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POWERING KENYA: UNDERSTANDING THE LANDSCAPE AND EXPLORING INVESTMENT POSSIBILITIES

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Abstract

Kenya has a power generation system that is highly dependent on hydro sources, while frequent droughts cause dramatic drops in water levels at many reservoirs supplying the country's hydroelectric plants. This combination results in severe power shortages across the nation, which cascade down the power supply chain and provoke a series of distortions in the system.

There is an indispensable need for a more reliable, more cost-competitive, and more accessible electricity system if the country wants to sustain its economic growth and meet future electricity demand. This paper identifies specific investment niches, including:

- the modification of diesel and gasoline generators to run on methanol or ethanol
- off-grid solar systems, particularly home solar electric systems
- the erection of 5,000 km of transmission lines
- innovative financial solutions to finance connection fees to the electric grid

Finally, several recommendations are offered for key stakeholders to consider:

- the simplification of complex regulatory requirements
- assessment of the experience of IPPs (independent power producers) to create the conditions for more and improved IPPs
- the procurement of power in a more competitive manner, not as a consequence of direct agreements
- the standardization of the favored power technology for different counties in Kenya through clear protocols according to the most cost-efficient criteria

- the mapping and segmentation of the population that lacks access to electricity and the subsidizing of the difference between what households can afford and what electricity costs

This paper stresses the need to address two challenges:

1. Expanding access to electricity, given that more than 50% of the Kenyan population is deprived of this development enabler.
2. Guaranteeing a reliable power system, capable of sustaining growth and meeting internal demand in the medium and long term.

With renewed efforts from policy makers to revamp the energy sector, the current scenario offers an unprecedented opportunity for investment, especially in renewables. However, several challenges remain to be solved:

1. Electricity equity. In rural areas, there is extremely low access to electricity (6.7% of the population). With less than $9 a month available to spend on energy, 50% of the households that currently have no access to electricity do not reach the minimum boundary at which access to electricity can be granted, which is around $15 a month.
2. Transmission and distribution losses account for 1.56 thousand GWh per year, enough to provide electricity to 1.3 million households for a year.
3. The frequency of power outages and blackouts causes companies to register losses equivalent to 5.6% of their annual sales.

Keywords: Kenya; Africa; Electricity access; Power; Investment; Renewable

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POWERING KENYA: UNDERSTANDING THE LANDSCAPE AND EXPLORING INVESTMENT POSSIBILITIES

Executive Summary

For years, Kenyans have joked about "Kenya Paraffin Lamps and Candles" when referring to the Kenya Power and Lighting Company (KPLC) on account of the frequent electricity blackouts. There is a power generation system that is highly dependent on hydro sources, while frequent droughts cause dramatic drops in water levels at many reservoirs supplying Kenya's hydroelectric plants. This combination results in severe power shortages across the nation, which cascade down the power supply chain and provoke a series of distortions in the system:

1. The price of electricity increases as the unavailable hydroelectric power is substituted by the available thermal-based electricity, which relies heavily on costly oil products.
2. As a result of the increase in the electricity tariff, access to electricity decreases and commodity prices increase – since electricity is embedded in all manufactured products – and this in turn widens the gap between the rich and the poor.
3. Commercial and industrial customers suffer heavy losses as a result of outages and blackouts, which lowers productivity among Kenyan manufacturing firms and renders them less competitive than those in neighboring countries.
4. Entrepreneurship is discouraged and foreign direct investment inflows face barriers.
5. Uncertainty is created in the market as to whether the country will be able to sustain growth and meet future demand.

Acknowledging all of the above, this paper stresses the need to address two challenges:

1. Expanding access to electricity, given that more than 60%[1] of the Kenyan population is deprived of this development enabler
2. Guaranteeing a reliable power system, capable of sustaining growth and meeting internal demand in the medium and long term

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[1] According to information gathered by the International Energy Agency.

Connection fees remain one of the main obstacles to electricity access. This is despite renewed efforts to provide greater access to electricity since the creation of the Rural Electrification Authority (REA) and despite significant cuts in the fees – in the best-case scenarios, with a 90% subsidy, it still costs KSh15,000[2] ($150).[3] Moreover, the electricity tariff of $15.84 per month for average residential consumption of 100 kWh (kilowatt-hours) is beyond the available discretionary income for energy purposes of unconnected households. Half of such households have about $14.50 per month and they are potential customers of solar off-grid systems such as M-Kopa. However, the other half of unconnected households have about $9 per month, making them unprofitable for grid and off-grid power suppliers alike.

In addition to the high concentration of unreliable sources in the power generation mix, other factors affect the reliability of the power supply system, such as the poor condition of the transmission and distribution networks, which translates into annual transmission and distribution losses to the magnitude of 18% of total output.[4]

Notwithstanding the abovementioned, with renewed efforts from policy makers to revamp the energy sector as outlined in the Kenya Vision 2030 development program, there is exuberance, optimism and hope that the country will manage to have reliable power supplies to support its economic growth. This is reflected in the unprecedented amounts of investment in the sector, which shot up from virtually zero in 2009 to $1.3 billion in 2010 across technologies such as wind, geothermal, small-scale hydro and biofuels. New power plants across Kenya are blooming like acacia seeds after a rainstorm. They range from the geothermal plants in the Rift Valley to coal plants on the coast, from which the government aims to harness a generation capacity of 23,000 MW against a projected peak power demand of 16,905 MW by 2030.[5] The Vision 2030 program included a medium-term plan aimed at increasing generation capacity by 5,538 MW by February 2017.[6]

However, new evidence[7] shows that the underlying macroeconomic assumptions supporting the plan overestimate the country's economic growth and that, by implementing the 5,000 MW-plus program, Kenya would be left with excess power generation capacity, which would result in higher electricity prices for end consumers.

There is an indispensable need for a more reliable, more cost-competitive, and more readily available electricity system if the country wants to sustain its economic growth and meet future electricity demand. This paper identifies specific investment niches, including:

- the modification of diesel and gasoline generators to run on methanol or ethanol
- off-grid solar systems, particularly home solar and mini-grid systems

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[2] The full connection cost is KSh150,000 ($1,453) per household.

[3] Using a conversion rate of 100 Kenyan shillings to a dollar.

[4] "Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage." World Bank, "Electric Power Transmission and Distribution Losses (% of Output)" (under "Details"), http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?locations=XM&page=4, accessed on May 12, 2017.

[5] Least Cost Power Development Plan 2011/2031.

[6] Government of the Republic of Kenya, Second Medium Term Plan 2013-2017 – Transforming Kenya: Pathway to Devolution, Socio-Economic Development, Equity and National Unity, Nairobi, 2013, p. 20.

[7] See Figure 7.

- the erection of 5,000 km of transmission lines
- innovative financial solutions to finance connection fees to the electricity grid

Finally, we offer several recommendations for key stakeholders to consider:

- the simplification of complex regulatory requirements
- assessment of the experience of IPPs (independent power producers) to create the conditions for improved IPPs
- power pricing mechanisms according to order of merit, in a more competitive manner rather than as a consequence of direct agreements (power purchase agreements)
- the mapping of the population with no access to electricity, categorizing households according to income level and available income for energy consumption, and determining the most cost-efficient technology to provide access to electricity to the different households according to their resources and needs
- the elaboration of protocols to standardize the most cost-efficient technologies to provide access to electricity to unconnected households
- given that lack of community consent is another barrier for the take-up and use of electricity, it is necessary to assess and improve the engagement of local communities and landowners in all phases of new project infrastructure

Introduction

This paper examines the different resources that can be harnessed to power Kenya. The paper is divided into four sections. The first section scrutinizes the legal and regulatory framework, and the power supply structure that derives from the legal framework. This section concludes by asking whether the legal and regulatory provisions for liberalizing the power generation system in Kenya have resulted in a more competitive market or not.

The second section describes the power supply and demand system in the country, and it concludes with two remarks. First, there is a mismatch between the projected figures and the actual figures for GDP growth, peak load and installed capacity. Second, there is a need to remove the affordability-related and availability-related barriers to unlock the array of social benefits (related to the Human Development Index) and economic benefits (related to GDP growth) that come with greater access to electricity and higher power consumption per capita.

The third section shows investment opportunities in the power supply system – especially in power generation – while acknowledging there is momentum that is aligned with national policy priorities and the multilateral donors' agenda. The 40% of the population with a low level of monthly electricity consumption and the 60% of the population with no access to electricity represent a lucrative opportunity for investors as long as the business plan addresses the three key challenges that limit electricity access:

- Affordability: power needs to be supplied in the most cost-efficient manner possible while all costs must be cut and reduced to the fundamentals.
- Availability: the technology must be able to reach households living in remote areas, far from the national grid, as well as those living in the slums.

- Reliability: frequent power outages and blackouts persist and, whether the fault is with generation transmission or distribution, they represent a significant challenge for electricity expansion and use.

This paper gives special prominence to extending access to electricity. Of particular relevance are the investment opportunities available with off-grid technologies, which would enable many Kenyans outside the national grid's reach to access electricity and enjoy the associated degree of development.

Extending access to electricity to all Kenyans would translate into greater economic growth. Moreover, improvement in the electricity system would enable the country to enter an industrialization phase, which is the goal of Kenya's central government. The energy policy that will support this new era of industrialization is expressed in Vision 2030 and the Least Cost Power Development Plan (LCPDP). Kenya Vision 2030 was launched in June 2008 and it aimed "to transform Kenya into a newly industrializing, middle-income country, providing a high quality of life to all its citizens by 2030."[8] The plan rests on three pillars: economic, social and political. The three pillars are anchored on eight key enablers, energy being one of them. Vision 2030 included a medium-term plan that aimed to increase generation capacity by 5,538 MW by February 2017.[9]

The Least Cost Power Development Plan 2011-2031, effective since March 2011, estimated that peak load would grow from 1,155.85 MW in 2011 to 15,026 MW by the year 2031, which would be 13 times the starting level. This would require an expansion of the installed capacity.

