AFRICA'S ENERGY FUTURE

ENERGY LEAPFROGGING POTENTIAL IN FOUR AFRICAN COUNTRIES

Politecnico di Torino
ENERGY CENTER
EST ENERGY SECURITY TRANSITION LAB
Istituto Affari Internazionali
Fondazione Compagnia di San Paolo

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About the authors

IAI

Lorenzo Colantoni, Researcher at the Energy, Climate and Resources Programme (ECR) of IAI
Luca Franza, Scientific Advisor of the ECR Programme of IAI
Giulia Sofia Sarno, Junior Researcher at the ECR Programme of IAI

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ESTLab @ EnergyCenter

Ettore F. Bompard, Scientific Director Energy Security Transition Lab (ESTLab@EnergyCenter) and ordinary professor at the Energy Department of the Politecnico di Torino
Stefano P. Corgnati, Vice-Dean for Research at the Politecnico di Torino, memeber of the Board of Governors of the ESTLab@EnergyCenter
Daniele Grosso, Scientific Executive Manager EST Lab.
Pierluigi Leone, Ordinary Professor at thr Energy Department of the Politecnico di Torino and part of the Energy Center Lab

The Energy Security Transition (EST) Lab @ Energy Center is one of the reference centres of the Politecnico di Torino for the analysis of the energy transition and security. EST aims at providing a science-based support to the policy decision making process and implements the concept of "dynamic" think tank, developing methodologies, models and tools able to continuously track the evolution of the analysed systems and to capture the different dimensions related to them. Moreover, the approach of the EST Lab is "instance-driven", i.e. it starts from the real instances of national and international institutional, industrial and research stakeholders and provides answers to them through a vision and "technologies" able to produce positive impacts on the society.

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This report is also associated to a website, which highlightes the results of the research with animated data and contains an easily and freely accessible database showing the fundamental data on energy leapfrogging in Africa.
It is available at **africaenergy.iai.it**

Introduction

From an energy perspective, over the past decade sub-Saharan Africa has been witnessing the most radical change in its history. In 2013, from the first time since independence from colonialism, energy access in the region increased – and this improvement steadily continued over the following years, particularly in key countries such as Kenya and Ethiopia. Universal energy access is now an achievable target for the first time in the history of the continent. Yet, what is most extraordinary is how this process has developed: African countries are now able to skip the intermediate steps characterised by an inefficient or unsustainable use of energy commodities, like those experienced in other regions such as China or South East Asia during their development phases. This is enabled by a mix of technological, regulatory and financial reasons, in which the energy transition is playing a key role. Indeed, the widespread renewable-energy potential of African countries (able to largely satisfy internal demand, even in high demand-growth scenarios) could represent a crucial springboard for enabling the continent to experience a rapid, socially and economically sustainable development – and for making Africa one of the active players in the global energy transition. Sub-Saharan Africa might be able to leapfrog from a situation of low or no availability of energy to a sustainable and universally accessible supply. Such progress is, however, threatened by several factors – currently compounded by the COVID-19 crisis, which has slowed down the steady growth in energy access that was previously underway. The smaller budgets available to both African governments and consumers relative to industrialised countries are a significant constraint. [1] An understanding of the factors at play in energy leapfrogging thus remains as necessary as ever in order to guarantee the continuation of such a historical shift in energy access in Africa.

This report thus analyses the variables influencing energy leapfrogging (debated in this paper: Part 1) and then estimates the leapfrogging potential for four illustrative countries in sub-Saharan Africa (Ethiopia, Kenya, Nigeria and Mozambique – detailed in the datasheets comprising Part 2). These countries have been selected to guarantee a full coverage of the region from a development and geographical perspective. The analysis focuses in particular on the Sub-Saharan section of the continent since northern Africa shows a completely different energy landscape, characterised by a higher level of access and of infrastructure development. Additionally, the focus of this report is on access to electricity, with only limited reference to clean cooking and transportation, this being the most promising sector with regard to energy leapfrogging.

The Four Pillars of Energy Leapfrogging

Analysis on energy leapfrogging can be conducted by investigating four main pillars – i.e. four "leaps forward" able to rapidly ensure the implementation of the new energy system.

1. From fossil fuels (and traditional biomass) to RES

This pillar discusses the environmental-sustainability component of energy leapfrogging, with a focus on greenhouse gas emissions and climate change. It concentrates on estimating the potential for the main technologies (solar photovoltaic [PV], wind, hydro and geothermal); possible competition with domestic fossil-fuel resources; and the existing policies and subsidies for renewable energy sources (RES) and climate action.

2. From centralised to distributed generation

This pillar debates the singular development of energy networks in sub-Saharan Africa, which is marked by an unprecedented diffusion of off-grid solutions. The relevant section below considers factors such as the dispersion of the population and the state of rural electrification, coordination or competition between on- and off-grid solutions, and the national and regional policies applied to the sector.

3. From a classical electricity market to a novel business approach

This pillar considers the state of national and regional energy markets and their readiness to host and promote new solutions and players. It evaluates the availability of energy finance; the sustainability of energy tariffs; and the openness of the market to new and private players, which are key to raising the funds needed to sustain the current level of electrification.

4. From "analogic" to digitalised energy systems

This pillar analyses the digital developments that are key to supporting the diffusion of new energy technologies – particularly off-grid ones. With these being fundamentally linked to digital payments, apps and even blockchain technologies, this section debates the digital readiness of African countries in relation to energy usage – from mobile penetration to access to micro finance, and micro or mobile transactions.

These pillars largely reflect the so-called "3 Ds" of energy – i.e. the three developments that are recognised as crucial for the energy transition and leapfrogging: **decarbonisation**, **decentralisation** and **digitalisation**.

1. From fossil fuels to RES

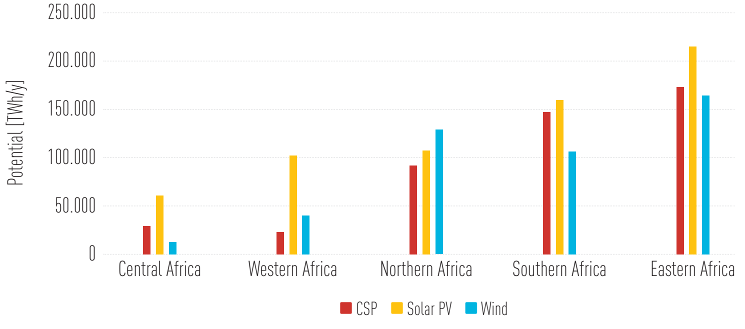


Fig. 1
CSP, solar PV and wind potential in different African regions (elaboration based on IRENA data).

The first "leap", from fossil fuels to renewable energy sources (RES), is an essential element in ensuring decarbonisation. Currently, Africa's energy system mostly relies on fossil- fuel commodities (oil, solid fuels and natural gas), which in 2017 accounted for 52.2% of the continent's Total Primary Energy Supply (TPES); and on traditional biomass, which covered 45.2% of the TPES [2].

While fossil fuels have a well-known detrimental impact in terms of their contribution to climate change and air pollution, the widespread use of traditional, solid biomass also brings negative consequences. Presently, in Africa about 900 million people (more than 70% of the whole continent's population)lackaccesstocleanfuels – e.g. for cooking and heating – and indoor air pollution at the household level is responsible for about 500,000 premature deaths per year. Moreover, the intensive use of biomass leads to a significant depletion of forests, with a consequent further negative impact from the environmental perspective [3].

Africa is characterised by a significant amount of available fossil fuels: in 2018, proven reserves accounted for 7.2% of the world's total for crude oil, 7.3% for natural gas and 1.3% for coal [4]. However, development based on domestic consumption of fossil-fuel commodities is incompatible with those environmental-sustainability targets that have been set at the global level and embraced by African countries – among them, the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda, the 2015 Paris Agreement and the Agenda 2063 of the African Union [5], [6], [7].

The switch from traditional energy systems to a new, sustainable mix based on RES will require a greater role for electricity, the energy use in which renewables are advancing at the quickest pace. Yet, the continent is still lagging behind in the electrification process; currently, electricity covers only 9.4% of Africa's total final energy consumption compared with a world average of 18.9%. Electricity only reaches about 50% of the African population, and approximately 600 million people still lack access to it [2], [3]. While this underscores the need for major investment, it also stresses the possibility of directly implementing a system already based on electricity generation from RES, without the necessity of reconverting and adapting an already existing, traditional power-generation and transmission/distribution system – as has been the case for Europe and the United States (US).

This possibility is supported by the huge renewables potential that characterises African countries. In fact, even when considering the limited estimates provided by available studies, the exploitation of the theoretical PV potential of the whole of Africa could lead to electricity production of about 660,000 terawatt hours per year (TWh/y) – i.e. roughly a thousand times current consumption (equal to 652 TWh/y). This theoretical potential is mainly located in eastern and southern Africa (220,000 TWh/y and 160,000 TWh/y, respectively), followed by northern Africa (about 110,000 TWh/y), western Africa (100,000 TWh/y) and central Africa (60,000 TWh/y)[1]. Similarly, the theoretical potential for Concentrated Solar Power (CSP) is also remarkable, being estimated at 470,000 TWh/y continent-wide. Considering both solar PV and CSP, this huge potential has so far been exploited to a very limited extent as the installed capacity in 2017 was equal to 3 gigawatts (GW) forPVandto1GWforCSP.Thisis mainly due to a lack of capability on the part of national institutions to manage integrated expansion plans and to build economies of scale, allowing decreasing subsidies and sustainable investments.

With regard to wind, theoretical annual productivity has been estimated at about 460,000 TWh/y – located particularly in northern Africa (chiefly Algeria and Egypt), with about 130,000 TWh – and in eastern Africa (especially Sudan and Somalia), with about 170,000 TWh/y. As for solar, the current installed capacity is far from a significant exploitation of this resource [7]. The potential of solar PV, CSP and wind in the different African regions is summarised in Figure 1.
Considering other renewable sources, hydropower is currently the most heavily exploited in Africa, with 35 GW of installed capacity in 2017. However, the present and future impact of climate change on hydro generation makesv an effective assessment of its potential difficult, even if there is evidence of further exploitation potential, in particular in the Democratic Republic of the Congo and in Ethiopia. However, in the overall assessment of the costs and benefits related to the exploitation of hydropower, negative externalities like the impact on landscape, biodiversity

1. Northern Africa: Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia.
Eastern Africa: Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania, Uganda.
Western Africa: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo.
Central Africa: Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Sao Tome and Principe.
Southern Africa: Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Seychelles, South Africa, Swaziland, Zambia, Zimbabwe.

and local communities in the areas involved will have to be considered – particularly with regard to large-scale plants. Nevertheless, hydropower remains a key source of energy given that in the sub-Saharan region (and notably in central and south east Africa) a potential of about 22 GW for small-scale hydropower and 3.4 GW for mini-hydropower has been assessed. Finally, a lower potential, of around 15 GW capacity, has been estimated for geothermal energy – mainly concentrated in the eastern part of the continent [8].

