FROST & SULLIVAN

Digitization of Energy Transmission & Distribution in Africa

The Future of Smart Energy in Sub-Saharan Countries

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INTRODUCTION

The global energy ecosystem is in the middle of a significant change. The industry is moving away from conventional large-scale infrastructure with a heavy reliance on fossil fuel-based generation, to focus on clean sustainable energy and embracing the power of digital – or smart – technology.

With the digital transformation of the energy sector rapidly gaining traction on a global scale, new opportunities are emerging to help deliver efficient, affordable and reliable electricity to consumers. And key to this transformation is the deployment of innovative technologies and new business models to facilitate change.

Over the last decade, we've seen the emergence of smart grids as a flagship application for digital technology in energy. Trends such as renewable energy integration, automated metering, grid decentralisation and growth in distributed generation have driven this need for smarter solutions and we anticipate a huge acceleration in the years to come.

Meanwhile, Africa faces a very unique set of challenges as it looks to embrace the new future of energy. The continent has the lowest electrification rates in the world, a strong reliance on fossil fuel power, rapid industrial growth, and in many instances relies on aging and inefficient systems.

In this Whitepaper we'll be exploring the opportunities and challenges faced in Africa – and in particular in Sub-Saharan Africa (SSA) – as the new future emerges. In particular we'll look at the exciting role of smart technology to transform our grids as we begin to see continuous change in the way energy is generated, distributed, traded, managed and stored.

The future of transmission and distribution (T&D) in Africa will be defined by the convergence of energy infrastructure with digital technology to drive efficiency and deliver a fundamental change in the relationship between consumer and supplier.

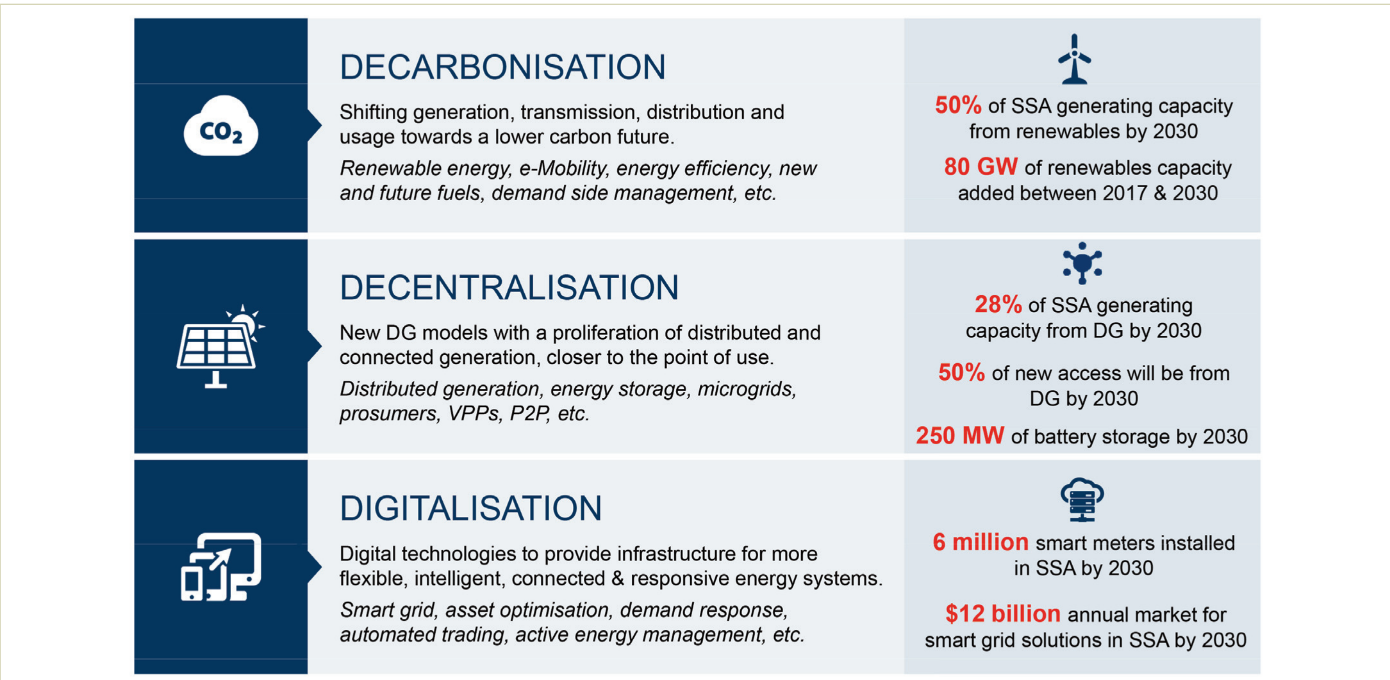
THE FUTURE OF ENERGY IN AFRICA

The 3 global headline trends in the energy industry today (the 3 Ds – Decarbonisation, Decentralisation and Digitalisation) are driving a full scale disruption and transformation of the sector, meaning there are both challenges and opportunities ahead for companies playing in this space.

Decarbonisation is driving growth in renewable energy and energy efficiency; Decentralisation is driving innovative new business models such as virtual power plants (VPPs), demand response, distributed generation, digital sub-stations and microgrids; and Digitalisation is increasing customers' control over their energy usage to save money and raise energy efficiency.

The 3Ds Transforming the Future of Energy

"Energy will be cleaner, more accessible, intelligent, connected and responsive"



Source: Frost & Sullivan

Africa, however, is still grappling with its energy "trilemma" of finding a way to produce affordable, reliable and sustainable energy for its entire population.

SSA has more people living without electricity than any other region in the world. With an electrification rate of only 43%, according to the International Energy Agency (IEA), there are 590 million people living with no access to electricity. And the vast majority of those live in rural regions where many people rely on solid biomass in the form of fuelwood and charcoal for cooking.

Businesses across Africa have to deal with frequent power cuts which cause significant loss of revenues. The World Bank reckons that if they had continuous energy supplies, sub-Saharan Africa's economies could be growing by two percentage points a year faster, on average, than they do now.

Transmission and distribution networks are seen to be the weakest links in the SSA power systems and hence represent a huge opportunity area for improvement. Meanwhile, more than 600,000 Africans – many of which are children – die each year from air pollution caused by cooking with wood and charcoal. This calls for cleaner sources of accessible energy to meet the needs of rural households, at an affordable cost.

Those who do have access to electricity do not have access to a reliable power supply and frequent power outages are part of people's daily lives. This can be attributed to the insufficient and aged power infrastructure, causing as many as 32.7 power outages in one country per month. According to the World Bank, the resulting loss incurred from these power outages can be as much as 10% of annual sales. Wood, domestic kerosene and diesel generated power are used widely across SSA to cope with regular loss of power, resulting in high monetary and environmental costs.

In order to reach the consumer, generated power has to pass through complex networks involving transformers, overhead cables and large equipment. A percentage of power is inevitably lost during this process; this percentage grows when the transmission infrastructure is faulty, aged or has not been set up correctly.

SSA experiences significantly higher transmission losses than many other regions. The losses vary per country with total average of 20% with some countries as high as 50%, compared with the accepted averages of 7% - 10% in much of the rest of the world. Not only is SSA facing the challenge of meeting electricity demand, it also has to deal with a percentage of its electricity being lost during transmission and distribution, creating further challenges.

Going forward, SSA needs to go beyond maintaining and repairing aged infrastructure; in order to truly advance the power sector, significant changes need to be made. To do this, a holistic approach needs to be adopted; one that ensures sustainability, reliability and longevity of power supply.

Today's total installed generating capacity in SSA is 122 GW, almost three quarters of which is fossil fuel-based with hydro power contributing 22% to the energy mix. Many of the coal-fired power plants are reaching maturity and water is becoming an increasingly scarce resource as climate change takes its toll; this poses a serious threat to the security of power supply. It is clear that SSA needs to build on the 1% contribution of modern renewable energy, as well as add new generation sources to the energy mix.

