Re-imagining the future of power in Sub-Saharan Africa
Africa faces a unique challenge – we have an energetic population estimated at over 1 billion people yet our household electrification rate is the lowest in the world with only one in three Sub-Saharan Africans having access to electricity. To realize the potential of Africa’s economies with a population projected to increase to 1.7 billion by 2040, access to affordable, reliable and sustainable power is critical.

In collaboration with our customers, GE is leading transformation in the power industry. GE’s first turbine installation in Sub-Saharan Africa can be traced as far back as the early 1950s and last year, GE reached its 100th power plant installation in Sub-Saharan Africa. We now have an installed base of over 300 turbines in 22 countries in the region, adding up to about 80% of the total energy installed in Sub-Saharan Africa.

While we still have a long way to go, progress is visible and many Governments across the region have plans to substantially increase installed capacity and electrification in line with the UN’s Sustainable Development Goal 7 to achieve universal access to affordable electricity by 2030.

For the first time in 2018, electricity access in Sub-Saharan Africa surpassed the population growth. There is hope in achieving universal access to electricity in the 21st century if countries can diversify their energy mix and design policies that make their energy economies attractive to financiers.

The global and regional power industry trends are continuously shifting. While these key themes are part of the power solution in Africa, an essential and skilled workforce, flexible solutions and the ability to partner together as equipment providers, EPCs, financiers, investors and governments are critical to success.

There is a great need to find solutions to Africa’s power situation collaboratively through partnerships between both Government and private investors. We are honored to play a role in this changing narrative and to be part of the conversation on Powering Africa Forward. Together, we can accelerate the progress.

Elisee Sezan
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Re-imagining the future of power in Sub-Saharan Africa
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Currently at 64GW, the region’s power generation capacity is projected to grow at 4% each year across the various fuel sources to help meet the energy demand of the growing African population. The region’s current energy mix, primarily dominated by hydro and coal, is becoming more diversified following the rising interest in renewable technologies such as solar and wind.

Key themes in the regional energy transformation are centered on the 3Ds; Decarbonization, Decentralization and Digitization. On decarbonization, efforts to reduce greenhouse gas emissions have influenced the preference for wind, solar, geothermal and hydro as part of a more environmentally friendly energy mix. To ensure power generation reaches the populations that need it most, Sub-Saharan Africa’s grid needs development. It is estimated to be unavailable, on average, only 6% of the time. Hence, the drive for a more decentralized power system to support affordable distributed power technologies. Under digitization, technology is seen as a primary driver of efficient energy supply with internet enabled solutions such as smart grids and automated metering.

Sub-Saharan Africa needs power and there is an overdependence on governments to resolve this crisis. Governments are further challenged with the task of providing affordable and reliable power in a timely manner. With funding from non-governmental organizations (NGO), financial institutions and partnerships with private investors and independent power producers (IPP), the current narrative that two out of three people in the region needs access to electricity is expected to change. Current projections are that IPPs and public-private partnerships (PPP) will account for 35% of the region’s installed capacity, excluding South Africa, by 2020.
Since 2010, power capacity in Sub-Saharan Africa has increased by 40% from 85GW to 119GW, with the last five years producing double digit growth in capacity additions. Across the region, the energy mix has historically been dominated by hydro, except in South Africa, where coal remains a major source of power generation. The generation mix has gradually begun to diversify with an increased presence of gas, diesel, and renewables. Gas power generation capacity has almost tripled since 2010. Of greater note is the emergence of wind and solar, having grown from 50MW in 2010 to a capacity of nearly 5GW in 2017. Critical factors that have impacted the energy mix are increased incentive to utilize domestic fuel sources, skills development priorities for local workforce, and environmental events.

Power generation capacity in Africa is forecast to grow at about 4% per year through 2040 to peak at 570GW. Our expectation is that generation will continue to increase across all fuel sources, with a majority share of new additions being powered by gas and renewable generation technologies.