Biomass and bioenergies, on the other hand, deserve a separate discussion. As previously mentioned, the current, traditional use of biomass is not compatible with sustainable development as it is mainly based on the use of solid biomass by households, which burn it through inefficient and polluting technologies – such as old stoves used for cooking – without any filtering systems. For this reason, the large amount of biomass presently used in Africa is rightfully not counted as part of the renewable energy share in the continent's energy mix. More efficient uses – including the transformation of solid biomass into other forms, like biogas, biofuels and pellets – would have some advantages. Even then, however, their impact in terms of deforestation, modifications of land use and air pollution will also have to be taken into account when evaluating bioenergies. From this perspective, the production of biogas from waste and organic by- products, and of advanced biofuels for the transport sector or electricity from agriculture residues, seems a promising option – especially in West Africa.

Therefore, there is broad scope for moving directly towards a renewables- based energy system in African countries that could even meet overall energy needs in the case of a significant increase in consumption as a direct consequence of rapid economic development. Moreover, it must be stressed that such a change in the energy paradigm will be intrinsically intertwined with the adoption of high-efficiency technologies (such as electricity-based ones) – thereby limiting the expected growth in energy consumption, which could thus be decoupled from economic development and gross domestic product (GDP) growth.

From a policy perspective, the situation described above reflects sub-Saharan Africa's political and geographical heterogeneity. Support for renewables is a cross-cutting topic in the sphere of the continent's Nationally Determined Contributions (NDCs), as 45 out of 53 of these NDCs include renewables targets but regulations and support measures vary significantly. Tenders are slowly spreading as an instrument of RES deployment in the most advanced countries, such as Kenya, while many African nations are still implementing more consolidated (yet less successful) measures such as feed-in tariffs. Generally speaking, most African countries still lack the stability needed on the regulatory side to attract investors, often due to the insufficient political independence of their energy ministries or, where they exist, energy agencies. However, a few countries are slowly advancing in this sense – including some, such as Ethiopia, with a history of strong centralisation of their energy system. Regardless of the domestic situation, achieving universal energy access through a sustainable energy mix will require strong international cooperation and support – from inside and outside the continent. Such support could come from both an evolution of the current development framework towards de-risking renewable investments in Africa and from further development of the already-existing five African Power Pools (North, Western, Eastern, Central and Southern).

2. From centralised to decentralised generation

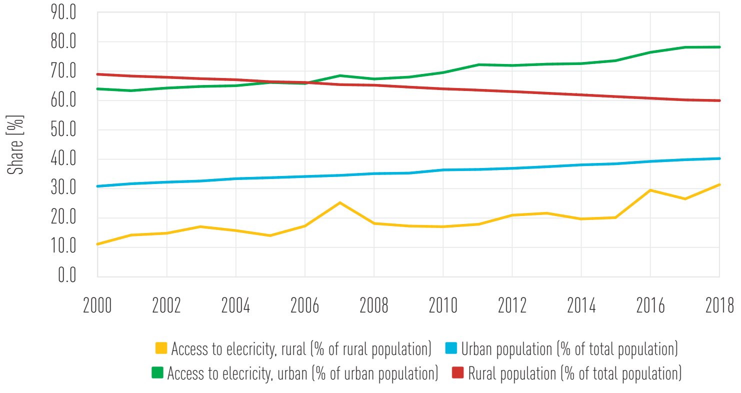


Fig. 2
Historical trends of urban and rural population shares and of the related access to electricity in Sub Saharan Africa (elaboration based on World Bank data).

A development pathway strongly based on electrification will require the identification of a suitable "architecture" for such a system. Historically, Europe's evlectricity system has been based on centralised generation, with a limited number of large power plants and a wide transmission network. While this is still an option that sub-Saharan Africa will have, decentralisation – based on "smart" or micro-grids – will be key to reaching universal energy access considering the dispersion of the African population and the fact that the lack of energy mostly affects the continent's rural population. In this sense, the adoption of decentralised options can reduce the time required to reach these goals and the related costs. For comparison purposes, China and India, starting from a number of persons without access to electricity similar to the current figure observed in Africa, have been able to reach 95% electricity access rates in 35 years (from 1965 to 2000) and 16 years (from 2002 to 2018) respectively. However, electrification there has mostly been underpinned by fossil fuels, especially coal. If it were to meet SDG 7 objectives by 2030[2], Africa would only have about 10 years to achieve the same result. Mini-grids could play a particularly relevant role in rural areas, where they are expected to represent the greater part of new connections over the coming decades, and in urban areas not yet reached by the existing grid. According to 2018 data, sub-Saharan African access to electricity is 78.1% in urban areas, where 40.2% of population lives, and 31.5% in rural areas, where 59.8% of population lives (Figure 2 shows the historical trends of these shares) [9]. Therefore, the main reduction in lack of electricity access will reasonably be obtained via decentralised solutions. This could provide further indirect benefits as it could accelerate the shift of household consumption from traditional, inefficient solid biomass to electricity, thus resulting in a significant reduction in negative health consequences and deaths.

In general, the convenience of investing in decentralised solutions over traditional investments

2. The target of SDG 7 is to "Ensure access to affordable, reliable, sustainable and modern energy for all". See https://sdgs.un.org/goals/goal7

in transmission/distribution network expansions mainly depends on the density of final users. In fact, an extension of the existing network can be more cost-effective where the population density (and, consequently, the density of consumers) is higher, while mini-grids, with limited distribution networks and without a transmissionlayer,canbeeconomically suitable solutions in remote areas and where the number of users is low. This is equally true of stand-alone off- grid systems like household PV, and also for other alternatives that couple generators and end-use technologies – such as PV systems able to directly feed electrical appliances, lighting systems and mobile-phone chargers. Mini-grids, however, require a given minimum electricity demand in order to make the required investment sustainable, and are thus a better option in areas where industrial and productive sites and services (such as schools and hospitals) are present. Even if traditional on-grid solutions are still expected to play a major role in the near future, investments in mini-grids and off-grid stand-alone solutions in sub-Saharan Africa could reach about 20% of the total new capacity investments made up to 2040 [3] – pointing to an unprecedented role for electrification.

Presently, the continent has about 1,500 already-installed mini-grids, located chiefly in western Africa, and more than 4,000 planned mini- grids, supported by decreasing technological costs favouring their penetration and by new regulations able to incentivise the participation of private investors. In the same way, off-grid systems, mainly leased by private companies to final users, are increasing; in 2018, they were able to ensure access to electricity to about 5 million persons in sub-Saharan Africa – particularly in the eastern part of the continent.

According to this assessment, directly implementing an increasing number of decentralised solutions for power systems in Africa could be an effective solution for the coming years. Coupling between the existing grid and these systems seems, in fact, to be a suitable option for rapidly reaching sustainable-development targets. Building a flexible "architecture" could enable a better exploitation of Africa's renewables potential without requiring long-term expansion plans for current networks, which in turn could face several technical and economic barriers and thus result in a limited positive impact – at least over a short- to medium-term time horizon. It will, however, be fundamental to coordinate the necessary expansion of the grid, which is mostly run by national governments, with the development of off-grid solutions, which are largely driven by private initiatives. This approach is needed in order to guarantee that the (usually cheaper) on-grid generation will not bring unsustainable competition to the more expensive mini-grids once it expands into new areas. Furthermore, a lack of such coordination in the early stages of energy-system development could cast significant doubt on the profitability of off-grid solutions, thus reducing the appeal of the sector to potential investors.

3. From classical market to a novel business approach

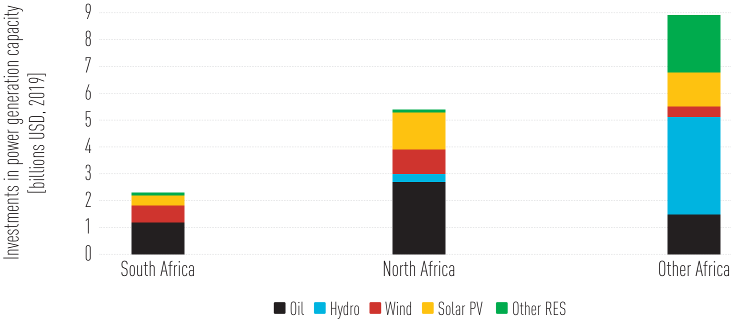


Fig. 3
Investments in power generation capacity in Africa in 2020 (source: IEA – Elec- tricity Market Report, 2020 [11]).

A new scheme widely based on decentralised power generation from renewables (mainly solar and wind), characterised by a non-controllable variable output and a limited predictability will require flexibility, smart operation, and digitalisation. This can open up opportunities for novel technologies and business models and calls for a change in the structure of the electricity market. Developed regions like Europe have already experienced a transition towards competitive markets at least in terms of generation and retailing, while a monopolistic configuration can still be observed in transmission. Growth in distributed electricity generation requires action to effectively integrate the prosumers into the system and to build organised energy communities. Since, as previously mentioned, distributed generation could play a crucial role in Africa's development, leapfrogging to innovative market mechanisms seems particularly convenient.

Market reform can play an important role in stimulating investments for energy leapfrogging. Annual investments to 2040 in the power sector will have to grow significantly in order to ensure achievement of the Sustainable Development Goals for "affordable and clean energy"; the International Energy Agency (IEA) has estimated that they will need to double from today's levels (as shown in Figure 3). This significant increase cannot be achieved without a structural modification of the current sub-Saharan African market system.

In fact – even if, formally, 29 of the 54 African nations allow private participation – the majority of those countries still show vertically integrated utilities in their power sectors, in which private investments are very limited or completely absent. Commonly, one large monopolist is responsible for an entire country's electricity chain (generation, transmission, distribution and retail supply to consumers). Only 10 of the 54 have unbundled utilities with independent transmission- system operators or, at the very least, legally unbundled transmission systems. The main consequence of this traditional market approach is the limited development of the electricity grid, since it relies on governmental funding or on funds coming from international financial institutions operating to support country development (which are limited by definition). In sub-Saharan Africa, only six countries (Angola, Ghana, Kenya, Nigeria, Uganda and Zimbabwe) have vertically unbundled power structures with private-sector participation [11]. Unbundling needs to be accompanied by reforms to ensure smooth operations in the electricity sector (e.g. congestion management, balancing) and coordination on investments to avoid bottlenecks and to match supply and demand in the long term. Non-discriminatory third- party access needs to be ensured in practice – not just on paper.