As a result, we are seeing a shift in the balance of generation. The decreasing cost of renewable energy technology makes it an attractive alternative and wind power and solar PV are rapidly gaining popularity across the region. There are also signs of slow decrease of fossil fuel-based generation. SSA's power systems of the future will need to be more adaptable to change with the ability to accommodate new sources of generation. Frost & Sullivan's projections show that 80 GW of renewable energy capacity will be added between now and 2030, meaning that almost 50% of the region's electricity will be generated from renewables.

The need to support industrial growth and urbanization, as well as rural electrification, will also drive the move towards distributed energy systems, including smart solutions such as microgrids, virtual power plants, digital sub-stations and energy storage. For the industry as a whole, there will be a huge future opportunity to meet Africa's challenges by integrating renewable energy, especially distributed generation, and digital technology to deliver the connected and flexible solutions of tomorrow.

TRANSMISSION AND DISTRIBUTION INFRASTRUCTURE - ADDRESSING THE WEAKEST LINK

The IEA states that as a region, SSA aims to achieve 100% access to electricity by 2030. Until recently, it would have taken many decades and heavy investment into large scale transmission and distribution infrastructure for this to be in any way achievable. Poor maintenance of existing infrastructure is one of the biggest issues in the region and is one of the main causes for high levels of power supply instability. Even though there has been a significant increase in generation capacity in the last 10 years, the delivery of electricity is still a point of weakness due to the malfunctioning of aged transmission and distribution infrastructure.

This is where digital technology and smart grid solutions have a huge role to play in accelerating change. We've moved into the era of dynamic multi-directional energy flow with the capability to create autonomous, flexible grids. Networks of connected sensors and controllers interact with grid infrastructure to deliver monitoring tools alongside optimisation software and grid automation solutions. Self-healing grids are becoming a reality as real-time distribution data is used to detect and isolate faults and to reconfigure networks to minimize customer impact and downtime.

But simply expanding and modifying centralized grids won't provide immediate benefits to SSA's entire population. Approximately 80% of those without electricity reside in rural areas that are often isolated from the bigger cities and towns, making it difficult to provide power through national grids as transmission expansion projects can often take up to 4 or 5 years to realize.

According to the IEA, the average rural electrification rate of SSA is the lowest in the world, currently standing below 25%. This has motivated governments to put significant efforts into rural electrification projects in numerous countries such as the Rural Electrification Program (REP) in Kenya, the Nigerian Rural Electrification Agency (NREA) in Nigeria and the Rural Electrification Agency (REA) in Tanzania.

Given the technological advancements in the energy space, however, the time it takes and the level of infrastructure needed to increase rural electrification will significantly reduce. Emerging, scalable sources of renewable energy-based generation, such as solar and wind power, will change the face of energy in rural SSA and enable the development clean energy across the region.

When combined with new solutions such as grid automation software, microgrids and energy storage this is where more rapid change and powerful positive outcomes can be achieved. At the interface between user and grid, data analytics and dynamic communication will move beyond automated metering to deliver better customer engagement, demand response solutions and remote maintenance, management and control.

THE FUTURE OF ELECTRICITY GRIDS

Conventional grids are typically characterized by partial control, poor technology integration and optimization, reactive maintenance, and fragility of systems. But the grids of the future will include solutions of varying capacities spread across multiple locations to deliver flexibility, reliability, control, actionable data insights, remote diagnostics, predictive maintenance and ultimately self-healing capabilities.

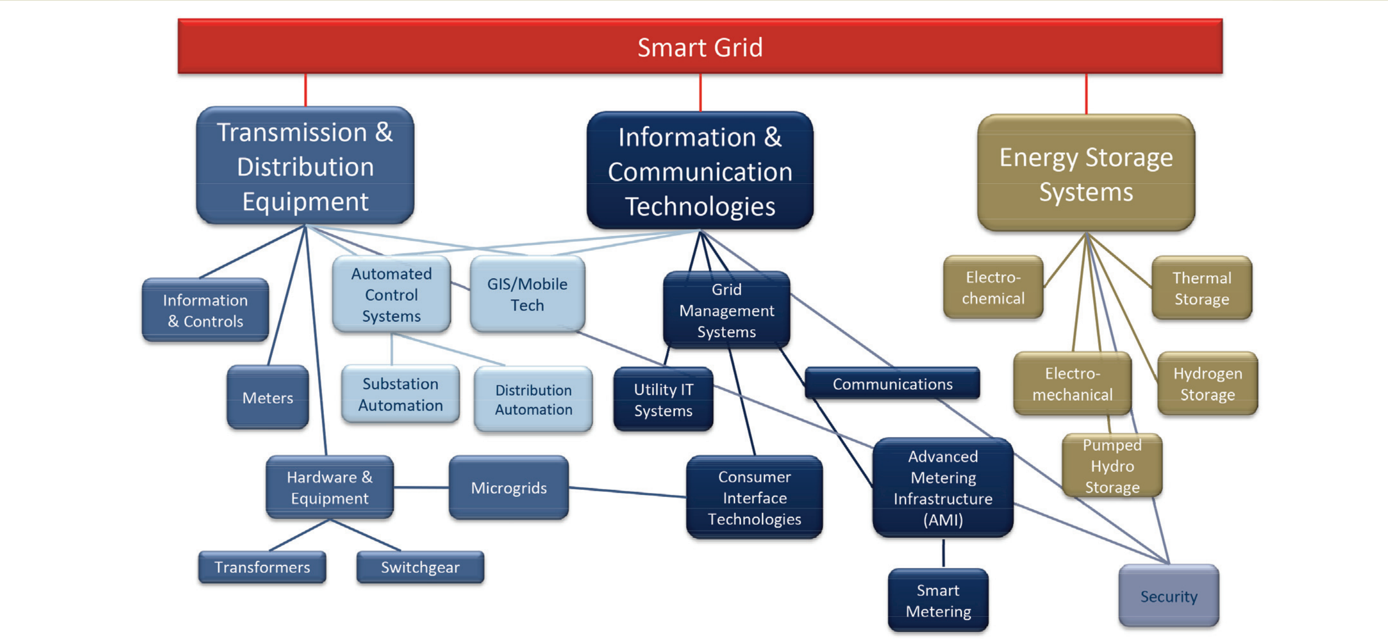
We'll increasingly see changing business models with incumbent generation becoming less important and decentralised generation gaining traction. This is especially relevant in Africa, where 80% of those with no access to electricity live in rural areas, often very far from the nearest national grid connection.

In SSA – just as in many regions globally that struggle with similar issues – there are challenges with ageing infrastructure, growth in electricity demand and challenges of integrating an increasingly diverse mix of energy sources. Legacy grids and conventional technologies will tend to hinder the efficiency that can be achieved in the following ways:

- Limited input/outputs which limit access to data to support decision making;
- Limited real-time visibility over the network;
- Limited control over the network;
- Vulnerability to inaccuracies;
- Integration of new energy sources or new equipment causes downtime due to the complex hardwiring required to ensure compatibility;
- Single flow of electricity so generation surpluses are not effectively leveraged;
- High cost of repairing or replacing large aged equipment required in an analogue system;
- Loss of revenues resulting from inaccuracies in meter readings

The digital transformation of grids allows users to take a holistic approach to achieve efficiency, flexibility, transparency and long-term sustainability. By utilizing internet of things (IoT) technology, the smarter grids of tomorrow will deliver all-encompassing solutions based on the convergence of operating technology (OT) with information technology (IT) and incorporating emerging concepts such as distributed generation and energy storage.

The Converging Elements of Smart Grids



Source: Frost & Sullivan

There are three main pillars of a smart grid under which all the technologies fall; these are transmission and distribution (T&D) equipment, information and communication technologies (ICT) and energy storage systems. Smart grids boast improved energy delivery through many characteristics.