> "The government of Kenya in its LCPDP for period 2011-2031 identified that geothermal is the least-cost choice technology to meet Kenya's growing energy demand. The cumulative geothermal capacity target is 5.5 GW [5,530 MW] for the planning period, which is equivalent to 26% of the system peak demand by 2031. Wind and hydro power plants will provide 9% and 5% of total capacity respectively by 2031.[10]
>
> "The present value of the total system expansion cost over the period 2011-2031 for the reference case development plan amounts to US$41.4 billion, expressed in constant prices as of the beginning of 2010."[11]

Is this perhaps an overambitious target? Not quite. After all, in Africa, Kenya is not unique in its desire to expand its power generation capacity, and quickly. Angola, for instance, is aiming to increase its annual generating capacity from 1,800 MW to 9,000 MW by 2025, while South Africa is adding about 15,000 MW to its grid, which is about as much as what the rest of sub-Saharan Africa currently produces.

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[8] Kenya Vision 2030, "About Kenya Vision 2030," http://www.vision2030.go.ke/about-vision-2030/, accessed May 13, 2017.

[9] Government of the Republic of Kenya, Second Medium Term Plan 2013-2017 – Transforming Kenya: Pathway to Devolution, Socio-Economic Development, Equity and National Unity, Nairobi, 2013, p. 20.

[10] International Energy Agency, "Least Cost Power Development Plan 2011-2031," http://www.iea.org/policiesandmeasures/pams/kenya/name-127279-en.php?return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy9yZW5ld2FibGVlbmVyZ3kvIj5SZW5ld2FibGUgRW5lcmd5PC9hPjwvbmF2Pg,,&s=dHlwZT1yZSZzdGF0dXM9T2s, accessed May 13, 2017.

[11] Idem.

The installed power capacity doubled in Kenya from 1,197 MW in 2007 to 2,334 MW in 2015. Geothermal expanded from 128 MW in 2007 to 627 MW in 2015. Expansion in installed capacity and economies of scale have enabled a significant drop in upfront connection fees from KSh100,000 in 2007 to KSh15,000[12] in 2015, which still represents one of the main insurmountable barriers to obtaining access to electricity in the country.

The electricity produced in the country is still unreliable and Kenyan firms lose approximately 9.3% of sales (revenues) due to power outages. The severe droughts experienced in 1999 affected power generation to such a degree that the government negotiated with the World Bank to fund three emergency diesel-fired power plants. These plants were installed by independent power producers (IPPs) at Embakasi (75 MW), and Ruaraka (30 MW), in Nairobi, at a total net project cost of $120.57 million. The country was on its knees as the Kenya Power and Lighting Company (KPLC) was the only generator, transmitter and distributor of electricity.

Although, in the past, the generation, transmission and distribution of electricity were in a vertically integrated system in the hands of KPLC, the electricity subindustry in Kenya has gradually evolved from a monopolistic market to a relatively competitive market. Electricity generation has been liberalized, with several licensed IPPs already operating in the generation system. While the Kenya Electricity Transmission Company (KETRACO) retains control of the transmission, distribution and retail activities are in the hands of KPLC and the Rural Electrification Authority. The Energy Act of 2015 opened up electricity distribution to private investors.

The progressive liberalization of the electricity market has resulted in the presence of 11 IPPs.

> "Its first IPPs date back to 1996, and since then the country has closed 11 projects for a total of approximately 1,065 MW and $2.4 billion in investment. Although these numbers are small from a global standpoint, IPPs will soon represent more than one-third of Kenya's total installed generation capacity."[13]

However, the actual process of procuring new power through IPPs has performed below expectations in terms of producing the expected decrease in electricity prices and making the overall power supply more reliable.

Furthermore, in Kenya, it takes 97 days for a business to obtain an electricity connection after requesting one, compared to 34 days in nearby Rwanda. The waiting period to get connected to the electricity grid together with the tedious bureaucratic process involved represent a deterrent to entrepreneurship.

There are also significant challenges in transmission and distribution. At 17.5% of total output, transmission and distribution losses due to the poor state of the grid and theft place the country between the boundaries of low-income countries (18%) and lower-middle-income countries (15.7%). If the country is to meet expected future demand, as forecast in the Least Cost Power

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[12] KSh15,000 represents 10% of the total connection cost, 90% of which is subsidized.

[13] Anton Eberhard, Katharine Gratwick, Elvira Morella, and Pedro Antmann, *Independent Power Projects in Sub-Saharan Africa: Lessons From Five Key Countries* (Washington, D.C.: World Bank Group, 2016), https://openknowledge.worldbank.org/bitstream/handle/10986/23970/9781464808005.pdf, p. xl.

Development Plan and Kenya Vision 2030, Kenya needs "to develop approximately 10,345 km of new lines at an estimated present cost of USD 4.48 billion."[14]

This paper has found that the underlying macroeconomic assumptions about the expected electricity demand were too optimistic in Kenya Vision 2030 and the Least Cost Power Development Plan was too optimistic: they overestimated economic growth. Thus, if installed capacity is expanded in line with these estimates, the country will be left with excess capacity, which will translate into higher electricity tariffs. Overinvestment would lead to idle capacity, heavy sunk costs and suboptimal utilization of resources. The associated costs would be passed on to customers, and the gap between connected and unconnected households would widen further.

Although shortcomings in the electricity sector threaten Kenya's long-term economic growth and competitiveness, they also provide an unprecedented opportunity for investment. Renewable energy sources have come to dominate power generation in Kenya, as they account for 81.3% of total power generated, while fossil fuels account for the remaining 18.7%. More specifically, geothermal plants account for the largest source of total electricity generation in Kenya at 43.1% of total power production, while hydropower is a close second at 36.8%. At the end of 2014, Kenya was among the 10 countries with the largest amount of geothermal capacity installed.[15]

Various businesses seek to tap into natural resources to generate electricity. M-Kopa Solar, for example, is a novel initiative that offers solar panels to provide electricity in informal settlements and it allows payment in instalments. To date, it has sold 350,000 systems in Kenya, Uganda and Tanzania.

The Legal and Regulatory Electricity Framework

When Kenya was under British rule (1895-1963), in March 1920 the Parliament in what was then the Colony and Protectorate of Kenya passed the Electric Power Act, "to facilitate and regulate the generation, transmission, transformation, distribution, supply and use of electric energy for lighting and other purposes […]."[16]

The Electric Power Act of 1920 established concepts that would have lasting significance in the country's electricity regulatory framework long after Kenya became independent of British rule. Moreover, the Act created a system of licenses to regulate the emerging electricity market. The concepts dealt with in the Act included bulk supply and bulk supply area, compulsory acquisition, and distributing area. Although the Act opened up electricity generation, transmission and distribution to everyone, both public and private, public bodies had precedence when competing for licenses in a specific area:

> "Where two or more applicants make applications for licences under this Act for the supply of electrical energy for the same area and one of such applicants is a public or local

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[14] International Energy Agency, "Least Cost Power Development Plan 2011-2031," http://www.iea.org/policiesandmeasures/pams/kenya/name-127279-en.php?return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy9yZW5ld2FibGVlbmVyZ3kvIj5SZW5ld2FibGUgRW5lcmd5PC9hPjwvbmF2Pg,,&s=dHlwZT1yZSZzdGF0dXM9T2s, accessed May 13, 2017.

[15] Renewable Energy Policy Network for the 21st Century, *Renewables 2015: Global Status Report* (Paris: REN21 Secretariat, 2015), p. 48.

[16] The Electric Power Act (Nairobi: Government Printer, revised edition 1986), http://kenyalaw.org/kl/fileadmin/pdfdownloads/RepealedStatutes/ElectricPowerActCap314.PDF.

authority having jurisdiction for other purposes in such area or part thereof, the application of such authority shall take precedence of any other application."[17]

Since 1989 Kenya has experienced an ongoing process of reforms aimed at preparing the terrain for further competition. The enactment of the Restrictive Trade Practices, Monopolies and Price Control Act of 1989 promoted competition by reducing the direct control of prices in the economy. The Competition Act of 2010 provided for the establishment of the Competition Authority of Kenya, "which has a mandate of consumer protection through competition including receiving and investigating consumer complaints."[18]

The structure of Kenya's electricity supply may be traced back to reforms that swept the industry in the mid-1990s. During the '90s, Kenya, along with many other growing economies in Africa, had to design a new strategy to maintain economic growth, since funding from the European Union was diverted to Eastern Europe as a result of the end of the Cold War and the need to rebuild the nascent economies in the former Soviet Union. Furthermore, "as the country emerged from an aid embargo, one of the main objectives of these reforms was to attract much-needed private sector investment to complement limited public sector funding."[19] It is within this general context that the Electric Power Act of 1997 should be read.

This Act established the foundation of Kenya's current energy regulation regime by *unbundling* power generation from transmission and distribution. At that time, KPLC, "which had served as an integrated utility since 1954, was unbundled. The KPLC began to focus exclusively on the transmission and distribution of electricity, while the Kenya Electricity Generating Company (KenGen) took over all public power generation activities."[20] The Act enabled a transition from a vertically integrated structure – in which the generation, transmission and distribution were run by the same state corporation (KPLC) – to a horizontal integration framework, where KenGen and IPPs generate power while KPLC transmits and distributes it.

The sector was further restructured in the 2000s, when KETRACO was formed to provide power transmission, while KPLC remained in charge of power distribution. In addition, the Energy Act No. 12 of 2006 consolidated all laws relating to energy, including those relating to electricity, and provided the legal framework for the establishment of the Energy Regulatory Commission as the energy sector's sole regulatory agency, with responsibility for the economic and technical regulation of the electricity and petroleum subindustries.

The Energy Act of 2015 was passed in August that year, with the result that the licensing of electricity transmission and distribution was liberalized. The Act also suggests further reform of legal and institutional frameworks to facilitate a competitive wholesale market structure in the country.

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[17] Ibid., p. 14, Cap. 314, provision 6.

[18] CUTS International, "State of Electricity Reforms in Kenya, Country Base Paper" (Rajasthan, India, 2012), http://www.cuts-international.org/ARC/Nairobi/REKETA/pdf/Country_Base_Paper-State_of_Electricity_Reforms_in_Kenya.pdf.

[19] Anton Eberhard, Katharine Gratwick, Elvira Morella, and Pedro Antmann, *Independent Power Projects in Sub-Saharan Africa: Lessons From Five Key Countries* (Washington, D.C.: World Bank Group, 2016), https://openknowledge.worldbank.org/bitstream/handle/10986/23970/9781464808005.pdf, p. 100.

[20] Ibid., p. 11.

