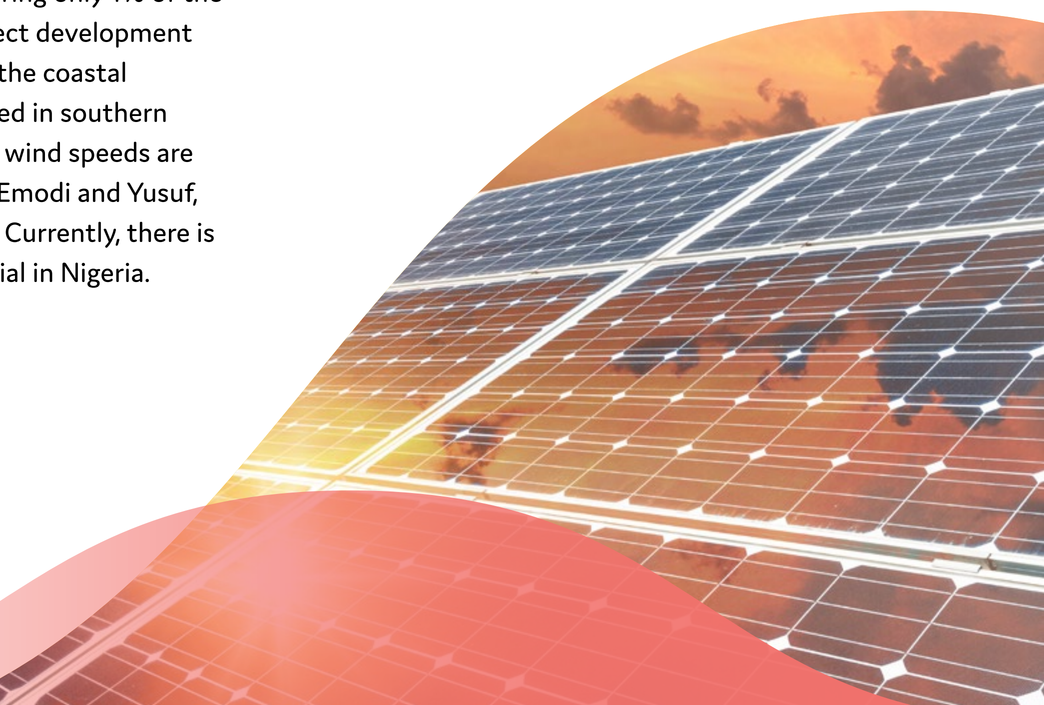
The country has moderate wind potential with average wind speeds at 10 metres (m) height ranging between 2.1 m/second (s) and 8 m/s with the highest values (greater than 7 m/s) located in the northern part of the country. IRENA estimates the technical potential for wind at 3.2 GW considering only 1% of the suitable land can be utilised for project development (IRENA and AfDB, 2022). Apart from the coastal and offshore locations, the wind speed in southern Nigeria is relatively low, while higher wind speeds are experienced in the northern region (Emodi and Yusuf, 2015; Idris, Ibrahim and Albani, 2020). Currently, there is no estimate of offshore wind potential in Nigeria. However, the Federal Ministry of Power says that it is conducting an offshore wind mapping. For this study, it is assumed that only onshore wind turbines will be deployed in Nigeria. The target of the National Renewable Energy Action Plan (NREAP) is to achieve 0.17 GW of grid-connected wind capacity by 2020 and 0.8 GW by 2030.

Hydro

Nigeria has a large hydro potential of around 24 GW and a small hydro potential of about 3.5 GW. This potential for the most part is yet to be exploited. In 2015, Nigeria had about 1.9 GW installed capacity of large hydro and about 60 megawatts of small hydro (ECN, 2014b; IHA, 2021; U.S. Department of Trade, 2021).

Biomass

Exploiting the huge potential of biomass resources in the country, especially in the form of agricultural residues for power generation, will go a long way to resolving the current energy crisis in Nigeria (Simonyan and Fasina, 2013). While there exist many biomass options for power generation, this study considers only agricultural residues as feedstock for biomass power plants (ECN, 2015a).



Primary Energy in Nigeria

The primary energy supply of Nigeria is highly renewable at a share of approximately 47%. Biomass dominates the energy mix in Nigeria with a share of 43%. This is due to its extensive use for heating and cooking purposes where substantial progress remains to be made in terms of access to clean cooking fuels, as shown in the later sections. The biomass subsector in Nigeria is highly informal with a lot of uncertainties regarding its usage, especially in rural areas, and issues relating to fuel stacking in the Nigerian buildings sector. It is also unclear to what degree biomass is used in the Nigerian industry sector. Thus, the share of biomass in Nigeria's primary energy supply may be greater than the value from the model due to differences in methodological approaches, energy access levels and efficiency values of the modelled biomass technologies.

As per the Nigerian National Bureau of Statistics living standards survey, there was only about 18% access to clean cooking (gas and electric stoves) in Nigeria in 2019 (NBS, 2020). However, international statistics suggest that access to clean cooking in Nigeria was around 13% in the same year (IEA, IRENA, UNSD, World Bank, WHO, 2022, p. 7). The data discrepancies may be attributed to the differences in survey and measurement techniques and what constitutes clean cooking. Most cooking uses traditional biomass, which indicates that air quality can be substantially improved by moving to other technologies and many deaths associated with air pollution avoided.