Benefits and Opportunities from Smart Grid Solutions

Benefit	Opportunity
Increased grid flexibility	Smart grids provide multiple opportunities for automation at any point of the value chain.
Demand response and demand side management	Through two-way digital communication and control capabilities, operators are able to manage electricity flow to and from the consumer by switching off unnecessary appliances.
Increased interoperability	All equipment complies with International Electricity Commission (IEC) standards code 61850, ensuring that all equipment will be easily integrated into the system with no downtime required.
Facilitate integration of diverse generating assets	With increased interoperability, integration of all power generation types, including renewable energy sources and distributed generation, is made easier.
Preventative maintenance	Through the use of smart sensors, all components of the grid are monitored and faults are simple to identify and locate, allowing them to be repaired or replaced before the rest of the grid is compromised.
Cyber security	Improved resilience to cyber attacks on the grid.

Source: Frost & Sullivan

Smart grids not only create the potential to combat SSA's power sector challenges, they also provide the opportunity for the region to develop its renewable energy capabilities and, therefore its long-term sustainability.

INFORMATION COMMUNICATION TECHNOLOGY INTEGRATION

Before the arrival of smart grids, power flowed in a single direction from a limited number of generation plants to the substations. There was no need for dynamic grid management as it was run on predictive grid performance profiles that were compiled over many years.

With the bi-directional power flow enabled by smart grids, and the incorporation of decentralised sources of energy into the grid at any point, we cannot rely solely on predictive grid performance profiles and require real-time grid performance data to be communicated efficiently. ICT is therefore considered to be the backbone of the smart grid since communication through telecommunications is the element that makes the grid 'smart' by replacing the conventional analogue system with a digital system. What makes it digital is that there is no copper wire running from the outdoor equipment into the indoor controllers and it is all run on pure optic fiber as the major telecommunication for the substation local area network.

Almost all smart grid strategies are founded upon the availability of telecommunications network capabilities as it plays a crucial role in both the management of the grid and the transmission and distribution of power throughout the grid. The goal of telecommunication infrastructure in a smart grid is to support real-time or deferred bi-directional data transmission. This enables stakeholders to efficiently manage the grid through increased speed and volume of data output, providing utilities the opportunity to maximise cost reductions, increase power reliability and increase customer satisfaction, all of which are critical in SSA.

WIDE AREA MONITORING AND CONTROL

The real-time monitoring and visibility of power systems over all sections of the grid allows operators to observe the performance of grid components. Since upgrading its transmission system, Malawian utility, Escom, has experienced improved efficiency and reliability of the transmission network, while reducing transmission losses. This enables one to check the health of equipment and allows for major cost-saving benefits associated with predictive maintenance and self-diagnosis. If there is a fault, the fault area can be isolated so that the entire grid is not compromised, reducing the extent of possible power outages.

Case Study: GE Supporting Malawi to Strengthen its Grid

Improving the stability of the ESCOM's grid will pave the way toward increased economic growth for Malawi.

CHALLENGES

Malawi faces serious challenges of frequent power outages and low electrification rates with only 10% of Malawians connected to the grid. Power outages are due to two reasons: aged and faulty transmission infrastructure and a generation deficit caused by low dam levels reducing the amount of electricity generated from hydro power plants. Additionally, 98% of power produced in Malawi is generated in the Southern part of the country, resulting in long distance delivery and increased possibility for transmission losses.

As such, ESCOM's goal is to improve Customer Service and Service delivery, improve the electricity access rate, and improve communication and networking with stakeholders.

SOLUTION

With funding from the Millennium Challenge Corporation (MCC) through Millennium Challenge Account - Malawi (MCA-Malawi), ESCOM is improving its transmission network by installing GE's latest Energy Management System (EMS) e-terra platform solution and Remote Terminal Units and telecommunication upgrades across 15 substations that have modernised the grid, allowing for real-time remote monitoring, planning and optimization of ESCOM's transmission systems nationwide. The smart software used in EMS facilitates the integration of different sources of power, preparing ESCOMs grid for new sources of power, gearing the country up for the increase from 6% to 22% renewable energy share target it has set for 2030. Remote terminal units have been installed in existing and new substations. This enables efficient delivery of much needed electricity to Malawians country-wide with reduced transmission losses.

The existing telecommunications system has been upgraded by GE in order to decrease the system downtime that has previously prevented customers from purchasing prepaid electricity. GE has provided training the implemented solutions to ESCOM employees in order to grow technical know-how and to ensure operational ease.

Malawi plans to connect its grid to three neighbouring countries: Zambia, Mozambique and Tanzania. Having a modern grid will facilitate smooth grid interconnections and efficient power supply over long distances.

The main system analytics involved in monitoring and control include wide area situational awareness (WASA), wide-area monitoring systems (WAMS), and wide-area adaptive protection, control and automation (WAAPCA). The data retrieved can be analysed to make accurate predictions through data analytics, of which the value is three-fold: to aid the decision-making process, to mitigate and disturbances to the grid and to promote reliable power supply.

RENEWABLE AND DISTRIBUTED GENERATION

Smart grids use a combination of sensors, remote terminals and computer software to control and account for the variability that is inherent in power generation from renewable energy sources used in distributed generation, such as solar and wind energy. Smart grid automation and control ensures electricity supply and demand is balanced, avoiding system-wide failures.

With renewable energy capacity in Africa set to increase from 35GW in 2018 to 115 GW by 2030, according to AREI, this role of smart technology will be critical in SSA to ensure a smooth transition.

ENERGY STORAGE SYSTEMS

Energy storage systems can help mitigate the impact of variability from renewable and distributed generation. Battery storage can be used to take the surplus power generated from renewable sources, as well as provide power when there is a deficit in power generation.

For example, South African utility Eskom is undergoing a large-scale energy storage pilot project in order to increase the capacity of its national grid, eliminating the use of diesel fuel for peaking power and backup power generation.

Energy storage systems can also make it possible for renewable energy to be used as baseload power, despite its inconsistency. Kenya is in the planning phase to build large-scale solar storage batteries to fully integrate its solar systems to the national grid.

DISTRIBUTION GRID MANAGEMENT

Intelligent Electronic Devices (IEDs) are sensors used in substations that can reduce the durations and geographic spread of power outages. Smart IEDs are used for predictive maintenance through performance-based management in which they check each, ensuring healthy functionality. If an IED is not in good health the system generates a warning.

Case Study: Why ZESCO Went Digital with GE Grid Solutions

ZESCO's vision is to be the hub of electricity trading in the region by 2025. Digitizing it's electricity grid is key to achieving this vision.

ZESCO Limited, the Zambian state-owned utility is responsible for the generation, transmission, distribution and supply of electricity to the country. Maintaining reliable power supply and reducing outages are critical priorities for the utility in order to enable growth in the mining and manufacturing sectors – backbones of the Zambian economy.

In an effort to stabilise the power supply, ZESCO contracted GE France to upgrade it's Muzuma substation to a digital substation with 330KV transmission lines in preparation for the MCL power generation plant that was in progress. The resulting solution is the first digital sub-station in Africa addressing many of the challenges that ZESCO faced previously:

The increasing cost of maintenance and repair of conventional equipment

Due to the aged infrastructure, the equipment was experiencing high failure rates and often needed to be repaired or replaced. Manufacturers no longer produced those product lines making spares difficult to find and very expensive.

Lack on hardware interoperability

A major challenge with conventional power systems is that equipment does not comply to an international standards set by the IEC, causing difficulty where equipment interaction is required and new equipment is introduced. Interoperability is especially important for cross-border interconnections with the rest of the SADC region.

- **Limited availability of information**

  Limited Input/Output channels are available in conventional systems, limiting the amount of information that is available related to voltage, currents, active and reactive power, and frequency measurements. Inaccuracy is also an issue.

