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Renewable Energy Development in Africa: Lessons and Policy Recommendations from South Africa, Egypt, and Nigeria

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Abstract

Nigeria, South Africa, and Egypt make up the top three largest economies in Africa and the trio have huge renewable energy resources. By taking the cases of the three countries, the study analyses the giant strides made in the uptake of renewable energy in Africa and identifies some of the major challenges facing many African countries in developing their renewable energy sectors. South Africa and Egypt provide cases of transformational growth in the uptake of renewable energy driven by market-oriented policies and strategies, while the Nigerian case typifies policy constraints that limit the optimal exploitation of renewable energy in various countries in Africa. The analysis of the Nigerian case reveals specific challenges in the policy and institutional landscape that impede the uptake of renewable energy and use in the country, which if addressed could catalyse renewable energy integration in Nigeria, among other African countries that are faced with similar challenges. Based on the experience of South Africa and Egypt, actionable recommendations that are realistic in the African context are made towards addressing the challenges.

***Keywords*:** Renewable energy, Africa, renewable energy policy, renewable energy investment, renewable energy integration, policy, sustainable development, energy transition

10.1 Introduction

The coming into force of the Agenda 2030 promoted by the United Nations generated a multi-stakeholder commitment to the realization of the 17 sustainable development goals (SDGs) enshrined in the agenda. Since coming into force, there has been increasing interest in development paths that help to meet the present needs without reducing the possibility and potential of future generations to meet their needs [1–5]. In this pursuit, the role of energy access has been identified both as a sustainable development goal and also as a

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driver of other goals within the framework [6]. Moreover, the sustainability concerns on fossil fuels are leading to catalysed commitment to the exploitation of renewable energy sources (RESs) across the globe [7, 8]. Africa is at an advantage by nature given the abundant RESs available across the continent [9]. The possibility for decentralised generation of renewable energy (RE) also makes it fit to meet the energy need of the huge share of the African populace living in rural and remote communities that are not favored by the economics of grid extension. Moreover, the environmental friendliness of the generation and use of RE also help nations to reduce their carbon emissions, thus helping them to meet their Nationally Determined Contributions (NDCs) to the Paris Agreement [10–14]. However, exploiting available RESs comes with multidimensional challenges and addressing them largely depends on the effectiveness of the RE policy and institutional frameworks adopted across nations.

The accelerated growth in RE generation in many nations with relatively low RESs *vis-à-vis* the slow pace of RE development in nations with abundant potentials shows that clean energy transition requires more than the availability of RESs. As of 2015, the cumulative installed capacity of solar photovoltaic (PV) technology in Africa was slightly more than 2.1GW (Figure 10.1) while Europe had a cumulative installed capacity of over 95GW with Germany accounting for 40GW. Yet, Africa has more solar energy resource compared to Europe [15, 16]. Indeed, the experience of various nations that are advanced in the uptake of renewable energy highlights the crucial role of appropriate policy frameworks and implementation strategies in creating an enabling environment that drives the various dimensions of RE development [17].

The uptake of RESs in Africa has been majorly limited to large hydropower projects and traditional use of biomass for cooking yet Africa has abundant solar, wind and biomass energy potentials [18]. The availability of various RESs for utility-scale exploitation has been demonstrated across many African countries; nonetheless, the diffusion of the

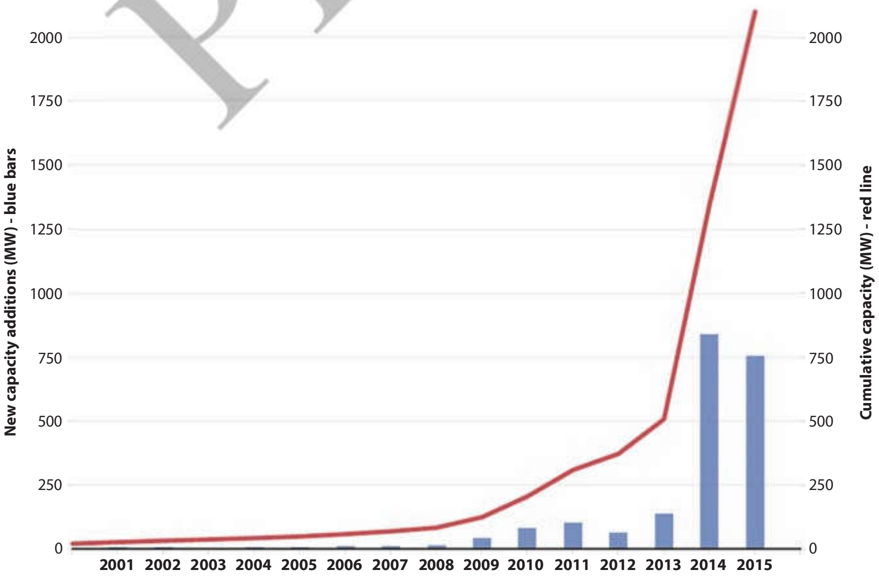

Figure 10.1 Installed capacity of solar PV in Africa (2000-2015). Source: IRENA, 2016 [16].

associated renewable energy technologies (RETs) requires an appropriate policy instrument that will de-risk and incentivize investments in the sector [19]. Therefore, the level of renewable energy development attainable in African countries will be largely determined by the robustness of the policy instruments in increasing the interest and capacity of stakeholders from demand and supply ends.

10.2 Existing Knowledge and Contributions to Literature

South Africa's transformative growth in clean energy transition has been lauded internationally and it provides a model for other African countries. In 2015, the United Nations Environment Programme (UNEP) ranked South Africa among the top 10 countries that attracted the highest RE investment in the world. With a USD 4.5 billion investment in its renewable energy sector, South Africa recorded the 7th highest RE investment in the world in 2015. The investment represents a 329% increase from its USD 1 billion RE investment in 2014 [20]. Similarly, the progress made in Egypt also provides a case of remarkable growth in renewable energy development driven by appropriate market-oriented policy frameworks and transparent implementation strategies with significant participation by private players. Egypt recorded the largest investment in Africa's renewable energy sector in 2017. In that year, 24 large-scale RE projects with 1.3GW total capacity reached financial close totaling a USD 2.6 billion investment in its RE sector. Though it missed the rank of "top 10 countries" in the world with the largest RE investments, UNEP called it "next to the top 10" countries [21].

Nigeria, South Africa, and Egypt make up the top three largest economies in Africa and the trio have huge renewable energy resources. Despite the enormous renewable energy resources and the development of diverse policies and targets, the uptake of renewable energy in Nigeria remains low. Egypt and South Africa, though still emerging in their renewable energy sectors, have recorded significant progress. The need for Nigeria, among other developing countries, to draw lessons from the pragmatic energy policies and implementation strategies adopted in Egypt and South Africa has been highlighted in the literature and by multilateral organisations [19, 21, 22]. Hence the need for a comparative analysis to facilitate the learning.

Diverse studies have examined various themes on renewable energy development in Nigeria, South Africa and Egypt in separate case studies with varying recommendations for the respective countries [23–29]. However, holistic comparative studies are required to facilitate learning from the countries. There are limited comparative and review studies that compare renewable energy sectors in the three countries, and they have been analyzed below in Table 10.1 to identify the gaps in literature from which this study derives its unique contributions. Other relevant comparative studies involving one or more of the countries are also included in the analysis (Table 10.1).

Most of the studies on renewable energy development in the selected countries have analyzed the renewable energy development in each of the countries in separate studies. There are also a number of comparative studies, some comparing one of the countries with other non-African countries, others comparing the countries with other African countries, others focusing on a particular RET or scale. However, there are limited comparative studies between the three countries. Indeed, the existing literature made contributions

Table 10.1 Relevant comparative analysis and review.

S/N	Author	Objective and methodology	Countries examined	Relevant findings and recommendation
1	Amandine Nakumuryangon and Roula Inglesi-Lotz, 2016 [30]	compares south Africa's RE development with those of OECD and other African countries by analyzing their respective RE generation, use and share in energy mix	South Africa, Other African countries, OECD countries	despite the high share of fossil in its energy mix, South Africa leads RE development in Africa, however, it ranks below OECD countries, hence has room for improvement
2	Akintande *et al.*, 2020 [31]	using a Bayesian Model Averaging approach, the model developed a model on RE consumption in Africa's top five most populous countries	Nigeria, South Africa, Egypt, Ethiopia and Democratic Republic of Congo	increase in population, energy demand, electricity use, development of human power are major factors that influence renewable energy use in the selected countries
3	Olanrewaju *et al.*, 2019 [32]	- conducted a panel data analysis to examine the pattern of RE consumption in the top five most populous and largest economy in Africa	Nigeria, South Africa, Egypt, Ethiopia and Democratic Republic of Congo	- natural gas rent is positively correlated with RE generation and use while energy and carbon intensities, oil rents and coal rents have negative correlation with the exploitation and use of RE - recommends higher tax rate on fossil fuels to subsidise renewable energy development

(*Continued*)

Table 10.1 Relevant comparative analysis and review. (*Continued*)

S/N	Author	Objective and methodology	Countries examined	Relevant findings and recommendation
5	Abubakar Kair Aliyu Babangida Modu Chee Wei Tan 2018 [34]	review of the development of RE in South Africa, Egypt and Nigeria	South Africa, Egypt and Nigeria	- highlighted the need for appropriate technology, skills and awareness are crucial to RE development - identified policy regulation as a factor for the varying level of growth in the RE sectors of the three countries - Focused on the technology-related challenges to highlight the need for improved energy efficiency, extension of the grid, advance technologies for energy storage and seasonality changes to increase RE generation
6	Abdullahi Abubaka Mas'ud Asan Vernyuy Wirba Jorge Alfredo Ardila-Rey, 2017 [35]	reviewed wind energy potentials and development in Cameroon and Nigeria, drew lessons from wind energy development in South Africa	South Africa, Cameroon and Nigeria	- commitment of the government and private sector is crucial to wind energy exploitation and development - there is need to secure more donor funding, project failure can be minimised by ensuring effective project procurement strategies and development of feed-in-tariff for wind energy

(*Continued*)

Table 10.1 Relevant comparative analysis and review. (*Continued*)

S/N	Author	Objective and methodology	Countries examined	Relevant findings and recommendation
7	I.M. Bugaje, 2006 [36]	reviews energy policies in South Africa, Egypt, and Mali ; and how they are contributing towards addressing their respective energy challenges	South Africa, Egypt, Nigeria, and Mali	- deployment of solar PV technology to meet non-industrial energy uses such as schools, clinics, and homes - need for policy development to drive the diffusion of solar thermal technologies for heating and cooking - development of local capacities for the local manufacturing of improved cooked stoves and establishment of centres for information dissemination and guidance on energy appliances and use
8	Tyeler Matsuo, 2019 [37]	examined the shows the impact of their varying approaches and results in diverse auction designs of large scale RE projects and the development of the renewable energy industry in the two countries	South Africa and Mexico	- the development of RE comes with a trade-off hence the need to develop strategies would minimize the undesirable impact of the trade-off - While the increasing attention on RE would facilitate the path to decarbonisation, it will also increase reliance on foreign RE value chain if RE development is implemented without complementary effort to develop local capacities.