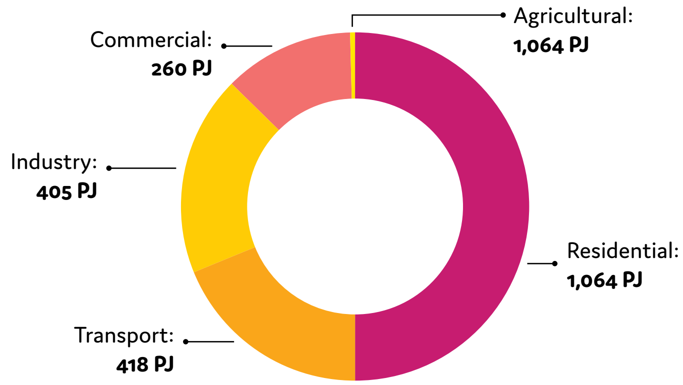
Oil makes up a similar share of primary energy requirement as bioenergy. While Nigeria is trying to get its refineries working at optimum capacity, the existing capacity is insufficient to satisfy the local demand for petroleum products. To meet this requirement, 80% of the refined oil products used in Nigeria are imported from abroad (PWC, 2017). Despite the ongoing construction of a large oil refinery capable of refining up to 650 000 barrels per day (George, Payne and Zhdannikov, 2021), Nigeria has much to gain from pivoting towards domestic renewable energy sources in place of domestic fossil fuels. As shown in Pai et al. (2021), global fossil fuel employment may drop by 80% in a 2°C scenario compliant with the Paris Agreement, while renewable-based employment could increase fivefold. Nurturing local development of abundant renewable energy resources would potentially spur local innovative renewable energy champions in such a scenario, which would enable the creation of local jobs and spin-off industries.

Natural gas, other renewables and hydropower make up the remainder of the primary energy requirement of Nigeria and are used in the power sector for the most part. The low penetration of variable renewables such as wind and solar shows the opportunity that lies in integrating them in the power sector, given the substantial cost reductions of the technologies in recent years and the enormous natural resource that Nigeria has, especially for solar power (IRENA, 2021b). Among the many advantages of these technologies, their modularity makes it easier to operationalise in a decentralised setting and in combination with storage can reliably provide power to a significant extent.

Unlike many other countries, Nigeria has relatively low coal use. At present, there is no coal power generation of note in the country. The current local consumption is mainly from the cement, brick, foundry and bakery industries.

All this shows that while the primary energy supply of Nigeria has a very substantial non-fossil share, its composition has negative externalities that, if changed going forward, could allow for improved air quality, domestic job creation and economic expansion.

Figure 1: Total final energy consumption by sector in Nigeria 2015 (2 155 PJ) based on model results and validated through a range of stakeholder engagement



Nigeria's Power Sector

"Around USD 34.5 billion in total investment will be required to provide electricity access to all households by 2030."

Nigeria's electricity supply system can be grouped into two: centralised (grid-connected) and decentralised (off-grid) systems. The centralised system consists of the large-scale generation of electricity at centralised facilities such as large hydro and thermal plants. The decentralised electricity supply system consists of a few kilowatts to megawatt capacities such as captive diesel and gasoline generator sets as well as renewable energy technologies (such as solar home systems, streetlights and mini-grids).

The total installed capacity of grid-based systems is around 13 GW. However, today's available on-grid peak generation varies and hovers around 4.5 GW. Nigeria's on-grid generation is dominated by natural gas power stations (86%) and large hydropower plants (14%). However, unavailability of gas, machine breakdowns, seasonal water shortages and limited grid capacity have severely limited the operational
performance of these power plants (Yetano Roche et al., 2020). This situation has led to led to acute shortages of electricity supply across the country with blackouts lasting for several hours in a day. The situation has also made many households and business units result to self-generation of off-grid electricity using diesel and gasoline generator sets as back-up. In terms of installed capacity, there is considerable uncertainty about the total capacity of fossil fuel-based selfgeneration. However, in accordance with the number of generators imported annually into the country, it is assumed that around 15 GW of diesel and petrol-based generation capacity were available in the country as of 2015 (Solar Plaza, 2017), while another study suggests around 30.5 GW (Tambari, Dioha and Failler, 2020).

Today, around 84% of urban households use back-up power supply systems such as fossil diesel/gasoline generators and/or solar-based systems, while about 86% of the companies in Nigeria own or share a generator (Ley, Gaines and Ghatikar, 2015; Elinwa, Ogbeba and Agboola, 2021). Given the several million captive generators imported into the country, Nigeria leads Africa as the highest importer of generators and is also one of the largest importers worldwide.

Nigeria's erratic power supply systems and the relatively expensive captive generation negatively impacts the economy from the residential to the industry sector. Owing to the high costs of captive generation, households and small and medium-sized enterprises spend between two and three times more on kerosene, diesel and petrol than they do on electricity from the grid (All On, 2016). In industry, government figures suggest that the cost of self-generating power makes Nigerian products approximately onethird more expensive than imports (FMITI, 2014). For these reasons Nigeria needs to improve the provision of electricity in the country in terms of both access and reliability in order to reduce the use of captive diesel and gasoline generators.

The transformation of Nigeria's electricity supply system is plagued with several challenges, some of which are common to both the centralised and decentralised systems. The main challenges facing the entire power sector include inadequate financing, relatively high investment risks and policy uncertainty (Latham & Watkins, 2016). The setbacks facing the centralised system are insufficient generation capacity, weak transmission and distribution infrastructures, gas supply constraints, seasonality of water levels, and governance (Latham & Watkins, 2016; Wijeratne et al., 2016). Recent policy developments such as those that were intended to meet the goals of the National Policy on Renewable Energy and Energy Efficiency aimed to address aforementioned challenges include the feed-in tariffs for renewable energy, new metering regulations and guidelines allowing large consumers to purchase power directly from generating companies.

