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The Potential of Digital Technologies for Centralized Electricity Systems in Sub-Saharan Africa

Hugo LE PICARD

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Summary

The expansion of centralized power grids is vital for economic and social development in sub-Saharan Africa. The population of sub-Saharan African is expected to almost double in 30 years according to the United Nations (UN), reaching 2.1 billion inhabitants by 2050, including 1.2 billion city-dwellers. The continent will therefore need to provide jobs for the young people who are entering the labor market in greater numbers every year. An additional 20 million jobs will have to be created every year over the next 20 years to absorb this new influx of labor. In view of this, expansion of the industrial sector should help reduce endemic poverty in the region, while harnessing the continent's population growth and rapid urbanization. However, such developments are significantly curtailed by the inadequacy of sub-Saharan centralized power grids.

In addition to low rates of access to electricity, the regions' grids are undersized. In 2018, installed capacity throughout sub-Saharan Africa (apart from South Africa) amounted to approximately 80 gigawatts (GW), or nearly two times less than France (130 GW). Grids are also beset by obsolescence and mismanagement that has a significant negative effect on economies. For instance, in 2014 Nigeria experienced more than 32 power outages per month, each lasting approximately 12 hours, or the equivalent of 16 full days without electricity each month. These power outages represent a significant cost for sub-Saharan countries' economies, ranging from 1 to 5% of national gross domestic products (GDPs). More than half of sub-Saharan companies now believe lack of access to reliable electricity is a key constraint for their business.

For the industrial sector to grow, priority should be given to reinforcing central grids in addition to pursuing electrification targets. This is to improve their reliability and equip them to serve 1.2 billion city-dwellers by 2050. Enormous investments in new generating capacity and grid infrastructure are required to achieve these objectives. In 2018, approximately only $20 billion was invested in generation and $10 billion in grids for the whole of Africa from all sources, whereas more than $120 billion is needed in annual investment. Development finance institutions (DFIs) alone cannot finance the expansion of the continent's power sector. Consequently, the sector has to rely on private investment, but DFI initiatives for Africa's electrification can be a source of confusion and duplication. These DFI initiatives are sometimes in direct competition with

each other and with the private sector in areas such as generation. In order to encourage private investment, which is essential, it will be necessary to clarify the roles of the various actors present in the region's electricity sectors, whilst simultaneously letting DFIs concentrate on segments that cannot be developed solely by the market, such as network infrastructures.

Private investment, particularly in renewables, has also been curtailed by the poor financial situation of public utilities. These public utilities are caught in a vicious financial circle that reduces service quality, increases their costs, and further sustains their financial problems. After decades of unfinished reforms, the power grids have scarcely changed and IPPs (independent power producers) often continue to produce on the fringes of markets where public utilities have retained a high degree of control. In many countries, however, in response to a growing urban population and the sector's difficulty in expanding at the same rate, poor grid reliability has led people and businesses to develop greater autonomy from the central grid. This is not without repercussions for the sector's development.

Today, the priority should be an improvement in the system's financial base, i.e., the distribution sub-sector: with satisfactory service quality for customers, well-maintained infrastructure and revenue from electricity sales properly collected. To this end, smart grid technologies will play a key role. However, in sub-Saharan Africa, smart grid development strategies cannot be based on those from other parts of the world. They must primarily try to determine to what extent these new technologies can address the short-term needs of sub-Saharan grids. Therefore, these new technologies must firstly be used to improve revenue collection, grid reliability and resilience.

Smart meters are the key element in smart grids. They deliver multiple benefits for the entire sector: increased revenue collection and reduced theft for distribution companies; energy savings, protection against overcharging and new services for consumers. However, the continent-wide deployment of these technologies faces various obstacles. The lack of standards restricts the development of a continent-wide competitive environment that in turn curtails potential cost reductions. These standards are also necessary to prevent smart meter compatibility issues with local technical and environmental specificities. Furthermore, other social factors, such as the predominance of multi-family housing in some African countries, may reduce incentives for households to adopt these technologies.

Automatic control and management systems can be deployed to improve grid management and the reliability of electricity supply. For instance, these systems can be used to detect and locate power outages and resolve some of them remotely and quickly. This helps to reduce significantly the length of power outages and the resulting economic losses. In the longer term, these systems could enable a move from an approach of improved grid management to one of optimization, particularly in asset maintenance.

With the development of digital technologies, new markets are opening up, such as for storage batteries. These batteries can be used throughout the power sector's value chain, in particular to improve the reliability and quality of the electricity supply. Batteries can have several functions, such as being used for automatic grid frequency regulation, storing overproduction by renewables during low-demand periods, or even serving as a backup battery capacity for consumers.

Finally, the digitization of centralized grids is not the only way to develop a more resilient power sector. New innovative solutions are appearing in areas where grids are particularly unstable, such as connected mini-grids.

After several decades of reform, the situation in the power sector has scarcely changed and the place of renewables in the continent's electricity mix is still minimal. Only a rapid improvement in the financial viability of electricity utilities, using digital technologies, would facilitate a switch to smart grids and the large-scale deployment of renewables on the continent. Close cooperation between public institutions and the private sector is more necessary than ever.

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Introduction

Shortly after being appointed President of the European Commission, Ursula von der Leyen stated her intention to lead a "geopolitical" Europe and to make Africa one of its foreign policy priorities. Her first official trip was to the African Union's headquarters in Addis Ababa. One of the pillars of the Africa-European Union (EU) Partnership is to accelerate energy transition in Africa. Today, weakened by the COVID-19 crisis, Africa needs sustainable energy more than ever, for its economies to recover and grow.

Sub-Saharan growth is highly dependent upon raw material prices, which are volatile, and the region has now been hit by recession: 3% of average growth in the last three years and -1.6% forecast for 2020.[1] Sub-Saharan Africa exports very few manufactured goods (around 22.9% of its exports)[2] and imports $48.7 billion[3] worth of foodstuffs per year. In addition, climate change is already striking the continent, reducing agricultural productivity and bringing increasing devastation, such as the recent torrential rainfall in Niger.