For this and other reasons, it is crucial to have an independent regulator monitoring the market. The plans carried out in some African countries could represent a valuable reference point for a change of paradigm to be pursued across the whole continent. Kenya is probably the best example: since 1997, the companies managing its electricity generation and those operating transmission, distribution and retail supply have been separated from each other. Furthermore, Kenya has set up an independent Energy Regulatory Commission (ERC) devoted to the definition of the regulatory framework, and since 2008 it has introduced a Feed-in-Tariff (FiT) system through an ad hoc policy for renewables (namely solar, wind, small hydro, biomass and biogas, and geothermal). Under this policy, Independent Power Producers (IPPs) receive a tariff for the electricity that they generate (US$ 0.11 per kWh for wind and US$ 0.12 per kWh for solar) [13]. Moreover, with the "Updated Least Cost Power Development Plan for the study period 2017 – 2037", the country plans to move towards an energy auction system – at least for solar and wind-energy markets (keeping the other RES under the FiT scheme).

Ghana, Mauritius, Uganda, South Africa and Zambia have already defined a renewables auction scheme [14]. The auction mechanism needs an overall coherence with the policies and plans set by each country to support electricity system development and RES penetration, and independent management and well-designed power purchase agreements (PPAs). However, this is not the case in all countries of the region. Even if this new system might be perceived negatively by the IPPs, since it reduces their earned tariffs, it could help in lowering prices for wind and solar PV power and in allowing the penetration of the market by new players.

Energy leapfrogging on the African continent will thus require private investors participation, coupled with a decrease in the cost of RES technologies, greater market competition (able to

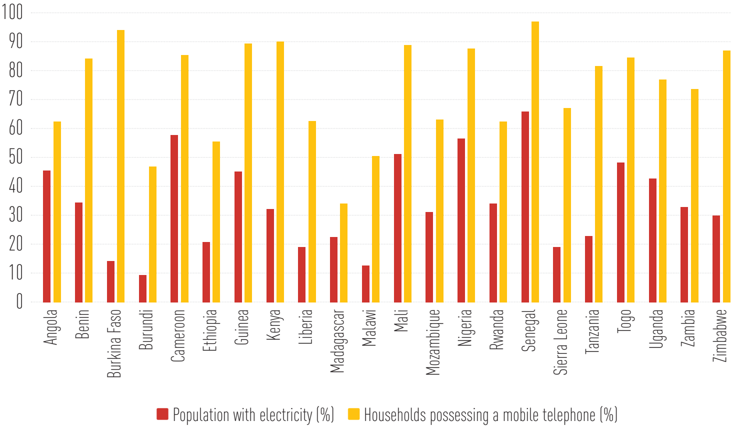
enhance overall system efficiency, promote grid development and reduce electricity prices), and the introduction of transparent rules and independent regulatory bodies. These market dynamics will be further intertwined with other elements, such as the technical evolution and the increasing digitalisation of the energy sector. Considering the latter development, which is discussed in depth in the following section, a relevant role could be also played by blockchain. This is a set of "blocks" (i.e. data records), linked into a chain through cryptography techniques; these blocks cannot be modified or deleted by a single player but are managed and verified on the basis of automatic and shared protocols. In this way, blockchain represents a so-called "distributed ledger" that allows digital transactions among players in a secure way without the need for central verification authorities. These measures, even if initially applied in a limited set of fields, can extend to other areas and are potentially able to develop new market and business models thanks to high flexibility and speed (as information is available almost instantaneously) and to the possibility of bypassing the need for intermediary brokerage in transactions.
In particular, blockchain could represent a significant option for building a new electricity market when its penetration has already begun, on the basis of three main aspects:

- disintermediation;
- simplification; and
- operational improvements.

Disintermediation is strongly coupled with decentralisation, and its implementation could lead to a relevant reduction in operational and transaction costs in the wholesale market, cutting out third-party intermediaries and allowing for a direct relationship between producers and retailers or final users – an option that is particularly fitted to the current evolution of the African framework. With regard to the second aspect, blockchain can simplify relations between market operators, ensuring secure transactions that could be based on so-called "smart contracts" (which do not need third parties), as well as enhancing the interoperability of systems. Finally, blockchain can be helpful in supporting the improvement of network operation through the above-mentioned smart contracts and by increasing the controllability and efficiency of the system. [16], [17]. While still at an early stage, the use of blockchain in sub-Saharan Africa is slowly increasing in several sectors – particularly that of cryptocurrencies – and could soon extend to the economy as a whole, benefitting from the growing and cross-cutting decentralisation observable in Africa.

4. From “analogue” to digitalised systems

Fig. 4 ▶
Share of population with electricity access and of households possessing a mobile phone in several African countries (elaboration based on [19]).



The implementation of blockchain technology requires the development of a solid Information and Communications Technology (ICT) infrastructure. However, and even more importantly, it is also strongly related to the other possible pillar of renewables-based energy systems, digitalisation – the fourth component of energy leapfrogging for African countries.

Digitalisation is key to several aspects of energy-systems' evolution towards renewables-based electrification. For instance, digital systems can enable demand response that, through continuous monitoring of the system, can optimise the matching between demand and supply. This demand response, together with storage systems, increases the flexibility of the overall system, thus permitting an increasing share of renewables – in particular, of variable and hard-to- predict sources like solar and wind.

ICT development can also be a crucial enabler for enhancing the role of renewables. In this sense, many African countries have already experienced a fast evolution in their communications systems, which represents a promising development in the framework of leapfrogging towards energy digitalisation. Across the continent, the development of communications tools started directly with the rapid spread of mobile phones – basically, skipping the intermediate step of landline devices. Currently, the share of ownership of mobile phones is higher than the electrification rate almost everywhere on the continent. Indeed, even in countries characterised by very low electrification rates, the ownership of mobile phones is significant – and often higher than 70% (Figure 4).

Mobile telecommunications can efficiently support the penetration of renewables-based decentralised energy systems, especially in rural areas that are covered by mobile signal but not reached by electricity infrastructure. Indeed, in these areas, companies can implement business models based on so-called pay-as- you-go(PAYG)approaches,whichcan be applied to the remote management of stand-alone renewables systems. The customers' mobile phones can be used as payment tools, thus overcoming the absence of a traditional, "physical" banking system and providing them with the possibility of using stand-alone units (like rooftop PV plants). In particular, customers can pay through their mobile phones in regular instalments, leading them to eventually become owners of the plant. Alternatively, they can pay a givenfeefortheenergyservicesthat allows them to consume the electricity generated without paying significant connection fees at the start, as has previously been customary.

In this way, companies are also able to undertake remote monitoring of the devices – collecting data on their use, tracking users' payments, activating/ deactivating a service or a device and so on. This makes the existing mobile infrastructure an effective option for facilitating access to different energy services and for accompanying the penetration of renewables-based solutions.vv In addition, the possibility of digitally connecting single energy-production units (like household rooftop PV systems) and consumption assets (like electrical appliances, electric vehicles and industrial-production systems) would allow the development of local energy communities of prosumers and overcome the traditional categorisation nto producers, retailers and consumers.

From an operational point of view, digital sensors – able to generate a significant amount of data – provide real-time information regarding the key functional parameters of power plants and the status of networks. This data is helpful in enhancing efficiency – for example, by reducing transmission and distribution losses, whose average value in 2018 in Africa was equal to 16%, and higher that 20% in countries like Ethiopia, Kenya and Ghana. It can also lower operating and maintenance costs (allowing for predictive maintenance), decrease unplanned outages (again, due to better monitoring and an improvement in maintenance) and increase the operational life of the infrastructures (in that they will be operated and maintained in a more effective way over time). This better operation is also reflected in significant monetary savings, which the IEA quantifies at 80 billion$/y at the global level over the period 2016–40 [18], [19].

Conclusions

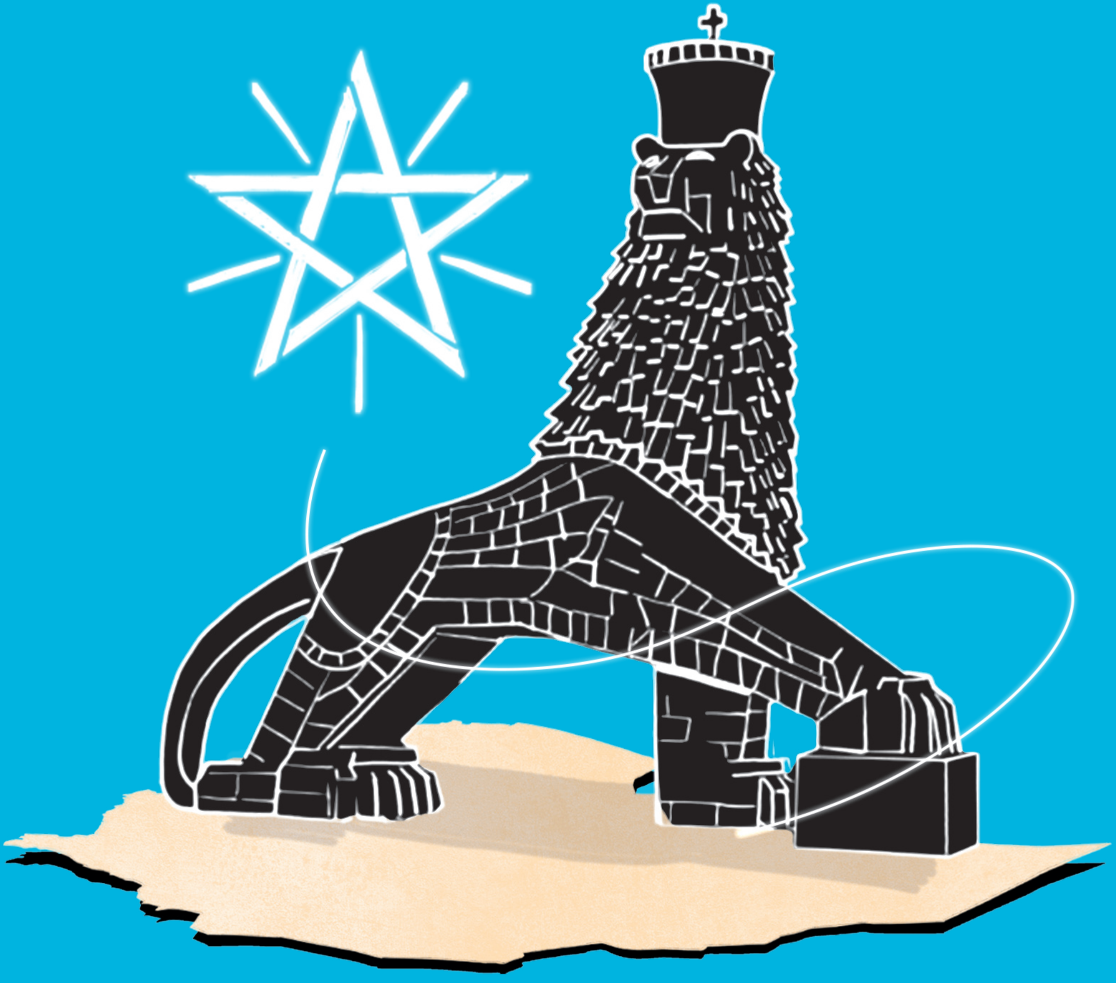
Energy leapfrogging is an important component of Africa's sustainable development. The four pillars analysed by this study (renewables penetration, distributed generation, new market models with private participation, and digitalisation) are deeply interconnected and represent important elements of the decarbonisation process. The continent's large renewable potential gives it a strategic advantage that should be exploited. The use of renewable sources and the introduction of smart local-energy communities could promote a major socio-economic transformation by allowing a sharp rise in energy access, especially in rural areas. This transformation will increase demand for end-use energy services (like households' space cooling, water heating, cooking, lighting, use of electrical appliances and productive uses) and consequently improve the living conditions of the population (with both health and economic benefits). In turn, this evolution in the energy system could be an engine for the whole economy and could promote the development of new industrial value chains.