Structure of the Electricity System in Kenya

The electricity subindustry is one of the cornerstones of Kenya Vision 2030. For this economic growth horizon to be made reality, there are problems that must be solved: affordable electricity prices must simultaneously offer fair returns to investors while extending electricity access to those households without it; and the electricity system must be reliable and able to accommodate the changing load. We believe that expanding access to electricity will translate into an increase in power consumption and as a result it will boost economic growth.

> "Hu and Wang revealed that a 1% increase in energy consumption increases the real value added of industrial sectors by 0.871% and a 1% increase in value added of industrial sectors boosts energy consumption by 1.103%. They found a unidirectional causation from economic growth to energy consumption. However, energy consumption is found to cause economic growth in the long run."[21]

Kenya Power is responsible for ensuring that there is adequate line capacity to maintain the supply and quality of electricity across the country. The interconnected network of transmission and distribution lines covered 49,818 km and served 4.89 million customers as of June 2016.

> "The transmission expansion plan aims to provide an additional 3,178 MVA[22] of transmission substation capacity and 3,325 km of new transmission power lines over the next five years that will serve the increasing demand and customer growth."[23]

Power generation and distribution are open to private entrants according to a system of licenses that is regulated by the Energy Regulatory Commission (ERC) and guided by the energy policies drawn up by the Ministry of Energy and Petroleum (MoE&P). The ERC was created under the Energy Act of 2006. Its functions include: providing, monitoring and enforcing regulation; handling complaints; setting and overseeing tariffs; managing licenses. The policies drawn up by Kenya's energy ministry are guided by the principle of enabling access to competitively priced, reliable, quality, safe and sustainable energy, which is essential for the achievement of Kenya Vision 2030 and the Medium-Term Development Plan (2013-2017), which identify energy as one of the infrastructure enablers for transforming Kenya into an industrialized, middle-income country.

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[21] Lu, Wen-Cheng, "Electricity Consumption and Economic Growth: Evidence From 17 Taiwanese Industries," *Sustainability* (MDPI journal), December 2016, p. 3.

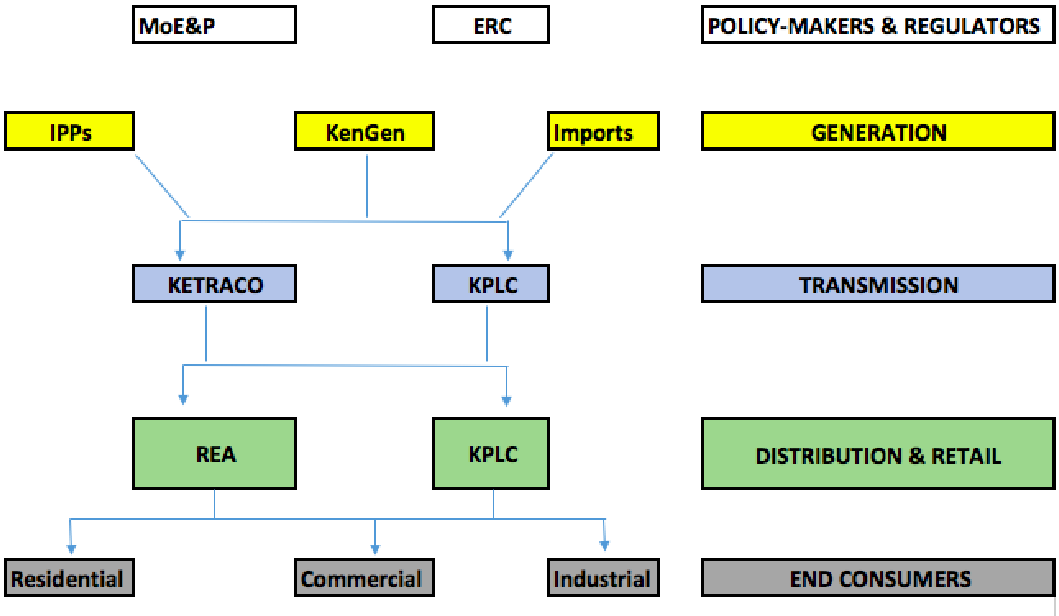
[22] Megavolt-ampere, a unit of measure of apparent power.

[23] KPLC, *Grid Development and Maintenance Plan 2016/17-2020/21* (Nairobi, 2016), http://kplc.co.ke/img/full/4GbgxauuUnXZ_GRID%20DEVELOPMENT%20final%202016.pdf, accessed May 13, 2017.

The electricity market in Kenya is a hybrid one and has the structure shown in Figure 1.

Figure 1

Structure of the electricity market in Kenya



Source: Prepared by the authors.

The main players in power generation, transmission and distribution in Kenya are:

Power Generation

The **Kenya Electricity Generating Company** (KenGen) is largely a state-owned company, with the government holding 70% of the shares. It is the leading electric power generation company in Kenya. KenGen accounts for about 75% of the electricity capacity installed in the country. The company utilizes various sources to generate electricity, including hydro, geothermal, thermal and wind.

Independent power producers (IPPs): in sub-Saharan Africa, Kenya is one of the countries with the most extensive experience in IPP projects. Its first IPPs date back to 1996, and since then the country has completed 11 projects accounting for a total of about 1,065 MW and $2.4 billion in investment. Most of the power plants developed over the past two decades run on medium-speed diesel/heavy fuel oil (MSD/HFO). Some power plants produce electricity from geothermal and wind sources.[24]

Power Transmission

The **Kenya Electricity Transmission Company** (KETRACO) was incorporated in 2008. It is 100% government-owned with a mandate to develop a new high-voltage electricity transmission infrastructure that will form the backbone of the National Transmission Grid, in line with Kenya Vision 2030. Its mandate is to plan, design, construct, own, operate and maintain high-voltage

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[24] Anton Eberhard, Katharine Gratwick, Elvira Morella, and Pedro Antmann, *Independent Power Projects in Sub-Saharan Africa: Lessons From Five Key Countries* (Washington, D.C.: World Bank Group, 2016), https://openknowledge.worldbank.org/bitstream/handle/10986/23970/9781464808005.pdf, p. 99.

electricity transmission lines and regional power interconnectors.[25] Perhaps one of the major challenges KETRACO faces is to reduce the transmission losses that currently cost the country heavily every year.

Power Distribution

The **Kenya Power and Lighting Company** (KPLC) is responsible for the transmission and distribution of electricity in Kenya. It is the offtaker in the power market, buying power from all power generators on the basis of negotiated power purchase agreements for onward transmission, distribution and supply to consumers. The company's key mandate is to plan for sufficient electricity generation and transmission capacity to meet demand; to build and maintain the power distribution and transmission network and to retail electricity to its customers. KPLC owns and operates most of the electricity transmission and distribution system in the country and sells electricity to more than 4.8 million customers (connections). The government has a controlling stake of 50.1% of the shareholdings, with private investors owning 49.9%. KPLC is listed on the Nairobi Securities Exchange.

The **Rural Electrification Authority** (REA) was established under section 66 of the Energy Act No. 12 of 2006 as a corporate body to enhance and accelerate the pace of rural electrification in the country. REA's mandate is to efficiently provide high-quality and affordable electricity connectivity in all rural areas and to achieve high standards of customer service through advancing community participation. To fulfill its role in line with Kenya Vision 2030, the authority has set the target of providing electricity to all of the following public facilities: all major trading centers, primary and secondary schools, community water supply bodies, and health centers. REA's current plan focuses on the electrification of primary schools.[26]

Concluding Remarks

Given the previous legal and regulatory framework, a horizontal power supply structure and the emergence of up to 11 IPPs, we would expect the following:

1. Diversification of power supply across power generating companies.
    a. In reality KenGen generates more than 75% of the electricity in Kenya.
    b. Power generation in Kenya shows a Herfindahl-Hirschman Index (HHI) well above 0.515[27] as of 2012/13, which indicates an extremely high concentration of activities by only a few firms, meaning low competition.
2. Greater reliability (secured) of the power generation system.
    a. In reality the country has a frequent number of outages and blackouts due to overdependency on hydro sources, which makes the country less resilient to drought.

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[25] KETRACO, "Our Mandate," http://www.ketraco.co.ke/about/index.html, accessed February 22, 2017.

[26] Rural Electrification Authority, "Project Implementation Updates," http://www.rea.co.ke/index.php?option=com_content&view=category&layout=blog&id=80&Itemid=497, accessed February 22, 2017.

[27] "The threshold for Kenya is defined as follows: an index below 0.1 indicates a non-concentrated index; an index between 0.1 and 0.18 indicates moderate concentration; an index above 0.18 indicates high concentration" – Energy Regulatory Commission, *Quality Energy for Quality Life – Annual Report, Financial Statements 2012-2013*, p. 64.

3. Greater affordability of the electricity tariff (lower electricity bills for end consumers).

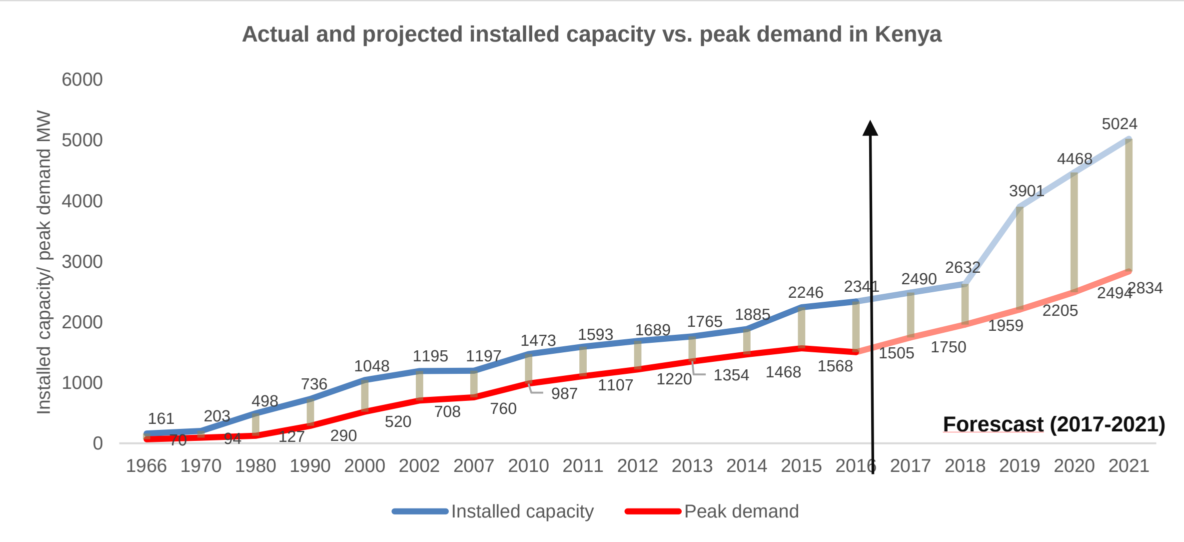
    a. In reality, at an average cost of $0.17 per kWh (kilowatt-hour), Kenya's electricity price is above the average in sub-Saharan Africa, which in turn has the priciest electricity of the world's regions. If we compare Kenya's electricity price to that of neighboring Ethiopia ($0.047 per kWh), Kenya's electricity price is 3.6 times more expensive.