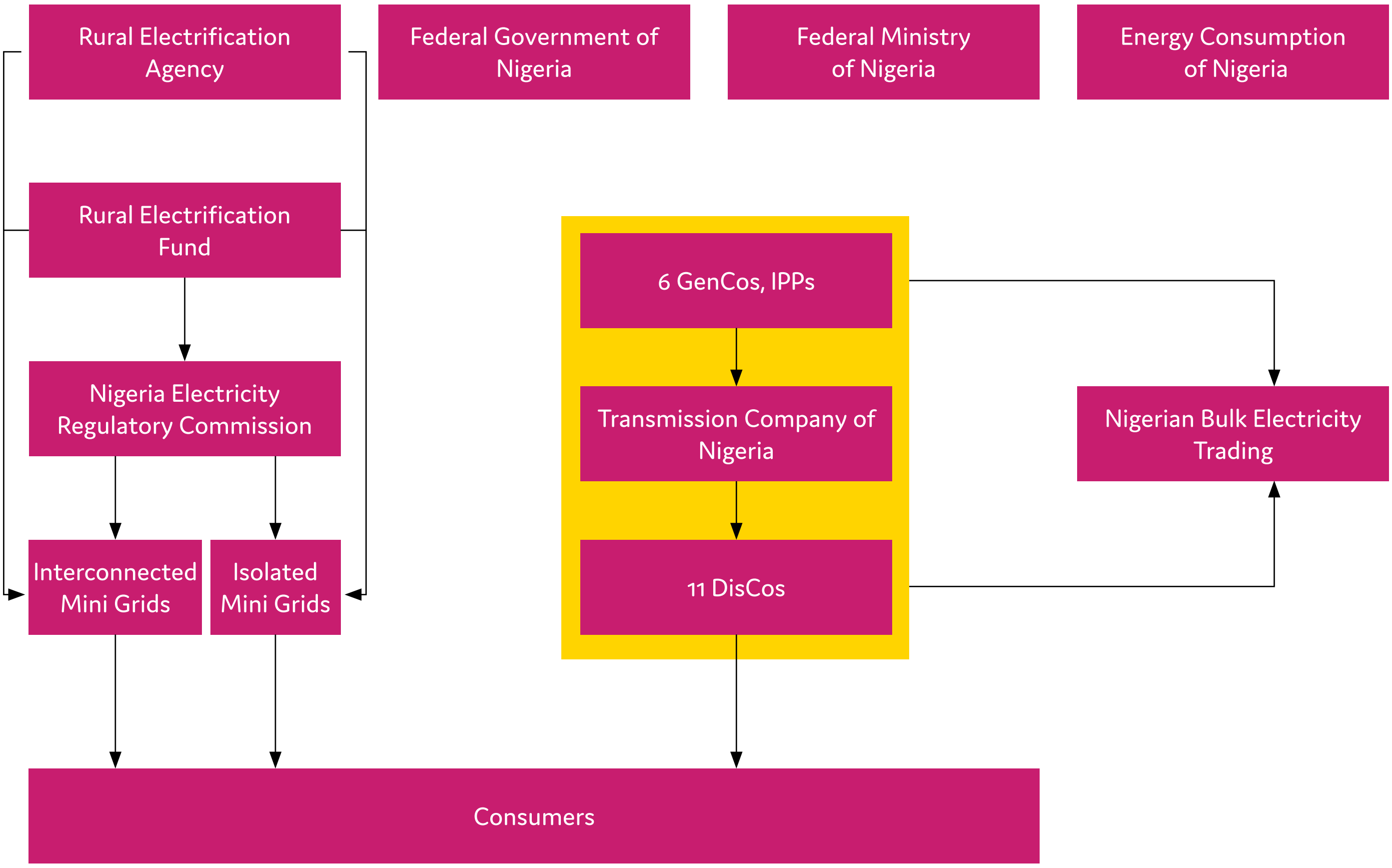
Nigeria has a huge potential off-grid market whether based on solar photovoltaic (PV) mini-grids or through solar home systems. Currently, based on life-cycle assessment, stand-alone solar PV systems are already cost-competitive compared with conventional diesel and gasoline generators used in the country as back-up (Esan et al., 2019). However, solar PV systems have higher initial capital outlay, which makes them unattractive for the poor consumers. Some of the key barriers for investments in the Nigerian decentralised renewables space include poor consumer affordability and poor enabling environment (Latham & Watkins, 2016). Recent policies and programmes, such as the 2016 mini-grid regulation introduced by the Nigerian Electricity Regulatory Commission and government removal of import duties on some solar components, aim to ameliorate the aforementioned challenges (NERC, 2016; Department for International Development, 2019).

While the Nigerian power sector continues to struggle, poor financing remains the key bottleneck to lack of progress. The Nigerian power sector will require substantially more investment to achieve constant power supply. In terms of improving electricity access, around USD 34.5 billion in total investment will be required to provide electricity access to all households by 2030 (Ohiare, 2015). The Transmission Company of Nigeria (TCN) suggests that rehabilitation and expansion of the grid will require an annual investment of USD 1 billion for the next ten years (TCN and PMU, 2017). Currently, the World Bank is financing a USD 486 million International Development Association credit for the Nigerian Electricity Transmission Access Project, to support the development of Nigeria's transmission system (World Bank, 2018). The African Development Bank, which is already working with the country on a USD 410 million transmission project, has pledged to invest an additional USD 200 million through the Rural Electrification Agency, in order to expand electricity access in the country (AfDB, 2020). Recently, the Nigerian federal government signed a six-year deal with Germany's Siemens AG for a three-phase electrification project aimed at increasing Nigeria's power to 25 000 megawatts (MW) that amounts to NGN 1.15 trillion (around USD 3.8 billion [2020]) (U.S. Department of Trade, 2021).

The institutional structure of the Nigerian electricity sector is presented in Figure 2 as featured in Adeyanju et al. (2020) and is composed of a range of different institutions.

With respect to transmission, the TCN manages the electricity transmission network in Nigeria. TCN is one of 18 companies that were unbundled from the Power Holding Company of Nigeria (PHCN) in April 2004 and is a product of a merger of the system and transmission operations parts of PHCN. It was incorporated in November 2005 and issued a transmission licence on 1 July 2006. TCN's licensed activities include electricity transmission, system operation and electricity trading. It is responsible for evacuating electric power generated by the electricity GenCos and wheeling it to DisCos. It provides the important transmission infrastructure between the GenCos and the DisCos' feeder substations across the country.