In light of this, expanding power grids is not only urgent, but is also an absolute priority for Africa's economic and industrial development. Although, the sub-Saharan region's population is approaching 1.1 billion, one inhabitant out of two still has no access to electricity.

Sub-Saharan Africa's centralized power grids are undersized and obsolete. In 2018, installed capacity throughout sub-Saharan Africa (apart from South Africa) amounted to approximately 80 gigawatts (GW), or nearly two times less than France for 20 times the population.[4] But paradoxically, the sub-Saharan region is richly provided with energy resources, particularly renewables (RE). With regard to grid infrastructures, sub-Saharan Africa (excepting South Africa) has on average 229 kilometers (km) of power transmission lines per million

1. "Sub-Saharan Africa. COVID-19: An Unprecedented Threat to Development", Regional Economic Outlook, International Monetary Fund, April 2020, available at: www.imf.org.
2. "World Development Indicators", World Bank, available at: http://databank.worldbank.org.
3. "Biannual Report on Global Food Markets", *Food Outlook*, Food and Agriculture Organization of the United Nations, May 2019, available at: www.fao.org.
4. "Africa Energy Outlook 2019", *World Energy Outlook Special Report*, International Energy Agency, November 2019, available at: www.iea.org.

inhabitants (pmi), compared to 800 km/pmi for France,[5] while its population density is two and a half times higher than France's.

Previous strategies to expand the sub-Saharan power sector have not delivered the expected results: progress in electrification is too slow and many vulnerabilities remain. However, the decreasing costs of RE and the digital transformation that is currently taking place in Africa, as in other parts of the world, affect all segments in the power sector value chain. This creates many opportunities for Africa, and in particular should enable sub-Saharan grids with obsolete technologies to transition directly to smart grids. Similarly, this would bypass traditional development models in the power sector, ignoring fossil fuels and moving directly to low-carbon technologies.

However, this development of sub-Saharan grids, although desirable, is still a long way off: there are many obstacles to overcome. This paper examines the problems facing the sub-Saharan African centralized power sector and the solutions that new digital technologies could provide for these challenges.

5. "Linking Up: Public-Private Partnerships in Power Transmission in Africa", World Bank, June 2017, available at: https://openknowledge.worldbank.org.

Economic Development in Sub-Saharan Africa with the Challenge of a Fragmented Power Sector

Accelerating industrial development to address population growth

Economic development in sub-Saharan Africa is absolutely essential: it has made progress in recent years, but with insufficient results and could be jeopardized by COVID-19-related crises. Out of the 780 million people in extreme poverty worldwide, living on less than $1.9 per day, more than half are in Africa.[6] Moreover, the continent is facing substantial population growth. According to UN projections, the sub-Saharan region's population will almost double in less than 30 years to reach 2.1 billion by 2050 compared to 1.1 billion nowadays. Similarly, most of the population will be concentrated in cities, which will account for 60% of the population, or 1.2 billion inhabitants by the middle of the century.

In addition to the issues of access to healthcare and education that population growth will create, the continent will also need to provide jobs for the young people who are already entering the labor market in ever increasing numbers each year. According to International Monetary Fund (IMF) projections, 20 million new jobs will have to be created in sub-Saharan Africa each year for the next two decades just to absorb the new entrants to the labor market.[7]

In view of these trends, the development of the industrial sector would be a good way to facilitate the region's economic development and subsequently reduce poverty, while harnessing the continent's population growth and rapid urbanization. Industry is a driver for innovation and a sector of significant employment generation: each job created in industry

6. "Implementation of the Third United Nations Decade for the Eradication of Poverty (2018–2027)", *Report of the Secretary-General*, United Nations, August 2018, available at: https://undocs.org.

7. A. Abdychev *et al.*, "The Future of Word in Sub-Saharan Africa", African Department, International Monetary Fund, December 2018, available at: www.imf.org.

results in three to four indirect jobs. However, in sub-Saharan Africa, the industrial sector's contribution to the continent's gross domestic product (GDP) remains low and is falling. It was 26.8% of GDP for the region in 2019 as opposed to 33.5% in East Asia and 42.4% on average in the Middle East and North Africa (in 2018).[8] In fact, it has gradually declined over the last three decades.

Grid instability is a key constraint for the economy

Reliable and affordable access to energy, particularly electricity, is a prerequisite for the industrial sector's development. Indeed, the obsolescence and mismanagement of many power grids in sub-Saharan Africa are major barriers to industrialization and job creation. For instance, power outages due to the poor condition of grids are common. In 2007, a sub-Saharan company experienced on average 77 hours of power outages per month.[9] Nigeria is an extreme case: in 2014 the country had more than 32 power outages per month, each lasting around 12 hours. This represented 384 hours of power outages, or the equivalent of 16 full days without electricity every month.[10]

This inadequacy of sub-Saharan power grids has a significant negative effect on economies, representing on average a cost from 1 to 5% of GDP depending on the country.[11] The value of losses due to power outages, calculated as a percentage of sales for companies, can be as high as 15.8% in some countries.[12] More than half of sub-Saharan companies also felt that access to electricity was a key constraint for their business.[13] Again, Nigeria is an extreme case:[14] the economic costs caused by power outages amount to more than $29 billion annually according to the IMF.[15]

8. "World Development Indicators", *op. cit.*

9. M. Oseni and M. Pollitt, "A Firm-Level Analysis of Outage Loss Differentials and Self-Generation: Evidence from African Business Enterprises", *Energy Economics*, November 2015, available at: www.sciencedirect.com.

10. "Enterprise Survey Indicators Data", World Bank, available at: http://enterprisesurveys.org.

11. N. Ouedraogo, "Modeling Sustainable Long-Term Electricity Supply-Demand in Africa", *Applied Energy*, vol. 190, p. 2017, available at: www.sciencedirect.com.