Installed Capacity

Peak load (maximum power demand) in Kenya as of December 2014 was 1,468 MW. If we subtract peak demand from total installed capacity (2,203 MW as of 2014), and we subtract 17.5% to account for technical losses and theft (2,203 × 17.5 / 100 = 385.53 MW) we obtain a reserve margin of 349.47 MW (2,203 – 1,468 – 385.53). As we can observe in Figure 2, Kenya's peak demand increased from 899 MW in 2004/05 to 1,585 MW in 2015/16, while the number of electricity consumers increased fivefold from 735,144 in 2004/05 to 4,890,373 in June 2016.[28]

Figure 2

Actual and projected installed capacity vs. peak demand in Kenya



Source: KPLC, *Grid Development and Maintenance Plan 2016/17-2020/21*, p. 11 (http://kplc.co.ke/img/full/4GbgxauuUnXZ_GRID%20DEVELOPMENT%20final%202016.pdf).

According to KPLC, in June 2015 total installed capacity in the country accounted for 2,299 MW. Table 1 shows installed capacity from 2006 to 2014, as well as disaggregates capacity by renewable and nonrenewable sources. When comparing installed capacity from renewable and nonrenewable sources, we observe a significantly higher compound average growth rate (CAGR) for renewables over time.

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[28] KPLC, Grid Development and Maintenance Plan, p. 10.

Table 1

CAGR in installed capacity in Kenya, 2006-2014

Year	Total Electricity Installed Capacity	Total Renewable Installed Capacity	Total Fossil Fuels Installed Capacity
	MW	MW	MW
2006	1,426.35	839.35	587.00
2007	1,291.35	867.35	424.00
2008	1,358.35	934.35	424.00
2009	1,403.35	979.35	424.00
2010	1,529.00	1,034.00	495.00
2011	1,701.00	1,092.00	609.00
2012	1,748.00	1,111.00	637.00
2013	1,870.00	1,155.00	715.00
2014	2,203.00	1,488.00	715.00
CAGR	**4.9%**	**6.6%**	**2.2%**

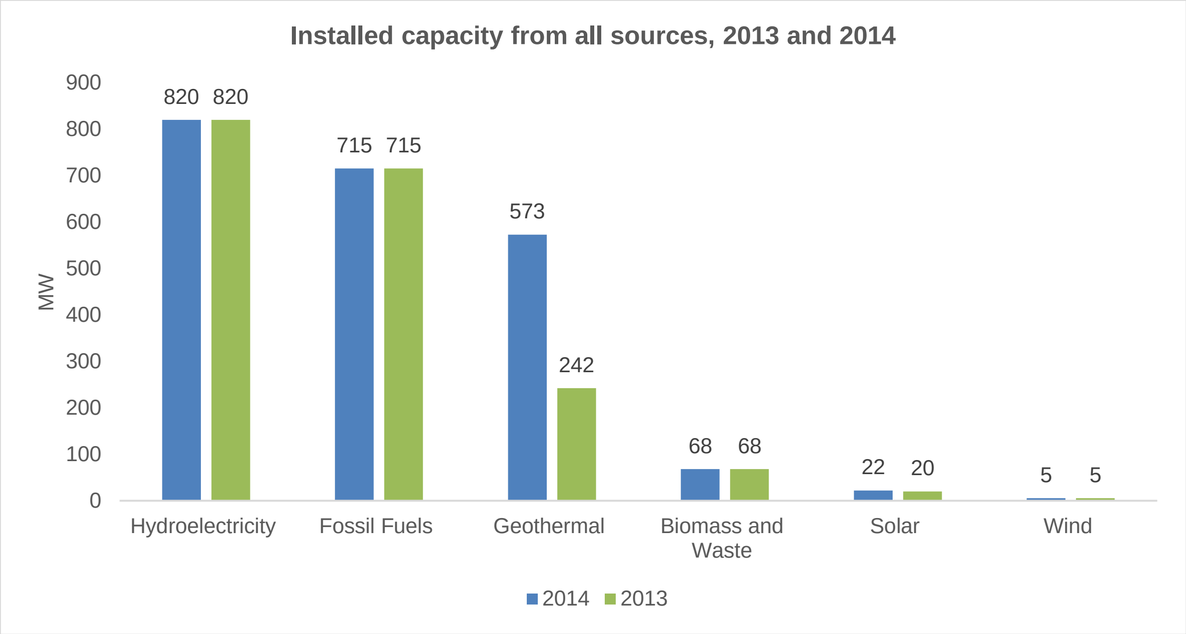
Source: Prepared by the authors, based on data from the U.S. Energy Information Administration, 2006-2014 (https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

Installed Capacity From Nonrenewable Sources

As of 2014, installed capacity from thermal oil plants – fossil fuel-fired plants – accounted for 32.7% of total installed capacity in the country. In 2014, installed capacity from fossil fuels was not expanded from the previous year, as we can observe in Figure 3.

Figure 3

Installed capacity in Kenya 2013 and 2014



Source: Prepared by the authors, based on data from the U.S. Energy Information Administration, International Energy Statistics, Kenya (https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

Installed Capacity From Renewable Sources

In 2014, more than 1,490 MW of power generation capacity involved renewable energy sources, which accounted for 67.7% of the total installed capacity in Kenya. Between 2006 and 2014, installed capacity from renewable sources showed a CAGR of 6.6%, three times the CAGR power capacity from fossil thermal sources.

Hydroelectric power continues to yield the largest power generation capacity in the country. Interestingly, although installed capacity from solar sources (22 MW) surpasses wind (5 MW), electricity generation from wind sources is higher (0.04 thousand GWh) than solar (0.03 thousand GWh) as we will discuss later. This is probably due to the fact that, in Kenya, the levelized cost of electricity (LCOE)[29] from wind sources is cheaper than from solar sources, which shows a lower utility factor.[30] (See **Appendix 1**.)

Kenya is an attractive market for renewables given a combination of factors such as the high insolation rate, excellent wind regime areas, abundant hydro and geothermal resources, zero-rated import duty and the removal of VAT from renewable energy equipment, and a government and business community committed to renewable electricity sources to fuel the country on the path to industrialization. Below, we provide a snapshot of the current installed capacity and the growth potential of all renewable sources:

1. Hydro power had an installed capacity of 820 MW as of 2014. Large-scale hydro has a potential to develop a total capacity of 4,500 MW, with 1,500 MW from projects of a capacity of 30 MW. Likewise, small, mini and micro hydroelectric systems (with capacities of less than 10 MW) have the potential to generate 3,000 MW nationwide.[31] Potential

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[29] The levelized cost of electricity in U.S. cents per kWh. This is an approximation for the price at which electricity would need to be sold to break even.

$$LCOE = \frac{Capital\ Cost\ \times CRF\ \times\ (1 - TD_{PV})}{8760\ \times Capacity\ Factor\ \times (1 - T)} + \frac{fixed\ O\&M}{8760 \times Capacity\ Factor} + \frac{variable\ O\&M}{1{,}000\ \frac{kWh}{MWh}} + \frac{Fuel\ Price\ \times Heat\ Rate}{1{,}000{,}000\ \frac{BTU}{mmBTU}}$$

The capital cost refers to the cost of the plant and it is expressed in U.S. dollars per kW. CRF is the capital recovery factor, whereby capital expenditure is transformed into annual payments using the formula: $CRF = \frac{D\ (1 + D)^N}{(1 + D)^N - 1}$, where D is the discount rate or the effective rate at which future income streams are discounted and it is usually 7% for generation, and N is the lifetime of the investment or the assumed lifetime of a new plant and the period over which the investment is computed, usually around 25 to 30 years. T stands for the tax rate paid (applied after depreciation credits). D_{PV} stands for the present value of depreciation and depends on the MACRS (Modified Accelerated Cost Recovery System) schedule, which varies across technologies, while 8760 is the number of hours in a year. The capacity factor is expressed as a percentage and the average capacity factor will be used primarily (annual average percentage of power as a fraction of nameplate capacity), and the maximum capacity factor is used in the absence of the former. Fixed O&M stands for the fixed operations and maintenance cost of the plant per capacity, so it is expressed in U.S. dollars per kW. Variable O&M refers to the variable operations and maintenance cost of the plant per capacity, so it is expressed in U.S. dollars per kW. Fuel price means the fuel cost of the plant and it is expressed in U.S. dollars per mmBTU (million British thermal units). (The cost depends on the type of fuel used, the most expensive being fossil fuels.) Heat rate refers to the efficiency of the power plant in converting fuel into electricity and it is expressed in U.S. dollars per mmBTU. Source: Open Energy Information, "Levelized Cost of Energy – LCOE," http://en.openei.org/apps/TCDB/levelized_cost_calculations.html#lcoe, accessed May 14, 2017.

[30] "The ratio of the net electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same period." – United States Nuclear Regulatory Commission, "Capacity Factor (Net)" (NRC Library, Basic References, Glossary), https://www.nrc.gov/reading-rm/basic-ref/glossary/capacity-factor-net.html, accessed May 14, 2017.

[31] Africa-EU Renewable Energy Cooperation Programme, "Renewable Energy Potential," https://www.africa-eu-renewables.org/market-information/kenya/renewable-energy-potential/, accessed March 25, 2017.

resources have been identified in the Lake Victoria Basin, Rift Valley, Athi River Basin, Tana River Basin and Ewaso Ngiro North River Basin. However, these projects are excluded from the Least Cost Power Development Plan.