The power capacity growth prospect is promising, however, the need to keep pace with the continent’s growing population is cause for urgency. Africa is projected to be home to 1.7 billion people by 2030, which will be a nearly 40% increase over population levels in 2015. While progress in electrification has been made, less than half (43%) of the sub-continent’s population still does not have access to electricity. Progress has also not been evenly distributed. The highest concentration of access gains has been in Kenya, Ethiopia, Tanzania and Nigeria, with Ghana and South Africa recording the highest access rates in the region. As a further example, Ghana and Botswana have benefited from an over 50% increase in access since 1990, but high population growth countries such as Uganda and the Democratic Republic of Congo have achieved less than an 18% increase in access since 1990.

Beyond powering homes and industry, further efforts are required to develop access to clean cooking fuels. As of 2017, less than 20% of the population had access to clean cooking fuels.

Sub-Saharan Africa presents a vibrant and complex landscape across which to consider the impact of the global electricity system transformation. This report will explore the relevance and impact of key global electricity sector transformations on Sub-Saharan Africa.
ENERGY TRANSFORMATION IN ACTION

Decarbonization
The need to reduce greenhouse gases is a priority for the energy ecosystem. Global carbon emissions from fossil fuels increased by 1.2% in 2017. Progressive use of cleaner energy sources such as gas and the development of new technologies harnessing digitization will eventually lead to the further decarbonization of the economy. The immense renewables potential for Sub-Saharan Africa presents opportunities for meeting the region’s energy needs with abundant unlimited energy. Decarbonization can be achieved through a diversified, environmentally friendly power generation mix including wind, solar, geothermal and hydro.

The decarbonization of electricity is well underway as demonstrated through the rapid uptake of renewable energy technologies across the world and falling renewable power generation costs. Kenya, Ethiopia, Tanzania, South Africa and Nigeria, have in the last five years increased their adoption of affordable renewable energy and distributed technologies. Across the region, renewable energy has provided 34% of new connections since 2012, and off-grid and mini-grid systems, 6%. The move to add renewable resources in Sub-Saharan Africa’s energy mix signals the start of the process of decarbonization - reducing the carbon-intensity of the electricity we use. There is, however, the need for Sub-Saharan Africa countries to create policies and frameworks to promote renewable energy solutions. Renewable technology adoption will continue to grow and by 2030, account for over 60% of new access globally. GE is committed to technologies that support decarbonization and a balanced energy mix. A balanced energy mix will be critical to delivering affordable and reliable power and ensuring environmental sustainability.

Wind
Wind presents an ideal source of energy for markets seeking an independent fuel source. However, reforms are required to implement appropriate policy frameworks to reduce capital costs associated with wind power generation and make it an attractive investment option for IPPs.
Solar
Globally, the cost of solar photovoltaic (PV) modules has decreased since 2009. Between 2010 and 2017, the cost of electricity from solar PV was lower by almost three-quarters and is expected to continue to decline. Although solar irradiation in Africa is one of the highest levels globally, the installed capacity in Africa for solar is around 2GW, representing less than 1% of the world’s solar capacity. In Sub-Saharan Africa, a majority of areas experience in excess of 2000 kWh of solar radiation annually. Solar is compatible with micro-grid technologies for areas that do not have access to the grid. Solar power will experience increased orders in the future fueled by cost reductions and business models that make it more affordable than grid. Solar solutions offer an attractive opportunity as accessibility, affordability, reliability and efficiency are key variables to consider in terms of energy security in Africa.

Hydro
Africa has an estimated hydropower capacity of 300 GW, but only 8% of this is currently utilized, representing 84% of all non-fossil fuel energy use. The Grand Ethiopian Renaissance Dam in Ethiopia is expected to produce 6,000 MW once construction is complete. Hydropower accounts for over 50% of electricity generation in several countries including Uganda, Namibia, Zambia, Democratic Republic of Congo, Ethiopia, Togo and Mozambique. There is, however, the need to invest in storage systems to manage intermittency, especially due to climate events such as drought. To enable flexibility, hydroelectric pumped storage systems will continue to be important across the region.

Geothermal
Africa has a total installed geothermal generating capacity of over 644 MW. The geothermal capacity for the East Africa region is estimated to exceed 15,000 MW, representing a $40 billion investment opportunity. Geothermal is an appropriate technology to meet base load energy demand but the high initial financing costs and exploration risks have made it a challenge for countries to increase capacity.