Figure 2: Electricity sector structure of Nigeria



Nigeria's transmission network consists of high-voltage substations with a total (theoretical) transmission wheeling capacity of 7.5 GW and over 20 000 kilometres of transmission lines (NERC, 2021). Currently, transmission wheeling capacity (5.3 GW) is far below the total installed generation capacity of around 13 GW. The entire infrastructure is essentially radial without redundancies, thus creating inherent reliability issues. The grid is characterised by the poor voltage profile in the network (especially in the north due to its radial nature). Overloaded transmission lines and high technical and non-technical losses are a regular feature. The average transmission losses are around 7.4%, which is relatively high compared with emerging countries' benchmarks of 2-6% (NERC, 2021).

The transmission system also experiences a number of system collapses during the year. This shows that there exists critical infrastructure and operational challenges in the transmission subsector of the industry. IRENA's West Africa Planning report focused primarily on the regional expansion of the centralised power sector in the region and demonstrated the benefits of co-operation in power system expansion to Nigeria and the wider region out to 2030 (IRENA, 2018a). International transmission with other countries is limited to two lines with Benin (686 MW) and Niger (186 MW) (IRENA, 2018a). A new 650 MW line is also planned as part of the Nigeria-Benin-Niger-Burkina-Faso Power Interconnection Project (also known as the North Backbone Project) which is expected to be commissioned in 2022 (AfDB, 2021). Moving forward, deeper system integration within the Western Africa Power Pool will enable a more reliable power supply regionally and offer Nigeria the chance to export power to the wider region.

Renewable Energy Outlook

The previous sections have outlined the energy context in Nigeria and some of the opportunities and challenges that lie ahead. However, Nigeria's energy system is highly dynamic, and the government would benefit from periodically re-evaluating longer-term energy goals to reflect changing market dynamics and priorities for the country.

This section presents the IRENA Renewable Energy Roadmap (REmap) analysis and provides an outlook on the medium-term potential of renewable energy in the country. The macroeconomic factors that apply to any country serve as the basis of its development trajectory and also play a key role in determining its future energy demand trajectory and corresponding emissions.

Planned Energy Scenario to 2050

The PES is based on existing policy with no other substantial measures. As shown in Table 1, several policies and programmes have been developed for the Nigerian energy sector, which is not without ambitions despite the current challenges it faces.

Table 1: Summary of key national policies and action plans on renewable energy and energy efficiency

Policy/ Action Plan	Year	Short description	Responsible agency
National Energy Efficiency Action Plan (NEEAP)	2016	The NEEAP was developed by the FMP. It sets targets for energy savings and proposes actions for meeting the set targets. The NEEAP targeted 40% efficient lighting in households by 2020 and 100% by 2030; efficient energy increase by 20% by 2020 and 50% by 2030 in the transport, power and industrial sectors; the reduction of distribution losses by 15-20% by 2020 and less than 10% by 2030; and the achievement of 10% biofuel blend by 2020.	Federal Ministry of Power (FMP)
National Renewable Energy Action Plan (NREAP)	2015	The NREAP was developed by the FMP and reiterates the target to attain 30 gigawatts (GW) of power generation capacity by 2030, with a renewables share of 30%.	Federal Ministry of Power (FMP)
Nigeria Nationally Determined Contribution (NDC)	2015 (revised 2021)	In September 2012, the Federal Executive Council approved the Nigeria Climate Change Policy Response and Strategy and in 2015 the Nigeria NDC was approved. The NDC set conditional and unconditional objectives as 20% and 45% respectively. In its recent revision of its NDC its unconditional pledge is unchanged while its conditional reduction pledge raised from 45% to 47%, which can be conditionally achieved dependent on sufficient financial assistance, technology transfer and capacity building.	Federal Ministry for the Environment
Sustainable Energy for All (SEforALL) Action Agenda	2015	The SEforALL Action Agenda was developed by the FMP. The document provides useful information on energy access and energy efficiency as well as the renewable energy potential and market in Nigeria and relevant policies and barriers to be overcome. Targets include 30 GW of electricity by 2030, with a renewable energy share of 30%.	Federal Ministry of Power
National Renewable Energy and Energy Efficiency Policy (NREEEP)	2014	The SP-2015 was developed by the National Atomic Energy Commission. The goal of the Plan is the deployment of 1 000 megawatts (MW) of nuclear power in Nigeria by 2025 and 4 800 MW by 2035.	Federal Ministry of Power
National Nuclear Programme Strategic Plan (SP-2015)	2009 (revised 2015)	The SP-2015 was developed by the National Atomic Energy Commission. The goal of the Plan is the deployment of 1,000 megawatts (MW) of nuclear power in Nigeria by 2025 and 4,800 MW by 2035.	National Atomic Energy Commission

Table 1: Summary of key national policies and action plans on renewable energy and energy efficiency (cont.)

Policy/ Action Plan	Year	Short description	Responsible agency
National Biofuel Policy and Incentives	2007	This policy is aimed at creating a viable biofuels industry, reducing the nation's dependency on gasoline and reducing pollution of the environment. It targets 10% for fuel ethanol and 20% for biodiesel blending ratio by 2020.	Federal government of Nigeria
National Energy Master Plan (NEMP)	2007 (revised 2014)	The NEMP of 2007 defines the execution framework for the National Energy Policy. It covers all energy sources, energy consumption, capacity development, energy financing, energy database and the project cycle (planning, implementation, and monitoring and evaluation). The NEMP sets targets for the share of renewable energy (excluding large hydro) in the national energy sector to increase from 0.7% in the short term (2006-09), to 3.3% in the medium term (2010-15) and 10.6% in the long term (2016-30).	Energy Commission of Nigeria (ECN)
Rural Electrification Strategy and Implementation Plan (RESIP)	2006 (revised 2014)	The RESIP was initially prepared by the Power Sector Reform in 2006 and redrafted by a national power sector committee in 2014. Its aim is to expand electricity access in a cost-effective way, for both off-grid and on-grid electricity supply. The goal of RESIP is to achieve the electricity access target of 75% by 2025 and 90% by 2030 with at least 10% renewable energy sources, e.g., hydro, wind, solar, etc., by 2025.	Rural Electrification Agency
National Renewable Energy Master Plan (REMP)	2005 (revised 2012)	The REMP was developed in 2005 by the ECN in collaboration with the United Nations Development Programme (UNDP) and was later revised in 2012. The REMP sets out Nigeria's roadmap for increasing the national deployment of renewable energy and promoting sustainable development. The renewable energy capacity targets for the national power sector are 4 628 MW (10%) for 2015, 15 966 MW (18%) for 2020 and 63 032 MW (20%) for 2030.	Energy Commission of Nigeria
National Energy Policy (NEP)	2003 (revised 2006, 2013 and 2018)	The NEP was initially published in 2003 and later revised in 2006, 2013 and 2018. It was developed and implemented by the ECN. It covers all aspects of the energy sector, including renewable energy, energy efficiency and rural electrification. It defines, among others, a national target for 75% electrification rate by 2020 and a reduction of electricity generation, transmission and distribution losses from 15-40% in 2013 to less than 10% by 2020.	Energy Commission of Nigeria