Source: Authors' elucidation.

to knowledge but mostly focused on technology and economic dimensions of renewable energy. Some of the factors of focus and recommendations in such studies include seasonality and unreliability of RESs, high upfront cost, prevailing prices of conventional energy sources including taxes and subsidies, energy and carbon intensities, and trend of energy demand, among other technology and economic factors [30–33].

Indeed, a number of studies highlight policy and regulation as a crucial factor that influences the progress in renewable energy development [34, 36]. However, there still exists a dearth of knowledge on detailed and comparative analysis of renewable energy policies and regulations in the selected countries, a need the study addresses. In addition to the detailed analysis of the policy and regulatory frameworks, the study also makes a unique contribution in the extensive review and comparative analysis of the institutional frameworks of the three countries. Based on the review, the study crystallizes some challenges within institutional frameworks in Nigeria, which are yet to be characterized in literature, with recommendations from the institutional frameworks in South Africa and Egypt.

10.3 Renewable Energy Development in South Africa

10.3.1 Policies and Strategies

South Africa's White Paper on Energy Policy published in 1998 [38] sets the policy foundation for the country's RE development. Prior to the adoption of the policy, 60% of South African households had been electrified, out of which more than 2.4 million were electrified in the period 1991-1997. The paper established the interest of the government in the uptake of renewable energy. Before 1998, South Africa made no significant commitment to exploit its RE potential due to the excess generating capacity (39,000MW) of its national utility company (ESKOM) which was above the national electricity demand of 28,330MW in 1997 [39]. The integration of the South African science and research community in the policy development architecture for RE exploitation in the country enabled the government to make realistic projections which informed its policy decisions. The white paper envisions that RETs will be cost-effective and cost-competitive in the future as it is fast becoming in the present day. RETs were identified as least expensive energy alternatives (especially with the inclusion of social and environmental costs) for delivering energy to remote areas that are not favored by the economics of grid extension.

In 2003, the government developed the Working Paper on Renewable Energy (WPRE) which charted the course for the nation's energy transition with the first specific target (medium-term, 2003-2013) for the share of RE in its energy mix. It also highlighted governance, finance, technology, education and research as five support pillars towards meeting the targets. The government envisioned the development of solar, wind, biomass, and small hydropower plants with a cumulative capacity of 1,667MW (about 4% of the projected 41,539MW electricity generating capacity for 2013) to contribute 10,000GWh electricity to its projected final electricity consumption in 2013 [40]. The technical and financial support of development partners and the commitment of the government to the "2009 Copenhagen" to cut its emissions by 34% in 2020 and 42% by 2025 led to the massive roll-out of renewable energy projects across the country [41]. Also, the National Climate Change Response White Paper (NCCRWP) that was published in 2004 sets out the agenda of the government to reduce GHG emissions in strategic sectors. Given the domination of its energy sector by the fossil fuel and the depreciated plant efficiencies, the energy sector was the highest emitter of GHG emissions in the South African economy [42], thus providing another thrust for RE uptake in the country.

Moreover, the effort to reposition the South African electricity sector against the backdrop of the electricity "blackout" (electricity crisis) experienced in 2008 generated additional impulse for South Africa's commitment to RE [43]. In addition to its commitment to off-grid RE projects, in 2009, the government launched the Renewable Energy Feed-in-Tariff (REFiT) which attracted private sector investment for large-scale RE (on-grid) development by drawing on the experience of Germany in promoting the development of its RE sector. This culminated in a competitive tendering scheme which has been identified as a strategy for improving affordability for consumers and profitability for investors [41, 44].

In order to define its long-term (20-year) electricity generation plan by exploiting its various energy resources, the government designed an Integrated Resource Plan (IRP) in 2010 [45]. IRP outlines the vision of the government to add 17,800 MW RE electricity generation capacity to its energy mix by 2030. In 2012, South Africa adopted the Renewable Energy Independent Power Producer Procurement (REIPPP) programme. The REIPPP programme was adopted to reduce the country's reliance on coal and nuclear energy by developing large-scale RE projects using various technologies with total installed capacity of 17,800MW between 2012 and 2030, hence, reducing the country's emissions trajectory [46]. Through "Ministerial Determinations", which is being promoted by the 2016 Electricity Regulations Act [47], the government envisions additional installed capacity of 3,275 MW by 2016, 3,200MW by 2020 and 6,300MW by 2025 (that is, 30% of its electricity mix) as intermediate additional targets in view of realising its target of adding 17,800MW RE generation capacity by 2030.

Renewable energy outlook in South Africa

The implementation of the RE policies and strategies resulted in transformational growth in RE exploitation, especially solar energy, in South Africa which provides a model for other African countries as discussed in the following sections.

Solar energy

Approximately 194000km^2 land area in South Africa receives high radiation from the sun which represent one of the country's most abundant RESs [48]. Northern Cape in South Africa is one of the world's best sites for solar energy resource [49]. Although the expensive price of solar module which represents up to 50% of utility-scale solar PV projects (Figure 10.2) constituted a major barrier to solar energy generation, the diffusion of solar PV technologies has been catalysed by the falling price of solar photovoltaic (PV) [50].

Wind

Unlike solar energy resource that is available in various African countries at significant measure, wind energy potential is relatively low in Africa and available in only a few countries [52]. South Africa's wind energy resource represents one of the highest in Africa which is being exploited and estimated to be sufficient to power 56,000MW electricity generation installed capacity of wind turbine [53]. Based on its additional 700MW wind energy installed in 2017, South Africa ranked among the top 10 countries with highest additional

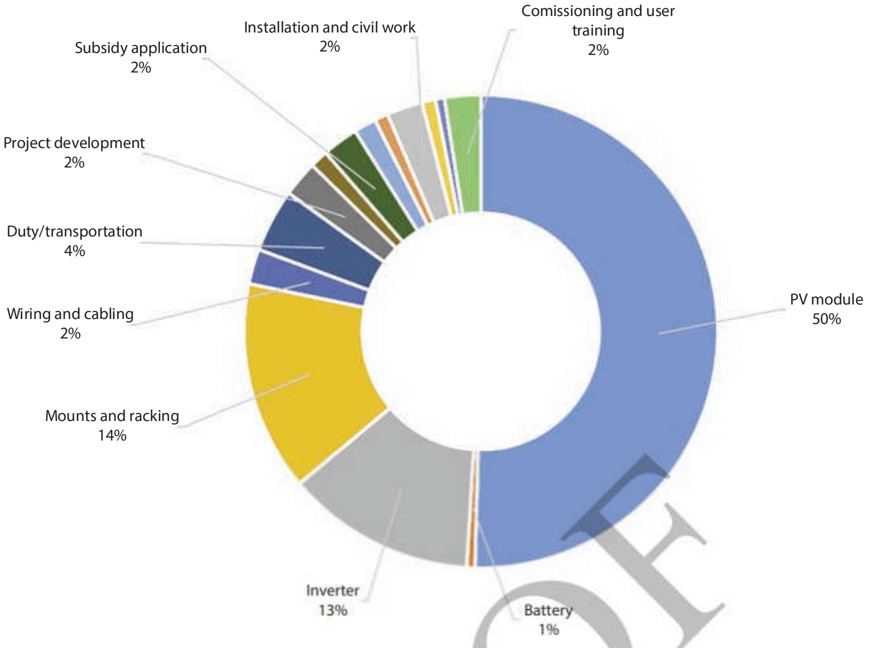

Figure 10.2 Share of total cost of a large-scale solar photovoltaic project in Africa. Source: IRENA, 2018 [51].

installed capacity for wind energy and the only African country that increased its for wind energy generation capacity in the year [54] (Table 10.2). Though its cumulative installed capacity for wind energy generation stood at 9MW from two pilot projects in 2010, the country increased its capacity to 2100MW from more than 20 wind energy projects in 2017 [54, 55].

Hydropower

Hydropower generation in South Africa dates back to 1892 when gold mines were powered by two 6kW hydro turbines [56]. A report from South Africa's Department of Energy shows that as of 2015, there were six utility-scale hydropower projects developed as integrated power projects (IPPs), out of which three were developed under the *REIPPP programme* and being fed into the grid. An aggregated 247MW hydroelectricity potential exploitable through small hydropower projects have also been identified especially in the Eastern Cape, Free state, Kwazulu-Natal parts of the country [57]. According to the African Energy Portal of the African Development Bank, the total installed capacity for hydropower generation in South Africa stood at 747.20MW in 2019 [58] from large- and small-scale hydropower plants.

Biomass

The traditional use of biomass constitutes a high proportion of energy use in Africa especially in the rural communities [59, 60]. South Africa has 42 million hectare of natural woodland and 1.35 million of plantation and trees which produces 1.2 million tons of wood fuel. This indicates a significantly high potential for energy generation from biomass [61]. For instance, in 2010, 80% of rural homes in South Africa relied on traditional wood fuel while charcoal accounted for 10% of its total primary energy use. However, there has been

Table 10.2 Increase in wind energy installed capacity in 2017 in the top 10 countries.

Country	Total end-2016	Added 2017	Total end-2017
		GW	
Top Countries by Additions			
China[1]	149/168.7	15/19.7	164/188.4
United States	82.0	7.0	89.0
Germany[2]	50.0	6.1	56.1
United Kingdom	14.6	4.3	18.9
India	28.7	4.1	32.8
Brazil	10.7	2.0	12.8
France	12.1	1.7	13.8
Turkey	6.1	0.8	6.9
South Africa	1.5	0.6	2.1
Finland	1.5	0.5	2.1

Source: REN21, 2018 [54].

adoption and diffusion of biomass energy technology which enables clean and more efficient use of biomass. The two major industrial applications of biomass energy technologies in South Africa are power generation for paper packaging companies and sugar mills, both generating 201GWh of electricity from biomass annually. There are, also, diverse small-scale biogas plants generating heat for cooking from animal wastes and a few industrial-scale plants generating biofuel from municipal organic waste, sewage, and animal waste, altogether generating several hundreds of MW [62].