12. "World Development Indicators", *op. cit.*

13. M. Oseni and M. Pollitt, "A Firm-Level Analysis of Outage Loss Differentials and Self-Generation: Evidence from African Business Enterprises", *op. cit.*

14. The rate of access to electricity is therefore not a good indicator for judging the power sector's expansion and should be put into context. This rate may be high in terms of the percentage of the population's access, without however representing "real" access to electricity. For example, Nigeria has a grid connection rate of 57%, but the grid only operates 18% of the time.

15. "Nigeria: 2019 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Nigeria", *Country Report*, No. 19/92, International Monetary Fund, April 2019.

For the industrial sector to develop, priority needs to be given to building grid resilience, in addition to electrification objectives. This is to improve reliability and prepare them to serve 1.2 billion city dwellers by 2050.

The development of the sub-Saharan power sector requires enormous investment

The sub-Saharan region currently needs significant investments in new power generating capacities and grid infrastructures.

The size of these investments depends directly on the desired electricity consumption levels to be supplied to the population with reference to the World Bank's indicator.[16] For instance, at consumption level 5, which is equivalent to full access, more than 95% of sub-Saharan Africa's population needs to have access to electricity via expansion of the central grids.[17] Total investments depend on these objectives: electrification of the region at consumption level 1 would cost $22 billion and more than $2.5 trillion at level 5.[18]

The International Energy Agency (IEA) calculates that in order to achieve universal and full access to electricity in the next 20 years, $120 billion per year (half of which would be for the grids) would be required.[19] In 2018, only about $20 billion was invested in generation and $10 billion in electrical networks, throughout Africa and from all sources.[20]

In view of the resources required, it is not possible for international institutions, such as the World Bank or the African Development Bank, to finance the development of the power sector alone. Cumulative investment by development finance institutions (DFIs) in the sub-Saharan power sector reached approximately $8 billion in 2015,[21] or approximately 6% of the total amount that would be required. In light of the significant investment requirements, international development assistance institutions are not enough. The private sector needs to be fully involved.

16. This indicator ranges from level 1, which corresponds to almost no access (just a few hours per day) to level 5 that is equivalent to full access.
17. A. Dagnachew *et al.*, "The Role of Decentralized Systems in Providing Universal Electricity Access in Sub-Saharan Africa. A Model-Based Approach", *Energy*, November 2017, available at: www.sciencedirect.com.
18. *Ibid*.
19. "Africa Energy Outlook 2019", *op. cit*.
20. *Ibid*.
21. M. Hafner, S. Tagliapiera and L. de Strasser, *Energy in Africa: Challenges and Opportunities*, New York, Springer, 2018, available at: www.springer.com.

However, this funding is slow to materialize in sufficient amounts because of the high risks associated with investment in the continent's power sector.

Public and private investments need coordination to succeed

DFIs are involved in all areas of the power sector in sub-Saharan Africa and their many initiatives can be a source of confusion or duplication. The book *Energy in Africa* by Hafner *et al.* (2018) lists no fewer than 60 international initiatives totally or partly focused on the region's power sector. There are seven such initiatives at the EU institution level alone. Thirteen individual or joint initiatives by Member States can be added to this. In light of all these initiatives, it becomes particularly difficult to understand the role of each one. Furthermore, the initiatives often go hand in hand with specific bureaucracy and onerous administrative procedures in order to release the funds. They therefore have high transaction costs for limited results.[22]

In some markets, like electricity generation, DFIs may be in direct competition with each other, as well as with the private sector, which contributes to slowing down the expansion of the power sector while increasing project risks for project developers. Therefore, the DFIs would benefit from refocusing their investments on segments where it is more difficult for the private sector to invest, for example in grid infrastructures.

22. *Ibid*.

European initiatives totally or partly focused on electricity in Africa

Initiative Name	Name of the Managing Institution
European Institutions	
The European Development Fund	Managers: European Investment Bank (EIB); European Commission (EC) Funders: Member States
The Africa Energy Guarantee Facility	EIB and EC
The Electrification Financing Initiative	EC, European Development Finance Institutions (EDFI) and the United States (US)
EU-Africa Infrastructure Trust Fund	Manager: EC Funders: EC through the European Development Fund (EDF) 12 Member States
ACP-EU Energy Facility	EC and Member States
EU-Africa Renewable Energy Cooperation Program (RECP)	Funders: EC, Austria, Finland, Germany and the Netherlands
EU Energy Initiative for Partnership Dialogue Facility (EUEI PDF)	Administered by: GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit [German Agency for International Cooperation]) Funders: EC, Austria, Finland, Germany, Netherlands, Italy and Sweden
European Countries	
Energising Development	Netherlands, Germany, Norway, United Kingdom, Switzerland and Australia
Energy and Environment Partnership South & East Africa	Finland, United Kingdom and Austria
Investment and Support Fund for Businesses in Africa	France (AFD [French Development Agency])
Sustainable Use of Natural Resources and Energy Finance (SUNREF)	France (AFD [French Development Agency])
Danish Climate Investment Fund	Denmark
FMO Infrastructure Development Fund/Direct Investment	Netherlands
DfID Impact Fund	United Kingdom (UK)
Energy Africa campaign	UK
Renewable Energy Performance Platform	UK
DEG — Direct Investments	Germany (KfW)
Promotional loan with PTA Bank	Germany (KfW)
Green Africa Power	UK and Norway
Nordic Climate Facility	Denmark, Finland, Iceland, Norway and Sweden

Source: from M. Haffner, S. Tagliapietra and L. de Strasser, Energy in Africa: Challenges and Opportunities*, New York, Springer, 2018.*

While the COVID-19 crisis is hitting all the world's economies, the sub-Saharan countries are at the forefront: with falling exports and raw material prices, they are experiencing a significant decrease in their foreign revenues. They therefore have little opportunity to reduce their national debt and, yet, they need to invest substantially in their particularly fragile healthcare systems to tackle the health crisis, as well as to stimulate their economies. In view of the pressing need for economic development and a low-carbon power sector in line with the objectives in the fight against global warming, the roles of the various stakeholders active in the region need to be clarified. Initiatives should be reorganized at the European level to avoid duplications, by merging identical initiatives and ensuring they do not compete with the private sector. This is to benefit better from all actors' expertise and ensure European funds are effectively allocated to achieve the intended goals in terms of the expansion of the African power sector, and encourage rather than deter crucial private investment.