- **Limited Grid visibility**

  Conventional systems limit the visibility of certain areas of the grid, making it impossible to know if there is any maintenance needed or disruption of power supply.

How has ZESCO benefited from going digital?

1. Reduced extent and duration of power outages
2. Improved interoperability
3. Reduced maintenance required
4. Cost savings
5. Increased revenue due to billing accuracy

This ensures that maintenance and repair are performed rapidly to reduce downtime and further system damage. Smart IEDs aid in locating and isolating faults to protect the rest of the grid from power disruption, automatic reconfiguration of feeders, and automation for distributed generation. Smart grid IEDs have provided Zambian utility, ZESCO, full grid visibility that was not possible with the traditional grid. This has helped reduce the extent and duration of power outages in the country.

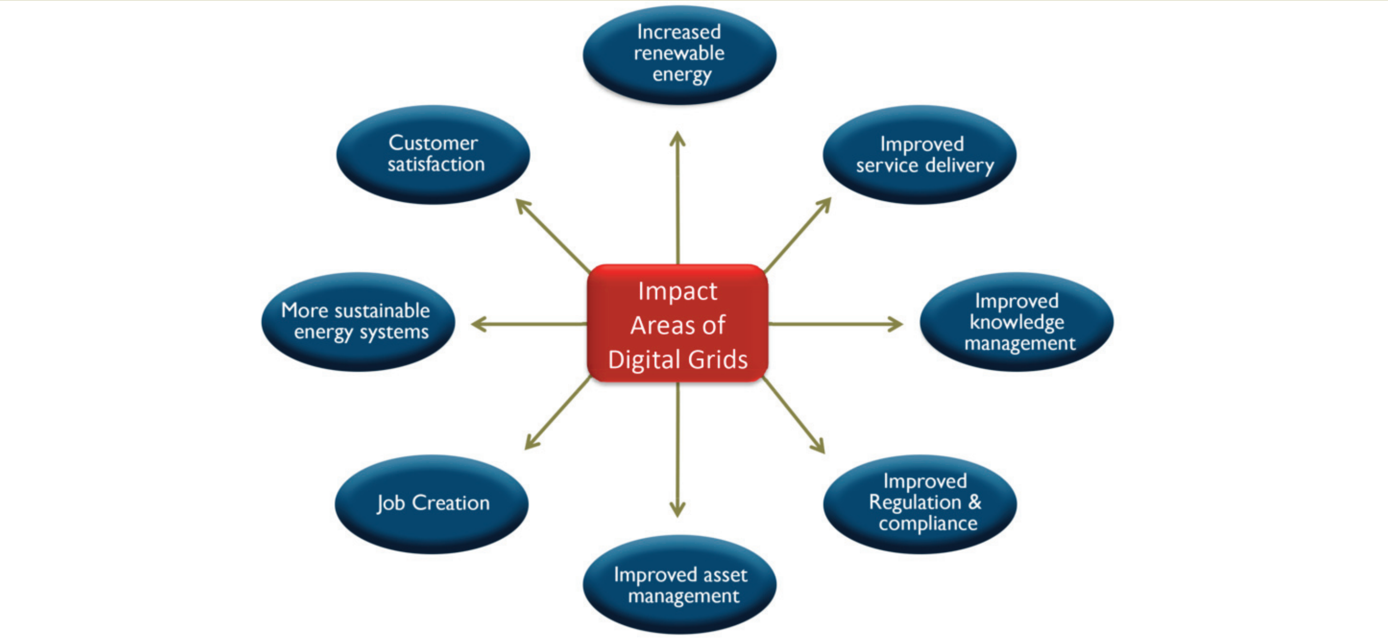
ADVANCE METERING INFRASTRUCTURE

Advanced metering infrastructure (AMI) – based on smart meters – encompasses an array of technologies that enable two-way flow of information on the amount of electricity consumed by an end-user, the time of consumption, the price of power at that time, enables the collection, storage and reporting of consumer data for any specified time frame.

AMI also provides the ability to identify the location and geographical spread of power outages through meter consumption data and signals that meters emit when power supply is cut and restored. Additionally, AMI can perform remote connection and disconnection, losses and theft detection and revenue management for energy retailers through effective cash collection and debt management.

Smart meters are among the fundamental building blocks of the smart grid and digital energy network. Although penetration is still low in SSA compared to many other regions, growth is rapid and the installed base will increase from around 550,000 meters in 2018 to over 5 million by 2030.

Key Impact Areas of Digital Grids



Source: Frost & Sullivan

GROWING POPULATIONS

SSA is experiencing rapid population growth, putting strain on its existing transmission infrastructure, as well as exacerbating the need to expand existing infrastructure into rural areas where 80% of those without access to power reside. Currently, decentralised and off-grid generation is the only viable way to access power in most rural areas. Microgrids, solar home systems and energy storage will all play a dramatic role in ensuring these rural communities have safe, reliable and clean energy for the basics, such as cooking, lighting, radio and mobile phone charging.

OPPORTUNITIES IN SUB-SAHARAN AFRICA

The rising costs of repairing and replacing equipment from a conventional power system are cause for concern since limited finances are one of the biggest constraints to the development and maintenance of SSA's power sector. For this reason a holistic approach is needed going forward, one that promotes sustainable function and easy integration.

Given SSA's unique position, we have the opportunity to leapfrog some of the large-scale power infrastructure that more developed regions are moving away from. As such, the digital transformation of the power networks of SSA represents a huge step towards future-proofing the infrastructure of the region.

DIGITIZING THE GRIDS IN SSA

The intricate complexity of SSA power systems and their extreme vulnerability to instabilities presents a huge opportunity for innovative companies and partners to address the critical issues of ageing infrastructure, interoperability, lack of visibility, and fault isolation through digital solutions.

Although the initial cost of digitizing the grid is often higher than repairing old equipment when needed, the long term cost is lower. When old equipment breaks down, it is not a simple case of replacing just one machine as manufacturers have often discontinued certain product ranges, forcing utilities to change or replace multiple units with newer models. The introduction of new equipment causes interoperability issues between the older and newer models which can cause system downtime. This not only results in revenue loss for the utility, but also revenue loss for businesses affected by the power outage.

The smart IEDs found in a smart grid help to monitor the health of the equipment, providing network operators with health status reports and alerting them if it is compromised. Data from IEDs is used to predict equipment repair and replacement needs allowing network operators to prepare accordingly and, in many cases, avoid a system failure, saving both time and money. Much of the energy infrastructure in SSA will soon reach the end of its lifespan, presenting the opportunity for the region to focus on upgrading its power infrastructure as opposed to replacing the same inefficient infrastructure.

On this note, the need for improved energy efficiency presents a significant opportunity in SSA. The cost to the economy from inconsistent power supply creates the need for efficient and continuous power supply to promote economic growth and reduce the reliance on expensive and environmentally taxing diesel-based generators. Implementing wide-area monitoring and control systems will allow for effective grid management resulting from full, real-time grid visibility. It will also enable grid fault identification and isolation to minimize the extent of power outages and decrease repair time.

In order to further promote security of power supply, there is a drive across SSA to increase the power trade within and between the regional power pools: Southern African Power Pool (SAPP), Easts African Power Pool (EAPP), West African Power Pool (WAPP) and Central African Power Pool (CAPP). For this to happen, transmission interconnections need to be developed between countries to allow for the transport of power.

Case Study: West African Power Pool goes digital with GE

WAPP will boost economic growth across the region by improving its electricity market platform, ensuring power outages are minimised and network stability is improved.

West African Power Pool (WAPP) comprises of 14 member states. It is a specialised institution of ECOWAS with the objective to control, manage and promote the exchange of energy in West Africa by integrating national power system operations into a unified electricity market.