2. Geothermal power had an installed capacity of 573 MW as of 2014, and a potential of 10,000 MW, of which at least 2,000 MW is located in the Rift Valley. Geothermal has comparably lower electricity production costs (see LCOE in Appendix 1) and it has been identified as a cost-effective power option in the government's Least Cost Power Development Plan.[32]

3. Wind power had an installed capacity of 5 MW as of 2014, and it generated 0.04 thousand GWh the same year. "Thanks to its topography, Kenya has some excellent wind regime areas. The northwest of the country (Marsabit and Turkana districts) and the edges of the Rift Valley are the two windiest areas (with average wind speeds of over 9 m/s at 50 m). The coast has lower but promising wind speeds (about 5-7 m/s at 50 m)."[33] Similarly to geothermal, wind power has comparably lower electricity production costs in Kenya. (See LCOE in **Appendix 1**.)

4. Solar power had an installed capacity of approximately 22 MW as of 2014, and a potential output of 23,046 TWh/year for photovoltaic. "Kenya has high insolation rates, with an average of 5-7 peak sunshine hours and average daily insolation of 4-6 kWh/m^2 [average annual insolation of 1,460-2,190 kWh/m^2]. 10-14% of this energy can be converted into electricity due to the dispersion and conversion efficiency of PV modules."[34] Photovoltaic standalone systems are becoming the bridge technology for the electrification gap between rural areas (6.7% electrification rate) and urban areas (58.2%). The Kenyan government is aiming to install 500 MW and 300,000 domestic solar systems by 2030. Moreover, hybrid PV-diesel island grids are multiplying. The REA plans to invest approximately $40 million in greenfield hybrid island grids.[35]

5. Biomass and waste had an installed capacity of approximately 68 MW as of 2014. A very conservative estimation – which considers only bagasse out of the many kinds of sugarcane and agricultural waste – suggests that the "total potential for cogeneration using sugarcane bagasse is 193 MW. Mumias Sugar Company (Independent Power Producer) generates 35 MW, out of which 26 MW is dispatched to the grid. However, opportunities within other sugar factories estimated to be up to 300 MW have not been exploited."[36]

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[32] Ibid.

[33] Ibid.

[34] Ibid.

[35] Ibid.

[36] Energy Regulatory Commission, "Biomass," http://www.renewableenergy.go.ke/index.php/content/29, accessed February 22, 2017.

Additional Installed Capacity: Kenya Vision 2030

Scaling up access to electricity and ensuring reliable power supply are key elements of Kenya Vision 2030, the country's developmental blueprint aimed at transforming the country into a "newly industrializing, middle-income"[37] economy before the year 2030, by creating jobs through the promotion of economic development, growth and competitiveness.

Kenya Vision 2030 included a medium-term plan that aimed to expand electricity generation capacity by at least 5,000 MW,[38] from 1,664 MW as of October 2013 to a total of slightly over 6,700 MW by February 2017.[39] The underlying macroeconomic indicator behind the desired level of additional power capacity assumed that the Kenyan economy would grow at an average annual rate of 7.6% between 2011 and 2018. (See Table 2.)

Table 2

Macroeconomic indicators underlying Vision 2030's medium-term plan

	Indicator	2011/12	2012/13 Projection	2013/14 Projection	2014/15 Projection	2015/16 Projection	2016/17 Projection	2017/18 Projection
Annual percentage change	Real GDP	4.5	5.4	6.7	7.8	8.7	9.6	10.6
	CPI Index (EOP)	10.1	6	5.50	5	5	5	5
	CPI Index (AVG)	16.1	5.9	6	5	5	5	5

Source: Prepared by the authors, based on data from the Kenya Vision 2030, Second Medium-Term Plan 2013-2017, Transforming Kenya: Pathway to devolution, socio-economic development, equity and national unity, p. 11 (http://www.vision2030.go.ke/).

The 5,000 MW-plus program – which is part of the Second Medium-Term Plan 2013-2017 – was initiated to increase generation capacity, facilitate increased national electricity connectivity, and to change the generation mix with the expectation of reducing overreliance on hydroelectric power and lowering the general price of electricity. Through this program, the generation of expensive thermal power, whose sources are fossil fuels, was expected to decrease, which should result in lower costs of electricity, due to the use of less fossil fuels as primary energy sources. Fuel costs are the main drivers of electricity costs.[40]

This capacity is expected to develop from 1,646 MW from geothermal, 1,050 MW from natural gas, 630 MW from wind and 1,920 MW from coal through IPPs under the power purchasing agreement framework. Figure 4 shows projected additions to the generation capacity.

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[37] Kenya Vision 2030, "About Kenya Vision 2030," http://www.vision2030.go.ke/about-vision-2030/.

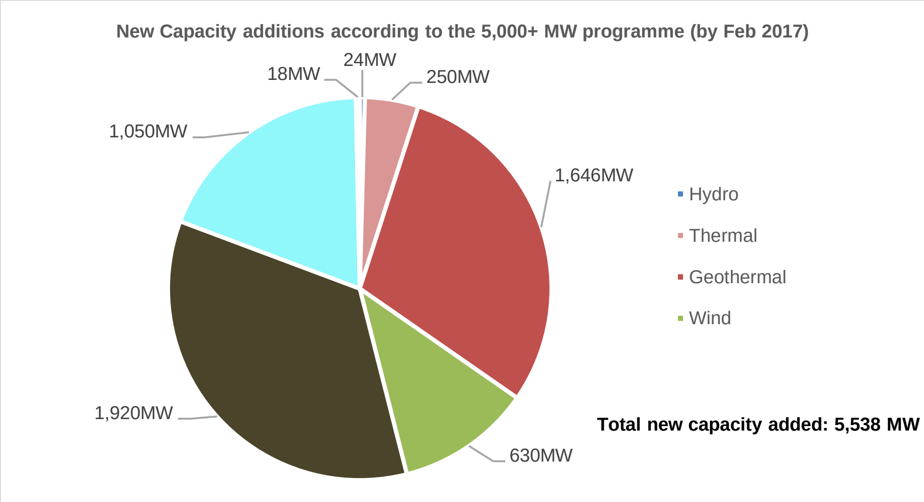
[38] Also referred to as the "5,000 MW-plus program."

[39] Government of the Republic of Kenya, Second Medium Term Plan 2013-2017 – Transforming Kenya: Pathway to Devolution, Socio-Economic Development, Equity and National Unity, 2013, p. 20.

[40] Between November 2016 and December 2016, the cost of electricity increased as a result of fuel adjustment charges, which increased from KSh2.34 per kWh in November 2016 to KSh2.85 per kWh the following month. See: Kenya National Bureau of Statistics, consumer price indices and inflation rates for December 2016.

Figure 4

Capacity additions under the 5,000 MW-plus program, 2013-2017



Source: Prepared by the authors, based on data from the Ministry of Energy and Petroleum, *National Energy and Petroleum Policy*, June 26, 2015, p. 70 (http://www.erc.go.ke/images/docs/National_Energy_Petroleum_Policy_August_2015.pdf).

Cumulative installed capacity – under the 5,000 MW-plus program – makes no mention of solar energy. However, given that Kenya straddles the equator, this form of renewable energy has great potential for growth and adoption: 70% of the land area enjoys more than 1,825 kWh/m^2 per year,[41] sufficient to provide electricity to more than 80% of Kenya's currently off-grid population. Kenya's average insolation is significantly higher than the average insolation in Germany – "in Germany where 40 GW of installed solar capacity is in place, the average irradiation value is just over 1,150 kWh/m^2/year if the slope is optimised."[42]

In the 5,000 MW-plus program, solar energy was left out, and there was a preference for coal-fired and liquefied natural gas (LNG) power plants. The amount of coal required to fuel the 1,920 MW coal-fired power plants was to be procured locally. The Kenyan government has been conducting coal exploration since the 1990s and has found more than 40 wells in the Mui Basin of Kitui County. The Kenyan government expects to get 4,500 MW of installed capacity from coal-fired power plants by 2030.

LNG-fired power plants could be fueled by the large, proven natural gas reserves in neighboring Tanzania, which has been in talks since 2016 about plans to build an onshore LNG export terminal at its southern port of Lindi.

The Kenyan government's plan to boost power generation capacity aims to achieve a CAGR of 42%,[43] compared to the 4.9% rate observed in recent years. (See Table 1.)

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[41] Francis Oloo, Luke Olang and Josef Strobl, "Spatial Modelling of Solar Energy Potential in Kenya," *International Journal of Sustainable Energy Planning and Management* 6 (2016): 28.

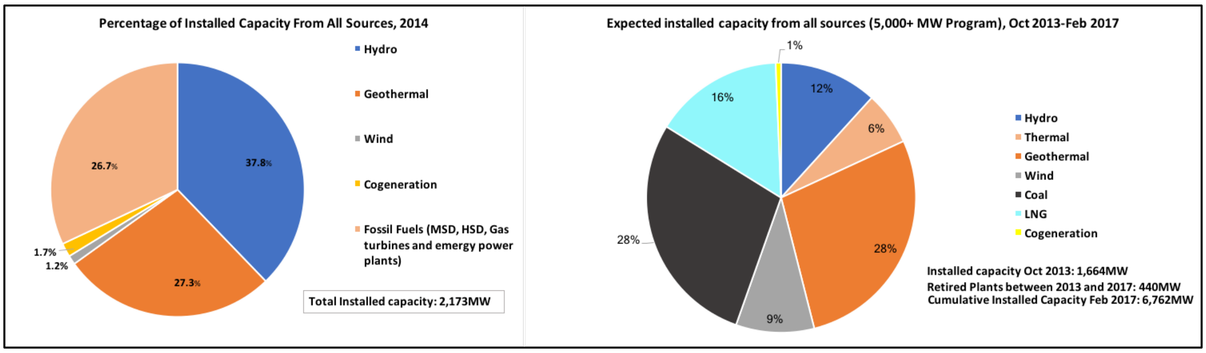
[42] International Renewable Energy Agency (IRENA), *Solar PV in Africa: Costs and Markets* (Bonn: IRENA, 2016), https://www.irena.org/DocumentDownloads/Publications/IRENA_Solar_PV_Costs_Africa_2016.pdf, p. 33.