Dead Locks in the Sub-Saharan Power Sector

A vicious circle maintaining obsolete grids

Most national electricity utilities are not financially viable and are considered as unreliable partners by project developers, thus limiting private-sector investment that is held to be particularly risky. This difficult financial situation, which applies to almost all electricity utilities in sub-Saharan Africa, besides constraining investment, jeopardizes the survival of existing power sectors.

Most of the electricity utilities do not cover their operating or fixed costs. Out of a World Bank survey of 39 sub-Saharan African countries, 18 did not recoup their operating costs and therefore faced short-term financial difficulties.[23]

Without an improvement in their finances, electricity utilities no longer have the resources to maintain adequate levels of grid reliability and to invest in their expansion. The sub-Saharan transmission and distribution grids are obsolete and subject to line losses that increase the cost of electricity. Twenty-four countries have losses over 20% and sometimes more than 48%.[24] To this must be added non-technical losses, such as electricity theft via illegal connections, as well as considerable difficulties the distribution companies have collecting payments for billed electricity. More than 10 countries have arrears of more than 20%.[25] Public utilities are also overstaffed, and electricity price levels are too low.

Consequently, a vicious circle has gradually taken shape. The main effect of the poor financial situation of these companies is reduced investment in infrastructure maintenance that in turn perpetuates obsolete grids. The quality of services worsens and there are chronic power outages: more than 32 on average per month in some countries.[26] Given this

23. C. Trimble, M. Kojima *et al.*, "Financial Viability of Electricity Sectors in Sub-Saharan Africa: A Quasi-Fiscal Deficits and Hidden Costs", *Policy Research Working Paper*, World Bank, August 2016.

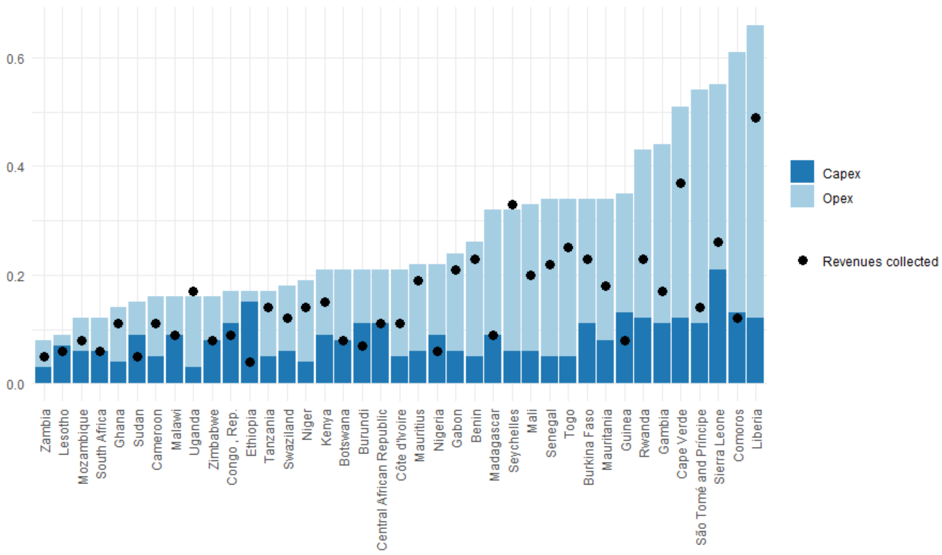
24. *Ibid.*

25. *Ibid.*

26. "World Development Indicators", *op. cit.*

deterioration, an increasing number of customers refuse to pay for services that have become substandard and this contributes to further revenue losses for the electricity utilities. These in turn reduce the share of financing allocated to the maintenance of facilities.

Electricity supply cost and revenue collected in dollars per kWh billed (2014)



Source: C. Trimble, M. Kojima et al., *"Financial Viability of Electricity Sectors in Sub-Saharan Africa: Quasi-Fiscal Deficits and Hidden Costs",* Policy Research Working Paper, *World Bank, August 2016.*

The financial challenge of developing the continent's renewable energy potential

For the large-scale development of renewables in sub-Saharan Africa, it is imperative that the sector's finances improve. For renewable projects to be financed on favorable terms, payment certainty is required throughout a power plant's lifetime, or for more than 25 years, as plants have high capital expenditure (CAPEX) for very low operating expenditure (OPEX). Such a time horizon involves many risks, which are higher when national purchasing companies face major financial problems, as this can threaten the stability of cash flows.

Therefore, there is a significant risk that the share of renewables will remain minimal in the region's electricity mix. Given rapidly increasing energy demand, "emergency" power stations are becoming increasingly attractive. These solutions take the form of electric generators in containers that are joined together to form power plants, or take the form of mobile floating power plants and can be installed in a few months or even weeks. These power plants are powered by coal or fuel oil and are leased at great expense from specialized companies.

Such power plants can be installed without any significant participation by national utilities. However, these solutions are particularly expensive: the electricity costs are two to three times higher than those of conventional power plants. These power plants tend to thrive in countries where the power sector's finances are in difficulties. Contrary to the original intentions, they often become established in the national electricity markets in the long term, either through renewed lease contracts,[27] or by being taken over by the public utilities.[28]

The British group, Aggreko, is reported to have more than 2 GW of generator capacity installed in Africa. The Turkish group, Karpowership, which specializes in floating power plants, may be involved in more than eight African countries with an estimated installed capacity of more than 850 MW on the continent.[29] It reportedly supplies a significant proportion of the electricity produced in many coastal countries, such as Ghana (26%), Mozambique (10%), Gambia and Sierra Leone (80%).[30]