Gas
Gas is positioned as a differentiator in increasing electrification access rates in Sub-Saharan Africa. Currently, natural gas is predominant in Nigeria, Cote D’Ivoire, Tanzania, Ghana and Mozambique. Nigeria leads proven reserves at 5.3 trillion cubic metres. Angola, Equatorial Guinea, Nigeria and Cameroon are key exporters of LNG. Gas complements renewable technologies such as wind and solar and could potentially replace oil which is used for power generation in most countries resulting in expensive electricity. There is the possibility of increasing regional trade from countries with gas. Currently, Mozambique exports gas to South Africa and Nigeria exports gas to Ghana, Togo and Benin. There is potential for LNG import projects in Ghana, Cote D’Ivoire, Namibia, Madagascar, Mauritius, South Africa and Kenya.
Digitization
The broad spectrum of Internet of Things (IOT) solutions help manage data and systems. While IOT adoption in Sub-Saharan Africa is relatively new compared to other emerging markets, one should not underestimate the transformative potential of these technologies. As governments focus on increasing energy access and utilities work to reduce transmission losses, the role of technology in driving overall efficiency of the region’s energy economy cannot be emphasized enough. The proliferation of internet enabled solutions such as smart grids, renewable energy integration, and automated metering are enhancing energy delivery optimization, particularly in South Africa and Kenya, where smart metering is reducing domestic and commercial consumption, increasing revenue collection rates and improving operational efficiency. Across the region, systems integration and controls remain critical for power generation, transmission and distribution. But perhaps, the most fundamental role of technology in advancing the region’s energy sector will be in these areas:

- Baseline analysis of projected power demand
- Customer behavior insights: consumption, purchasing and payment patterns
- Improved customer experience through better kilowatt delivery
- Smart grids that increase grid flexibility by ensuring interoperability of diverse power generating assets

Leveraging emerging technologies will drive the innovation and advancement needed around utility scale transformation and make generation and distribution costs more competitive. The region’s largely unbanked population has accelerated the adoption of alternative financial services, led primarily by mobile network operators. Sub-Saharan Africa enjoys an impressive mobile money economy, with experts projecting a shift from its heavy cash economy to a digital ecosystem in the long term. With half of the region’s population unable to access affordable, reliable power, and fewer than 50% of adults have an account with a formal financial institution, Sub-Saharan Africa presents the perfect opportunity for affordable renewable energy, distributed technologies and innovative financing models.

An increase in the adoption of solar technology, largely driven by a fall in prices and the shift from peer to peer lending to the widespread use of mobile money technology have led to new business models that are addressing these two challenges. In Kenya, M-Pesa, a platform that offers retail financial services via mobile phones, has enabled companies that provide rent-to-own solar energy solutions for the off-grid population through access to mobile money payments. These new solutions are decentralizing the finance and energy traditionally provided by large commercial banks and central utilities. The portable solar lanterns and solar home systems power multiple lights, mobile phones and small appliances, allowing populations that are not connected to central grid to have access to affordable and reliable power for their homes and small businesses.
At the core of these innovations, blockchain is a decentralized software mechanism that enables a public distributed ledger system. In recent times, it has emerged as a tool for the under-served finance segments. In Sub-Saharan Africa, it is still a nascent technology that has been embraced by early adopters mostly in East and South Africa.

**Decentralization**

Globally, the power landscape has been transformed by the arrival of increasingly affordable distributed power technologies. With diverse fuel options and flexible configurations, these technologies have been a key driver in the trend towards smaller, decentralized power systems.

The traditional centralized grid infrastructure, which only extends access to urban populations, faces significant issues with reliability and in most cases requires rehabilitation due to age and poor maintenance.

Achieving universal access in Sub-Saharan Africa will require significant capital investment, particularly if traditional centralized grid infrastructure is developed. An estimated $265 billion is required for distribution infrastructure development and $80 billion for transmission infrastructure development by 2040. Many African markets have adopted off-grid distributed power options as a way to more affordably address the electrification challenge. Global cost reductions in PV and battery storage, as well as regional business model innovation in mobile money have enabled off-grid solutions to grow in prominence over the last few years. Solar technologies have grown in access in the last decade, with sales of household size units estimated at over 10 million. Given the cost per connection for centralized grid expansion, off-grid electrification provides a feasible and cost-effective method to connect rural populations for many markets in Sub-Saharan Africa.