WAPP members have faced a number of difficulties including:

- Lack of maintenance of the existing equipment
- Fuel availability
- Non-technical losses
- Non-payment of bills

WAPP's Digitalisation Journey

Commencing in 2017, WAPP contracted GE to undertake a turnkey grid digitalisation project across the region to be completed by 2021. There are three main objectives of this project:

Improve reliability and stability of energy in the region: The implementation of GE's Energy Management System will enable remote monitoring and complete visibility of the entire grid across 14 countries.

Improve regional exchange through existing interconnections: GE's Market Management System (MMS) will allow real-time, day-ahead and intra-day markets integrated with power systems operation across WAPP members.

Optimisation of energy costs to the consumer: GE's MMS will ensure electricity is purchased at the best price and the Automatic Meter Reading solution will promote accurate billing with smart meters.

Interoperability is a key challenge with transmission interconnections due to different operating standards. With all smart grid components meeting the IEC 61850 standard, interoperability will no longer be an issue, promoting rapid completion of interconnection projects and smooth electricity trade thereafter. With this in mind, the SAPP has mandated its member utilities to begin to adopt digital grid solutions to ease the interconnection process, as well as promote the integration of renewable energy sources (both centralised and decentralised) into the power pool's energy mix.

INTEGRATING RENEWABLE ENERGY USING SMART GRID SOLUTIONS

One of the answers to Africa's energy problem is somewhat an obvious one: renewable energy. Africa boasts a wealth of opportunity for solar, wind, hydro and geothermal technologies. Renewable energy can offer a cheaper alternative to power generation across SSA. Renewable energy offers three key advantages for Sub-Saharan Africa—affordability, speed and decentralisation.

The African Renewable Energy Initiative (AREI) envisions a smart, distributed, people-centred energy system for Africa; one that supports a vast mix of renewable energy generation leading up to 2030. In this vision, all energy consumers from the household level to large enterprises, will also produce energy for their own use with potential for surplus energy to be feedback into the grid or stored for later use. This is Africa's energy system of the future and it is well on the way to achieving this with over 450 national renewable energy projects underway.

The AREI predicts that of the projected 190 million people who will gain access by 2030, 68% (of which two thirds is from renewable energy power plants) will do so through national grid connection and 32% will do so via decentralised generation of Renewable Energy. The biggest barrier to achieving the vision set out by the AREI is the lack of "smart" technologies that will allow the renewable energy to be easily incorporated into the national energy systems.

Adding new types of energy sources to the energy mix requires new equipment. This has caused a number of issues in the past. Smart grids promote renewable energy as a viable source of power by easing of integration and transition to renewable energy by being able to account for the variability that is inherent in renewable energy generation. It is pertinent that electricity supply meets electricity demand and, as such, an efficient system must be able to absorb the fluctuating supply associated with renewable energies such as solar and wind.

There are countries making strides and establishing long-term development policies, such as Kenya's Vision 2030 that serves as a blue-print for the country's economic, social and political development leading up to 2030. Kenya's main goal for its energy sector is to increase its energy supply and provide more people with access to electricity. This has resulted in a robust regulatory framework with the intention of attracting Independent Power Producers (IPPs).

South Africa has also led the way in expanding its national grid and developing its renewable energy capabilities through its innovative Renewable Energy Independent Power Producer Procurement Program (REIPPPP). Additionally, South Africa is implementing smart grid solutions to mitigate the financial burden of electricity theft in the country. On average, South African State-owned utility, ESKOM, loses approximately US $1.3 billion a year.

Astonishingly, electricity is the third most stolen commodity in the world, adding up to US $92 billion globally each year. ESKOM has combatted theft with smart meters that allow two-way communication between the meter and a central system so readings can be logged every hour.

DECENTRALISING POWER GENERATION

Moving to the goal of universal access to electricity in SSA, it is anticipated that 68% of new connections will be via national grids, while 32% will be through decentralised power generation.

Although there are many off-grid solutions available, especially in East Africa with Kenya, Tanzania and Ethiopia leading the off-grid market in SSA, these generally cater power consumption up to Tier 2 or 3, empowering individuals but limiting their growth.

Microgrids allow people in rural or isolated areas to climb the energy ladder by filling the gap between small-scale off-grid solutions and national power grid connections, not only giving them access to basic electricity needs, but giving them the opportunity to grow. Microgrids are expected to play a considerable role in assisting in the electrification drive and adoption of energy storage across Africa in the future.

In the African context, distributed energy is more fitting seeing as it is more mobile, scalable and affordable to fit the unique needs of a community. The addition of smart technology that allows for automation can be easily integrated to ensure smooth operation of the microgrid. African countries have the opportunity to avert an energy system where electricity is provided only through a centralised power grid of complex wiring and expensive legacy machinery that will take up to 4 years to reach a single rural community. Rather, SSA has the opportunity to power rural areas by moving straight to decentralised power generation from various renewable energy sources; forming a simpler and less expensive transmission and distribution system that can be scaled up according to increasing demand.

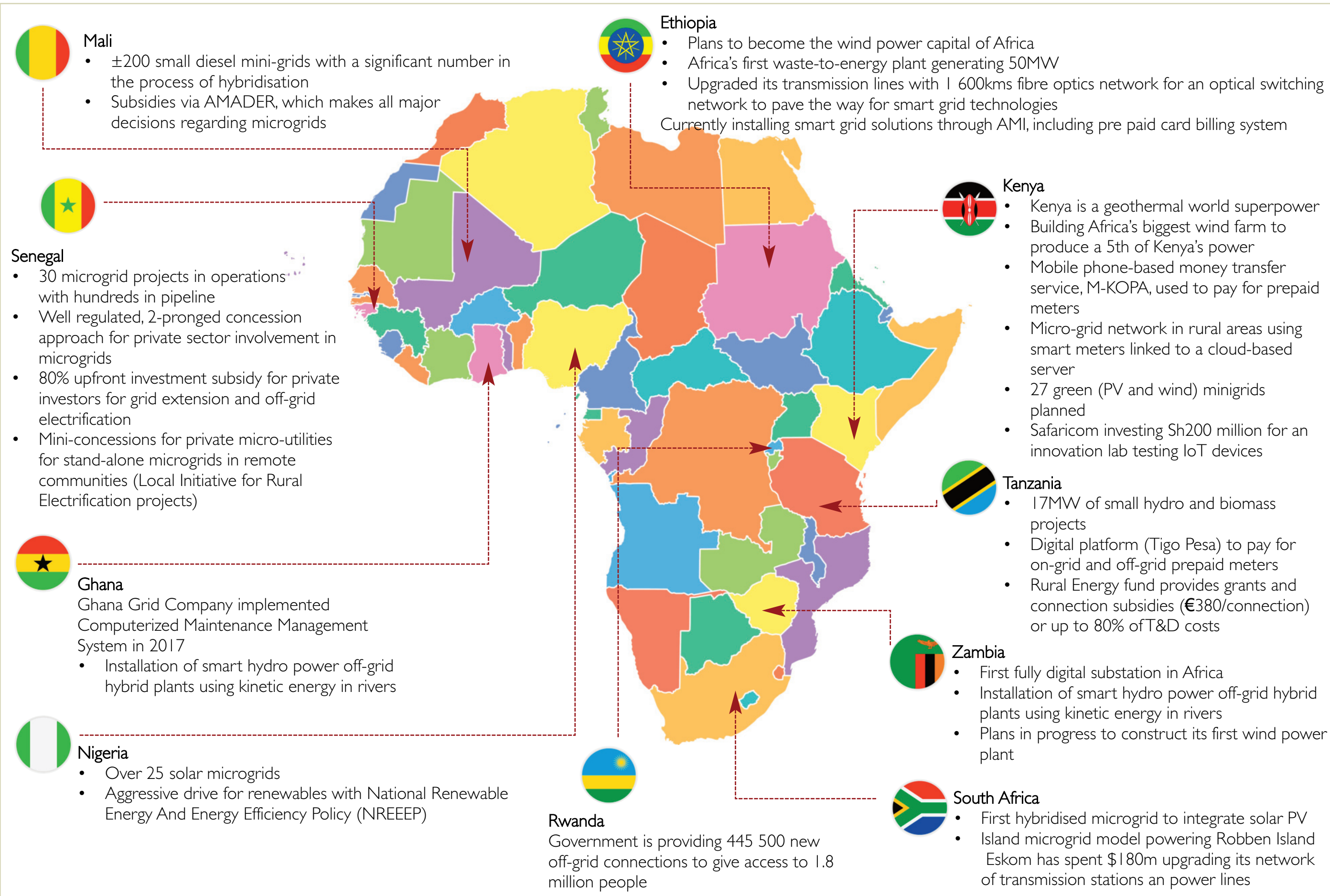
Microgrids are not a foreign concept to SSA, for instance ZESCO has used diesel generated microgrids to provide power to mines for years; however, this has come at a serious cost. Energy-intensive industries such as mining have made a concerted effort to reduce the cost of power generation to supply isolated mining operations by transitioning from diesel generators to renewable-based micro grids, typically fuelled by solar panels. The IEA posits that such changes can cut a mining firm's energy costs by 50%.