For the PES, it was assumed that the various programmes outlined in the Nigerian energy/climate policies would be realised. The main policy documents that served as the base for the PES scenario are:

- NEP
- NREAP
- NEEAP
- NDC
- Nigeria SEforALL Action Agenda
- RESIP

The stakeholder review workshop held in Abuja in January 2020 was instrumental in harmonising these various plans and policies with the latest developments in the country that have occurred since these documents were published. The final workshop held in Abuja in December 2022 was also essential in confirming the final study results were nationally representative. However, the other policy programmes shown in Table 5, which are not explicitly stated in these aforementioned documents have supported the development of the scenarios in terms of targets and structure overall.

In addition, it is assumed that diffusion of efficient and new technological options will continue based on previous and likely future trends without any substantial extra policy interventions. Where there was doubt on the feasibility of policy targets/frameworks, stakeholders' opinions were taken accordingly. There were also additional scenarios to explore the impacts of differing growth trajectories to help provide a deeper understanding of the sensitivity of the pathways developed to these assumptions.

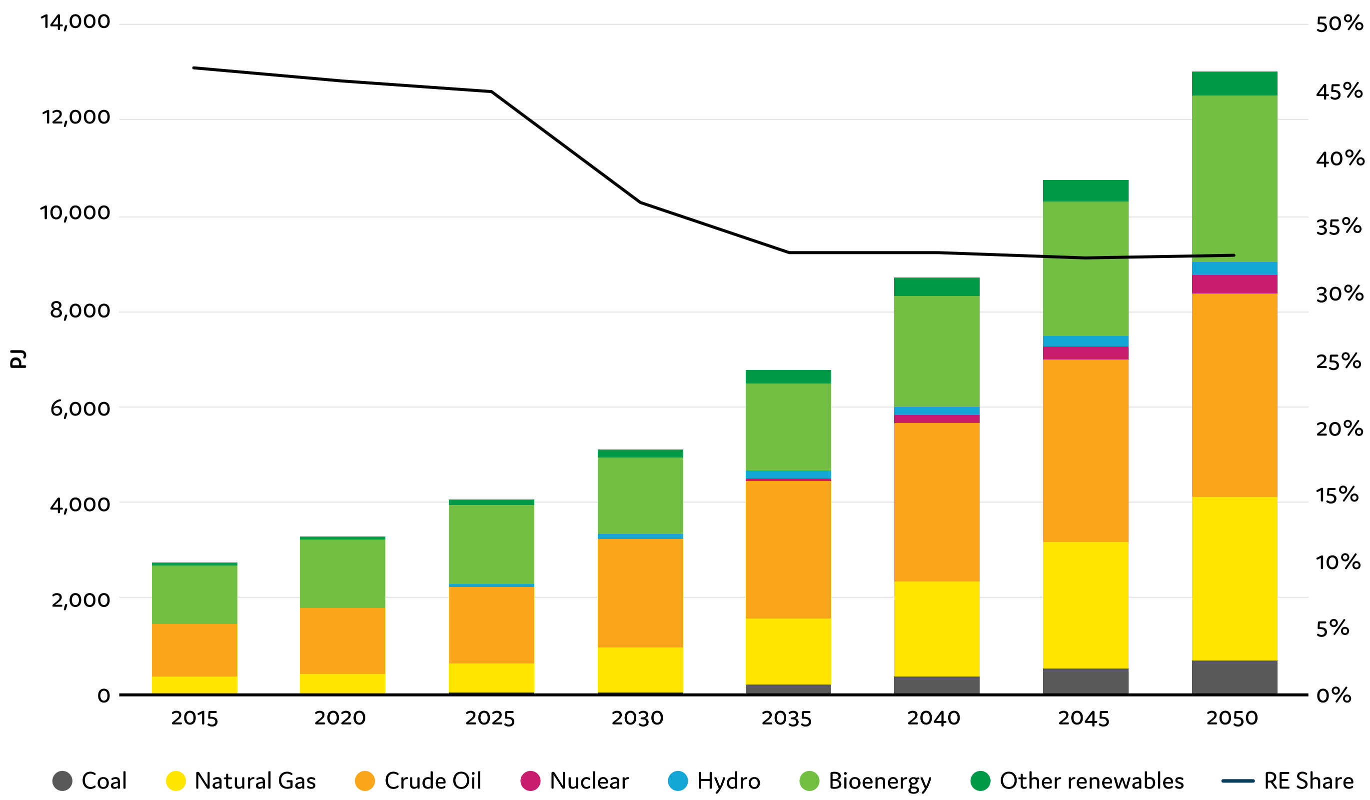
Primary Energy Requirements

Figure 3 shows the primary energy supply for the PES which represents a view on energy supply based on current and planned policies under a 7% GDP growth rate. Here, the total primary energy supply reaches 5 138 petajoules (PJ) by 2030 and 13 044 PJ by 2050. This indicates a rise by about five times in 35 years, largely attributed to the substantial expansion of the economy and population.