However, competition for land for food production and the need for diversity in crop production in order to protect land quality are two major concerns against plantation for biomass energy generation. As of 2006, South Africa had 4300km^2 (430,000 hectares) and 13,000km^2 (1,300,000 heactare) land area of sugar cane plantation[1] and forest respectively [63]. Apart from the REIPPP programme, the government also commenced working on a Biomass Action Plan in 2014. This resulted in an increase in its installed capacity for energy generation from biofuel and waste from 246.0 MW that generated 280.3GWh of electricity in 2012 to 264.7MW that generated 350.9GWh in 2019 [58].

10.3.2 Policy Impact on Renewable Energy Development

The REIPPP programme, through the competitive bidding scheme, catalysed the development of grid-connected RE projects in South Africa [46]. In 2011, the government selected,

[1] Sugar cane is one of the sugar-rich biomass with established conversion technology for production of biofuel [62] by burning bagasse (substrate of sugar cane).

through competitive bidding (setting the tariff in the REFiT as the cap), 28 private investors to add more than 140MW RE generation capacity with an investment of USD16 billion. An additional 36 renewable energy-based IPPs were also selected in 2013, also, through a bidding process such that by 2014, South Africa had approximately 1000MW of on-grid solar energy installed capacity that generated 213GWh/month of electricity. Also, in 2014, South Africa had about 600MW on-grid wind energy installed capacity that produced 130GWh/month in 2014 and the projects are fairly distributed across the country (Figures 10.3 and 10.4). As of 2015, 56 out of the IPPs that were selected through the bidding scheme added 2902MW electricity generating capacity from RE to the grid resulting from an investment of more than R200 billion (approximately USD14 billion) [64] constituting an additional 1902MW in one year, about a 190% increase from 2014.

The REIPPP programme helped to diversify the South African electricity sector from one generating company to a multi-player sector led by the private sector [46, 50]. The development of utility-scale IPPs also helped to improve social equality among the poor black population who had been marginalized on access to services over the years [65]. Moreover, the integration of the socio-economic development into the programme also facilitated improvement of human livelihood in host communities [46]. The IPPs are required to contribute to social and economic development in communities within 50km radius from their respective plants, an initiative that has generated about 110,000 direct jobs. The development of the IPPs

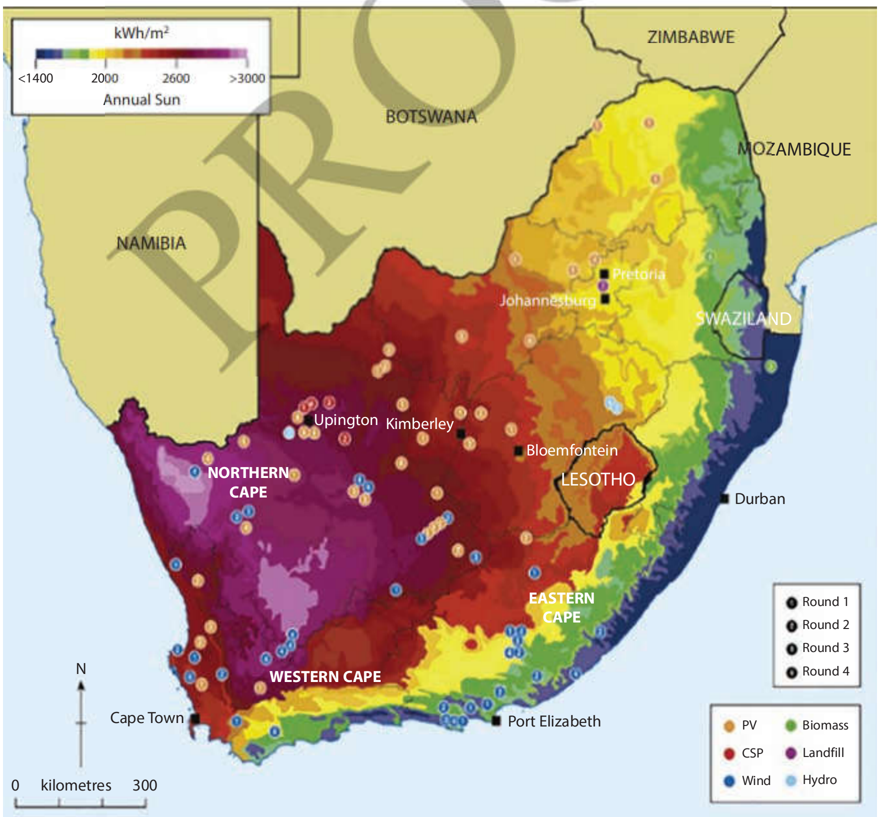

Figure 10.3 Distribution of renewable energy projects in South Africa. Source: McEwan, 2017 [49].

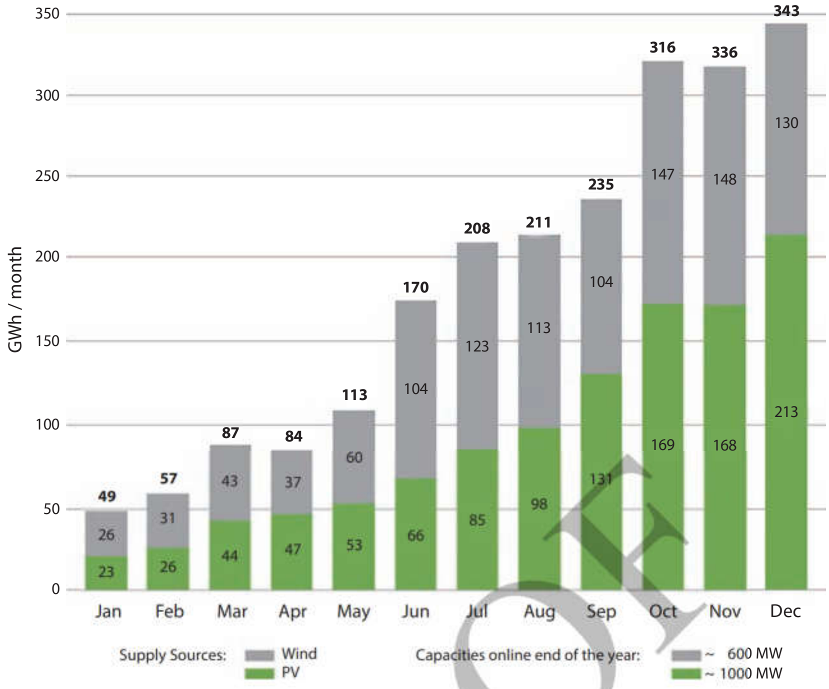

Figure 10.4 REIPPP growth in energy produced during 2014. Source: DoE, 2015 [57].

attracted over R53 billion (about USD3.7 billion) foreign investment and financing out of which R35 billion (about USD2.4 billion) is equity. The R35 billion foreign equity from the four round of bids through the REIPPP programme represents one-third of the total foreign direct investment (USD8.2 billion) in South African in 2013 [57]. The provision of guarantees by the government also reduced payment risks hence improving the bankability of the projects. All the IPPs, under the REIPPP programme, sell electricity to Eskom, the South African public utility company, and Eskom is required to pay for the electricity sold by the IPPs through Power Purchasing Agreements (PPAs) for up to 20 years. In the case that Eskom defaults, the payment guarantee provides that National Treasury of South Africa (NTSA) purchases and pay for electricity from IPPs. The second guarantee provides that the government pays the sponsors of IPPs in case of early termination of the projects by the government. The various support mechanisms and strategies for large-scale project development of RE projects resulted in the award of up to 112 IPPs in South Africa [66].

In addition to utility-scale projects, the total installed capacity of solar home systems (SHS) increased by 44MW without incentives from the government. In 2001, the government initiated the Rural Off-Grid Electrification Programme with an investment of more than R350 million (approximately USD24 million) in the bid to achieve universal household electrification by 2012. Through the programme, more than 95,000 SHS were installed especially across regions that have been initially marginalised in the provision of access to electricity among other public services [57]. This represents a major contribution to increasing access to electricity in rural households in South Africa. In 2013, the government adopted a New Household Electrification Strategy with the vision to provide off-grid energy systems aimed at electrifying 300,000 households to attain 97% household electrification by 2025 [67, 68].

10.4 Renewable Energy Development in Egypt

The Middle East, and North African (MENA) region receives 22-26% of the total global solar radiation which is sufficient to generate energy equivalent to 1-2 million barrels of oil [69]. Moreover, countries such as Morocco, Egypt, and Turkey also have abundant potentials for wind energy [70]. Despite the available potential, the progress in renewable energy exploitation in the region is relatively slow except in Egypt, Tunisia, Morocco, Jordan and Iran [71]. While the Egyptian energy mix remains dominated by fossil fuels, the country recorded significant progress in the exploitation of RE. As of 2019, RE accounts for 5,972.3 MW of the 64,586.30MW cumulative installed capacity for electric power production in the country. This comprises 2,850.80MW hydropower, 1668MW solar, 1,375.0MW wind and 78.5MW geothermal installed capacities [72].

10.4.1 Policies and Strategies

The remarkable growth in RE integration in Egypt is traceable to some of the laws and strategies implemented by the government. A Renewable Energy Master Plan financed by the European Union shows that with appropriate incentive, renewable energy, particularly wind and solar, could constitute 50% of the Egyptian energy pool by 2050. This may partly explain the commitment of the government to numerous RE policies, strategies, and incentives.

The Egyptian government began its effort towards RE exploitation in the 1970s which culminated in the adoption of a renewable energy strategy and setting up of the New and Renewable Energy Authority (NREA) in the 1980s [73]. Electricity generation in Egypt has been fossil-dominated [74] as 89% of the Egyptian electricity supply is generated from fossils fuels while renewables account for 11%, with hydropower representing 6-8% [75]. While its annual population and economy grow by 2.2% and 3% respectively, its electricity demand increases by 7% annually requiring an annual 2GW increase in generation capacity, thus posing a challenge to the Egyptian energy landscape due to its limited fossil fuel reserve [73]. It has been estimated that only 1.5 billion barrels of the Egyptian oil reserve will be left by 2030 [74]. The limited fossil fuels vis-à-vis the increasing energy requirement in the country (due to the growing population and the need to power the Egyptian economic expansion) propelled the effort of the government to tap into the self-replenishing RESs available to the country. In this pursuit, the government developed and is implementing various policies and strategies that are facilitating plurality in its energy mix by exploiting RESs in the country especially solar and wind energy.