In the medium term, small modular reactors (SMR) could play a role in replacing the fossil-fuel-fired emergency power plants, particularly floating ones to supply African urban areas. The operation of these barge-mounted plants, which would supply coastal cities, could remain under the control of the provider, and this would enable African countries, which do not have the capacity required to guarantee the operation, safety and security of land-based power plants,[31] to develop nuclear energy in their electricity mix. The Russian company, Rosatom, apparently has recently proposed to Nigeria one of its barge-mounted nuclear power plants to help the country overcome its electricity shortages, and a new generation of SMRs is in development in the United States.[32]

27. "Électricité : la Côte d'Ivoire prolonge de trois ans le contrat d'Aggreko à Vridi", *Jeune Afrique*, January 2015, available at: www.jeuneafrique.com.
28. O. Mbadi, "Électricité: comment Aggreko a eu raison du Cameroun", *Jeune Afrique*, June 2015, available at: www.jeuneafrique.com.
29. "Afrique du Sud: Karpowership se propose pour réduire le déficit énergétique", Agence Ecofin, February 2020, available at: www.agenceecofin.com.
30. J. Wagner, "Électricit é: les centrales flottantes du turc Karpowership changent la donne", *Jeune Afrique,* June 2019, available at: www.jeuneafrique.com.
31. C. Merlin, "Les petits réacteurs modulaires dans le monde: perspectives géopolitiques, technologiques, industrielles et énergétiques", *Études de l'Ifri*, Ifri, May 2019, available at: www.ifri.org.
32. *Ibid*.

In general, the greater the power sector's financial difficulties, the more likely investment is to be geared towards high-OPEX and low-CAPEX fossil fuel projects. By contrast, only a restructuring of the continent's power sector's finances will enable it to develop its vast high-CAPEX/low-OPEX renewable potential. The challenge of deploying renewables in sub-Saharan Africa is therefore not necessarily technical but financial.[33]

Multi-faceted energy use in sub-Saharan Africa and the deteriorating finances of the sector

Given the difficulties public utilities have in expanding their sector, consumers are tending to reappropriate access to electricity, even in areas covered by the grid. This is an underlying trend that will have an impact on the sector's finances and therefore on its development.

Consumer autonomy given failing grids

In light of the growing urban population and the sector's difficulties in expanding at the same rate, people and businesses increasingly have an incentive to use additional ways to generate electricity to meet their energy needs. Many decentralized technologies, originally designed for rural areas, have reached urban areas where consumers are using several means to tackle grid unreliability and optimize their electricity expenditure.[34] These investments in autonomous electricity generation capacity in areas covered by the grid is further facilitated by urban populations' higher purchasing power compared to rural areas.[35] In urban and periurban areas that are rapidly expanding due to the continent's extensive urbanization, these decentralized systems can be even more attractive in meeting user demand, as grid connection waiting times can be long[36] and the connection charges high.[37]

33. H. Le Picard, "Solar Power in Sub-Saharan Africa after COVID-19: Healing the Ills of the Sector", *Édito Énergie*, Ifri, May 2020, available at: www.ifri.org.

34. S. Jaglin, "Off-Grid Electricity in Sub-Saharan Africa: From Rural Experiments to Urban Hybridisations", HAL, 2019; A. Creti and M. Saliou Barry, "Pay-as-you-go Contacts for Electricity Access: Bridging the 'Last Mile' Gap?", 5th DIAL Conference on Development Economics, Université Paris-Dauphine, 2019.

35. E. Arik, "Le marché des groupes électrogènes dans les Suds", HAL, June 2019, available at: https://hal.archives-ouvertes.fr.

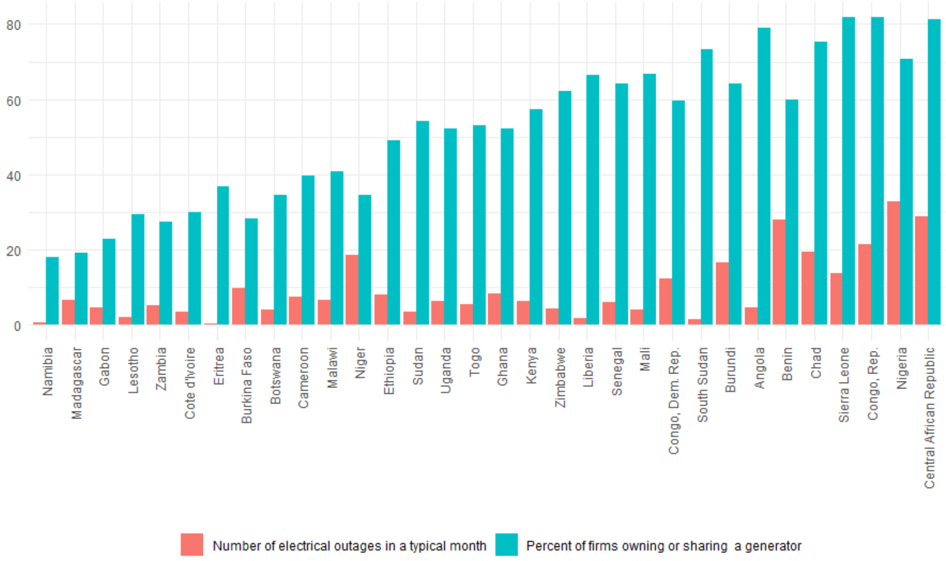
36. Up to more than 194 days in some countries. "Enterprise Survey Indicators Data", *op. cit.*

37. Fixed connection charges to the central grid can be more than $680, as in Botswana. See C. Trimble, M. Kojima *et al.*, "Financial Viability of Electricity Sectors in Sub-Saharan Africa: A Quasi-Fiscal Deficits and Hidden Costs", *op. cit.*

Auxiliary generators are the preferred means for dealing with grid failures. In sub-Saharan Africa, more than half of businesses have or share a generator: more than 80% in the Republic of Congo, Sierra Leone and the Central African Republic, and more than 70% in Chad, Angola and South Sudan. In Nigeria, the aggregate installed capacity of diesel generators is estimated to be around 10 to 15 GW,[38] or two to three times the available capacity of the central grid at around 6 GW for 2019.[39] In addition to the environmental and health problems that generators cause, they also incur substantial costs. The variable cost of self-generated electricity by diesel generators is estimated to be around three times higher than the costs of national grids.[40]

38. E. Arik, "Le marché des groupes électrogènes dans les Suds", HAL, June 2019.
39. "Quarterly Report. Fourth Quarter 2019", Nigerian Electricity Regulatory Commission, 2019, available at: https://nerc.gov.ng.
40. M. Oseni and M. Pollitt, "A Firm-Level Analysis of Outage Loss Differentials and Self-Generation: Evidence from African Business Enterprises", *op. cit.;* J. Steinbuks and V. Foster, "When Do Firms Generate? Evidence on In-House Electricity Supply in Africa", *Energy Economics*, May 2010, available at: www.sciencedirect.com.