Microgrids that are fuelled by renewable energy offer some stability to the grid, as well as a clean and cost-effective alternative to traditional diesel generated micro grids. The cost of technology components for solar, wind and battery storage will continue to decline, making renewable energy the clear choice for decentralised power generation. The compliance of renewable energy technology to IEC standards allows for easy integration to the national grid when it catches up to the area. With smart grid solutions, the bi-directional flow of power allows for power to be sold to the grid in the case of a surplus and for power to be bought from the grid in the case of a generation deficit. This gives individuals/communities the opportunity to become prosumers, creating room for growth.

HOT SPOTS FOR CHANGE

While we've been talking about SSA as a region with clear challenges, goals and opportunities, it's also apparent that every country has a unique set of circumstances and objectives. For example Senegal has emerged as a leader in microgrid deployment; Ethiopia plans to become Africa's leading wind power generator; Tanzania was among the first countries to introduce an online meter payment platform; and South Africa is the region's largest investor in new transmission lines.

Hotspots for Smart Grid Investments in SSA

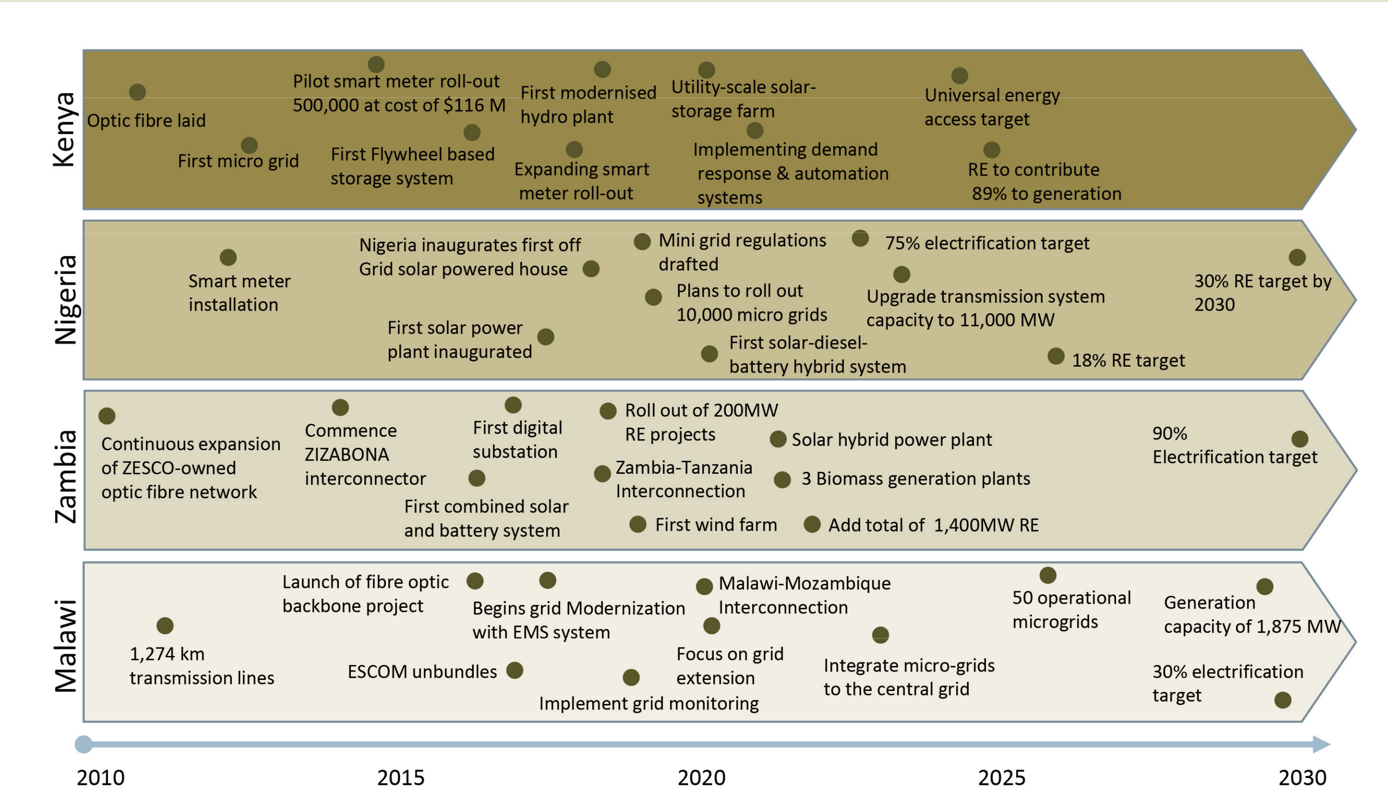


Source: Frost & Sullivan

To highlight both the differences and similarities, we've chosen Kenya, Nigeria, Zambia and Malawi to show the timeline for infrastructure development and the critical role that innovative technology will play in the future of energy in SSA. Although all four countries have differing challenges and objectives, they are all characterised by strong opportunities for smart grid implementation driven by common goals: electrification, grid modernization and renewable energy integration.

Timeline for Energy Infrastructure Development

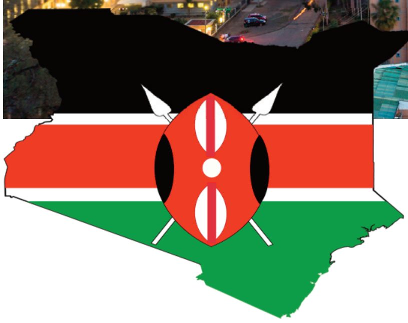
"Electrification, grid modernization and renewable energy integration will be key drivers of smart grid solutions across SSA"



Soruce: Frost & Sullivan

GE AFRICA COUNTRY HIGHLIGHTS

Kenya



Following the release of Kenya's Development master plan "Kenya Vision 2030" there has been a big drive to diversify its energy mix. Currently renewables contribute 84.5% to installed capacity, with plans to achieve 89% by 2030. Considering Kenya's geothermal potential, it is home to the world's largest geothermal plant, with plans to construct an additional plant in the next two years. Kenya plans to incorporate its solar capabilities into its grid by leveraging energy storage systems.

Kenya is currently a leader in the African off-grid solar market. Through decentralised generation and increasing renewable energy contribution, Kenya has an access rate target of 95% by 2030.