In order to implement this transformation, however, significant investments are required. Supporting policies, ad hoc incentive schemes and modifications of the regulatory framework are key enabling factors that will be necessary in order to overcome current barriers and allow Africa to leapfrog towards the global energy transition. This process will require a shift in the role of already-existing players and the entry onto the scene of new ones: cooperation agencies will have to partially move from directly financing projects to de-risking local initiatives through credit and guarantees (as is already happening, for instance, with the United States Agency for International Development's [USAID's] Power to Africa initiative). Private actors will have to play an increasingly important role, and it will be necessary to stimulate the growth of local businesses (from small to large enterprises). This remains an issue even for advanced countries such as Kenya, where the majority of the most successful companies are run partially or fully by foreigners. It will be necessary to counteract the unpredictable effects of the COVID-19 pandemic, which have already negatively impacted on energy access and energy leapfrogging in the region.

Above all, it will be necessary to understand that Africa must not lose the momentum it had generated. The continent's leapfrogging potential could turn a dramatic issue (the lack of energy access) into an opportunity, as many African countries now have the possibility to not only reach universal energy access but also to establish a sustainable energy mix, something that even industrialised nations are struggling to achieve.

ETHIOPIA

Leapfrogging at the crossroads



Overview

109.23 mln
The population
in 2019

45%
The population
with access to power
in 2018

8.4%
The GDP growth
in 2019

23,406 TWh/year
The solar PV potential

Ethiopia is one of the sub-Saharan African countries with the greatest potential for improving energy access. Starting from a mere 5% of its population with electricity access in the year 2000, it has already attained an electrification rate of 45% – a percentage that has more than doubled in the past ten years. [21] Universal access to power obtained mostly through renewables by 2030 is a concrete possibility for the country, thanks to its strong renewable energy production potential (including large shares of non-intermittent sources such as hydro and geothermal) and a high level of political engagement. Besides this, Ethiopia has shown a strong economic performance with double-digit economic growth over the past decade, mostly driven by public investment. [22] The country had also enjoyed relative political stability until the recent conflict in its northern Tigray region. [23] While public investment has been an engine of growth, the strong presence of the government in the energy sector is regarded as one of the major brakes on the country's leapfrogging potential. The monopoly of the state-owned Ethiopian Electric Power Corporation (EEPCo) was abolished, and the market only opened to private and international investors in 2017. Investments are still timid, and revenues scarce. The fact that a large share of the country's population lives relatively close to the existing grid leads to the expectation that energy access will mostly be expanded by connecting more households to the main network. On-grid solutions, however, need to be complemented by off-grid ones in order to achieve universal access – and the development of such solutions could benefit from the presence of a more competitive market. While Ethiopia could still reach universal energy access through a heavily state-led process, the structure of its energy sector could make such process more expensive than what could be achieved through an open and competitive framework.

1. From fossil fuels to RES

Almost all electricity currently generated in Ethiopia is obtained through renewable sources, mostly thanks to the large hydropower stations that became operational in the past decade. [21] The country's renewable energy production potential is, however, still largely untapped. Its exploitation could provide the energy required to grant universal access to power and sustain gross domestic product (GDP) growth. According to the national company Ethiopian Electric Power (EEP, which replaced EEPCo), the potential for hydropower is 45 GW, while for wind it is 100 GW and for geothermal 7 GW. [22] Such estimates are, however, to be considered conservative, particularly for geothermal, since in-depth investigations of available resources are still lacking – and an estimate of solar potential is not even available.

Current exploitation of such resources is low. Approximately 1% of wind and 5% of hydro production potential is currently being exploited. [24] Fossil-fuel demand is projected to increase, driven by oil demand in the transport sector and coal demand, which is expected to increase in all scenarios. Apart from environmental reasons, the absence of economically viable domestic fossil-fuel-production projects (apart from marginal gas production) and the negative impact of fuel imports on Ethiopia's trade balance should discourage the government to pursue an expansion of fossil-fuel-based power generation, including that involving coal. [21] The government's target on renewables is ambitious: Ethiopia aims to add 25 GW of new power-generation capacity by 2030, divided between hydro (22 GW), geothermal (1 GW) and wind (2 GW). A significantly smaller target has been set for utility-scale solar photovoltaic (PV) in such plans (300 megawatts [MW]). This is at odds with IEA projections, which foresee a significant increase in solar energy and regard solar as a key enabler of universal electrification in the country. In its Stated Policies Scenario (operating under the assumption that current energy transition macro-objectives and climate pledges are fulfilled), the IEA expects solar-powered electricity to grow from 1 terawatt hour (TWh) today to 3 TWh in 2025 and 11 TWh in 2030.

One particular obstacle needing to be overcome in order to expand renewable-energy production and use is Ethiopia's erratic regulatory framework (discussed below), which still lacks key tools such as feed-in tariffs. The growing use of tenders in the energy sector could, however, balance out such policy shortfalls. [25]

2. From centralised to decentralised generation

Despite the emphasis on off-grid solutions in the National Electrification Program (NEP) and in its 2019 revision, [26] decentralised options might end up playing a relatively marginal or complementary role in the country's energy-access campaign.

The NEP aims for the country to reach a 35% share of additional access through off-grid technologies by 2025; however, the highly centralised nature of the Ethiopian energy sector hampers the entry of private players, which could be catalysts of small-scale solutions. Most solar home systems and all off-grid programmes are still run by the state, sometimes in partnership with development institutions, despite the opening of the off-grid sector to competition in 2013. [27] The off-grid programme of the NEP has provided a few significant novelties, such as the opening of a credit line dedicated to private players and the lifting of most import duties for small-scale systems. Yet, it has so far failed to consolidate key aspects – among them, an accessible permit system (which remains complicated), [28] a clear identification of grid and off-grid areas, and the establishment of a floor for energy prices to guarantee profitability.

The lack of specific regulations to encourage the adoption of off-grid solutions by productive sites (e.g. in agriculture) is another issue. Sectors in need of a stable supply of electricity (which the grid still often fails to provide) would in fact particularly benefit from off-grid solutions.

The development of some decentralised solutions would help in achieving universal energy access. The grid might also seem to provide a viable solution for those living in the countryside (80% of the country's population), since according to the EEP some 90% of them are within 10 kilometres of the existing grid; [26] yet this figure does not account for the significant dispersion of households around villages, where the population often lives on farms 2-300 meters away from each other – thus significantly increasing the actual cost of connecting every household to the grid. Even if the success of decentralised solutions in countries like Kenya could be hardly replicated in Ethiopia, a further opening of the sector to private players and clearer regulations to stimulate off-grid solutions as complements to the expansion of the national grid would still be necessary to achieve the country's 100% electrification target.

3. From classical market to a novel business approach

The centralisation of the Ethiopian energy sector forms a barrier to the evolution of an open and competitive market. Until 2017, private involvement was practically non-existent – being limited to Engineering, Procurement and Construction (EPC) contracts for the development of plants that were commissioned, and then run, by the EEPCo; this is the case, for instance, for the three Gibe dams built by the Italian industrial group Salini Impregilo SpA (now Webuild SpA). However, the need to attract foreign investment to achieve its ambitious energy targets has led the government to introduce a number of substantial changes to the country's energy regulations over the past few years.

Public–Private Partnership Proclamation No. 1076/2018 was the most important element of change, as it strengthened guarantees for the involvement of the private sector in infrastructural projects – with energy being one of its priorities.

The much-anticipated Regulation to provide for Energy Operationvs, revising Energy Proclamation No. 810/2013 (which covers both on and off-grid renewable generation), will represent a significant step towards reform. However, despite being expected in 2018, this particular piece of legislation has not yet been approved. [29] Nonetheless, a series of Public–Private Partnerships (PPPs) has recently been finalised with companies such as Italy's Enel and Saudi Arabia's ACWA Power for the construction of solar plants. [30] [31] [32]

This will probably lead to the entry of the first Independent Power Producers (IPPs) into the Ethiopian electricity sector – the first Power Purchase Agreement (PPA) was actually agreed in 2020, for the Corbetti geothermal power plant after years of operation. [33] The existence since 2003 of a formally independent energy regulator, the Ethiopian Energy Agency, could further contribute to the forthcoming opening up of the sector.