Distribution of generators among companies and number of monthly power outages (2009-2016)



Source: "World Development Indicators", World Bank.

An expanding market for solar energy

The market of decentralized systems is growing in the region. Medium and large hybrid generators elicit strong interest among electricity-intensive companies. These solutions combine a diesel generator, solar panels and a storage system, and range from small installations to actual mini-power plants of up to more than 2 MW. These hybrid generators solve the problem of intermittent solar energy, while reducing fuel dependence. This market is currently eliciting strong interest in Africa, particularly with manufacturers that want to protect themselves from grid unreliability, but also with telecommunications companies that need a continuous power supply for their telecommunication towers.

Unlike auxiliary generators, solar home systems have almost zero operating expenditure (OPEX). Owing to the development of new business models, such as pay-as-you-go, the market has grown rapidly in sub-Saharan Africa. This market is now becoming increasingly mature. The main challenge for businesses now is to move from a start-up mindset to that of real formalized companies.

While nearly 3 million solar home systems were sold during the second half of 2019,[41] the empowerment of grid-connected consumers in

41."Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data", *Public Report*, GOGLA, December 2019, available at: www.gogla.org.

urban and periurban areas is opening up a new market. Besides the 600 million sub-Saharan customers without access to electricity, a further 700 million customers must now be added in urban areas who have access to electricity, but who are dealing with unreliable networks. Solar home systems could therefore partly replace small diesel generators. Nevertheless, although the solar home systems provide "comfort" electricity, their potential is very limited for business uses and means that this market is first and foremost aimed at residential customers.

These trends are not without consequences for the centralized power sector. This increasing autonomy for consumers when faced with a failing grid is likely to further complicate electricity utilities' financial situations by increasing arrears.

Given the current difficulties centralized grids face in sub-Saharan Africa, smart grid technologies will play a key role in the future.

The Future for Grid 2.0 in Africa

The myths and reality of smart grids in Africa

Smart grids have emerged from the rapid development of information and communication technology (ICT) that affects all areas in the power sector value chain.

These grids aim to achieve several objectives, both economic and environmental, in order to fulfill a need: better management of power grid assets amid increasingly complex interactions between various stakeholders in the sector. They aim to improve grid management, but also to increase resilience to severe weather, aging of assets and physical or cyber attacks.

Consequently, there is no universal definition of a smart grid: it is mainly an assembly of several technologies. Therefore, the transformation of conventional power grids into smart grids will not follow a single model, but will differ between countries around the world according to their respective objectives.

In sub-Saharan Africa, smart grid development strategies should not be based on those from other parts of the world. They should rather seek to determine to what extent these new technologies could fulfill the short-term needs of sub-Saharan grids while facilitating their gradual transition to smart grids.

Given the problems specific to the sub-Saharan power sector described above, a first step is to use these new technologies to improve revenue collection and grid reliability and resilience.

Smart meters: a key element of grid 2.0

Smart meters (SMs) are the key element of smart grids, and should facilitate radical changes in how we consume electricity. The SM market started to develop in the early 2000s and is now booming.

The many advantages of smart meters

The SMs deliver multiple benefits for the entire sector and can be used to improve and develop new services. In sub-Saharan Africa, these meters would increase revenue collection.

Post-payment billing is complicated to manage because the bank penetration levels are very low, whereas new mobile payment business models in the energy sector have demonstrated their effectiveness, particularly in the solar home system market. Mobile telephony has spread considerably on the continent. Its new services, such as mobile money, should facilitate payments by consumers and revenue collection for distribution companies.

In Côte d'Ivoire, the Ivory Coast Electricity Company (CIE) was able to increase collection significantly through SMs by diversifying payment methods in some areas. Consumers can select the method that suits them: payment via cell phones, Internet, payment points or even hand-held terminals. This also enables distribution companies to make savings by automating statements. In Kenya, smart meters enable large companies to benefit from preferential tariffs if they operate during off-peak hours.[42] Since September 2020, the national company, Kenya Power (KPLC), has introduced a new service that allows users to access their monthly bill directly from their cell phone via a USSD code. This new system also allows prepaid users to purchase tokens for their electricity consumption.[43]

For the consumer, the SMs enable energy saving through continuous information about their electricity use and expenditure. A consumer can monitor their electricity use and the related costs in real time, being informed of both of these at all times. The same principle applies to prepaid meters.[44] Studies on the use of prepaid meters have shown that they can double a household's energy savings.[45] Information provided by the meter also helps prevent users from being overcharged by electricity distribution companies that use estimated billing.

42. "Specialised Smart Meters for Discounted Tariffs Improve Business Prospects in Kenya", *ESI Africa*, July 2018, available at: www.esi-africa.com.
43. "Kenya Power Introduces USSD Platform for Customers to Manage Bills", *ESI Africa*, September 2020, available at: www.esi-africa.com.
44. M. Oseni, "Assessing the Consumers' Willingness to Adopt a Prepayment Metering System in Nigeria", *Energy Policy*, November 2015, available at: www.sciencedirect.com.
45. A. Faruqui, S. Sergici and A. Sharif, "The Impact of Informational Feedback on Energy Consumption – A Survey of the Experimental Evidence", *Energy*, April 2010.