Challenges to Kenya's power sector:

- Electricity demand currently exceeds generation capacity
- Ineffective grid management and monitoring
- Rising cost of fuel leading to increasing price of electricity for consumers
- Aged, inefficient and unsustainable grid system
- Prolonged drought due to climate change variability

Opportunities to go digital

Kenya presents a good case for grid digitisation and can benefit from the following smart grid solutions:

- Demand response and demand side management
- Automation and control systems
- Digital hardware and equipment
- Digital microgrids
- Battery storage systems

Nigeria

Highlights from Nigeria's power sector

Four key challenges facing Nigeria's power sector are:

1. High transmission losses
2. Unreliable power supply
3. Electricity theft
4. Revenue collection

Transmission losses in Nigeria stand at 50%, one of Africa's highest. The country's primary target is to reduce its transmission losses to 15%-20%.

Reliability of power supply is a major issue, forcing almost 80% of the population to use of back up power sources like diesel generators, costing $22 billion in fuel costs a year.

Through smart grid solutions like AMI and data analytics offered by wide area monitoring and control, Nigeria can combat electricity theft and low revenue collection from unpaid bills. The country's newly-privatized distribution companies are under pressure to modernize their infrastructure. Government has pooled $3 billion in institutional funding for near-term investment in transmission infrastructure.

Nigeria aims to increase its rural electricity access rate from 35% to 75% by 2030. This will require significant investment into microgrid technology. Decentralised generation is currently less than 500MW.
ECOWAS will install 60 000 microgrids by 2020, this will help drive the microgrid market in Nigeria.

Malawi

Malawi has one of the most severely constrained power sectors in sub-Saharan Africa with an **electrification rate of 10%** with a rural share of only 1%. The country aims to increase electrification to **30% by 2020 and 33% by 2030.**

Although large hydro dominates Malawi's energy mix with a 94% share of installed capacity, modern renewable energy contribution currently stands at 6% and will **increase to 22% by 2030** with significant additions of solar and wind power. In 2017, Malawian utility, Escom, held its first renewable energy tender, contracting 70MW of PV power across four sites in Malawi., this will be the first of many to come. **Peak demand currently exceeds generation by almost 100 MW, and there is a need to increase installed capacity.** 78 diesel-powered generators have been procured to fill the gap until generation can be ramped up.

Malawi is not connected to power systems with neighbouring countries and cannot therefore benefit from its memberships of the Southern African and the East African Power Pools. **Interconnection projects** to Tanzania and Zambia are under way. The Southern African Power Pool is driving for the digitisation of its members grids, as such, Malawi has begun to upgrade its power system with real-time remote monitoring, planning and optimisation of Escom's transmission system.

The upgrade will **enable interoperability** for cross-border interconnections and **integration of new renewable energy** sources into the grid.

Zambia

Zambia has begun the process of modernising its electricity grid by upgrading its Muzuma substation in 2015 to be fully digital relying on fibre optics instead of conventional analogue systems.

Zambia still faces a power generation shortfall due to an over-reliance on hydropower which accounts for 95% of the power generated in the country. Currently power demand in 1,949 MW with a predicted growth in demand of between 150 MW and 200 MW per year. and the sector is only able to generate 1,281 MW. Decreasing dam levels have resulted in an increasing power generation shortfall, and subsequent power outages.

Zambia has committed to a 47% reduction in carbon emissions and a budget of $50 billion by 2030 to meet these goals. In the energy sector, this will result in the proliferation of renewable energy sources such as solar, wind, geothermal power. Zambia has secured $2.8 million from the World Bank group to develop a 34 MW solar PV plant and plans to construct its first wind power are in progress. Zambia will develop its geothermal potential with a $1.5 million grant from the USTDA to build a 10 MW-20 MW geothermal plant.

Zambia's goal is to increase the rural access rate from 4% in 2017 to 51% by 2030.The focus on developing renewable energy capabilities, combined with Zambia's low total electrification rate of 26%, will help drive its renewable energy-based microgrid market. Microgrids in Zambia were traditionally diesel-based with was very costly, hybridized microgrids that incorporate renewable energy are gaining traction and present a significant opportunity in Zambia.

THE DIGITAL GRID ROADMAP FOR SSA

When we look out to 2030 and consider the timeline for change in SSA, four game changers have emerged that will have the biggest impact on the digital grid roadmap in the region: Renewable energy; energy storage; smart metering; and distributed energy.

These trends will converge to transform energy management in SSA against the backdrop of low electrification rates, rising energy demand, increasing urbanization, an overriding need for security of power supply, and cross-border electricity trade. Combined with a decreasing price of renewable energy technology, increasing connectivity and ongoing innovations in energy technology, we are poised for an exceptionally exciting decade of transformation and opportunity.

Digital Grid Roadmap in SSA

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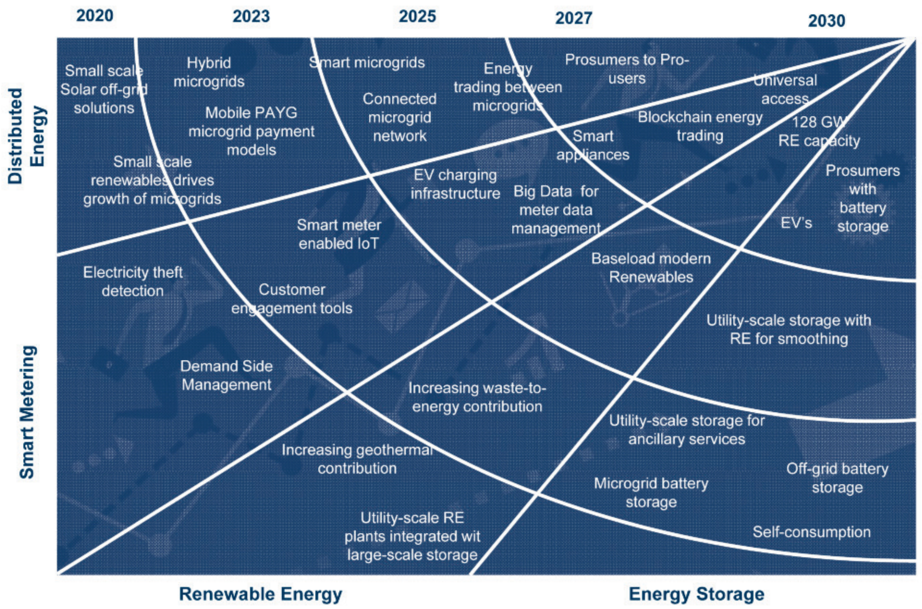


The process of digitizing the grid will be a more lengthy process in SSA than it has been in more developed regions. This can be attributed to the difficulty of securing financial capacity for such a transition. Inadequate finances have always posed a major barrier to infrastructure development in the energy sector. This has put SSA far behind more developed regions with Advanced Meter Infrastructure (AMI) only gaining traction now, 10 or more years after the USA and many parts of Europe. But as this is overcome, the benefits to all stakeholders are clear.