4. From "analogue" to digitalised systems

Despite government efforts in recent years, Ethiopia lags behind regional peers in terms of penetration of digital systems. In 2019, mobile penetration was significantly lower than in adjoining Kenya (41% of the total population, compared with 98% in its southern neighbour) or Ghana (whose uptake stood at 130%).[34] [35] [36] Internet penetration was also low, standing at 19% – less than half of Nigeria's 42%, albeit slightly higher than Mozambique's 18%.[34] [37] [38] The government has recognised Ethiopia's digital gap, publishing a detailed strategy to boost the digitalisation of the country, entitled "Digital Ethiopia 2025". [39]

This document does not refer directly to the application of digital measures to the energy sector, but it focuses on tools that are crucial for leapfrogging – an expression that the strategy explicitly uses on several occasions; among these, the spread of digital ID and of digital (and, specifically, mobile) finance will strongly benefit the country's energy sector.

Ethiopia has also shown a significant interest in the use of cryptocurrencies and of blockchain technology, yet so far only focusing on agriculture (one of the key sectors in the digital strategy). [40] The Australian blockchain company Lotus Energy has been recently awarded a contract to build a US$3 billion mini-grid in the Tigray region, [41] which could perhaps provide a chance to extend the use of the technology in the sector. However, centralisation and the lack of a consistent flux of mobile financial transactions (as are seen in, for example, Uganda and Kenya) will most likely delay the digitalisation of the Ethiopian energy sector.

KENYA

Africa’s innovation hotspot

75%
The population with access to power in 2018

5.4%
The GDP growth in 2019

2.3%
The population growth in 2019

2022
The target year to reach universal energy access

Kenya, where growth in access to electricity has been faster than anywhere else in sub-Saharan Africa, is probably the most promising country in East Africa for energy leapfrogging. While only 20% of the population was reached by electricity a decade ago, 75% of Kenyan citizens had access to electricity in 2018 and the figure could reach 84.5% in 2020 if IEA estimates are confirmed. [42] [43] This growth has taken place despite a relatively turbulent political background, which saw disputes over election results in 2007 and 2017, and a demographic increase that has been, and will continue to be, impressive – with the country's population rising at a rate that will probably see it double in size by 2050. [44] Several positive factors lie behind the solidity of this growth in access to power. Kenya's energy-demand growth has been driven on the macro level by a competitive, robust agricultural sector and by a growing (albeit still small) industrial sector. From a micro perspective, energy access for domestic consumers has been improved by the diffusion of domestic solar systems, which has been reinforced by significant internet penetration (43%, compared with 42% in Nigeria and 25% in Tanzania). [36] [38] [45] The development of geothermal resources and the significant (yet largely unexploited) potential for solar and wind energy could enable the country to abandon coal and nuclear projects, on which it focused in the 2000s. Challenges remain, however, particularly because Kenya's legislative and regulatory framework still lacks the coherence and solidity required to consolidate its leapfrogging potential. Kenya's economy has grown by 5% on average every year over the past decade, but this growth has been volatile and the country's economy remains exposed to external shocks – including those posed by the current COVID-19 pandemic. Inequality remains high in the country and the coronavirus crisis will probably increase it, fuelling political instability and threatening the expansion of access to power by the most fragile and often dispersed strata of the population. Kenya will also have to upgrade its electricity supply, boosting reliability in order to promote business; increase energy demand; and, thus, enhance the case for further and even more advanced electricity generation.

1. From fossil fuels to RES

The Kenyan energy system is characterised by a high penetration of renewables. In 2018 RES accounted for 81% of the Total Primary Energy Supply (TPES) and for 68.1% of the Total Final energy Consumption (TFC). However, these figures hide a very substantial use of traditional biomass for domestic purposes (mainly cooking), while the share of modern renewables in total final energy consumption only reached 3.5% in 2017. [47] Overall, renewable energy dominates power generation in the country – with a share of 80.2% in 2018. [48]
Pre-existing hydro generation capacity (820 MW) [49] has been strengthened by adding to the grid 504 MW of geothermal energy over the past six years. [50] The launch of the Lake Turkana wind farm in September 2018 added a further 310 MW of renewable-energy capacity. [51] Renewable potential in the country is high; hydropower has an estimated 6,000 MW potential – divided equally between large- and small-scale (less than 10 MW) generation projects. [52] Small-scale projects will be an important component of plans to reap the country's hydropower potential, considering the difficulties encountered in developing large-scale projects in Kenya (similarly to the rest of sub-Saharan Africa). At the same time, however, small-hydro potential is concentrated in a few areas in central and western Kenya, particularly in the Tana River drainage basin, thus limiting its potential to provide full energy access for the whole country. [52] As in most of East Africa, the estimates for wind-power potential are high in Kenya: they range from 1,739 terawatt hours per year (TWh/year) when only the windiest areas (capacity factor > 40%) are considered to 22,476 TWh/year when all the areas with a capacity factor higher than 20% are included. [53]

However, it is not clear how much of this potential could be turned into reality. The main obstacles to its development are both the expensive required extension of the grid and the logistics of transporting the turbines and the towers to site – two factors that have already, and significantly, impacted on the Lake Turkana wind project. Solar photovoltaic (PV) and solar thermal potentials are comparable to those for wind power – the former being estimated at 23,406 TWh/year, the latter at 15,399 TWh/year – but evaluations are limited due to the still narrow development of the sector. [53] Geothermal energy potential is conservatively estimated to range between 7,000 MW and 10,000MW (of which, about 2,000 MW are in the Rift Valley); [53] these figures could probably increase as exploration and exploitation technologies develop.

Prospects for exploiting fossil fuels in Kenya are highly uncertain because a full appraisal of reserves is missing, and low fossil-fuel prices and the availability of abundant supplies in global markets reduce the incentive to drill for more. The 2012 discovery of a 560 million-barrel reserve in Turkana has been followed by a lengthy negotiation between the Anglo–Irish company Tullow Oil and the Kenyan Government, which has not yet led to an agreement on the development of the reserve. [54] Similarly, the discovery of a 400 million-tonne reserve of coal in the Mui Basin has not yet led to production [55] – partly because the government has been ambivalent about coal. The suspension of the contested Lamu coal-power plant (the first in the country) in 2019 [56] will probably translate into a slowdown in the overall development of Kenya's coal sector. No significant gas resources have been found in the country.

From a policy perspective, the position on coal is unclear – as reinforced by the lack of coherence in official documents: the 2018 National Energy Strategy cites coal as "one of the indigenous sources of energy that will drive the development of strategic initiatives", but the National Electrification Strategy published in the same year does not mention the resource at all. Kenya is still missing a clear framework for renewables; targets are only set for oil (100,000 barrels a day by 2022) and for geothermal energy (2,275 MW by 2030). The lengthy process behind the authorisation of small and medium-scale PV plants, and the still very limited use of tenders, remain significant barriers to the development of renewables. [57]

2. From centralised to decentralised generation

Kenya is one of sub-Saharan Africa's leaders in decentralised energy generation, and it aims at significantly expanding its capacity in the years to come. The country's focus on solar home systems (SHS) over the past decade has been one of the leading factors in the electrification of its rural population – together with the development of mini-grids, which Kenya has promoted for several decades. [58] The World Bank-funded Kenya Off-Grid Solar Access Project (KOSAP) is the country's flagship initiative for off-grid access – but the country generally benefits from a long list of such projects and from a structured private sector, and SHS sales have exceeded 5 million units in the period 2014–18. [58] The first wave of expansion happened in the early 2010s, also thanks to the involvement of a number of donors such as the World Bank, the African Development Bank (AfDB) and the European Union (EU). This involvement has brought significant results; in December 2018, the country was estimated to have a total of 700,000 off-grid connections and the Kenyan National Energy Strategy aims to expand this figure by adding 1.96 million connections through SHS and 35,000 connections via new mini-grids. Even some of the 2.77 million new connections expected through grid intensification are to be achieved by the expansion of current mini-grids.

Despite recent success, however, the Kenyan off-grid sector is still facing challenges. In recent years, the uncertain development of regulations has slowed the expansion of the sector – particularly regarding mini-grids, which fell under the same rules as SHS despite the wider usage of the technology. The absence of the long-awaited mini-grid regulations – still to be published at the time of writing – has stalled investments and the entry of new players into the sector. Regarding SHS, the expected reintroduction of value added tax (VAT) on items needed for the production of solar and wind energy could represent a major drawback for a sector that has already been significantly affected by the consequences of the COVID-19 pandemic. [59] The expansion of off-grid solutions is vital for Kenya's access to power and the realisation of its energy leapfrogging potential. SHS will be key to reaching the 20-25% of the Kenyan population without access to power, composed largely of the most fragile strata of society living in rural areas and informal settlements. Mini-grids will be also key in expanding electricity usage in the agricultural sector, vital to the economy of the country. Solar pumps have already turned out to be significantly cheaper than traditional solutions, while a number of other applications – from cold storage to poultry farming – have proved feasible. [58] Aside from improved regulations, an expansion of consumer finance will be also necessary to guarantee the realisation of Kenya's energy potential.

3. From classical market to a novel business approach

Despite the consistent and strong involvement of the government, which owns a majority share in the two largest utility companies in the country (Kenya Power and KenGen), [60] the Kenyan energy sector is one of the most advanced in sub-Saharan Africa. This has been achieved mostly through a series of reforms that started in the late 1990s, and which were necessary conditions for receiving World Bank funding for the expansion of power generation. Consequently, generation and distribution have been unbundled, the entry of private "players" into the generation sector has been made possible and the tariff system is now reasonably reflective of energy prices. [60] This has made the Kenyan power sector one of the most attractive in sub-Saharan Africa for private investors, both domestic and international, and suitable for the introduction of new systems such as feed-in tariffs (already in existence) and energy auctions (under discussion at time of writing). [61] Although low when compared with non-sub-Saharan African countries, Kenya has achieved one of the best scores in the continent in terms of regulatory performance – particularly regarding accountability, on which it fares better than countries such as India and Egypt. [62]