The importance of standards in developing a continent-wide competitive market

Although the installation of smart meters provides benefits to both consumers and electricity distribution companies, in practice the deployment of these technologies faces various hurdles. The price of a meter is high, even though the market potential is rapidly expanding internationally and indicates that costs are likely to fall, particularly with the availability of Chinese meters. Yet, the cost of SMs is only the tip of the iceberg: the deployment of smart meters requires significant investment in telecommunications infrastructure.

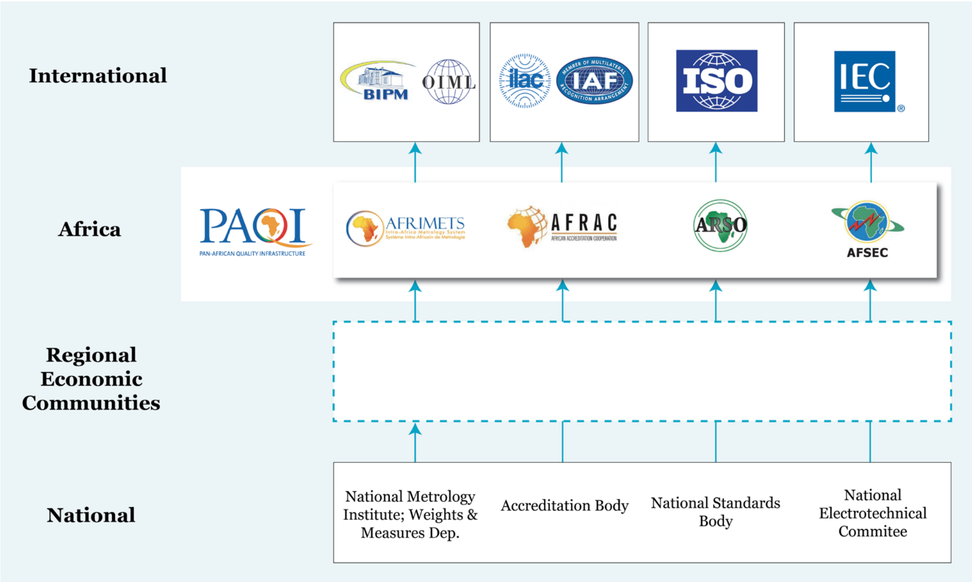
With this in mind, the lack of standards in the region is a major barrier. The imported smart metering systems are often incompatible with local telecommunications systems, which increases integration costs. For the market to expand in Africa, specific standards need to be implemented at continental level to establish a competitive environment that allows for economies of scale and therefore lower costs. This needs to be done while ensuring their compatibility with regional telecommunications infrastructure systems, which is not always the case. In East Africa, for example, an electricity utility implemented a deployment strategy for SMs using a different technology to the one specified in a call for tender to install SMs in the same region.[46] The African Electrotechnical Standardization Commission (AFSEC), which was established in 2008, recently published a guide on the application of standards for smart metering systems in Africa, with a view to continent-wide harmonization.[47]

A number of standards and best practices exist in other parts of the world, particularly in Europe, where Italy and Sweden have implemented ambitious programs to deploy second-generation meters. This knowledge of standards can be put to good use, even though it needs to be subsequently adapted to address sub-Saharan Africa's specific requirements. In this case, the standards need to be "tropicalized" to take into account the particular climate of African countries. In Mozambique, regional distribution companies deployed "two-part" meters to combat meter tampering in households. One part of the meter was placed in the home and the other, which collected information relating to the consumer's electricity consumption and sent it to the distribution company, was located outside, so that it was inaccessible to the user. However, these outside units proved to be unsuitable for local environmental conditions.

46. S. Papi, "One Guide to Rule All your Smart Metering Projects", *ESI Africa*, May 2019, available at: www.esi-africa.com.
47. "Guide for Application of Standards for Smart Metering Systems in Africa", AFSEC, 2018, available at: www.afsec-africa.org.

Owing to adverse weather conditions – rain and heat waves – the outside units had a high failure rate. Their replacement has incurred many additional costs at the operator's expense.

Integration of African agencies in the International Quality Infrastructure Network



Source: S. Papi, "Standardization as an Enabler for Accelerating the Adoption of Smart Metering Technology in Africa", Ifri's webinar series on the digital transformation of Sub-Saharan Electricity Networks, June 2020.

Practical difficulties installing meters

Other structural barriers may prevent the large-scale deployment of SMs. They have relatively long lifetimes of around 10–15 years, during which they must be profitable.[48] However, given high installation costs, electricity distribution companies are only interested in investing in their deployment for the wealthiest sectors of the population, for whom the cost-benefit ratio is highest. In the case of Zimbabwe, the national utility (ZESA) invested nearly $200 million in 2017 to install SMs for its most important consumers, as they represented approximately 60% of its revenue.[49] In poorer districts, distribution companies are encouraged to install less efficient technologies, such as prepaid meters, in order simply to increase the revenue collection.

48. S. Papi, "One Guide to Rule All Your Smart Metering Projects", *op. cit.*
49. "Zimbabwe: Power Utility to Invest in Smart Meters", *ESI Africa*, April 2017, available at: www.esi-africa.com.

The predominance of multi-family housing[50] in some African countries is another barrier to fitting second-generation meters. On average, 53% of households in sub-Saharan Africa are in informal settlements and around 13% in multi-family housing;[51] although these ratios vary significantly between the different countries. In Nigeria, 59% of households lived in multi-family housing in 2010.[52] The predominance of multi-family housing in some countries may pose a problem, as energy savings made possible by meters is only achievable if each household agrees to limit its electricity consumption. Yet each household has little incentive to make energy savings, because it knows that the related benefits or costs are shared by the community anyway.[53] Therefore, there is little incentive to adopt these technologies.