Nearly all Sub-Saharan Africa’s state-owned power utilities face operational, structural, and financial challenges. In light of this, a critical question to be addressed is how decentralized power regulation can most effectively be deployed such that it encourages private investment and reduces government dependency, as well as also implementing the necessary reforms to remediate the issues within the centralized utilities.

While decentralized power technologies do not produce significant generation output, the primary benefit of distributed solutions is their ability to accelerate access to the population, when compared to traditional grid infrastructure.

Given that the largest consumers of power are concentrated urban centers and industrial users, decentralization will have minimal impact on centralized generation. Rather the most significant impact will be socioeconomical as a result of the achievement of electrification targets.
Sub-Saharan Africa has one of the world’s lowest electrification access rates. Global programs like the United Nation’s Sustainable Energy for All (SEforALL), the United States’ Power Africa and the German Marshall Plan for Africa, are helping increase electricity access. The slow rate of power sector development, spotty governance and increasing population numbers counter the impact of these initiatives and amplify the region’s energy poverty.

**Financing and Regulatory Framework**

IPPs and PPPs have become an integral part of the region’s energy economy. In Sub-Saharan Africa, excluding South Africa, IPPs and PPPs will generate 35% of installed capacity by 2020. The IPP model, now the primary vehicle for investment in the region’s energy sector is expected to grow in reach and beyond its current concentration.

Uganda, Kenya, Namibia, Senegal, Ghana and South Africa have clear policies around private sector participation in their energy economy. Transparent and credible regulatory oversight, dynamic power sector planning and committed and experienced equity partners further enable IPP participation in these economies. 14 IPPs in Namibia recently committed to investing $111.7 million to add 70MW of capacity to the national grid, reducing the country’s reliance on imports from the Southern Africa Power Pool (SAPP).

Southern Africa matched a $100 million fund extended to it by the UN’s Green Climate Fund (GCF) to support the development of micro-grid projects. The $200 million investment will add 330MW of new generation capacity and reduce more than 700,000 tons of carbon dioxide per year.

The breadth of financing resources for Sub-Saharan Africa’s energy infrastructure is a mix of domestic funding by governments (budget allocation) and external funding in the form of multilateral institutions like the World Bank Group (WBG), African Development Bank (AfDB), government to government agreements, public-private Initiatives and OECD-DAC donors. African governments recognize the challenges of energy deficits and have continued to increase the domestic budget for power infrastructure financing.

In March 2019, the Development Bank of
**Energy Sector Management**

Two factors that determine the viability of the region’s energy sector are financial sustainability of utilities and tariff affordability. Improving operational efficiencies by reducing combined transmission, distribution and bill collection losses as a percentage of dispatched electricity are key to closing the revenue loss gap. Pre-paid metering systems align electricity payments with income flow and improve the rate of payment to utilities.

Electricity access and consumption cannot be improved if utilities continue to struggle with operational efficiencies as is the case in many of the countries in the region. Ghana, in February 2019, transitioned management of its utility to a consortium led by the Manila Electricity Company (Meralco). The new entity, Power Distribution Services (PDS) Ghana Limited will undertake reforms and projects that will address the inefficiencies in the country’s power sector, making it a more investor-attractive market.

Power sector subsidies in the region are substantial and regressive although politically expedient in most African countries. Subsidies are challenging to eliminate once implemented and the dependence on government to provide affordable power is a disadvantage for the region’s energy economy.

Driving an era of cost reflective tariffs in markets where citizens have not had access to reliable energy will be transformative. Targeted tariff increases to customers who need reliable power and can afford it is a solution to large utility deficits and low access rates. Most Sub-Saharan African countries have suppressed power demand. The lack of cost reflective tariffs makes it difficult to drive better international and private sector participation in the energy economy model.