In its New National Renewable Energy Strategy published in 2008, the Egyptian government declared its ambition to produce 20% of its electric power from RESs by 2020 [73]. Of this proportion, 12% is designated to be generated from wind energy, which is equivalent to 7200 MW on-grid wind energy generating capacity. The targets were revised and set at 20% of its electric power from RESs by 2022 and 42% by 2035 [51]. Similarly, the government published its *solar plan* in 2012 which is aimed at adding 3,500MW installed capacity for solar energy generation (700MW of solar PV and 2800 MW of CSP) by 2027 [76–78].

While the majority of the RE generation capacity is envisioned to be developed through private investment, one-third is to be funded by the government with the support of international finance corporations. The Strategy document outlines the plan of the government to attract foreign private players through a Competitive bidding scheme with the aim that the respective Feed-in-Tariff that will be determined through the bidding scheme. The strategy also allows private investors to develop private RE projects for private consumption and/or uptake to the national grid through Power Purchasing Agreements. The implementation of the Competitive Bidding Scheme resulted in the development of large-scale RE projects by private players through public finance supported by international financial organisations. Zero import duty for all RE equipment and device, long-term power purchase agreement spanning 20-25 years between IPPs guaranteed by the Egyptian's Central Bank and government among other strategies were adopted to de-risk private investment, thus attracting investors to the sector. The document also laid out the interest of the government to have RE projects participate in a Carbon Credit Scheme while setting up a dedicated public fund to subsidise the investment cost of private players while ensuring affordability for energy consumers. The Strategy also highlights the commitment of the government to research and development in view of increasing the country's human and knowledge capitals on renewable energy.

While the Egyptian Electricity Transmission Company (EETC) has responsibility for the competitive bidding scheme, the provision of land for projects is domiciled with NREA. In order to demonstrate its readiness for investment and guide investors' decision-making, the government earmarked 7600km^2 land area of the desert for RE projects and issued the permit for the land area to the NREA [51]. The government also conducted an environmental impact assessment of wind projects on the reserved land area.

In 2015, the government, through a Presidential Decree (No. 17/2015) reviewed its Investment law (No. 8/1997) to attract investment (including renewable energy) to the country. The law also provides for the provision of land at no cost or discounted fees for RE project [79]. By the revised law, importation of RE was set to attract 2% duty while sales tax was reduced to 5%. In addition, the new energy investment law also committed the government to subsidise technical training programmes and provision for social insurance for employees of electricity producers to improve human capacity development in the energy sector.

Table 10.3 presents the relevant public stakeholders in the Egyptian RE sector with their respective mandates. As the implementing agency, the NREA promotes electricity generation from RESs except for hydroelectricity which is being coordinated by the Hydro Power Plants Executive Authority (HPPEA). In view of ensuring quality control for standard installation, NREA developed a certification programme for solar PV installers which has already produced 100 PV installers in the country [73, 80]. Similarly, since the agency was set up by the government, a number of indoor and outdoor testing facilities have been established for quality assurance of RE devices and equipment being allowed into the Egyptian renewable energy market [51].

Towards cost competitiveness of renewable energy in Egypt

The substantial amount of subsidy on electricity and fossil fuels negatively impacts the cost-competitiveness of electricity generation from renewable energy. Until the enactment of the Law 203/2014, electricity tariff in the country was not cost-reflective. According to the World Bank, Egypt's energy subsidy accounted for 22% of the government's budget while subsidy on fossil fuels amounted to 7% of its GDP, more than the sum of the expenditure on health and education (5%) in 2013 [81].

Table 10.3 Institutional framework of renewable energy development in Egypt.

Role	Institution	Specific role
Planning	Supreme Council of Energy	Development of strategies for the energy sector and reports directly to the Egyptian Presidency
	Ministry of Electricity and Renewable Energy	Meeting the national electricity demand.
Regulation	Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA)	Regulates the cost of electricity based on the interest of all stakeholders and ensures transparency in the electricity sector
Execution	Egyptian Electricity Holding Company (EEHC)	Deals with electricity supply to the consumers
	Egyptian Electricity Transmission Company (EETC)	operates and manages the transmission grid, and it operates with the electricity distribution company.

Based on Elkhayat, 2016 [73].

The huge sum committed to the electricity sector as subsidy had an adverse effect on the country, which necessitated the development of a self-sustaining electricity industry that ensures profitability for investors and affordability for energy users. In this pursuit, the government announced, in 2014, increases in electricity tariffs for various users with the aim of reducing and ultimately phasing out electricity subsidies within five years [80]. The domestic users will have a 10-20% increment annually (with the exemption of the lowest energy consuming user category), commercial users, about 7% while industrial users will have more than 20% increment every year till 2018. The government also increased the prices of various fossil fuels. The gradual reduction and eventual removal of subsidy on electricity will improve the cost competitiveness of RE in the country.

10.4.2 Policy Impact on Renewable Energy Development

The significant growth in RE investment in Egypt provides some indications to the impact of the various policies and implementation strategies employed in the country. While the Egyptian renewable energy infrastructure built over 25 years has been estimated to be USD 1.3 billion, NREA awarded renewable energy (340 MW of wind farm and 60 MW Solar PV) contracts to the sum of USD 500 million in the first six months of 2015.

The following section discusses the impact of the policies on the exploitation of the various RESs in the country.

Hydropower

The concentration of about 94% of the Egyptian population along the River Nile provides an insight into the significance of the river to development and livelihood in the country. Until the 1970s, hydropower generation from the River Nile accounted for 50-60% of the total electricity generation in the country [51]. Despite the increasing installation of hydropower (Figure 10.5), its share in the electricity mix declined over the years to 12% in 2012 [53] and 7.3% in 2016 [82] due to the more rapid development of gas-fired thermal generation power plants to meet the growing electricity demand. Out of the 3,664MW potential capacity and 15,300GWh electricity production per annum exploitable in Egypt [53], the country has developed 2,800MW installed capacity generating 13,545GWh mainly along River Nile (Figure 10.5 and Table 10.4) in 2016. Hydro-electricity generation is mainly generated from five major hydropower projects that were developed on River Nile, namely High Dam (2100MW), Aswan I (280MW), Aswan II (270MW), Esna (85MW) and Naga hamadi (64MW).

Solar energy

Egypt has been a major target country for solar energy investment in recent years due to the high solar energy resource available to the country and the various policies and initiatives of the government. The location of Egypt in the global sunbelt makes it receive high solar insolation round its territories throughout the year. Egypt is estimated to have 2900-3200 h annual sunshine hours and direct power density ranging between 1970-3200 kWh/m^2 [83, 84]. The adoption of concentrated solar power (CSP) technology in Egypt dates back to 1910 when an industrial scale set of solar parabolic collectors was installed in Cairo for water pumping for irrigation [85], while, the uptake of solar energy through the solar PV commenced in the country in the 1980s [51]. Since then, the solar PV technology has been deployed for lighting, refrigeration, water pumping, desalination among other applications in the country [86, 87].

The government launched various initiatives to support the deployment of small-scale solar PV installations in the country [51]. The Cabinet of Ministers (CoM) Initiative

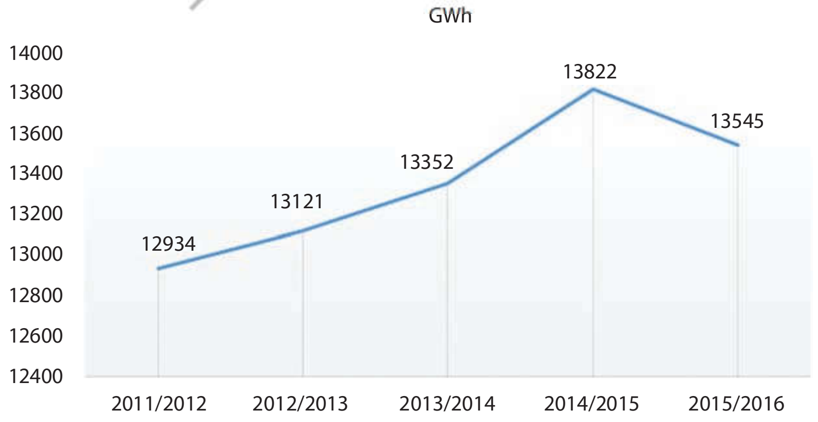

Figure 10.5 Electricity generation from hydropower between 2011 - 2016. Source: EEHC, 2016 [82].

Table 10.4 Hydroelectric power plants and their capacities in Egypt.

Station	Capacity (MW)	Annual electricity generation (GWh)
High dam	2,100	9,484
Aswan 1	280	1,578
Aswan 2	270	1,523
Esna	86	507
Naga Hamady	64	453
Total	2800	13,545

Source: IRENA (2018) [51].

mandates the installation of grid-connected solar PV on the rooftop of public buildings. Since the commencement of the initiative in 2013, 30 solar PV systems totaling 840kW have been installed. The total installed capacity of small solar PV in the country was estimated to be 6MW in 2013 while that of large-scale plants was 30MW in 2016 [51] while the total installed capacity for solar energy rose to 1,668MW in 2019 [88]. In addition, about 6,000 rooftop solar PV systems have been implemented in remote areas around the country [73].

In line with the New National Renewable Energy Strategy adopted in 2008, Egyptian Electricity Transmission Company (EETC) opened an auction for four RE projects totaling 520MW (200 MW Solar PV, 250 MW Wind, and 50MW CSP at West Nile and another 20MW at Kom Ombo) generating capacity in 2015. Table 10.5 provides information about the various solar energy projects being developed under the BOO, ECP and IPP schemes and planned to be on-stream by 2023.

Through the UAE Rural Electrification initiative, Egypt added 32MW to its cumulative solar PV installed capacity; comprising 30MW cumulative capacity of centralized PV projects, and 2MW from 6942 stand-alone PV systems.

Since it launched the first tenders for large-scale private RE electricity under the BOO scheme in 2009, EETC has opened tenders for a cumulative capacity of 200MW of solar photovoltaic in 2013; 250MW wind, 200MW solar photovoltaic and 100MW CSP in 2015. The adoption of the New National Renewable Energy Strategy in 2015 followed the enactment of the Renewable Energy Law by Presidential Decree (Decree No. 203/2014) [89] which empowers the bidding mechanism for Build-Own-Operate (BOO) contracts. The Egyptian Electricity Regulatory Agency also developed regulations to reduce the risk and boost investors' confidence in the sector. The IPPs built under the BOO contracts with purchasing power agreements (PPAs) are allowed to sell electricity to EEHC or directly to electricity distribution companies. Due to declining cost of renewable energy generation, the government adopted the competitive bidding (auction) procedure in 2017 for wind and solar energy projects. Projects can be implemented as a state-owned EPC contract or as IPP through PPA with EEHC using the BOO scheme [16, 51]. The BOO and IPP schemes catalysed the development of large-scale RE power plants with bidding opened for more than 1000MW capacity for solar and wind energy through the BOO scheme and three wind,

Table 10.5 Solar Photovoltaic Projects in view towards 2023.