Bioenergy is the dominant energy source in 2015 but its share declines from 43% in 2015 to 33% by 2030 and 27% by 2050, while supply rises from 1 129 PJ in 2015 to 1 622 PJ by 2030 and 3 478 PJ by 2050. Although the magnitude of supply of crude oil increases over the modelling time frame, its share in total primary energy mix is set to decline after 2030. The share of crude oil in the supply mix rises from 41% in 2015 to 45% by 2030 and then declines to 33% by 2050. The 2050 decline in the share of crude oil in primary energy supply mix is on account of the expansion of the utilisation of other energy sources such as natural gas as well as renewables.

For the modelling time frame, upward growth is observed in natural gas. Figure 3 shows that the share of natural gas rose from 18% in 2015 to around 24% by 2030 and 2050. Despite the magnitude of coal rising in the supply mix from 5 PJ in 2015 to 39 PJ (2030) and 696 PJ (2050), its share remains around 1% by 2030 and 6% by 2050. This can be attributed to the low domestic utilisation of coal in the country. Analysis shows that "other renewables" will increase from 17 PJ in 2015 to around 161 PJ by 2030 and 512 PJ by 2050. The share of "other renewables" in the primary energy mix will grow modestly from less than 1% in 2015 to around 3.5% in 2030 and 4.3% by 2050. Thus, by 2030 and 2050 in the PES, renewables (hydro, bioenergy and "other renewables") will account for around 37% (2030) and 33% (2050) of the primary energy supply mix.

Figure 3: Primary energy requirement under current plans and policies



Carbon emissions

The total carbon dioxide (CO_2) emissions from the energy sector increase from 119 million tonnes (Mt) in 2015 to 201 Mt in 2030 and 516 Mt in 2050 Figure 4, which corresponds to an increase of over threefold in 35 years. In the PES, the unconditional NDC CO_2 emissions target for 2030 is met but that the conditional NDC requirement would not be. In 2015, electricity generation is the largest source of CO_2 emissions in the energy sector. However, by 2030, the transport sector will become the largest source of CO_2 emissions in the energy sector and maintains this position up to 2050, owing to the huge growth of the fossil-powered transport system. In 2030, within the energy sector, transport emissions account for 47% and increase to 59% by 2050. The decline in the share of the power sector in total CO_2 emissions from the energy sector can be attributed to the rapid growth of renewable energy technologies deployment in the power sector, which are cost-effective to install at scale even without additional incentives.

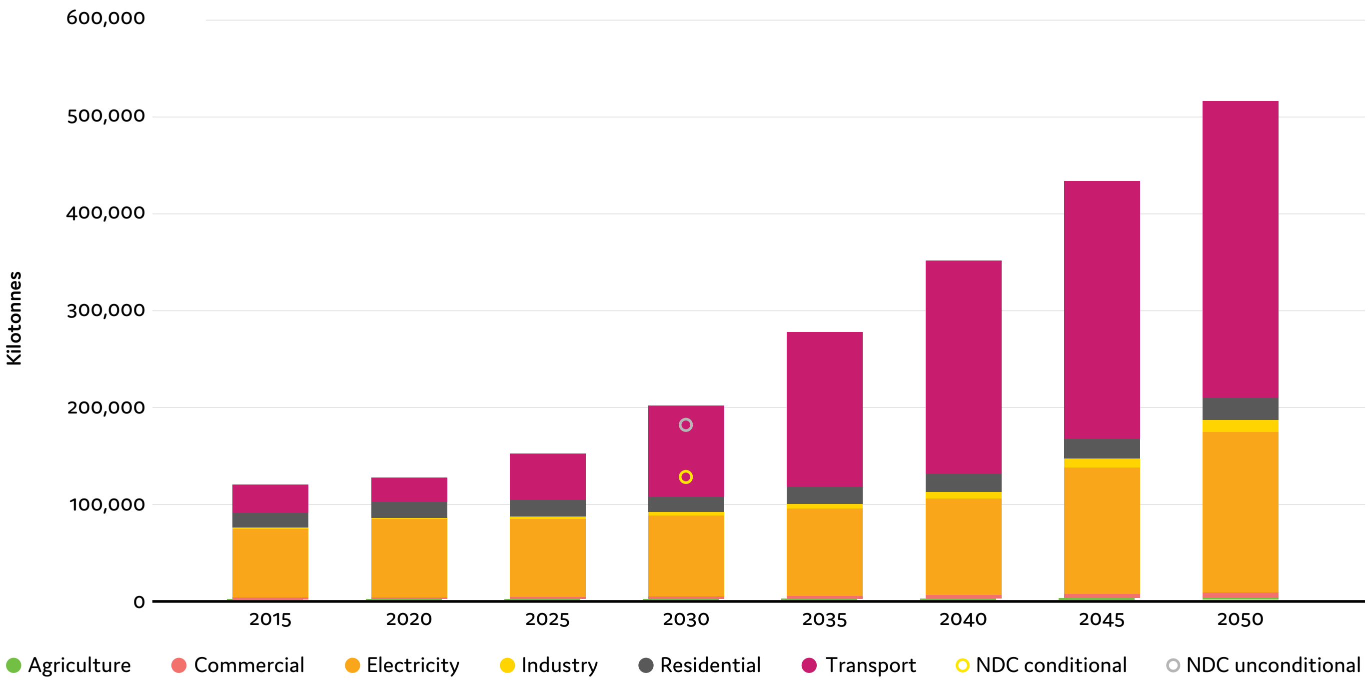
Final energy demand

The total final energy demand under current and planned policies grows from 2 155 PJ in 2015 to 3 765 PJ in 2030 and 10 351 PJ in 2050, increasing over four times in 35 years. The total final energy demand of the transport sector grows at the fastest pace, with a compound annual growth rate of 6.8%.