Towards automated grid management

To improve grid management and the reliability of the electricity supplies, control systems can be used on grid infrastructure to monitor closely system health indicators. For instance, when integrated with automatic management systems, a smart grid can detect and locate power outages and resolve some of them quickly and remotely. The cost of sending out a technician, which is expensive in terms of time and money, is saved. Smart grid sensors can also help reduce electricity theft through illegal connections by using alarm systems. In the longer term, these systems should also help optimize maintenance policy. They can be used to monitor changes in grid assets and their resilience, by checking transformer performance and the corrosion of high-voltage cables. This allows for a better understanding of how these assets react in response to local natural hazards, such as heatwaves or rainfall, which are particularly intense in Africa, and so helps optimize maintenance policy.

Batteries have many benefits and can be used throughout the power sector value chain to improve the quality of supply. Batteries are equipped with extensive digital monitoring capabilities and can perform tasks automatically and more efficiently than conventional solutions. Large-scale storage can improve the quality of grid electricity by automatically regulating the frequency, but also by storing generation by renewables during low-demand periods. Service contract models for deploying backup

50. Accommodation in which several families reside.

51. A. Kallergis *et al.*, "Housing Affordability in a Global Perspective", *Working Paper* WP18AK1, Lincoln Institute of Land Policy, November 2018.

52. M. Oseni, "Assessing the Consumers' Willingness to Adopt a Prepayment Metering System in Nigeria", *op. cit.*

53. *Ibid.*

batteries could be implemented, but almost no sub-Saharan country has so far introduced regulations to generate revenue from these services. Some major storage projects are, however, being developed in sub-Saharan Africa. South Africa issued a call for tenders last August to develop an 80 MW (minimum) centralized storage system,[54] which is a major step in achieving its objective of 1.4 GW storage by 2021.[55] Similarly, Senegal is looking to develop its first centralized storage project, located at the Taïba Ndiaye wind farm.[56]

Possible uses of electricity storage systems in sub-Saharan Africa

	Before meter (F.O.T.M)	After meter (B.T.M)
Grid level	• Integration of renewable energy sources • Load shift • Grid support • Frequency regulation • T&D service • Storage	
Commercial and industrial level		• Self-consumption of solar-generated electricity • Reduced fossil fuel consumption • *Back-up* • Smoothing • Energy price arbitration • Improved energy quality
Residential level		• Self-consumption of solar-generated electricity • Mini-grid (Off-grid) • Reduced fossil fuel consumption • Back-up

Source: A. Mburu, "EnerStore Africa", Ifri's webinar series on the digital transformation of Sub-Saharan Electricity Networks, June 2020.

Finally, the digitization of centralized grids is not the only way to develop a more resilient power sector. New innovative solutions are being developed, such as connected mini-grids. These systems make it possible to isolate mini-grids and make them autonomous during power outages or voltage drops in the central grid. This type of project is a good way to

54. A. Colthorpe, "South Africa's Eskom Opens Tender for 80 MW/320 MWh Battery Storage", *Energy Storage*, August 2020, available at : www.energy-storage.news.
55. A. Colthorpe, "South Africa Makes Huge Distributed Energy Storage Commitment", *Energy Storage*, October 2018, available at: www.energy-storage.news.
56. "Senegal Explore Grid-Scale Battery System Thanks to USTDA", *ESI Africa*, October 2020, available at: www.esi-africa.com.

promote the development of economic activity and reduce losses related to a central grid's unreliability, while benefiting from lower grid tariffs when central grids are in operation.

Conclusion

Economic development, and more specifically the development of industry, which is a major source of job creation, are today necessary for Africa to absorb its population growth and rapid urbanization. This will only be possible via access to reliable, low-carbon and affordable electricity on the continent.

However, despite support from many international initiatives, sub-Saharan Africa still lags far behind other continents, in terms of access to electricity, installed capacity and grids.

Even once connected to grids, there are many barriers that restrict electricity consumption. Unreliable services, which cause many power outages, have led companies to become autonomous from main grids by investing in costly and polluting additional means of electricity generation, which affect their competitiveness and curtail economic development.

Public utilities are caught in a vicious circle: their poor financial situation limits investment in expanding the sector and in maintaining existing infrastructure, which in turn reduces service quality and increases their costs. Companies are turning away from grids, payment arrears are increasing and financial difficulties are becoming more pronounced. As a result, the electricity sector invests in short-term, low-CAPEX/high-OPEX and extremely expensive power plants at the expense of renewable energies. This further aggravates the sector's financial difficulties.

After several decades of reforms, the position of the sub-Saharan power sector has scarcely changed. Digital technologies have a crucial role to play in escaping from this vicious circle, improving the financial viability of companies and stimulating investment in renewable energy. In doing so, the lack of grid infrastructures could be an advantage: investments could be made directly in these new technologies, which would enable sub-Saharan Africa to make a technological leap from obsolete to smart grids.

However, the approach to using these technologies cannot be the same as in industrialized countries. The new technologies must primarily be used to address the specific problems of sub-Saharan grids, namely: reducing arrears and electricity theft, automating grid management to improve service quality, increasing grid resilience to adverse weather, and improving asset maintenance in the sector.

With the new opportunities offered by these technological breakthroughs and their adaptation to local settings, assistance for public utilities with increased requirements to prevent poor governance, could give the expansion of the power sector in sub-Saharan Africa a new lease of life. The consolidation of centralized grids is a key issue in enabling the large-scale deployment of renewable energy on the continent and ensuring long-lasting economic and social development for Africa.

In its strategy to support the development of the sub-Saharan African centralized power sector, the new European Commission should make it a priority to review its policy in detail. An accurate evaluation should be made of the shortcomings of previous strategies, particularly with regard to the action of DFIs and cooperation with local public utilities and the private sector. Indeed, initiatives to assist the expansion of the power sector in sub-Saharan Africa have multiplied during the last decade, yet their overwhelming number is a source of confusion and inefficiency. In some cases, the initiatives are in direct competition with the private sector, such as in the generation sector. Therefore, European public investments mainly need to be focused on segments in which it is more difficult for the private sector to invest, particularly in centralized grid infrastructures that remain the backbone of the continent's power sector.