Project	Type	Status	Size	Contact
Kom Ombo	PV	Binding	200MW	BOO Scheme
West Nile	PV	Binding	600MW	Sky Power and EETCC BOO
West Nile		Binding	200MW	EETC BOO
West Nile		Binding	600MW	BOO Scheme
FIT		Operational	50MW	EETC PPA
FIT		Under development	1,415MW	EETC PPA
Hurghada		Tendering	20MW	NREA-JICA EPC scheme
Zafarana		Under development	50MW	NREA-AFD EPC scheme
Kom Ombo		Under development	26MW	NREA-AFD EPC scheme
Kom Ombo		Under development	50MW	NREA-AFD EPC scheme

Note: BOO = build, own, operate; EETC = Egyptian Electricity Transmission Co.; PPA = power purchase agreement; NREA = New and Renewable Energy Authority (Egypt); JICA = Japan International Cooperation Agency; EPC = engineering, procurement and construction; AFD = French Development Agency (Agence Française de Développement). Source: IRENA, 2018 [51].

solar and CSP projects with cumulative 1700MW installed capacity through the competitive bidding have been approved by the government [51].

Also, the Feed-in-Tariff (FiT) scheme was developed in 2014 to facilitate the development of small- and large-scale RE projects towards achieving 2,000MW installed capacity each from wind and solar energy [73, 90]. The maximum capacity under the scheme for each project is set at 50MW with PPA for 20 years for wind and 25 years for solar energy projects. The FiT scheme catalysed the development of grid-connected PV systems (which also covers wind energy) such that a total of 10MW solar PV capacity was added to the grid at the end of the first phase of the FiT scheme in 2016. The scheme has now been revised and extended to large solar PV plants.

Through these various programmes and initiatives, the government received over 20 bids for the development of various on-grid solar energy projects totaling 20,000MW capacity within 2 years. In addition to the solar PV, Egypt has also developed a 140MW solar thermal combined power plant. This comprises 20MW of solar thermal capacity and 120MW from a gas-fired combined-cycle plant which altogether generated 164GWh of electricity in

2015/2016. The solar component of the project is estimated to save 10,000 tons of conventional fuel annually, hence, cutting 20,000 tons CO_2 emissions [51].

Wind energy

As highlighted in the elucidation on the uptake of solar energy in Egypt; the FiT, Auction and Competitive Bidding schemes cover both solar and wind energy which are the two priority RESs of the government. Therefore, having discussed the schemes above, this section will be limited to the growth in wind energy uptake in Egypt.

Egypt has significantly high wind speed ranging from 8m/s to 10.5m/s at 25m altitude and power intensity between 300-600W/m^2 which has been estimated to be sufficient to power more than 20,000MW wind energy installed capacity [84, 85, 91]. Egypt commissioned its first wind farm with a 5.2MW total installed capacity in Hurghada in 1991. Another 63MW wind energy project was commissioned in 2000 and connected to the grid the following year. In 2006, the government developed a wind atlas which stratifies the country into regions based on their wind speeds [92]. The development of the atlas helped the government to identify viable locations for wind energy exploitation across the country. The capacity of the Hurghada wind farm was also increased to 305MW in 2007 and is now being expanded to add 1100MW to the Egyptian energy mix [53, 84, 93, 94].

In 2011, a series of large-scale wind energy farms (545MW) was commissioned in Zafarana. An additional 200MW capacity was installed in Gulf of El Zayt in 2015 which was developed in cooperation with four European countries using the EPC scheme [51, 53, 82, 94]. The progressive growth in wind energy investment increased electricity generation from wind energy by approximately 790% in 4 years, that is, from 260GWh in 2001/2002 to 2058GWh in 2015/2016. This resulted in increased savings of conventional fuel from 58Mtoe to 432Mtoe and CO_2 savings from 143,000 tons to 1.131 million tons within the same period [82]. Figure 10.6 provides shows the progression of electricity generation from wind energy while Table 10.6 provides an overview of proposed wind energy projects till 2023.

Based on: EEHC (2016a), Egyptian Electricity Holding Company Annual Report 2015/16; EU (2015a), "Integrated Sustainable Energy Strategy".

Figure 10.6 Electric power production (2004/05 - 2015/16) Source: IRENA, 2018 [51].

Table 10.6 Proposed wind energy till 2023.

Project	Technology	Status	Size	Contract
Gulf of Suez	Wind	Under development	250MW	NREA-KfW, EIB, AFD EPC Scheme
Gulf of Suez	Wind	Under development	250MW	GDF Suez, Toyota, Orascom BOO Scheme
Gulf of Suez	Wind	Under development	200MW	NREA-Masdar EPC scheme
Gulf of Suez	Wind	Under development	200MW	AFD-KfW EPC scheme
Gulf of Suez	Wind	Under development	2,000MW	Siemens EPC scheme
Gabal El Zayt	Wind	Under construction	220MW	NREA-Japan-JICA EPC scheme
Gabal El Zayt	Wind	Under construction	320MW	Italgen BOO scheme
Gabal El Zayt	Wind	Under construction	120MW	Spain-NREA
West Nile-1	Wind	Under development	250MW	Boo scheme
West Nile	Wind	Under development	200MW	Japan EPC scheme
West Nile	Wind	Tender-bidding Phase	600MW	NREA IPP scheme

Notes: AFD = Agence Française de Développement; EIB =European Investment Bank; JICA = Japan International Cooperation Agency.
Source: IRENA, 2018 [51].

Biomass

Biomass is another abundant resource available in Egypt from various sources. Studies show that 15.3 million tons of municipal solid waste was produced in the country in 2001 (three-quarters being produced in the urban areas), 27 million tons of crop residue was generated in 2003 while 2 million tons of sewage was generated in 2008 [53]. Being Africa's largest producer of rice, Egypt could add significant electricity contribution to its energy pool using rice straw.

Abdelhady shows that 3.1 million tons of rice straw produced in Egypt per annum is sufficient to generate 2,447GWh and reduce CO_2 emission by 1.2Mtons CO_2 annually in the country [95]. Despite its abundant biomass potential, there are no records of significant exploitation of biomass for clean energy generation. Though the government has demonstrated an appreciable commitment to RE development, through policies and initiatives, the focus has been on solar and wind energy in addition to increasing its hydropower generating capacity which has been in its electricity mix over the decades. Therefore, exploitation of biomass energy has been limited to the effort of donors and non-governmental organisations as biomass is yet to be included in any of the government's programmes. The limited growth in the exploitation of biomass for electric power production despite the huge available resource versus the remarkable development of solar, wind and hydropower brings to fore the crucial role of the government in facilitating the exploitation and use of RESs.

Impact of renewable energy policies and strategies on sustainable development

The FiT scheme and the resulting increase in the development of large-scale RE projects (Table 10.7) in Egypt has made a significant positive impact on development of the country. The sourcing of materials, components, and labour for the development of RE projects locally led to an increase in the number of solar PV companies, creation of employment opportunities through sub-contractors in the long term for operation and maintenance have altogether helped to boost the local economy. The dedication of desert for large-scale RE projects has resulted in increased population density in the desert regions, hence, attracted social facilities and services like schools, hospitals, roads, and water supply in addition to electricity supply to the interior part of the country which had been previously unserved by social services. This is contributing to decongestion of cities especially with the migration of skilled labors while increasing economic profile of villages and towns around the areas where projects are being implemented.

Whereas there has been no empirical study that analyzed the employment benefits of the recent progress on RE projects implemented in Egypt, findings from similar studies may provide some knowledge on the impact of the RE policies and strategies on employment in the country. Based on a study conducted by Estela Solar in 2008, the development of every 100MW solar thermal plant creates 400 new jobs in manufacturing, 600 jobs through contracts and installation and 30 annual jobs for management of the projects. Particularly, a scale-up investment plan designed by the World Bank and the African Development Bank for MENA region shows that the development of 5GW of CSP by 2020 in Egypt, Algeria, Jordan, Morocco, and Tunisia will generate employment for 64,000-79,000 people in these countries by 2025 [96].

Table 10.7 Ongoing renewable energy projects.

Capacity (MW)	Technology	Scheme	Scale
Wind	2,000	FiT	Utility
Wind	250	BOO	Utility
PV	2,000	FiT	Utility
PV	300	FiT	Rooftop
Wind	200	EPC	Utility
Wind	200	EPC	Utility

Source: Elkhayat, 2016 [73].

10.5 Renewable Energy Development in Nigeria

The Nigerian Electricity Power Authority (NEPA), the successor of previous national electricity companies (Table 10.8), was the sole player in the Nigerian electricity sector with mandates for generation, transmission, and distribution of electricity until 2005. In a bid to improve effectiveness in the sector, the government enacted the Electric Power Sector Reform Act (EPSRA) in 2005 which mandated the unbundling and privatization of the sector [97, 98]. The Act established the Power Holding Company of Nigeria (PHCN) and the Nigerian Electricity Regulatory Commission (NERC). While PHCN was established

Table 10.8 History of the Nigerian electricity sector.

Year	Reform
1886	A colony of Lagos installed two small power generating sets
1951	Electricity Corporation of Nigeria (ECN) Act of Parliament was established
1962	Niger Dams Authority (NDA) was established for the development of hydroelectric power: First 132 KV line
1972	ECN and NDA were merged and formed National Electricity Power Authority (NEPA)
1990	Commissioning of Shiroro power station
2005	Power Sector Reform Bill was signed into law by President Olusegum Obasanjo, to enable private companies to participating in electricity sector
2005	Establishment of the Power Holding Company of Nigeria (PHCN)
2005	Government commissioned independent power projects (IPPs) to generated and sell electricity to PHCN by increasing foreign participation in the electricity sector
2006	The six private generating companies and eleven private distribution companies were established
2006	Approval of construction of four thermal power plants with a combined capacity of 1,234MW
2013	Unbundling of the electiricity sector, the dissolution of the PHCN and the establishment of the Nigerian Electricity Regulatory Commission (NERC) to monitor and regulate the electricity sector
2013-Present (2020)	Electricity Generation Companies (GENCOs) and Distribution Companies (DISCOs) are owned and managed by the private sector while the Transmission is owned and managed by the government

Source: Ebhota and Tabakov, 2018 [99] (revised by the authors).

as a transient company through the period of the privatization and handing over of the sector to private players, NERC was established to have the regulatory oversight of the industry.