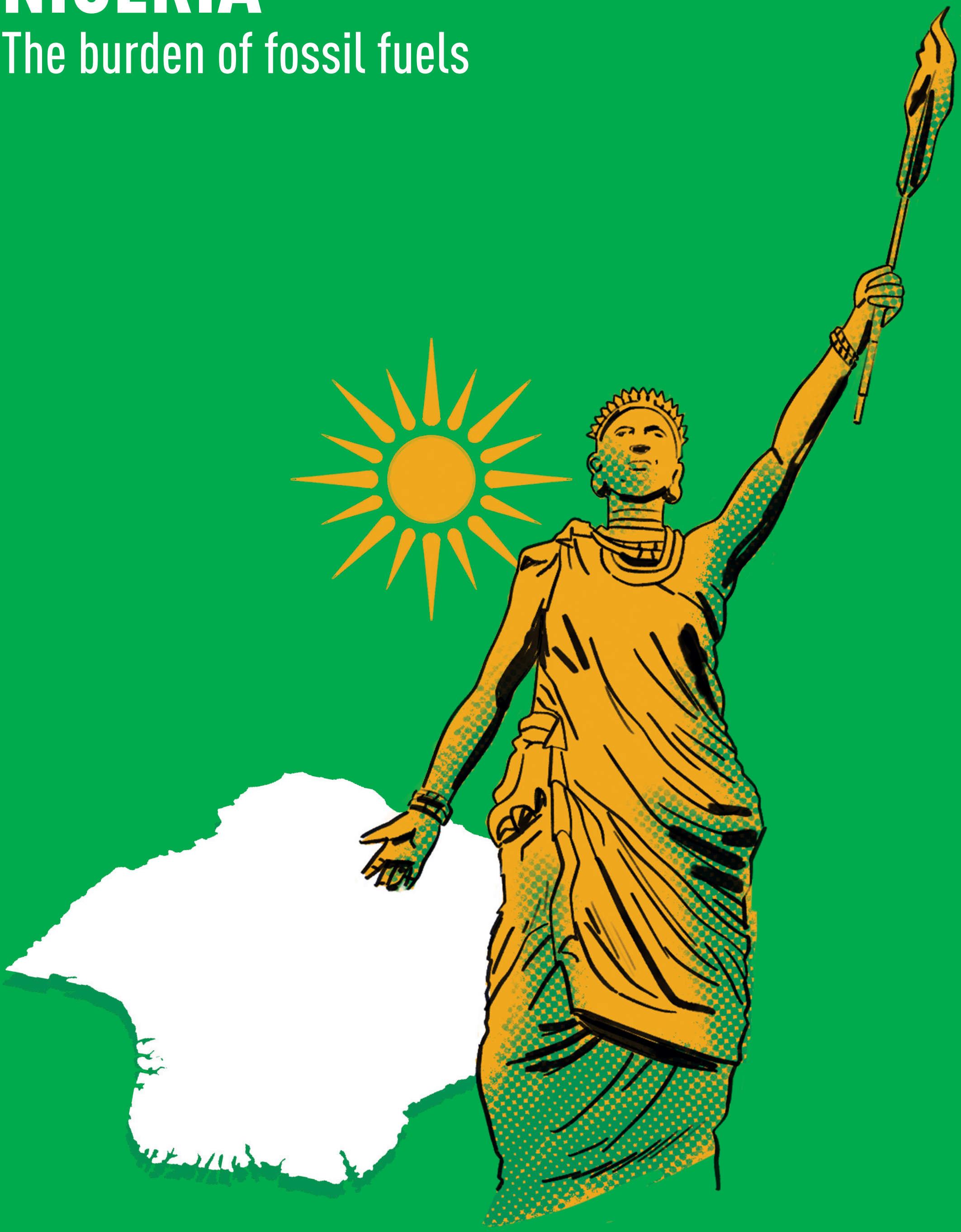
Many challenges remain, however. The gap between announced and delivered reforms is still high in the country, casting a shadow over the finalisation of many, much-needed regulations that should follow the 2019 Energy Act. Political influence in energy governance and in the determination of tariffs remains important, a factor which could prove troubling should the political situation turn unstable again (although the technocratic structure of Kenya's regulatory system partially insulates it from such turmoil). [60] The disparity between reform announcements and actual implementation has also been significant in all previous waves of reform in the sector – and so it remains, undermining trust in government and institutions. Nevertheless, the investments made in capacity building in the regulatory arena and the advanced status of Kenya's energy agencies indicate one of the most solid frameworks in the region for facilitating energy leapfrogging.

4. From "analogue" to digitalised systems

Kenya is particularly well positioned for the penetration of digital tools into its energy systems thanks to factors such as an early involvement in the technology, a relevant level of internet penetration and the diffused adoption of digital mechanisms such as mobile money. Indeed, Kenya has been the first sub-Saharan African country to launch pay-as-you-go (PAYG) services; [63] pioneer companies, mostly funded through international investors such as M-Kopa, have been particularly successful in terms of new connections and financial sustainability, and have now been joined by a growing number of smaller, Kenyan-funded businesses such as Suntransfer. The country has also integrated feed-in-tariffs into digital payment systems – allowing consumers to earn money through their contribution to the grid or, more frequently, to mini-grids. [64] This enabling regulatory environment has been largely matched by a significant expansion of internet access by the Kenyan population, whose number of internet users has increased substantially over the past five years with a remarkable 16% rise between 2019 and 2020. [36] In 2019, the country had 52.06 million mobile connections (out of a population of 51.39 million people). [36] The country is also improving its infrastructure by launching its 5G network, [65] building on a framework that is already one of the best in sub-Saharan Africa. [36] [38] The next step for Kenya will be to decrease the reliance of its digital sector, and particularly of PAYG businesses, on international investments, which local companies often find hard to access. [65] Access to local finance could boost the development of domestic businesses, decreasing the perceived risk and easing the extension of such services to rural customers – a risk that foreign companies are often reluctant to take. [66]

Digitalisation of the Kenyan energy sector extends beyond PAYG systems; Kenya plays an active part in the recently launched Energy Access Explorer, a World Resource Institute online tool analysing demographic, spatial, supply and demand data for energy planning. [67] The National Energy Strategy has, over the past decade, also used least-cost geospatial electrification planning, [68] following a geographic information system (GIS) approach that many have used in the country, to plan for energy access and the diffusion of solar power. [69]

NIGERIA
The burden of fossil fuels



Overview

214 mln
The largest population on the continent

1.424 mln barrels
The daily production of oil

200 kWh
The annual per capita consumption of electricity

90%
The electrification target by 2030

In Nigeria, several factors create a promising scenario for energy leapfrogging. The pressing need to diversify the country's energy mix to reduce dependency on imported fossil-fuel products and the government's commitment to increase electricity supply and reach universal access to support economic growth are two strong drivers. Its large renewable-energy resource endowment and ongoing political efforts to favour decentralised renewable-energy solutions strengthen the prospects for leapfrogging in Nigeria. Nevertheless, incomplete or contradictory regulation and a lack of effective implementation constitute obstacles to green and decentralised energy solutions. Nigeria has the largest population and economy in Africa, and is the continent's largest crude-oil producer. [70] At the same time it has one of the \lowest annual consumptions of electricity per capita in Africa, at 200 kilowatt hours (kWh) compared with 300 kWh in neighbouring Cameroon and 4,000 kWh in South Africa, the continent's second-largest economy. [71] The unreliability of Nigeria's transmission system is a major obstacle to supply. [72] The large demand–supply gap is partly overcome by the population through self-generation, making Nigeria the largest user of oil-fired back-up generators on the continent. [73] Heavily subsidised fossil fuels, a core energy source for self-generation, have disincentivised the uptake of decentralised renewable energy sources (RES) thus far. The 2020 announcement of their phase-out could significantly facilitate the uptake of RES solutions. Unreliable power supply has been identified as the second most significant obstacle to doing business in Nigeria [75] and is estimated to result in economic losses of about US$29 billion annually [76], affecting almost 78% of firms in the country. [77]With an electricity demand projected to nearly double over the next ten years, [78] addressing constraints to electricity supply is essential to support economic growth and social well-being in Nigeria.

1. From fossil fuels to RES

In addition to being Africa's largest crude-oil producer, Nigeria has proven reserves of 37 billion barrels of oil and 5.3 trillion cubic metres of gas. [79] These resources are the mainstay of the country's economy: oil and gas revenues account for around 10% of its gross domestic product (GDP) [79] and about 90% of exports. [80] Despite this, Nigeria imports more than 90% of the fuels it consumes due to its insufficient refining capacity – leading to a high energy-import bill and significant expenditure on fuel subsidies. [81] Diversification of the country's energy mix based on increased exploitation of RES would reduce its dependency on polluting foreign-fuel products. [82] In Nigeria, renewable energy from hydropower has been at the core of power generation for decades. Hydropower production takes place in three large plants: Jebba, Kainji and Shiroro (with a combined capacity of 1,930 MW). The share of hydropower in the energy mix has, however, recently been overtaken by that of natural gas. As of 2018, 81% of the country's power production derived from natural gas, 18% from hydro and less than 1% from solar (28 gigawatt hours [GWh]). [83] Factoring in the role of oil-fired back-up generators, gas and oil are the two main sources of electricity in Nigeria. [73] The country is endowed with a significant solar-energy potential: according to estimates, the potential for concentrated solar power and photovoltaic (PV) generation is approximately 427,000 MW. [84] Conversely, wind-energy potential is limited; [85] the average wind speed at 30 metres is 4–5 metres per second, which is modest but still justifies installations in some locations. [84] The potential for hydropower is estimated at 14,750 MW (11,250 MW large hydro; 3,500 small hydro), [85] meaning that there is expansion potential relative to current use. The Government of Nigeria has demonstrated a strong commitment to support RES. A key policy is the 2016 National Renewable Energy and Energy Efficiency Policy (NREEEP), which sets a target of 30 GW of electricity generation by 2030 with over 30% of it (13,800 MW) grid-connected renewable energy. [84] The target includes solar PV (5,000 MW), solar thermal (1,000 MW), wind (800 MW), biomass (1,100 MW), small/medium hydroelectric (1,200 MW) and large hydroelectric (4,700 MW). [82] Yet to date, no large-scale grid-connected RES project has been successfully implemented apart from in the arena of hydropower, even if some solar and wind projects have been launched over the years and more have been announced. Some relevant examples are the 14 solar plants waiting to start development since 2016 (see below) and the Katsina wind farm (10 MW), which was announced in 2005 and built after long delays but never started operating. [86]