[43] Considering 1,664 MW (October 2013) as the base line and 6,700 MW (February 2017) as the end line, and the period in between.

Figure 5 illustrates the actual generation capacity mix in 2014 compared to the projected generation capacity mix for 2017 under the 5,000 MW-plus program, once all the new generating plants are in place.

Figure 5

Current installed capacity vs. expected installed capacity after implementation of the 5,000 MW-plus program, 2013-2017



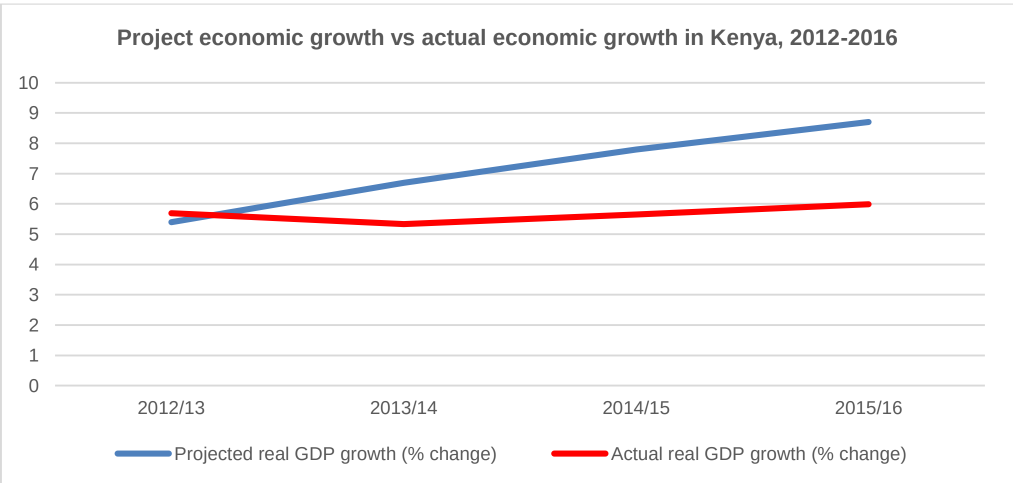
Source: Prepared by the authors, based on data from the Ministry of Energy and Petroleum, National Energy and Petroleum Policy, June 26, 2015, pp. 69-71.

The pie chart on the right of Figure 5 shows the cumulative installed capacity, comprising the actual capacity as of 2013 along with the new additions planned in the 5,000 MW-plus program. If the medium-term plan had been implemented according to schedule, the cumulative installed capacity by February 2017 would have been 6,762 MW, a figure far higher than what it actually is today.

However, if we step back and analyze in detail the underlying assumptions that support Vision 2030 and its medium-term plan in terms of capacity additions, we realize that the projected economic growth scenarios were too optimistic. The government forecast a CAGR in GDP at an average of 12.66% between 2012 and 2016, whereas the actual CAGR was 1.29% for that period. (See Figure 6.)

Figure 6

Projected GDP growth (Vision 2030) vs. actual GDP growth in Kenya, 2012-2016



Source: Prepared by the authors, based on the Second Medium-Term Plan 2013-2017 of Kenya Vision 2030 (projected GDP growth), p. 11 (http://www.vision2030.go.ke/); International Monetary Fund, World Economic Outlook (October 2016) (actual GDP growth), p. 47 (http://www.imf.org/external/pubs/ft/weo/2016/02/).

Based on these far too optimistic macroeconomic assumptions, the government estimated that peak demand would jump threefold to 4,755 MW by 2020. Thus, if the 5,000 MW-plus program is not adjusted according to actual economic growth, the medium-term plan will leave the country with excess power capacity, which will, in turn, result in higher electricity costs for end consumers.

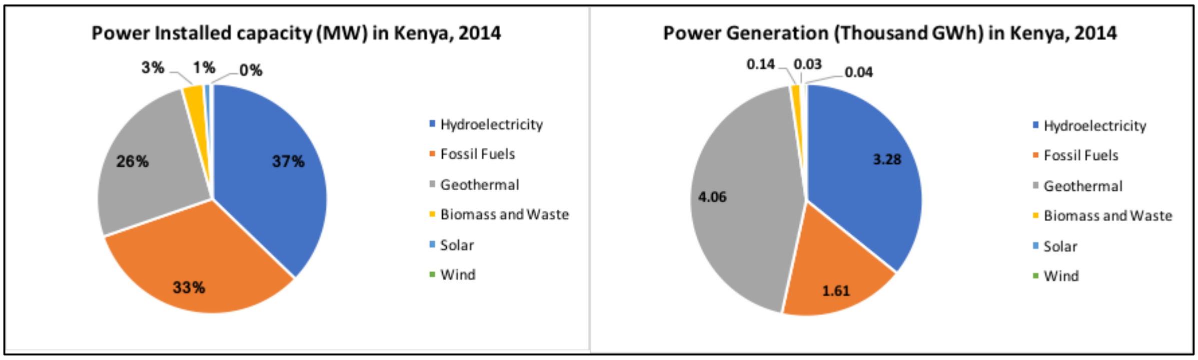
Power Generation

In the previous section, we analyzed installed capacity (MW). In this section we will discuss the energy (MWh) that is actually produced from these sources of installed capacity.

With 80% of electricity generation stemming from renewable sources, Kenya has one of the greenest electricity generation mixes in the world. Although hydroelectricity continues to capture the largest share of the country's installed capacity, in a country that faces extreme periods of drought, overdependence on hydro poses serious intermittency problems, which over time has been translated into greater generation from geothermal sources. (See Figure 7.)

Figure 7

Installed power capacity and power generation in Kenya, 2014

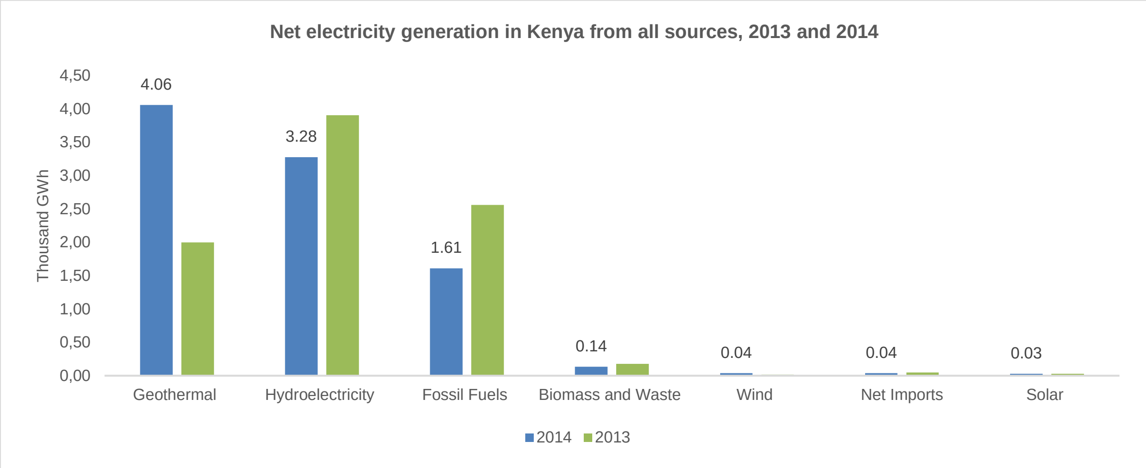


Source: Prepared by the authors, based on data from the U.S. Energy Information Administration, International Energy Statistics Kenya (https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

However, regarding electricity generation, as can be observed in Figure 8, in 2014 geothermal surpassed hydro for the first time, making it the largest electricity generating source in the country. Furthermore, based on government plans and geothermal potential, it looks like this source of energy will remain Kenya's main power contributor in the medium to long term.

Figure 8

Power generation from all sources in Kenya, 2013-2014

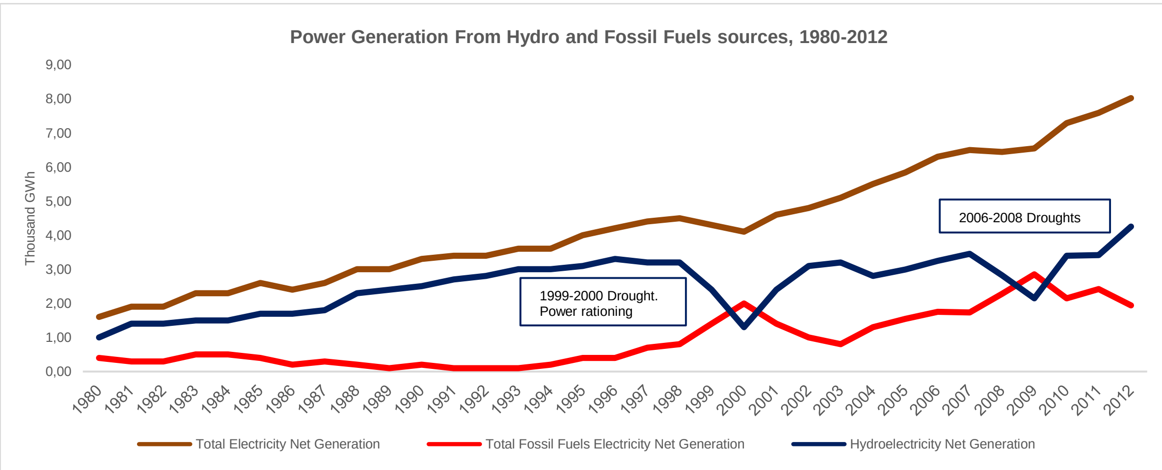


Source: Prepared by the authors, based on data from the U.S. Energy Information Administration (https://www.eia.gov/beta/international/data/browser/#/?pa=000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

For the period between 1999 and 2012, data in Figure 9 show an inverse relation between hydro and fossil fuel plants in terms of electricity output, which suggests that when hydro is not available, it is replaced by fossil fuel-based electricity generation. The largest drops in electricity generation took place in 1999 and from 2006 to 2008 and were the result of major droughts in the country. The effect of these droughts on power generation from hydro sources was cancelled out by corresponding increases in electricity generated from fossil fuel sources. As power generation from hydro sources falls into a trough, fossil fuel-based electricity generation peaks, and vice versa. In addition, Kenya imports electricity to compensate for such reductions in electricity output.