10.5.1 Policies and Strategies

The Energy Commission of Nigeria (ECN) developed the National Energy Policy (NEP) [100] with the aim of increasing energy security by diversifying the Nigerian energy mix. The policy envisions the exploitation of renewable and non-renewable energy resources including energy-efficiency strategies to facilitate sustainable development and achieve 75% electrification rate by 2020. The policy promotes the need to increase the contribution of RE to the Nigerian energy mix. ECN drafted the first edition of the policy in 1993 and revised in 1996, an effort led by the Ministry of Science and Technology. While the policy was awaiting approval, the dynamic change in the economic landscape that has erupted over time, necessitated the revision of the 1996 revised policy by an inter-ministerial committee. The revision was aimed at making the provisions of the policy attract private investment to the sector. The participation of the private sector is believed to be crucial to increasing investment in the sector while the profit-making objective would help to improve on the managerial inadequacies in the sector. The policy was approved in 2003 and revised twice in 2013 and 2016 [101].

The first Rural Electrification Strategy and Implementation Plan (RESIP) was developed for the Power Sector Reform team of the Bureau of Public Enterprise in 2006 and it outlines the rural electrification plan of the country till 2040 [102]. The plan outlines the vision of achieving 75% electrification rate by 2020 which would necessitate annual electrification of about 471,000 households in rural communities till 2020 and over 513,000 households every year from 2020 to 2040. This was envisioned to be achieved through small- and large-scale energy projects from renewable and non-renewable energy sources.

By drawing on the first RESIP that was published in 2006 among other policies, outcomes of workshops and consultations; the Nigerian Rural Electrification Agency (REA) developed a new RESIP [103]. The Plan was approved in July, 2016 towards further implementation of the EPSRA that was enacted in 2005 and the Rural Electrification Policy prepared in 2005 and approved in 2009. The plan is to be implemented with the Rural Electrification Fund which is to be provided by the government among other stakeholders. The Fund will provide part-funding for RE projects in rural communities. The government envisions attaining 75%, 90% and universal (100%) electrification access by 2020, 2030 and 2040 respectively through on-grid and off-grid solutions with not less than 10% electricity consumption being generated from RESs. Based on the plan, achieving these goals will require annual electrification of additional 1.1 million rural households from 2015-2020 and 513,000 rural households from 2020-2040. Achieving these goals will require total energy investments of USD 0.836–1.38 billion[2] from 2015-2020 and an equivalent of USD

[2] The projected investment NGN 317.8 – NGN 525.8 billion is stated in the Nigerian local currency, Naira (NGN) and has been converted at an exchange rate of NGN 380 = USD 1 sourced from the Central Bank of Nigeria as of October 23, 2020. The same rate has been used for subsequent conversions.

1.33–2.18 billion (NGN 507.2 – NGN 830.2 billion)[3] from 2020-2040. This put the required total investment from 2015-2040 to achieve universal electrification by 2040 at USD 2.17–3.68 billion (NGN 825 billion and NGN 1.4 trillion).

In 2012, the Renewable Energy Master Plan (REMP) was developed with the aim of exploiting RESs in the country to increase energy access, especially in rural communities. The plan envisions provision of energy access for economic, social and environmental development of the nation [104]. The Plan also outlines fiscal incentives such as zero import duty on equipment for the manufacturing of RE devices, 10-year tax holidays for new RE companies while existing companies are to be charged 50% of the prevailing tax rate. The document particularly states that the importation of component for the development of Solar PV projects will attract zero import duty. The incentives also include a minimum of 10% tax rebates for individuals and organisations (that are subject to income and profit tax) who adopt RETs at their private costs.

Moreover, NERC adopted the Multi-Year Tariff Order (MYTO) 1 in 2008 which outlines electricity prices to be charged by electricity-generation companies. The Multi-Year Tariff Order (MYTO) 2, the successor of MYTO 1, came into force in 2012 and was amended in 2015 and active till 2018 [105]. It outlines a new Feed-In-Tariff (FiT) for electricity produced from RE and supplied to electricity distribution companies (DISCOs). The FiT is denominated based on the various energy technologies (onshore wind, ground-mounted solar PV, small hydro that are less than 30MW and biomass) to be cost-reflective and are subject to minor review once in six months based on local and international economic factors (such as local inflation rate and Naira-USD exchange rate) and major reviews once in five years. Based on the provisions of the Order (MYTO 2), considerations on the FiT will be given to companies that can demonstrate that the economic implications of their generation differ from the assumption of the MYTO 2.

Also, in view of decreasing the country's reliance on the importation of refined petroleum products, the government also developed the Biofuel Blending Mandate in 2013 [106] which outlines the commitment of the government to the blending of petrol with up to 10% ethanol and diesel with 20% biodiesel.

In view of providing a specific policy structure for stakeholders with particular interests in RE and energy-efficiency (EE) policies, the Nigeria Renewable Energy and Energy Efficiency Policy (NREEEP) was developed mainly as an extraction from the Nigerian Energy Policy (NEP). NREEEP was approved in December 2015 and it outlines various targets for various RESs (Table 10.9) and various incentives to be provided by the government towards meeting the targets [107]. As strategies towards overcoming the challenges of RE development in Nigeria, the policy outlines various fiscal and financial incentives of the government covering the interests of investors and energy users in the country. Some of the fiscal incentives include:

- Minimum of 10-year tax holidays for new renewable energy companies and 50% profit tax reduction for existing ones
- 10-25% tax rebate for individuals and organisations that acquire RETs from their private funds (but the rebate should not be more than 10% of the total cost expended on RETs)
- Zero import duty on imported renewable energy equipment and components

[3] At an exchange rate of NGN 380 = USD 1 of the Central Bank of Nigeria as of October 23, 2020.

Table 10.9 Targets and timelines for electricity generation from renewable energy.

S/N	Resource	2012	Short term (2015)	Medium term (2020)	Long term (2030)
1	Hydro (LHP)	1,938.00	2,121.00	4,549.00	4,626.96
2	Hydro (SHP)	60.18	140.00	1,607.22	8,173.81
3	Solar	15	117.00	1,343.17	3,211.14
4	Biomass	-	55.00	631.41	3,211.14
5	Wind	10	50.00	57.40	291.92
All Renewables plus LHP		1,985.18	2,438.00	8,188.20	23,134.80
All Energy Resources (On-grid power plus 12,500MW of self-generated power)		21200	24,380	45,490	115,674
% of Renewables plus LHP		23%	10%	18%	20%
% RE Less LHP		0.8%	1.30%	8%	16%

Source: MoP, 2015 [107].

The financial incentives outlined in the policy include:

- Provision of low-interest loans (not exceeding 5% interest) for RE and EE projects from development financial agencies
- Provision of subsidies that covers up to 30% of the upfront cost of RE and EE projects implemented as personal and organization projects.

In order to attract investment for electricity generation from RESs, NERC put into force FiT for electricity generated from RESs. The new regulation also mandated electricity DISCOs to procure 50% of electric power from RE plants while the counterpart 50% should be procured from Nigeria Bulk Electricity Trading (NBET) Company. The regulation also grants automatic integration of electricity generated from small[4] RE plants and the commission intends to adopt the bidding scheme to facilitate the implementation of large RE projects.

In 2016, NERC developed the Mini-Grid Regulation [108] to boost investors' confidence by "de-risking" mini-grid investment in the country. The regulation categorized mini-grid projects into Isolated and Interconnected mini-grid projects. The difference lies in that interconnected mini-grids are connected to distributions lines of a licensed DISCO covering the area. Also, interconnected mini-grids are operated in underserved communities while isolated mini-grids operate without connection to a distribution grid and are operated in unserved communities. Isolated mini-grid project with installed capacity below

[4] A plant with capacity ranging from 1MW to 30MW.

100kW can either be operated as a 'Registered' mini-grid or mini-grid 'with Permit' while the development and operation of mini-grid project with installed capacity above 100kW (100kW – 1MW) required the acquisition of Permit.

Mini-grids operated with permits are required to be developed and operated based on specified codes and standards, and operators must meet other associated requirements as stipulated by NERC. This includes that the tariff for electricity consumers should be calculated using the Multi-Year Tariff Order (MYTO) methodology. However, mini-grids operated as registered mini-grids are not required to meet the standards. The possession of Permit assures the advantage of recovery of investment cost should the electricity distribution company covering the area extend its network to the community being served by mini-grid with a permit. The registration of the mini-grids, on the other hand, only helps the government to be able to track the evolution of mini-grids operating in the country. The regulation requires that potential operators who want to operate as Mini-Grid Permit Holders are required to confirm the eligibility of an unserved community and ascertain that there is no plan for the distribution company in the area to extend the grid to the target community within the following 5 years after implementation of the proposed mini-grid.

Apart from isolated mini-grids which are developed in unserved (off-grid) communities, the regulation also makes provisions for interconnected mini-grids that may be developed in underserved (connected but low quality of supply) communities. All interconnected mini-grids are required to be operated "with Permit" and require a tripartite mini-grid between the developer, the community and the distribution company operating in the area. Table 10.10 summarizes the various RE policies, plan, and strategies that have been developed in the country.

10.5.2 Policy Impact on Renewable Energy Development

Despite the development of various policy, strategies and regulations; the growth of renewable energy exploitation is slow relative to the available renewable energy sources available in the country (Figure 10.7). Apart from large hydropower projects that were implemented over decades, the development of RE projects in Nigeria has been largely limited to small-scale solar energy applications. The following sections discuss the various RE potential and the extent of their exploitation.

Hydropower

Nigeria has technical and economic viabilities for high hydropower generation and currently has 1930MW installed hydropower capacity mainly from Kainji, Jebba and Shiroro dams on rivers Niger and Benue. Only 64.2MW out of the 3500MW estimated potential for small hydropower in Nigeria has been exploited [99, 104]. Currently, it generates 6,985 GWh of electricity annually which represents about 21% of its proven potential. However, the development of a 3050MW Mambilla hydropower project which would have boosted hydropower generation in Nigeria commenced in 1982 [109] but has remained uncompleted till date (2020). Studies have shown that Nigeria has the potential for 12,954.2 MW hydroelectricity installed capacity that is yet to be exploited [104, 110].

Table 10.10 Summary of renewable energy policies in Nigeria.