The percentage share of the residential sector in final energy demand is largest in 2030, accounting for around 35% of the total. However, by 2050, the transport sector will overtake it and contributes the most to final energy demand with a share of about 45%. The share of the residential sector is seen to fall over time since the size of its energy consumption grows slowly, while that of the commercial and agriculture sectors grows more slowly across the study horizon.

The renewable energy share of total final energy consumption (TFEC) is also anticipated to decrease along the study horizon from just below 50% in 2015 to about 40% in 2050. The substantial growth in renewable energy use in industry does not mitigate the rapid expansion of the transport sector, where the renewable energy share is only 7% by 2050. The growth in demand in the residential sector is not that significant compared with other sectors; in proportional shares of TFEC it goes from 49% in 2015 to just 18% in 2050. This owes to demand growth in other sectors but is also due to significant efficiency gains over the period achieved through the roll-out of clean cooking technologies. The composition of final energy demand trajectories for each sector are further elaborated in the proceeding subheadings of this section.

Figure 4: CO_2 emissions by sector based on current plans and policies



Actions Needed Now

Nigeria is at a key point in time to capitalise on its abundant renewable energy resources to meet the growing needs of its population while simultaneously addressing socio-economic challenges. To do so requires a broad and comprehensive set of policies for all the sectors of its economy which will facilitate the transition away from fossil fuels with all the economic and health benefits that would follow. Renewable energy technologies will be key in achieving a sustainable energy mix for Nigeria.

Broad-based national planning will be required to plan and manage the energy transition so that the benefits outweigh the costs and are evenly distributed across the country. Accelerating the energy transition and maximising its benefits require an integrated energy planning approach that combines targets and commitments with holistic and long-term plans, including the deployment of energy transition technologies, the phasing-down of fossil fuels (and their direct and indirect subsidies) and the thorough consideration of their socio-economic impacts.

An integrated long-term plan should be developed in co-ordination among different ministries and national bodies. The energy plan must consider the different transition pathways including electrification, the deployment of green gases, sustainable biomass and solar thermal among key enabling infrastructure. The plan must be based on specific needs, macroeconomic conditions, availability of resources, the infrastructure already in place, and the level of development of different regions, accessibility and cost of technologies.

Developing and implementing an integrated long-term plan requires strong co-ordination and a robust institutional structure. This is especially the case when it comes to electrification with renewables, as it calls for the synchronisation of the deployment of renewable power plants with measures to deploy electricity-powered technologies in in a timely fashion.

Among other measures, a fiscal system is needed that facilitates the adoption of energy transition solutions while disincentivising new investments in fossil fuel technologies and supporting a national phase-down and -out of these technologies aligned with a climate compatible pathway. Policies and measures are also needed to facilitate access to finance, foster innovation and raise awareness among consumers – and citizens in general – to support the uptake of transition-related technologies.

Development of financing mechanisms for distributed renewables and technologies (microfinance, margin money finance, etc.) in addition to information campaigns will also be key to roll-out of a whole host of goals achieved in the Transforming Energy Scenario (TES) in terms of clean cooking, distributed solar photovoltaic (PV) and battery installations.

A long-term, integrated energy plan is also necessary to coordinate the deployment of renewables- based solutions with measures to raise energy efficiency and develop the needed infrastructure while minimising stranded assets. Based on the long-term energy plans, corresponding investments are needed to upgrade existing and develop new infrastructure, often as a prerequisite to attracting private investments in energy-transition-related solutions. Such an integrated energy plan can help minimise stranded assets for a given climate ambition by developing national strategies that leverage existing infrastructure and expertise.

Recommended Actions

This section highlights the key barriers identified throughout the Remap process and the corresponding actions to overcome them. The adoption of these recommended actions would contribute to the widespread use of renewable energy throughout Nigeria. In order to ensure the realisation of the huge renewable energy ambitions outlined in the TES, the proceeding policies and measures are recommended.

Power

- **Improve the existing financing mechanisms and explore further regulatory options.** Despite the demonstrated benefits of renewables, the adoption of renewable energy technologies in Nigeria is still growing at a slow pace compared with what is obtainable in other countries within the region, such as Egypt, Kenya and South Africa. Fostering innovative financing mechanisms for distributed renewables and utility-scale technologies such as blended finance and microfinance will help deliver higher penetrations. Especially in the substitution of diesel generators by standalone solar systems and mini-grids which have a higher upfront cost but significantly lower operation cost. The government's existing policies/programmes in this regard are already on the right track but need to be actively implemented. Furthermore, the existing Renewable Purchase obligation (RPO) mechanisms need to be strengthened and made workable. Having clear and transparent RPO target formulation while setting standardised and transparent procedures to determine the targets and making such targets mandatory while ensuring strict enforcement are important elements towards promoting renewable energy technologies in the country.

- **Improve and expand the regulatory framework for decentralised renewable energy solutions.** Nigeria has been successful with a progressive regulatory regime for mini-grids (both off-grid and on-grid) backed by various dedicated financing schemes (such as the results-based financing facility and minimum subsidy tender). It is important that this framework architecture continue to evolve as technologies develop and new applications emerge with participation of both public and private sectors.

- **Accelerate electrification of end uses and promote policies that would support it.** The energy transition both globally and in Nigeria requires electrification, but it must happen in an orderly and well-managed fashion. Proactive policy making is necessary to avoid some initial pitfalls. Delaying action policies can lock in fossil fuel solutions and reduce opportunities for sector coupling. Ineffective policies can create additional barriers (e.g., transitional barriers or reputational barriers) that will reduce the attractiveness of electrified solutions and increase the challenges of achieving the energy system outlined in the TES.