2. From centralised to decentralised generation

Nigeria's electrification rate is 56.5% (2018), with a significantly lower share for rural areas where electricity is available only for 31% of the population (2018). [87] In total, approximately 80 million people lack electricity access in the country. Moreover, even in the areas reached by the grid, the supply of power is highly unreliable. Data shows that businesses suffer a monthly average of 32.8 electrical outages with an average duration of 6.5 hours. Nigeria is one of the worst-performing countries in sub-Saharan Africa when it comes to outages, according to several parameters. [88] It has 12.9 GW of installed capacity, but on average just 3.0 to 4.5 GW are available – mostly due to outdated infrastructure, poor maintenance and transmission constraints. [71] As a result, self-generation using small diesel or petrol generators is significantly widespread and is estimated to have a 42 GW capacity. [71] In this context, there is vast potential for RES-based off-grid technologies to substitute for fossil-fuel generators and to reach unelectrified areas. The Rural Electrification Agency of Nigeria (REA) has estimated that the mini-grid market has potential to scale to over 10,000 sites by 2023, providing power to 14% of the population and creating an annual revenue opportunity of US$3 billion. [89] The implementation of REA projects will be supported by the World Bank, African Development Bank and other development partners through the Nigeria Electrification Project. [90] As of 2018, estimates show that across the country around 30 mini-grids are operational with a total installed capacity of 1 MW. [91] The Government of Nigeria has demonstrated commitment to support scaling-up of the off-grid sector through several policies and regulations. The latest is the 2017 Nigerian Electricity Regulatory Commission Mini-Grid Regulation, which provides a comprehensive regulatory environment aiming at boosting private-sector participation. Another key policy is the 2016 Rural Electrification and Implementation Plan (RESIP), which recognises the need for a cost-effective combination of centralised and off-grid solutions in order to achieve the set target of 90% electrification by 2030. [92] Off-grid solutions are identified as the best solution for remote settlements and in some cases for rural areas, as well as an important step in creating conditions for the viability of future grid extension. [90] However, the RESIP refers explicitly to both fossil fuels and RES off-grid solutions. A more specific target concerning off-grid RES is set in the 2016 National Renewable Energy Action Plan (NREAP), which establishes a target of 40% of rural population served with off-grid (mini-grids and stand-alone) renewable solutions by 2040 (starting from 1.2% in 2010). [82]

3. From classical market to a novel business approach

The privatisation of Nigeria's energy sector began in 2005 with the Electricity Power Sector Reform Act (EPSRA), which remains the main relevant piece of legislation. It has laid the foundations for the transition from a vertically integrated and publicly owned electricity network to an unbundled and largely privatised one. The privatisation process was concluded in 2013 and determined a structure based on a single, government-owned entity, the Nigerian Bulk Electricity Trading (NBET) that purchases electricity from private generating companies through Power Purchase Agreements (PPAs) and sells to private distributors through vesting contracts. In 2016, NBET signed the first 14 PPAs with IPPs to build on-grid solar plants (1,125 MW). However, the development of the projects has been put on hold by disagreements between the government and IPPs on tariff structure, by the signing of put-and-call option agreements and by extended negotiations for Partial Risk Guarantees with the World Bank due to the high degree of insolvency in the sector. [78] At present, no new PPAs have been signed by NBET but three state governments (Kaduna, Nasarawa and Oyo) are in the process of signing PPAs for new solar plants. [78]

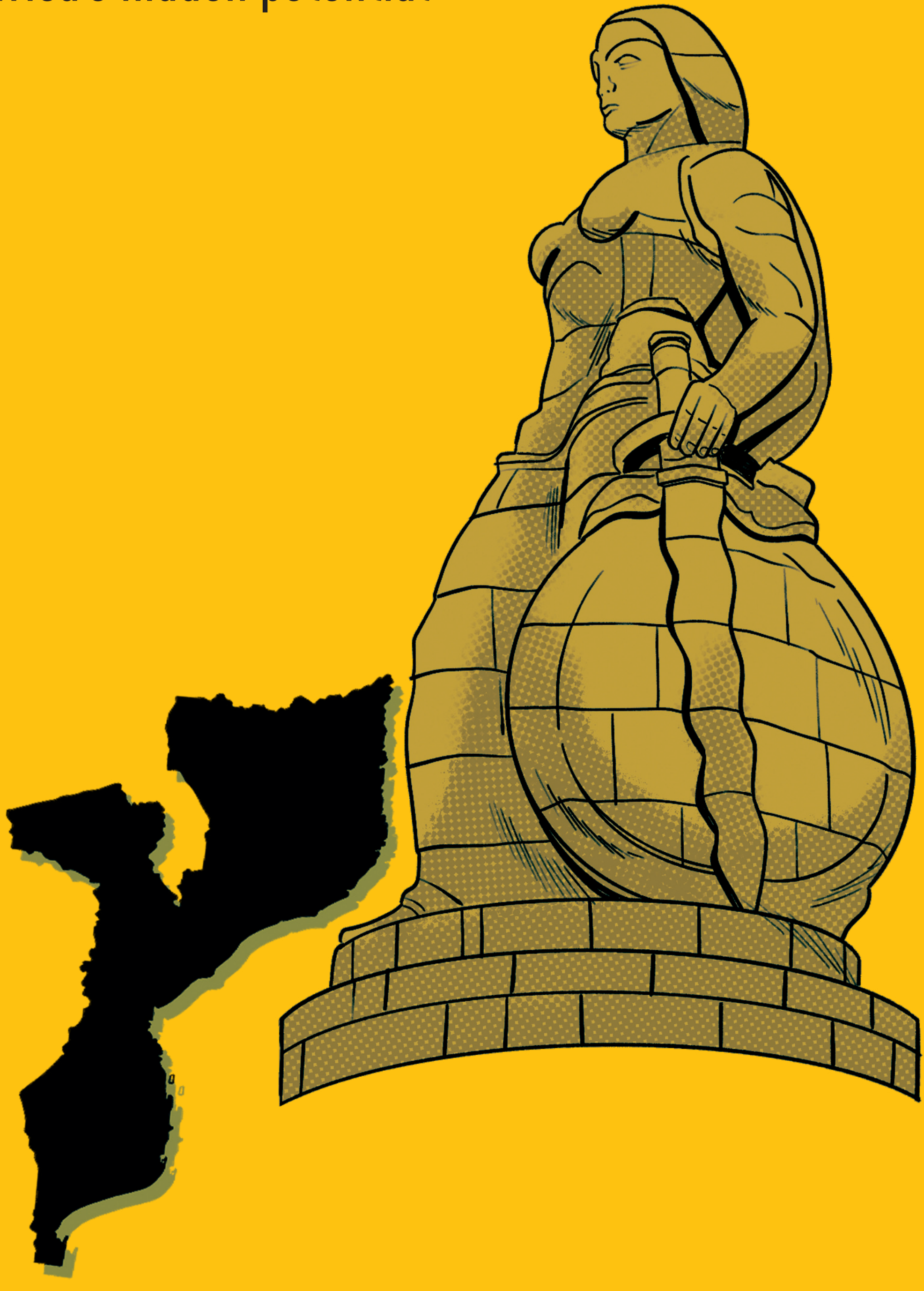
Incentives have been introduced to stimulate private investments in the RES sector, including tax holidays, soft loans and special low-interest loans. [78] A feed-in tariff regulation was adopted in 2015 but never implemented, while recently value added tax (VAT) exemptions were introduced for selected RES items. On the other hand, import duties for solar equipment recently increased from 0% to 5%.[78] addition, the Regulation on Mini-Grids introduced a compensation mechanism for grid arrival, a multi-year tariff order (MYTO) to calculate cost-reflective tvariffs, a fast-track permit process for small systems and a 24-month development-exclusivity period against unanticipated competition. [92] Efforts to improve the enabling environment allowed early market growth. However, the widespread lack of effective implementation of existing policies represents a significant risk, hampering further market development. Overlapping mandates and lack of interrelation between ministries and agencies has created confusion among the many regulations applicable to RES and off-grid sectors, which is one of the reasons for scarce implementation[92]

4. From "analogue" to digitalised systems

In Nigeria the use of mobile money is still very limited, accounting for just 5.6% of the adult population. [93] However, mobile penetration reached 88% in 2018 and is growing rapidly; [94] thus, there is vast potential for mobile-money uptake. The main reason for the current low use has been identified in the 2012 regulation of the Central Bank of Nigeria, which established that mobile-money operations are bank-led, limiting Mobile Networks Operators' (MNOs) ability to provide mobile-money services. [95] Examples from other African countries show that adopting a less restrictive regulatory framework to include MNOs significantly increases mobile-money penetration. The key difference between the two models is that subscribers do not need a bank account to access MNO-driven mobile-money services, thus allowing the latter to reach unbanked individuals and boosting financial inclusion (which has remained stagnant at around 40% since 2014 in Nigeria). Moreover, mobile money guarantees a reliable payment system in the off-grid sector, thus representing a catalyst for private investments. [96] In Nigeria the lack of a robust payment-collection system for off-grid services is generating a perception of high risk in the market, discouraging private investments. Facilitating the uptake of mobile money with proper regulations is therefore an essential element in fostering the growth of off-grid RES-based solutions in the country. Despite the limitations of the existing regulations, in 2013 the Dutch solar off-grid company Lumos and MTN (the largest mobile network in Nigeria) signed a partnership to provide solar home systems (SHS) with a pay-as-you-go model in Nigeria, becoming leaders in the sector. [97] In 2020, they announced the launch of two new, more technologically advanced SHS products that will guarantee savings up to 70% ...will guarantee savings up to 70% and the possibility to charge a broader spectrum of devices [98] In addition to mobile money, the substantial and rapidly growing penetration of mobile phones in Nigeria will provide other significant opportunities for the digitalisation of the energy sector. Indeed, the impact on internet penetration is significant as mobile phones are the only technology to access the internet for the majority of the country's population. Internet penetration in Nigeria has also reached a high share compared with that of neighbouring countries (42%),[38] and 90% of the population is covered by 2G networks. [97] This makes the country well positioned for the uptake of internet-based technologies in the energy sector, ranging from payments to data gathering and energy efficiency. Despite the encouraging data on internet penetration, broadband speed still represents a weak spot for Nigeria, which is lagging behind in the adoption of 4G (and even 3G) compared with regional peers. To address this issue, the Ministry of Communication and Digital Economy launched in March 2020 a new national broadband plan that aims at achieving 90% population coverage with 4G/5G networks by 2025. [99]

MOZAMBIQUE

Africa's hidden potential



Overview

2022
The target year to reach universal energy access

2040
The year energy demand is expected to quadruple

38 per km²
The population density

1,290 dollars
The GDP per capita in 2019

Despite a vast and diversified availability of energy resources on its territory, Mozambique has one of the lowest electrification rates on the continent. This is mostly due to an underdeveloped power-distribution network, poor infrastructure, and regulatory barriers to the development of new power projects. Moreover, its low population density (38 people per km2 compared with 90 in Kenya, 108 in Ethiopia and 215 in Nigeria) makes projects to expand energy access relatively more expensive.