S/N	Policy document	Highlight
1	Rural Electrification Strategy and Implementation Plan (2006)	• Attain 75% Electrification rate by 2020 – Electrify 471,000HHs annually in rural communities till 2020 • Attain universal electricity access by 2040 – Electrify 513,000HHs annually in rural communities from 2020 - 2040
2	Electric Power Sector Reform Act (2005)	• Establishment of Power Holding Company of Nigeria (PHCN) in the interim of privatisation of the sector
3	Multi-Year Tariff Order (MYTO) I (2008-2013)	• Fed-in Tariff for Generating Companies (GENCOs) (2008 – 2013)
4	Nigeria Renewable Energy Master Plan (2011)	• Targets: RE to contribute 13% of total electricity generation in 2015, 23% in 2025 and 36% by 2030 • Small-hydro: 600 MW in 2015 and 2, 000 MW by 2025; • Solar PV: 500 MW by 2025; • Biomass: 50 MW in 2015 and 400 MW by 2025; • Wind: 40 MW for wind energy by 2025; • Fiscal and Market Incentives
5	Multi-Year Tariff Order (MYTO) II (2012-2017)	• Provided Feed-in Tariff for renewable electricity subject to biannual minor reviews and major reviews once in five years
6	National Renewable Energy and Energy Efficiency Policy for Nigeria (2015)	• Interest of the government in RE development for large scale • Highlight fiscal and market incentives
7	National Electricity Regulatory Commission Mini-Grid Regulation (2016)	• Catalyse mini-grid development • De-risk the sector • Licensing: Registered and Mini-Grids with Permit
8	Nigeria Feed-in Tariff for Renewable Energy Sourced Electricity (2016)	• Feed-in Tariff for RE electricity

Source: Authors' elucidation.

Solar

Nigeria receives solar radiation of 3.5–7.0 kWh/m2-day for 5-6 hours/day throughout the year [111, 112]. Studies show that with state of the art of solar PV technology, the installation of PV on 1% of Nigeria's total surface area will be sufficient to generate 1,850,000 GWh of electricity per annum [113, 114]. Though the uptake of solar energy in Nigeria remains

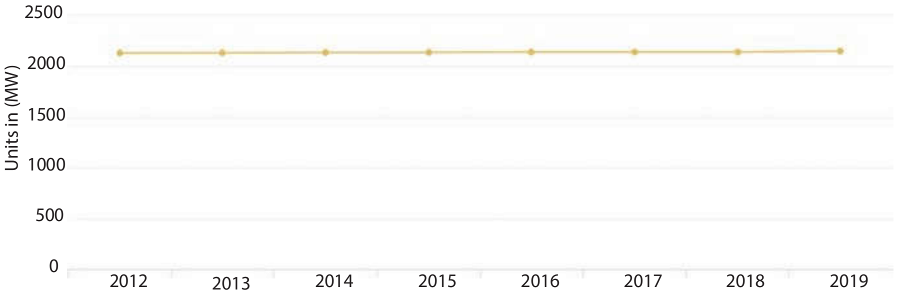

Figure 10.7 Renewable energy generation capacity in Nigeria Source: African Energy Portal (managed by the African Development Bank), 2020.

insignificantly small relative to its estimated potential, solar PV represents the most deployed RET in the country apart from large hydropower.

There has been increasing support for the deployment of solar PV for distributed energy generation in the country by development partners and multilateral organisations. Currently, there are a number of mini-grid projects that have been developed in rural communities in Nigeria with none exceeding 100kW installed capacity. Also, solar home systems, solar street lighting, refrigeration of vaccines in hospitals, are other common applications of solar PV technology in Nigeria. According to the African Development Bank, Nigeria has 29.95MW of Solar PV as of 2019 [115] relative to 427,000MW [114] estimated potential. However, the RE sub-sector recently began to receive a boost with funding for rural electrification from the government, the World Bank and the Africa Development Bank [116]. This has resulted in the development of two public funded solar hybrid projects in two public universities in the country, namely 2.8MW at Alex Ekweeme Federal University and a 7.1 MW in Bayero University. The projects were developed within the Energizing Education Programme by the Rural Electrification Agency, which aims to develop 28.5MW of solar hybrid projects during its first phase with a target of 89.6 MW during its second phase [117].

Wind

Unlike solar energy potential which has been proven to be sufficient for electricity generation across the country, the exploitable wind resource is mostly in Nigeria's middle belt region [118]. The government commenced the development of Nigeria's first major wind energy project with a capacity of 10MW in Katsina state but the project has remained uncompleted 10 years after it was launched [53]. The various reasons identified by stakeholders for the non-completion of the project highlight the need to reduce the coordination and administrative bottlenecks in the implementation of RE projects in the country. The reasons also point to the need to facilitate improvement in other sectors of the economy such as security and increase the local human capital for RE projects in Nigeria [119, 120].

Biomass

Nigeria has abundant biomass potential from fuelwood, crop residue, municipal and solid waste among other sources which account for its 144 million tons of biomass potential annually [121]. Studies show that Nigeria uses 43.4 million metric tons/year of fuelwood which has been estimated to have 6.0 x 10^6 MJ energy content. However, only 5-12% of the energy content is being converted to useful heat energy for cooking and other domestic applications based on the efficiencies of the technologies being employed [122–124]. The resulting fast loss of the vegetation induces various environmental concerns. Solid waste also constitutes a major energy resource that has remained largely untapped in Nigeria especially in the major cities with high rates of waste generation. Lagos, with its over 21 million estimated population [125], is the most populous city in Nigeria and Africa, and produces over 9,000 metric tons of waste daily. Apart from contributing to Nigeria's energy pool, energy generation from solid waste will also reduce environmental pollution [126].

10.6 Conclusion and Policy Implications

By taking the cases of South Africa, Egypt, and Nigeria, the analysis presents the progress made in the exploitation of RESs vis-à-vis the policy and institutional frameworks driving them including some of the major challenges that limits RE development in Africa. Based on lessons drawn from the approaches underlining the giant strides (South Africa and Egypt), actionable recommendations are made for other African countries (taking the case of Nigeria) that are largely limited in the exploitation of their RESs.

10.6.1 Policy Implications from South Africa and Egypt

Based on the approaches and experience of South Africa and Egypt, the following strategies were identified to have been crucial in catalyzing renewable energy integration, and, could provide guideposts for Nigeria among other African countries:

1. Timely approval and implementation of policies: The analysis of RE development in South Africa and Egypt emphasis the need for effective coordination of various institutions of the government with mandates on RE development in African countries. This is crucial to ensuring timely approval of policies, thus preventing the extended delays in the approval of renewable energy policies and administrative bottlenecks that has limited development of large-scale RE projects in many African nations. In addition, the participation of civil society organisations (CSOs) in the sector is needful to pressurize the government for policy actions and follow-up on the implementation.
2. Intermediate reviews of policies: In addition to the implementation of policies, the approaches of the two countries highlight the relevance of intermediate reviews of policies during their lifespan. Many times, real-life realities differ from the assumptions which form the basis for policy design, hence, the need for intermediate reviews of policies and implementation strategies. Such reviews should be based on the impact of the policies, the new realities of the sector and the economy at large at the local and global levels. This will help to improve the effectiveness of renewable energy policies and strategies employed in the sector.
3. Integration of socio-economic development into RE projects: The analysis also highlights that the integration of the social and economic development of host communities in renewable energy programmes helps to catalyse development in the communities. The REIPPP programme in South Africa

mandates IPPs to contribute to the development of communities within 50km radius from their sites. As discussed in previous sections, the strategy catalysed the growth of the communities where large-scale RE projects have been developed. Such an approach, if adapted to the contexts of other African countries, would also help to improve the relationship between project developers and the host communities in African countries. This would help to build a sense of ownership in the host communities, thus ensuring the commitment of target communities and foster the security of the project facilities and the contractors working on the project.

4. Development of standards codes, testing facilities and training courses: The development of standard codes and testing facilities including training courses are crucial for quality assurance of RE products that are being imported to African countries. As discussed in the case of Egypt, the Egyptian strategy for renewable energy development is complemented by quality assurance and human capacity building. The development of testing laboratories and training courses in Egypt helped to prevent the diffusion of RE devices and equipment with poor quality in the country while the courses helped to raise renewable energy workforce with appropriate competences in the country. High level of quality assurance is crucial to the sustainable deployment and integration of RE in the African energy mix. Similarly, it is important to develop certification training for installers of PV and other RETs. The dual effort will help to prevent infiltration of low-quality renewable energy products into the country and also improve capacity and competence of RE engineers and technicians for development and maintenance of RE projects.
5. Enactment of renewable energy laws: The development of RE in Africa requires not only policies and strategies, but also laws that will enforce the implementation of the RE policies and the associated strategies. The adoption of the Egyptian New National Renewable Energy Strategy in 2015 followed the enactment of the Renewable Energy Law by Presidential Decree (Decree No. 203/2014) which put into force the build-own-operate (BOO) mechanism that catalysed renewable energy development in Egypt. Also, the government of Egypt through a Presidential Decree (No. 17/2015) reviewed the Investment Law (No. 8/1997) through which the Egyptian government reduced various import duties and taxes including the provision of subsidies to attract renewable energy investment into the country. Moreover, the implementation of policies may be also be affected by changes in government; therefore, the enactment of laws to back renewable energy policies would ensure the sustainability of policies, thus, promote investors' confidence in the policies given the long-term nature of renewable energy investments.
6. Grid reliability: The development of grid-connected renewable energy projects partly depends on the level of reliability of the grid network. There is a need to improve on the reliability of the grid in African countries as this would facilitate investment in on-grid RE projects and thus eliminate the cost of batteries in renewable energy development. Funds that would have been expended on batteries could be diverted to increase the capacity of the projects. In addition, the elimination of the cost of batteries will reduce renewable

energy investment, hence, increase the participation of more players in the sector.

7. Large-scale renewable energy investment: Through the various policies and implementation strategies adopted in the two countries, the governments emphasized their commitments to large-scale exploitation of renewable energy. Many of the policies and strategies provided an enabling environment including diverse incentives and mechanisms that are targeted at large-scale renewable energy investors. The implementation of the policies and strategies contributed largely to the increasing growth in large-scale renewable energy investments in the two countries.
8. Diversification of renewable energy uptake: South Africa and Egypt have benefited from diversifying their renewable energy mix. The governments of the two countries adopted and implemented support mechanisms covering the various RESs that are available in their countries. The support mechanisms provide the bedrock for simultaneous development of various RESs in the two countries and as a result, both countries have recorded significant progress in the uptake of RE especially from solar, wind and hydropower[5].