- **Modernise the transmission and distribution infrastructure.** The analysis shows that the Nigerian grid needs to be prepared for the integration of large-scale renewables. Efforts should be placed on strengthening the existing central grid, and more efforts should be placed on developing interstate/intercity regional transmission capacity for optimum utilisation of available power. The TES requires relatively higher deployment of renewable energy technologies into the existing system. Planning for integration of renewables into the grid is a key requirement for the success of renewable power. Investments are essential to support infrastructure and renewable energy development and should be accorded high priority. As Nigeria's transmission system is not very mature, it presents an opportunity for the country to develop its power transmission system in a modern fashion. Moreover, a smart grid will go a long way to support the management of intermittent solar and wind. As Nigeria's decentralised supply system grows, it becomes pertinent to integrate it into the central grid. In some cases, decentralised generators can produce surplus energy that can become wasted if not supplied to the central grid. Here, a smart grid system will help to accommodate this surplus and provide the needed compensation accordingly. Furthermore, electricity theft is a major issue in the Nigerian electricity sector. A smart grid system will help to curtail this issue. Additionally, greater use of distributed PV can reduce the need for transmission and provide valuable upstream benefit.

- **Invest in renewable over fossil energy.**
  The analysis shows that it is cost-effective to invest in renewable energy technologies over fossil fuels such as coal, owing to the declining costs of renewables (all TES levels). The Nigerian Energy Masterplan and Vision 30-30-30 seek to integrate coal into the Nigerian electricity supply mix. However, there is currently no existing coal power plant in the country. While acknowledging that plans are under way for the deployment of coal-based technologies, the current scenario also presents an opportunity for Nigeria to develop its electricity system in a more sustainable manner by leapfrogging fossil-based technologies and focusing more on cost-effective renewables. Beyond environmental sustainability issues, Nigeria is still a developing country in dire need of financial resources to drive its developmental agenda. Thus, there is no room for wastage of resources on technologies that are not cost-effective. It will be to Nigeria's benefit in terms of environment and economics to abandon the current coal plans and invest more in renewable energy. Such targets and goals for renewables need to be translated into policies and measures. Quantified quotas for renewable power can be considered, along with a system for issuing and tracking energy attribute certificates. Structured procurement policies such as feed-in tariffs, premiums and auctions are instrumental to address context-specific barriers and risks and to serve specific objectives.

- **Develop a robust database for renewable energy potentials and a corresponding pipeline of bankable projects.**
  Apart from solar and hydro, there is a considerable dearth of information regarding the potential of renewable resources in the country. There is a need for comprehensive assessment of wind energy potential in the country for both on- and offshore wind. As observed from the analysis, the potential for geothermal, wave and tidal energy is yet to be quantified and thus, no plans yet to develop these renewable energy resources in the country. It is recommended that the federal government perform a detailed assessment to have a robust database of Nigeria's renewable energy potential. This will help to support planning for renewable energy development and also show the possible locations for renewables deployment.

Key Findings and Messages

Nigeria is at a key point in time to capitalise on its abundant renewable energy resources to meet the growing needs of its population while simultaneously addressing socio-economic challenges. To do so requires a broad and comprehensive set of policies for all the sectors of its economy which will facilitate the transition away from fossil fuels with all the economic and health benefits that would follow. Renewable energy technologies will be key in achieving a sustainable energy mix for Nigeria.

Nigeria is at a key juncture in time; with a growing population and a range of socio-economic challenges, it requires sustainable energy sources to meet the growing needs of all the sectors of its economy and achieve universal access to modern energy services. This report demonstrates how renewable energy technologies will be key in achieving a sustainable energy mix and meeting the growing needs of the country.

Universal provision of energy services for cooking and power are key objectives of national energy policies, in addition to priorities of energy affordability, energy security, and reduced air pollution and carbon dioxide (CO_2) emissions. Renewable energy sources can be a driving force in achieving all these goals because they are some of the lowest-cost energy sources today and are domestically abundant and less polluting than conventional or traditional sources of energy.

This study shows how, under current plans and policies, Nigeria will experience substantial increases in primary energy requirements and CO_2 emissions. However, the analysis also shows that various economic growth rates over time imply the need for structural changes in the economy as well as for induced shifts in the patterns of end-use demands. The study presents how an increased renewable uptake scenario, named the Transforming Energy Scenario (TES), sees future capacity expansion of Nigeria's electricity supply system provided largely by renewables, which reduces primary energy requirements (because most of the renewables deployed are more efficiently converted to useful energy than fossil fuels) and greenhouse gas emissions in tandem with increased electrification compared with the Planned Energy Scenario (PES), which represents what would occur under current and planned policies.

In the Transforming Energy Scenario (TES):

- The share of primary energy requirements met with renewable energy reaches 47% by 2030 and 57% by 2050.
- Investment in renewables is more cost-effective than the conventional pathway. The TES has lower investment costs than the PES, USD 1.22 trillion (2010) compared with USD 1.24 trillion (2010), while delivering the same energy service.
- Achieving the TES will require a shifting of and scaling up of investments in Nigeria in the short term to avoid fossil fuel lock-in infrastructure investment with long lifetimes such as natural gas pipelines.
- Improvement upon existing efforts to promote clean cooking and access to modern forms of energy are needed.
- Expansion of existing appliance efficiency and lighting programmes is needed.
- An acceleration of electricity capacity additions, especially distributed solar photovoltaic (PV), in the power sector will be key to unlocking Nigeria's renewable energy resources.
- Hydropower will also be key in balancing the centralised power system by offering flexibility to mitigate solar power variability. The TES sees hydropower reaching 13 GW in 2030 and 15.5 GW in 2050.
- Faster adoption of biofuels and electric vehicles (EVs) when combined with an increased role for public transportation, will help to sustainably meet growing transportation demand
- Nigeria would benefit from the promotion of the adoption of solar process heat in large industries where it could deliver a reliable supply of thermal energy and reduce local air pollution.
- Efficient irrigation pumps and tractors in the agriculture sector should be promoted to improve energy security by reducing the impact of internal fuel price volatility on the sector.
- Irrespective of the level of GDP growth, CO_2 emissions are on an upward trend. Energy sector CO_2 emissions were about 119 million tonnes (Mt) per year in 2015 and in the PES rise rapidly to 516 Mt per year by 2050. In the TES these grow much more slowly to 189 Mt per year by 2050.
- Coordination of policies will be essential to unlocking integrated energy transition planning and ensuring its success.

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