Another obstacle is Mozambique's limited financial resources for investing in expanding energy access (a purchasing power parity GDP per capita of 1,290 in constant 2017 international dollars, compared with Ethiopia's 2,103, Kenya's 4,193, and Nigeria's 5,156). The modernisation of Mozambique's energy system is crucial for boosting economic growth and local prosperity, considering that 53% of its firms experience regular power outages [101] and electricity prices are high compared with the regional average (respectively, 10.4 US Dollar cents per kilowatt hour [USDc/kWh] and 23.66 USDc/kWh for industry and the residential sector). [100]

Progress in the liberalisation of the energy market and the recently adopted target to reach universal electricity access by 2030 create momentum for expanding renewable-energy production and use in the country, especially through off-grid solutions, creating a vast potential for leapfrogging.

Mozambique is the third-largest holder of natural gas and the largest hydropower producer on the continent. [102] Despite the substantial domestic demand, the country currently exports a significant share of both gas and hydropower. In 2018, electricity and energy-product exports accounted for around 45% of its total exports, [103] and natural-gas rents accounted for 4.4% of Mozambique's gross domestic product (GDP). [104] By 2040, domestic energy demand is estimated to quadruple in Mozambique, as well as in other neighbouring Southern African Development Community (SADC) countries. [105] As a result, the government has the twofold objective of reaching universal domestic electricity access and becoming a Southern African energy powerhouse. Renewable energy has been increasingly identified as a key to meeting domestic demand in a timely and cost-effective way.

1. From fossil fuels to RES

Between 2011 and 2013, the Government of Mozambique conducted a comprehensive study of its solar, hydro, biomass, wind, geothermal and maritime resources, recognising vast domestic renewable energy generation potential. [106] Solar holds the greatest promise according to the Renewable Energy Atlas of Mozambique, thanks to good irradiation levels – particularly in the north of the country. Solar also offers grid connection opportunities in areas like Maputo and Tete, where infrastructures are already robust. In other areas of the country, to harness the solar potential, off-grid solutions are needed. [107] The energy potential of the country is not limited to renewables but includes significant fossil-fuel resources, accounting for 23 billion tonnes of coal reserves and 104 trillion cubic feet (Tcf) of natural gas. [108] As a result of the recent diversification of its energy sector in favour of fossil fuels, the share of renewables in Mozambique's total energy consumption has been declining, dipping for the first time below 90% in 2014 [108] and declining to 79.1% in 2015 and 59.5% in 2017. [109]Despite this trend, renewables still account for the majority of energy consumption in the country – even if the major renewable source is traditional biomass, which is largely unsustainable.

With regard to power generation, the renewable energy source (RES) installed capacity was 2273 MW in 2019 with a further 16.06 MW of renewable-power capacity in off-grid systems. [110] Hydropower currently dominates the overall production of electricity, accounting for around 85% in 2018. [112] The contribution of solar power to total electricity generation is still very limited, accounting for 2.0 GWh – less than 1% of the total – in 2018. [110] New developments will help in expanding the use of solar: the Mocuba (40 MW) power plant started to feed the national grid in August 2019, [112] the Metoro (30 MW) plant is under construction at the time of writing [113] and three more solar plants will be built in the next few years (adding 120 MW). [114] In addition, in 2017 the Energy Fund (FUNAE) identified a project portfolio for off-grid solar power consisting of 343 projects, including 10 mini-grids (1–3 MW) and 111 micro-grids (1–100 kilowatts [kW]). [115] In recent years, Mozambique has adopted several strategies and policies designed to promote and facilitate access to renewable energy. The New and Renewable Energy Strategy (EDENR) for the period 2011–25 was adopted in 2011; it recognises the need to develop the use of renewables and to define strategic objectives. [107] The strategy's main objectives include the development of RES technologies, the promotion of public and private investments in RES and the reduction of the environmental damage caused by the consumption of traditional biomass and fossil fuels. [107] EDENR addresses the use of renewables for both off-grid and grid-connected solutions. The adoption of feed-in tariffs, tax incentives and benefits to promote the use of RES was included in the strategy but actuation is still pending, hampering project implementation. No specific target for renewable-energy use has been adopted. [107]

2. From centralised to decentralised generation

As of 2018, only 31% of Mozambique's population had access to power. [116] Furthermore, access to electricity is mainly available in urban areas: in 2018, rural access was less than 8%, with priority given to schools, health centres and administrative offices. In the countryside, around 68% of the population lives widely dispersed across rural areas – one of the main barriers to the extension of the grid. [117] Today, over 90% of the population that enjoys access to electricity does so through the main grid. [118] On the other hand, over 95% of total domestic needs in rural areas depends on expensive and unreliable diesel generators or forest resources. [119] To address this situation, the Government of Mozambique launched the National Energy for All Programme, which aims to achieve 100% electrification by 2030. [120] Even though the government's focus is on grid expansion, off-grid renewables-based solutions are identified as key technologies for reaching remote areas, promoting rural development and fighting poverty. [107] To support the 2030 electrification goal, the Ministry of Mineral Resources and Energy – through the Energy Fund (FUNEA) – recently launched a portfolio of off-grid renewables projects budgeted at US$500 million. They are solar and hydro projects – namely, micro- and mini-grids and small stand-alone systems. The aim of the initiative is to mobilise private and donor financing in the sector. [115] According to the IEA, in Mozambique decentralised solutions will represent the least-cost option for 55% of new connections over the next 20 years, whereas, for the remaining 45%, connection to the grid is the best solution as they are located reasonably close to existing or planned grid. [105] Despite government efforts, off-grid solutions are underdeveloped and the participation of the private sector remains limited. One of the main issues behind this outcome is the lack of a definitive rural-electrification plan that would minimise the risks to grid arrival in off-grid sites, enabling firms to plan their investments. According to current regulations, once the grid reaches off-grid areas the operators have to revert to the national tariff, which undermines the business model, and no compensation or regulatory protection is foreseen. [118] The lack of a national target for off-grid take-up in the framework of the 2030 electrification goal is another significant obstacle.

3. From classical market to a novel business approach

The participation of the private sector in Mozambique's energy market is still largely regulated by the Electricity Act adopted in 1997. The Act opened up the country's electricity sector to private actors through the establishment of concession contracts awarded via competitive public tenders by the Ministry of Mineral Resources and Energy, and through the establishment of Power Purchase Agreements (PPAs) with the national company, Electricidade de Moçambique (EDM). [121] The projects arising from these contracts can be realised under a Public–Private Partnership model, following the existing PPP Law (2011). [121] A revision of the Electricity Act has been discussed by the government since 2018, but at the time of writing it is still pending. [122] The aim of this revision is to ensure financial sustainability and to foster competitiveness in the energy sector, through measures such as the simplification of authorisation procedures for electricity-production projects, including RES-based off-grid ventures, and the provision of adequate legal guarantees to investors. In 2017, an independent Energy Regulatory Authority (ARENE) was created; its role includes fostering cost-reflective tariffs, promoting free competition and acting against abuses of dominant positions in the sector. [123]

Since 2015, out of four new generation plants (with a total of 440 MW), three were developed, financed and constructed with private-sector participation as Independent Power Producers (IPPs) with long-term PPAs established with EDM. [124] Moreover, the first two solar plants, Mocuba and Metoro, were built as IPPs and three more are planned to be similarly developed.

Despite these positive steps forward, some significant barriers still prevent greater participation by the private sector. Difficulties in obtaining access to capital undermine the upscaling of renewables and off-grid solutions. [107] Other obstacles are a lack of standardised PPAs [119] and PPP-law requirements for the involvement of local government, investments and taxation arrangements that work against private-sector business models, and scalability. [118] Moreover, the majority of private investments remain dependent on government interventions or donor-funded initiatives. The tendering process for green mini-grids is also the same as for large energy projects, which makes it more complex for applicants – particularly, local businesses – to obtain a concession contract. Unrealistically low price expectations created by social electrification programmes risk undermining the appeal of private-sector-led projects, while subsidised fuels reduce the incentive to switch from diesel to solar power generation. High import duties and value added tax (VAT) applied to renewable-energy equipment represent a considerable barrier, as well as the lack of quality standards for RES products. [107] Finally, the lending scenario is very challenging for RES projects as local banks perceive them as high-risk ventures and interest rates can be as high as 40%. [118] Recent donor programmes focused on enhancing the enabling environment for private investments in the RES sector in Mozambique have included the African Development Bank's (AfDB's) Sustainable Energy Fund for Africa grant. The programme supports the implementation of a feed-in-tariff system, targeting also small/medium projects, the provision of standardized PPAs and other key elements to improve the investment climate.

4. From “analogue” to digitalised systems

In Mozambique, internet penetration is currently at 18% – a low share compared with that of neighbouring nations. [37] More importantly, the country has not yet reached the 20% critical mass needed to start reaping the benefits of network effects for information and communications technologies (ICTs), which include economic growth and growing opportunities for the private and public sector (including in the energy arena). [125] The main factor hampering access to the internet is reportedly the cost of internet-enabled devices; lifting the excise duties applied to entry-level internet-enabled devices could thus have a very significant impact. Moreover, strategies to stimulate demand, such as e-literacy programmes, and a legal framework to protect electronic transactions are much needed and yet missing in the country. Mozambique boasts a very large urban–rural gap in internet access: 24% of the urban 15-year-and-older population uses the internet, whereas in the rural areas this demographic accounts for a mere 4%.[125] This location gap is particularly problematic as it undermines the use of internet-based technologies for off-grid energy solutions targeting rural areas.

Mobile penetration stood at 46% in 2017 – again, a lower share compared to Mozambique’s neighbours. [37] In the same year, a scant 22% of the country’s population had a mobile money account. [37] Some legal requirements constrain the use of mobile money – namely, the small number of adults in possession of the ID documentation required to open an account and the age limit, established at 21 years, which already cuts off 55% of the population. [126] Limited trust and awareness of mobile financial services are also a barrier – an issue reflected in the absence of mobile money from the financial education programme run by the Bank of Mozambique. [126] A more significant presence for mobile banking, especially in rural areas, would have a significant impact on the off-grid market as it would allow the use of PAYG (pay-as-you-go) business models, which have enjoyed enormous success in nations like Kenya, Tanzania and Uganda. In other countries where PAYG-model penetration has not been significant, local microfinance has played a key role in the uptake of the off-grid market. However, in Mozambique the microfinancing ecosystem is still limited, and lending by existing institutions in the off-grid sector is almost absent. [118]

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