10.6.2 Barriers to Renewable Energy Development in Africa: The Case of Nigeria

Despite the existence of various policies among other regulatory instruments, the uptake of renewable energy resources in Nigeria has been minimal relative to the potentials available in the country. A number of authors have identified that the barriers to RE development in Nigeria are typical of the challenges of RE sectors in other developing countries, especially in Africa. As discussed above, the approaches of South Africa and Egypt provide some successful models ("best practices") which could provide actionable strategies to fast-track clean energy transition in Nigerian among other African countries. This section discusses the challenges of RE development in Nigeria examined through the lens of the strategies adopted in South Africa and Egypt:

1. Timely approval and implementation of policies: Extended delays in the approval of policies pose challenges to the relevance of the policies and their effectiveness. The extended delays before the approval of policies make policies outdated when they are approved and as such have minimal relevance and effectiveness in meeting their objectives. As highlighted above, Nigeria's first National Energy Policy was developed in 1993 and reviewed in 1996 while awaiting approval. Due to the extended delay in the approval of the policy, changes in the economic dynamics necessitated another review of the

[5] The generation of energy from biomass is also growing in South Africa especially with the development of small-scale plants while the uptake of energy from biomass in Egypt is limited to the effort of donors and non-governmental organisations as biomass has not been included in any of the programmes of the Egyptian government.

policy before it was approved in 2003. This may suggest the need to intensify efforts towards facilitating timely approval of policies.

In addition to the delays in approval is the delay in the implementation of the policies. Whereas the various regulations, policies and incentive mechanisms that have been developed and approved in many African countries would have helped to attract investors to their respective RE sectors, many of the policies are not implemented years after they have been approved. This aligns with findings by Sesan [127] for the Nigerian case, who highlights that there is a poor effort towards policy implementation in Nigeria. Despite the existence of the NREEEP, there has been no significant implementation of the policy, hence, the challenges the policy seeks to address still persist in the sector. The NREEEP [107] which was approved in 2015, provides for various incentives such as zero import duty, tax holidays for new actors in the sector and 50% reduction from the prevailing tax rates for existing actors, among others. Based on the experience of South Africa and Egypt, the incentives would have helped to attract private investment into the RE sector. Due to a lack of implementation, the impact of this policy is yet to be visible in the sector.

2. Intermediate review of policies: The intermediate review of policies within their lifespans helps to draw on the lessons learnt during their implementation and the changes in the dynamics within the target sector and the overall economy to re-orient the policies to fit into current realities and more realistic projections. The Nigerian case shows that some of the policies and regulatory instruments in the Nigerian renewable energy sub-sector were reviewed within their lifespan; however, some of the reviews became necessary due to extended delays in the approval of the policy. As presented in the analysis above, the Nigerian Energy Policy (NEP) which was drafted in 1993 has been reviewed four times. Two of the reviews were carried out before the approval of the policy due to the approximately 10-year delay in its approval while the other two reviews have been conducted after its approval in 2003. MYTO 2, which came into force in 2012, was also amended in 2015 and active until 2018.
3. Integration of socio-economic development into RE projects: The development and completion of some of the large-scale RE projects suffer setbacks due to challenges in other sectors of the economy. Nigeria's first major wind energy project is a 10MW wind farm in Katsina state which has remained uncompleted more than 10 years after its commencement. Whereas there are no official reports from the government on the reasons for the delay, media interviews with the contractor highlight that inadequate coordination of the project between the state (Katsina) and federal governments, and, the kidnapping of expatriates are some of the reasons for the non-completion of the project. Therefore, improving on the governance and administration of public projects and addressing the challenges in other sectors of the Nigerian economy such as security is crucial to RE development in Nigeria. For instance, the improved security architecture could have prevented the case of the kidnapping of contractors as experienced on the 10MW wind farm in

Katsina state of Nigeria. Drawing on South Africa's REIPPP, the integration of the social and economic development of host communities would help to build a sense of ownership of renewable energy projects within neighbouring communities, hence their commitment to the security of the projects and the workforce that is working on the projects.

4. Development of standard codes, testing facilities and training courses: There has been increasing interest in RE exploitation in Nigeria, yet, the demand remains insufficient to spur local commercial manufacturing of RE components in Nigeria. The lack of commercial manufacturing capacity within the country makes Nigeria, among other African countries, a destination of renewable energy components manufactured from various countries across the globe. This puts the country at the risk of infiltration and diffusion of low-quality products. The deployment of low-quality RE components and equipment has been identified to be a reason for the early failure of RE systems in Nigeria which led to mistrust of solar PV technology in the country especially at the early stage of the adoption of the technology in Nigeria [128]. This call for the development of standard codes, testing facilities and training of professionals for quality assurance of the renewable energy components and equipment imported into the country. Apart from the poor quality of products, poor installation practice and inadequate maintenance are two other factors that also contribute to early failure of RE projects. This may suggest the need for the development of courses to improve the competencies of the RE workforce in Nigeria. Indeed, there are a few organisations that offer training for solar PV installers in Nigeria. For instance, the Nigeria Energy Support Programme (NESP) being implemented by GIZ has supported a number of private organisations to offer some renewable energy courses. However, making significant progress on capacity building for RE development in Nigeria will require more effort towards making such courses available and affordable round the country. The development of degree programmes on renewable energy within the Nigerian university system will be of significant contributions to RE development in the country.
5. Enactment of renewable energy laws: Unlike the case of Egypt where the laws were enacted to catalyse RE development in Nigeria, no law that is dedicated to the RE sector has been enacted in Nigeria. For instance, the government of Egypt through a Presidential Decree (No. 17/2015) reviewed the Investment Law (No. 8/1997) through which the government reduced various import duties, taxes including the provision subsidies to attract renewable energy investment into the country. NREEEP and REMP also make similar provisions for various incentives such as zero import duty, tax holidays for new actors in the sector and 50% reduction from the prevailing tax rates for existing actors, among others. However, the provisions are yet to make impacts in the sector due to delay in their implementation. Drawing on the Egyptian approach, the enactment of laws that would foster the implementation of the various mechanisms, provisions, and incentives embedded in NREEEP and REMP will help to facilitate the development of renewable energy in Nigeria.

6. Large-scale renewable energy investment: Apart from the large hydropower plants that have been developed decades ago, investment in renewable energy in Nigeria has been largely limited to solar home systems and solar mini-grids with none exceeding 100kW capacity. There have been several Memorandum of Understanding (MoU) signed between foreign investors and the government for the implementation of large-scale RE projects but none has been developed years after the agreements were signed. For instance, a US-based solar energy company signed an MoU with the University of Ilorin in Kwara state of Nigeria to develop a 500MW solar energy plant worth USD 2.3 million. The project was planned to commence in May 2016 and to be completed by October 2016, six months after commencement [129]. To date, the project is yet to be developed. In 2012, the government of Kaduna state, one of the states in the northern part of Nigerian signed an MoU with a German company to develop a 30MW solar energy plant worth 50 million euros in the state [130]. Similarly, the state also signed another MoU with an Indian solar energy company to develop a 100MW solar energy plant in the state [131]. However, none of the projects have been developed to date. These are typical of several large-scale RE projects planned to be developed in various parts of the country by foreign private investors that are yet to be developed. This may suggest concerns on the policy environment and the administrative bottlenecks on large-scale renewable energy investments in Nigeria.
   An improvement in the coordination between the various institutions with mandates within the energy sector in African countries may also be considered. The Nigerian Federal Ministry of Power has the mandate to develop energy policies while ECN has the responsibility to implement the policies and energy planning [132]. The coordination of ECN by the Ministry of Science and Technology may impede effectiveness in its interactions with the Ministry of Power in coordinating the sector. As learnt from the cases of South Africa and Egypt, the Nigerian government needs to implement mechanisms targeted at large-scale investors to facilitate large-scale RE investment in Nigeria.
7. Grid reliability: The high upfront initial final commitment for installation of RETs especially solar PV technology constitutes a strong barrier to the uptake of RE in Nigeria, among other developing countries. However, the cost of batteries constitutes a high share of solar PV projects, especially with the need for the replacements of the batteries at intervals during the lifecycle of the projects. As discussed in previous sections, the cost of batteries constitute up to 57% of the lifecycle cost of solar mini-grids. Therefore, the development of on-grid solar energy systems would result in a decline in the investment costs of solar energy systems for investors and increase the affordability of tariff by consumers. Despite the advantage of grid-connected solar energy systems, the low reliability of the Nigerian electricity grid network poses a barrier to the development of such systems in the country, hence, the need for improvement in the reliability of the national grid.

8. Diversification of renewable energy uptake: Apart from large hydropower projects that have been developed in Nigeria over decades, the new RE projects in the country has been majorly limited to the diffusion of solar photovoltaic technology. There is no significant effort towards exploitation of other renewable energy sources in the country. While the policies developed cover various technologies required to exploit the renewable energy sources in Nigeria, most of the programmes and support mechanisms by the government among other stakeholders have been focused on solar PV technology for the exploitation of solar energy. However, the ability of Nigeria to bridge the energy supply deficit in the country will largely depend on its effort to tap the diverse RESs available in the country.

The case of Nigeria depicts the cases of many African countries that have abundant renewable energy potential but are faced with multidimensional challenges that limit their abilities to optimally exploit them. Therefore, the level of energy security that will be attained in such countries will depend largely on their abilities to overcome these challenges. The South African and Egyptian approach and experience provide models which could be adapted to the context of other African countries to catalyse their renewable energy development.

10.7 Conclusion

Electricity generation in Africa has been dominated by fossil fuel; therefore, the integration of RESs in the African electricity mix requires a new paradigm in its energy sector. Being unconventional energy sources, the exploitation of RESs comes with multidimensional challenges especially in developing economies.

The study analyses RE exploitation and use in Africa by taking the case of South Africa, Egypt, and Nigeria which are the three largest African economies and all possess abundant RESs. South Africa and Egypt provide cases of transformational growth in the uptake of renewable energies driven by policies and strategies that cover the various dimensions of renewable energy development. The Nigerian case, on the other hand, exemplifies multidimensional constraints faced by many African countries that limit the optimal exploitation of their renewable energy sources. Based on the significant progress made on RE development recorded in South Africa and Egypt, the study discusses the various policies and programmes including the implementation strategies guiding the renewable energy sector in the two countries. By drawing from the renewable energy policies, programmes and the implementation strategies in the two countries, recommendations were made for other African countries, taking the case of Nigeria, which, if adapted to their local context, could facilitate renewable energy development especially through private sector investment for utility-scale RE projects.

In summary, the study highlights the need for a holistic and system-wide institutional and regulatory instrument for the deployment and diffusion of RETs. Such instruments should also include actionable strategies for the underlining fiscal and financial instruments required to mobilize investment to the sector, without forgetting the relevance of capacity building to required manpower.

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