Despite an abundance of capital, financiers are frustrated by the lack of well-structured projects, especially for transmission and distribution, that support attractive rates of return available across the region. The region could improve future project economics and attract a wider range of investors, including private offices, sovereign wealth funds and individuals worldwide, through effective power sector reform and the reduction of inefficiencies in the energy value chain. Ideally, the region aspires to achieve an energy economy that balances investment, affordability, access and reliability.
POSITIONED TO WIN

GE’s Hybrid Distributed Power Unit Powers Digo Village

Ethiopia has abundant renewable energy resources and the potential to generate over 60,000 megawatts (MW) of electric power from hydro, wind, solar and geothermal sources. The Grand Ethiopian Renaissance Dam (GERD), which is currently under construction, is expected to be the largest hydroelectric dam in Africa and to generate 6,450 MW of electricity at full capacity. In 2018, the Federal Government of Ethiopia launched the National Electrification Program (NEP), a comprehensive plan to reach universal access to electricity by 2025. Ethiopia is the second-most populous country in Africa and with a population spread out throughout the country, therefore ideal electrification solutions must be both on-grid and off-grid.

The GE off-grid hybrid power system is ideal for remote villages and hard-to-reach operations but can also provide increased reliability when grid supply is inadequate. In Ethiopia, the scalable micro grid system powered by a Hybrid Distributed Power unit provides reliable, sustainable and cost-effective power to 1,500 inhabitants of Digo Village, powering a health clinic, school, administrative offices and homes.

GE’s Hybrid Distributed Power combines PV solar panels, batteries, and a diesel generator to provide reliable, cost effective power to a mini-grid system. GE’s Predix platform, designed for digital industrial IoT, maximizes the use of clean solar power and batteries for the unit. This pioneering technology proactively troubleshoots issues with any system before they become a problem for customers. The variable speed diesel generator provides essential backup when battery power is insufficient. The entire system is containerized inside a standard shipping container that can be efficiently and speedily installed.

The Digo village Hybrid power system is GE’s third installation in Ethiopia and the second in Sub-Saharan Africa. In 2017, GE funded two similar units in Ethiopia at Health Centers in Guba and Ashoka in Southern Nations, Nationalities, and Peoples’ Region (SNNPR) region. In the Democratic Republic of Congo, the hybrid distributed power system will provide power for small businesses, schools and other organizations in Goma.
GE Power's Software Technology Transforming Botswana's Grid Network

The Government of Botswana, through the National Energy Policy, has set a national electricity access target of 100% by 2030. The country aims to increase access to affordable, safe, reliable, adequate and more sustainable power for both rural and urban populations. An efficient process from generation to consumption of power requires a stable transmission and distribution system that is sustainable in the long term to ensure supply security. Electricity transmission and distribution systems that are aged can be transformed through digital technologies to drive efficiency. A smart grid ensures increased efficiency, affordability and reliability of electricity to consumers by minimizing losses in distribution and reducing power interruptions. The technology anticipates problems before they occur and if they do occur, smart grid management systems analyze maintenance requirements and re-routes power to minimize the outage. Through data analyses, GE service engineers can attend to the issue quickly and effectively.

To improve grid efficiency, GE is working with the Botswana Power Corporation (BPC) to design, supply, install, test and commission a SCADA/Energy Management system at the principal grid control centers in BPC’s headquarters in Gaborone and the back-up control center in Francistown. The system will lead to a more optimized, dependable and responsive grid network by reducing down-time and improving revenue collection. BPC will also benefit from a single platform for both Gaborone and Francistown thereby increasing efficiency.

The benefits of a smart grid solution include demand response and demand side management, increased grid flexibility, integration of diverse generating assets, preventive maintenance and increased interoperability. Smart grid solutions also improve resilience to cyber-attacks on the grid.

Trends such as renewable energy integration, automated metering, grid decentralization and growth in distributed generation will drive the need for smarter solutions in future.
**A Regional Commercial Bank Finances Off-Grid Energy Access Across Africa**

Sub-Saharan Africa’s existing grid faces availability challenges leaving many remote communities unserved. However, governments have little appetite or the balance sheet to support the development and maintenance of backbone infrastructure.

With reduced technology costs, enhanced storage efficiencies and increasing tariffs, off-grid (mini-grids and solar home systems) solutions have never been a more attractive solution. An Africa focused, client-centered regional banking institution is bringing safe, reliable and affordable power to large unserved communities across the region, with several success stories in Kenya, Namibia and Uganda.