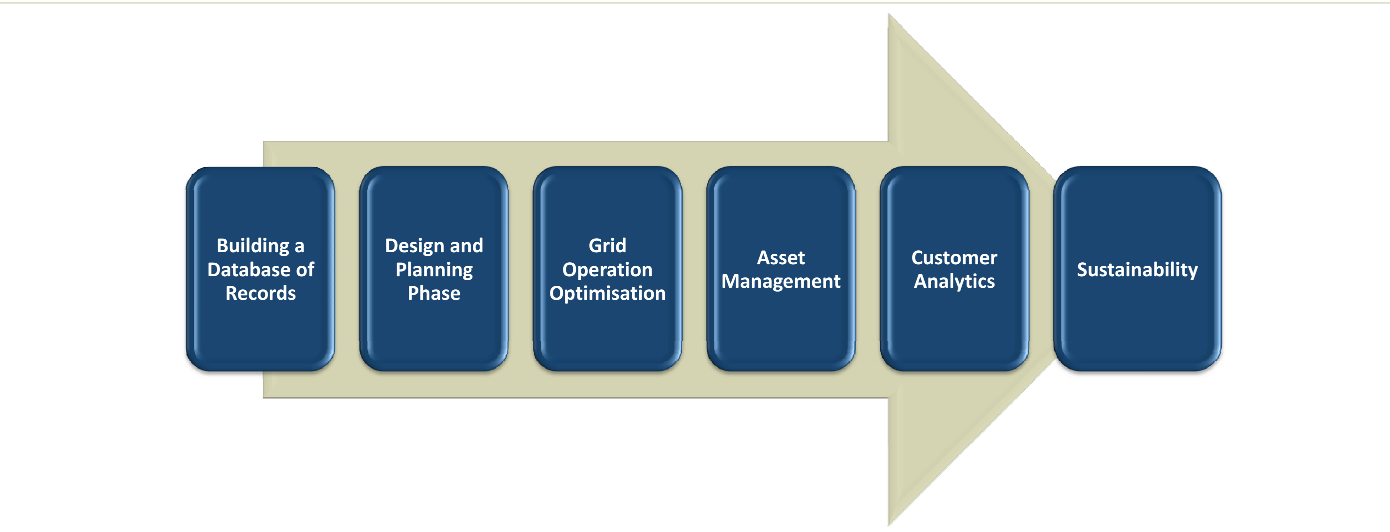
Governments with rural electrification programmes like REA and RERA will need to work together and strive for similar goals so the region as a whole will have a similar drive. Regional Economic zones (e.g. SADC) and regional power pools, non-profit organisations, funding organisations, and institutions like AfDB. USAID and SE4All will all have a collaborative role to play.

GE'S DIGITAL GRIDS OFFERING AND VISION FOR AFRICA

As the transformation of the global energy sector continues, it is important for countries in SSA to choose the right technology partner to take them through the grid modernisation journey. GE has a suite of solutions to cater to every step of process.

Although there are many directions to take in the grid modernisation journey, GE focuses on 6 steps utilities and industries can follow to ensure that they are building a smart grid that will guarantee quality and reliability of power supplied to customers, and optimise overall grid function, contributing to the longevity and sustainability of the grid going forward.

The GE Vision: Steps to Grid Modernization



Source: GE, Frost & Sullivan

BUILDING A DATABASE OF RECORDS

The first step in the grid digitalisation journey is to create a database of records. Ultimately, this is a map of the existing electricity network of a utility; this is called a network digital twin. GE's network digital twin is a mathematical model of the electricity network, allowing each aspect of the grid to be mapped out. This will reveal the complete customer connection link.

For instance, it will show you that a customer is connected to a specific transformer, and that transformer is connected to a specific distribution substation, that is connected to a specific transmission substation which gets supplied from a specific generator, and so forth.

The network digital twin can also be used as a simulator to test certain conditions placed on the grid in order to review the potential impact of these conditions. This will lay the groundwork for any smart grid and serve as a precursor to the design and planning phase.

DESIGN AND PLANNING PHASE

In the design phase, a utility will use the network digital twin to form the basis of their network planning by knowing how many customers they have, where their customers are geographically, and how they are physically and logically connected to the network. GE's Smallworld Electric Office, Smallworld Design Manage and Smallworld Analysis and Optimization serve as a complete set of tools to design, cost, maintain and analyse planned additions to the electricity network.

Using the geospatial network data held in GE's Smallworld solution, optimization engines can rapidly compare the load and flow for a given network and maximize the network size for the least cost. The Smallworld solution allows utilities to adequately and accurately plan for the future, taking current and future grid scenarios and requirements into consideration. Considering the ever-changing landscape of the energy ecosystem, designing a grid for the future is of the utmost importance.

GRID OPERATION OPTIMISATION

A major benefit of smart grids is the possibility to significantly improve the reliability of power supply through a range of smart grid solutions, ensuring power disruptions are kept to a minimum. With GE's Energy Management System (EMS), it is possible to stop potential problems before they occur on the grid itself and prevent disruptive cascading outages through Wide Area Monitoring Systems (WAMS) which provides full visibility of the grid in real time.

The client can select the scale of the solution ranging from small pilot schemes to large scale deployments. With this, network operators can maximize line capacity whilst maintaining stability. If outages do occur, GE's smart Outage Management Systems (OMS) will detect the fault, isolate it and notify the repair crew for immediate dispatch to resolve the identified issue. This is made even more accurate by knowing the exact location of customers and their connections provided by the network digital twin in the initial grid digitalisation steps. Since EMS can monitor real-time consumer needs it is possible to reduce transmission losses by implementing GE's Volt/VAR technology which enables the adjustment of voltage and reactive power on distribution lines in response to demand from users. This ensures line capacity matches real-time demand and power is not lost unnecessarily.

ASSET MANAGEMENT

Intelligent GE Protection and Control devices protect critical electrical equipment in the substation and ensure safe reliable power up and down the transmission line. They work to continuously monitor system health of equipment by employing both predictive and early-detection tools. This is a smarter way to track ageing equipment that needs replacing before it malfunctions, and with GE's asset optimisation technologies operators can get the most out of their equipment before having to replace them. Once a fault is detected it is isolated and analysed and rapidly resolved. All equipment complies with IEC 61850 standards and proprietary protocols are not owned by any one supplier, allowing for easier integration with existing infrastructure.

CUSTOMER ANALYTICS

Smart grids offer increased opportunity to proactively engage with the consumer through AMI such as smart meters providing network operators access to consumer energy profiles making it possible to manage the grid according to the consumer data generated.

An advantage of GE's smart meters is that they are communications-neutral and are compatible with any protocol utilities choose. Other benefits include revenue protection for utilities, improved meter performance and accuracy and load forecasting and planning. GE's demand response solutions work in synergy with smart meters and smart appliances to restrict power supply for high energy applications during peak hours. This can be very useful when waiting for new generation projects to come online.

SUSTAINABILITY

A key advantage of a smart grid is the ability to easily integrate new sources of power generation into the grid, especially renewable energy which is particularly challenging with a traditional grid. GE's Renewable Energy technologies enable integration anywhere along the grid. GE's solutions can also help forecast renewable potential and store excess renewable generation with GE's battery storage solutions by flattening out the inherent ups and downs of generation that relies on nature.

Power generation is relatively fixed and stable, but demand tends to fluctuate on a daily basis. When energy produced is higher than energy demanded, the excess is lost. With the battery storage solution from GE, however, excess energy generated charges the batteries and the stored energy can be distributed when demand exceeds generation. This is especially important for times when conditions for renewable energy generation are unfavourable such as in the evenings or winter months. Battery storage solutions allow individual users to actively participate by installing their own solar panels and storing excess energy to sell back to the operator, thereby developing the prosumer business model for Africa where solar power potential is abundant.

GE has a complete range of solutions that can bring any electricity grid to the forefront of the grid modernisation journey. GE not only timelessly delivers on turnkey grid modernisation projects, it also offers training to individuals across the grid on how to efficiently manage the new technology and systems to ensure smooth operation and improved grid lifespan. The knowledge transfer is a vital part of any project.

CONCLUSIONS: THE JOURNEY TO DIGITAL GRIDS

Smart grids will play a key role in a country's transition to a sustainable energy system in a number of ways, mainly through facilitating smooth integration of new energy sources, especially renewables; promoting interoperability between all types of equipment; enabling the growth of distributed generation and its potential incorporation into the main grid; supporting demand-side management; and providing flexibility and visibility of the entire grid.

Through its Grid Solutions business, GE is a global leader in the delivery of advanced smart grid solutions for a whole host of applications and unique local circumstances. In Africa, the company has a clear and powerful vision for bringing next generation solutions to countries that are evolving fast.

As we have laid out in the Whitepaper, Africa has the opportunity to leapfrog ahead not once but twice, skipping both polluting fossil fuels and, increasingly, the electricity grid itself. The digitization of grids will be the most critical enable of this exciting journey.

Schedule a dialogue with our team to discuss your strategic growth development

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