Figure 9

Power generation from hydro and fossil fuels in Kenya, 1980-2012



Source: Prepared by the authors, based on data from the U.S. Energy Information Administration (https://www.eia.gov/beta/international/data/browser/#/?pa=000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

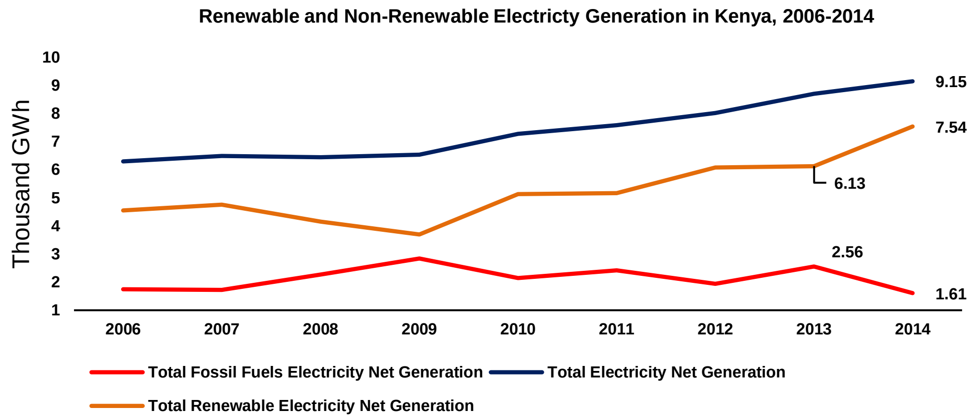
Hydro is one of the least expensive types of energy. While building the required facilities is capital intensive, these are generally less expensive to operate than those for fossil fuels. Whether or not tariff rates increase (and by how much) could depend on how well a utility has prepared, hedged, or diversified its power procurement portfolio for the eventuality of extreme drought conditions.

Nonrenewable Sources

In 2014, power generation from fossil fuel sources dropped sharply from the previous year, decreasing from 2.56 thousand GWh to 1.61 thousand GWh, which in 2014 represented 17.6% of the total net electricity generation in Kenya. Figure 10 shows the change in net electricity generation in Kenya from renewable and nonrenewable sources.

Figure 10

Electricity generation in Kenya, 2006-2014



Source: Prepared by the authors, based on data from the U.S. Energy Information Administration (https://www.eia.gov/beta/international/data/browser/#/?pa=000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015)

Fossil fuel electricity is generated by thermal plants that are fired from fossil fuels. Fuel costs are one of the main components of the electricity tariff. The tariff that IPPs charge the utility under a power purchase agreement formula is comprised of two main components: the energy charge and capacity payments. The energy charge due to IPPs is very much driven by fuel costs and transportation costs. The monthly energy charge (MEC) payable in USD, is calculated as follows: MEC = NEO × ECR, where ECR is the energy charge rate, which is expressed in dollars per kWh. ECR is the result of adding together two components:

1. The fuel, which comprises the base fuel price (the FOB or free on board component expressed in dollars per kWh) and the base fuel transport cost component (also expressed in dollars per kWh). This is referred to as the fuel component of the ECR.

2. The value agreed upon between the seller and purchaser regarding the base variable O&M (operations and maintenance). This is referred to as the nonfuel component of the ECR.

NEO stands for the aggregate Net Electrical Output (kWh) of the Plant in that month.

Renewable Sources

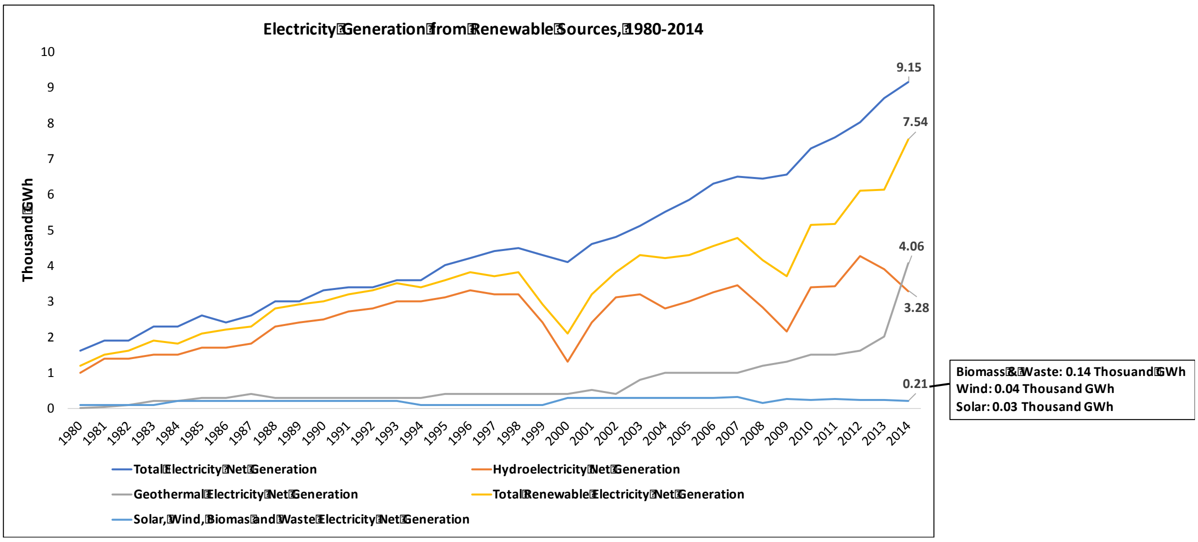
Renewable electricity sources accounted for 86.12% of Kenya's total power generation in 2014. Figure 9 shows that, in the past, hydro was the major source of power generation in Kenya. However, due to insufficient rainfall and significant disruption caused by drought, the government has been shifting investment to geothermal power plants, which are not affected by Kenya's climatological conditions. In 2014, geothermal accounted for 44.37% of net power generation, surpassing hydro for the first time in the country's history. Moreover, in the same year, "Kenya installed more than half of the world's new geothermal capacity."[44]

Hydroelectric power accounts for 36.8% of total electricity generation while wind, solar and biomass combined account for less than 1%. Renewables have the potential to enhance energy security and reliability, generate income and create employment, enable substantial foreign exchange savings by reducing dependence on imported fuels with their attendant price volatility, and mitigate climate change as they have minimal adverse effects on the environment. This state of affairs has compelled the government to establish a zero-rate import duty on and remove value added tax (VAT) from renewable energy, its related equipment and accessories.

Figure 11 shows net electricity generation from all renewable sources in Kenya. Net generation from biomass and waste sources comprised 0.14 thousand GWh in 2014, compared to 0.04 thousand GWh for wind and 0.03 thousand GWh for solar.

Figure 11

Net power generation from renewable sources in Kenya, 1980-2014



Source: Prepared by the authors, based on data from the U.S. Energy Information Administration, International Energy Statistics, electricity, Kenya (https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

[44] Renewable Energy Policy Network for the 21st Century, *Renewables 2015: Global Status Report*, p. 31.

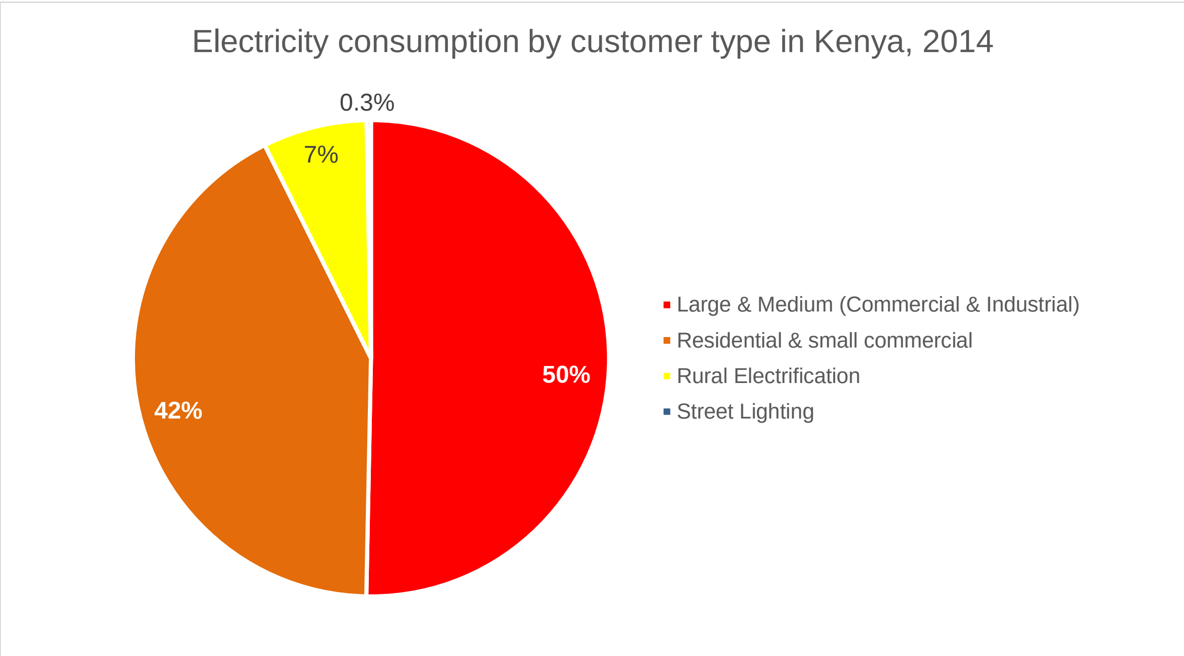
Power Consumption

Now that the supply side of the electricity subindustry has been analyzed, this section deals with the demand side.

Figure 12 shows electricity consumption by customer type. Large and medium commercial and industrial customers accounted for 50% of electricity consumption in Kenya in 2014, whereas residential and small commercial customers accounted for 42%.