Through its partnership with leading off-grid pay-as-you-go energy companies, the bank is providing financial solutions for solar asset investments. Solar panels (customizable per customer needs) are mounted on roof tops in both rural and affluent communities, and payments made in installments via the pay-as-you-go model.

Since 2017, the bank has committed over $80 million of funding to pay-as-you-go companies in East Africa, effectively disrupting the market for financing off-grid renewable solutions and remains committed to accelerating Africa’s growth trajectory through increased investment and growth in the solar home systems market.

The current model presents some challenges and the bank, and its partners recognize this. The plan over the next few months is to design a customer intelligence system that drives sophisticated data collection and can influence baseline analyses of customer behavior patterns (consumption and payment habits). With the intelligence gathered, the bank and its partners can project future demand, design a credit scoring system based on customer purchasing behavior and improve customer experience through better kilowatt delivery.

With a system like this in place, the bank can amplify its financing solutions for solar home systems as part of new home purchases beyond South Africa.
THE PATH FORWARD

The challenge for most Sub-Saharan African countries is improving electricity access for their growing populations and the scale of the electrification challenge means no single fuel can solve this problem. The energy mix will shift from the traditional hydro and coal to accommodate renewables and gas. The timescale for development of renewables energy infrastructure means gas has a large window of opportunity to become the preferred fuel source in the short and medium term. Nigeria, Angola, Tanzania, Mozambique and Senegal have large enough gas reserves for export to neighboring countries. Since 2010, GE’s Gas Power Systems business has added 6GW to the grid in Sub-Saharan Africa and delivered the best performing products and solutions portfolio across the region. With over 120 years of experience in the energy business, GE covers the entire plant spectrum with its world-class gas and steam turbines, generators, condensers and digital solutions.

Through strategic partnerships with governments and key energy sector stakeholders GE equipment, total plant design, integration and execution capability is producing both reliable baseload and flexible emergency power solutions across the sub-region.

Key success stories across the region include:

- 70% of Ghana’s thermal power runs on GE equipment. GE has added over 600MW of power to the country’s grid with plans to develop additional 900MW in the next two years; the 400MW Bridge Power project will be the first LPG-fired power plant in Africa and the largest LPG fired power plant in the world. The Atuabo Waste to power IPP will be the first TM2500 plant to use otherwise flared isopentane gas as a fuel source. The Cenpower IPP financed by the AFC will achieve commercial operation in 2018 and will bring online 350MW of power – enough electricity to power over two million Ghanaian homes – and the 200MW Amandi power plant which will come online in 2019 will run on GE’s latest and greatest 9E technology offering superior fuel flexibility for the country.

- 3GW+ of GE heavy duty and fuel-flexible gas turbines have been committed to meet Nigeria’s power generation ambitions.

- 80% of Angola’s gas-powered generation runs on GE technology bringing electricity access to approximately 2 million Angolan households. The Soyo 1 combined cycle power plant will produce up to 750MW of electricity upon completion. In addition, over 20 units of GE’s innovative trailer mounted gas turbines are installed on the Angolan grid, bringing fast and efficient electricity access to remote communities.

- In Cote d’Ivoire, the Azito power plant, one of the first ever combined-cycle power plants in the country, produces more than one-third of the country’s electricity and runs on GE technology. The first ever gas turbines and the first IPP project also run mainly on GE technology.

Technology and skills transfer are at the core of the work GE does in countries across the region. Our existing projects have achieved up to 70% of local content and three times more jobs created in the countries we operate. GE has delivered on programs for supplier development, and scholarships and internships for engineering students, with special focus on female engineers. We support collective advocacy and a regional approach to the sub-region’s energy challenges.
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GE Power is a world leader in power generation with deep domain expertise to help customers deliver electricity from a wide spectrum of fuel sources. We are transforming the electricity industry with the digital power plant, the world’s largest and most efficient gas turbine, full balance of plant, upgrade and service solutions as well as our data-leveraging software. Our innovative technologies and digital offerings help make power more affordable, reliable, accessible and sustainable.

Learn more at: https://www.ge.com/power/regions/africa