Figure 12

Electricity consumption by customer type in Kenya, 2014



Source: Prepared by the authors, based on Kenya National Bureau of Statistics, *Kenya Facts and Figures 2014 (https://www.knbs.or.ke/kenya-facts-and-figures-2014/).*

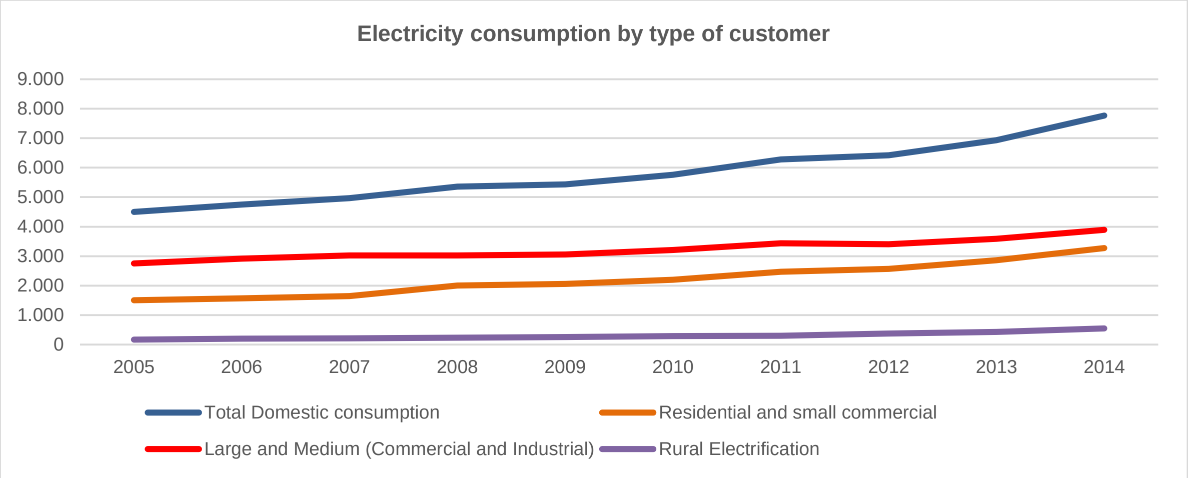
Figure 13 shows a progressive convergence between large commercial and industrial customers and residential and small commercial customers. On the other hand, we can observe that consumption in rural areas has remained consistently low over time.

Average monthly electricity consumption per capita for all types of customers in Kenya is around 155 kWh, which is below the average for sub-Saharan Africa (around 162 kWh). The average monthly electricity consumption of residential customers is around 100 kWh. For the retail price, the electricity tariff in Kenya is divided into three blocks. The first block is usually called "subsistence power consumption" and comprises 50 kWh[45] at an average retail price of KSh558.90, as of December 2016.

[45] Average electricity retail price for 200 kWh was KSh3,497, as of December 2016. See National Bureau of Statistics, Consumer Price Indices and Inflation rates for December 2016.

Figure 13

Electricity consumption by type of customer in Kenya, 2005-2014

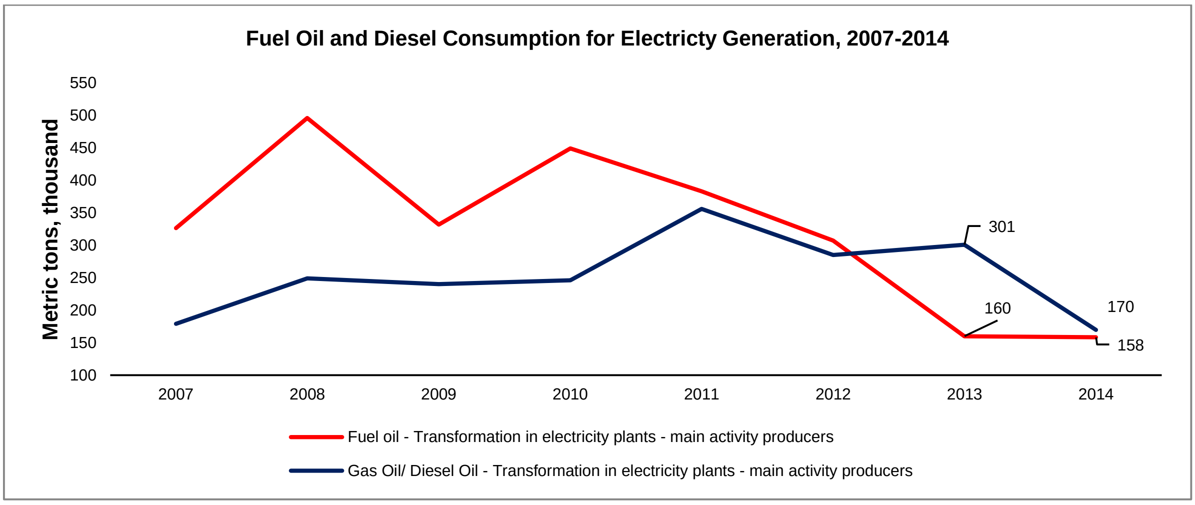


Source: Prepared by the authors, based on Kenya National Bureau of Statistics, *Kenya Facts Figures from 2005-2014 (https://www.knbs.or.ke/publications/).*

Fuel product consumption in cogeneration or combined heat and power (CHP) and thermal plants for electricity generation purposes decreased in 2013 and 2014. Figure 14 shows how, between 2013 and 2014, fuel oil dropped from 160,000 metric tons to 158,400 metric tons. Over the same period, diesel decreased abruptly from 300,000 metric tons to 170,000 metric tons.

Figure 14

Fuel oil and diesel used for power generation in Kenya, 2007-2014



Source: Prepared by the authors, based on data from the United Nations Statistics Division's Energy Statistics Database (https://unstats.un.org/unsd/energy/edbase.htm).

In 2014, petroleum accounted for 22% of Kenya's total consumption of primary energy, while coal – used mainly by cement manufacturers – provided about 1%. Nevertheless, coal – which is used principally for electricity generation – is the most affordable fuel worldwide and has the potential to become a reliable and easily accessible energy source. “In September 2014, a 900–1,000 MW coal plant was awarded to a consortium led by the Kenyan companies Gulf Energy and Centum Investment Company.”[46] As of December 2014, all coal utilized in Kenya was imported, with consumption averaging less than 1% of the total national primary energy demand in the period between 2006 and 2014. Therefore, it has potential for growth, especially after the commercial discovery of substantial reserves of the mineral in Kitui County in 2010.

In 2016, according to sources from the International Energy Agency, the country’s electricity access (in terms of population) stood at 40%. Therefore, if economic development is to be spurred on through adequate access to energy, Kenyans will need to have greater access to the electricity grid or gain access to off-grid power options. It is imperative to ensure affordable and reliable access to electricity, not only as a welfare policy but because, as studies have shown, there is a positive correlation between electricity consumption per capita and real GDP growth. Expanding access to electricity would unlock numerous economic and social benefits: “Considering electricity as a representative of modern energy, electricity consumption has significant correlation with GDP as well as HDI [Human Development Index] for 120 countries, and the countries which mark high consumption level of per capita electricity, attain upper rank of both economic activities (GDP per capita) and HDI.”[47]

Challenges

Electricity Access: Availability and Affordability

There are three axes relating to access to electricity: whether households can afford the up-front connection fees and monthly electricity bill (affordability); physical access to the electric grid (availability); and whether electricity is readily available on demand (reliability). This section will focus on the affordability and availability aspects.

The grid’s connectivity can be approached from a technical or an economic perspective. There are households that are not connected to the grid because the grid network does not cover their areas – they are out of the grid reach. Then there are households living within the grid reach that are not connected because they cannot afford the associated economic costs.

In Kenya, half of the population with no access to electricity has only $14.50 of available monthly income for energy consumption. With only $14.50 a month, people cannot afford grid electricity, which at an average consumption of 100 kWh would cost about KSh1,584 ($15.84) as of March 2017,[48] and this is without even factoring in connection fees of at least KSh15,000. This half of the population with no access to grid electricity and with $14.50 a month available for energy consumption is, in reality, the target of companies offering home solar systems, such as M-Kopa. However, the other half that is deprived of access to the electricity grid only has $9 a month for energy consumption. At this price, these households can afford only small amounts of kerosene

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[46] Anton Eberhard, Katharine Gratwick, Elvira Morella, and Pedro Antmann, *Independent Power Projects in Sub-Saharan Africa: Lessons From Five Key Countries* (Washington, D.C.: World Bank Group, 2016), https://openknowledge.worldbank.org/bitstream/handle/10986/23970/9781464808005.pdf, p. 99.

[47] Makoto Kanagawa and Toshihiko Nakata, “Assessment of Access to Electricity and the Socio-Economic Impacts in Rural Areas of Developing Countries,” *Energy Policy* 36, no. 6 (June 2008): 2018.

[48] Regulus, “Electricity Cost in Kenya,” https://stima.regulusweb.com, accessed in March 2017.

or charcoal or free-of-charge but highly polluting firewood.[49] These households, usually located in slums, cannot afford either grid electricity or off-grid electricity at 2017 prices.

Some 60% of Kenya's population is not connected to the grid. The numbers are even worse when access to electricity in rural Kenya is compared with access in urban Kenya. The distribution network offers 90% coverage in urban Nairobi but this drops to less than 10% in Kenya's rural northern and western areas.

However, even for many Kenyans who have grid coverage, the connection cost of about KSh15,000[50] ($150) is still prohibitive. Indeed, at an average cost of $0.17 per kWh[51] for all types of consumers, Kenya's electricity price is above the average for sub-Saharan Africa, which in turn has the priciest electricity of the world's regions. If we compare Kenya's electricity price to that of neighboring Ethiopia ($0.047 per kWh), Kenya's electricity price is 3.6 times more expensive. The price is set by the Energy Regulatory Commission at cost-reflective tariffs to make sure investors in the electricity markets will recover their investment.

As of the end of 2016, about 40% of the Kenyan population had access to electricity (18.42 million people out of 46.05 million), which meant a significant increase from 2012 when only 16% of the population had access to electricity, according to KPLC.[52] The increase is due to a combination of factors: the expansion of installed capacity due to further market liberalization, the diversification of the electricity mix with a resulting decrease in electricity prices and connection payments, the construction of new transmission and distribution lines, and the creation of the Rural Electrification Authority with a clear mandate to expand electricity access. Although we must applaud and recognize this colossal achievement in such a short period of time, access to electricity in Kenya is still an issue of concern and will continue to be so insofar as the country wants to continue growing.

A study commissioned by the Ministry of Energy and Petroleum in 2014 determined that, despite the successful electrification of public facilities in rural areas, most households in the neighborhoods of those facilities remained disconnected from the grid. Thus, the electrification of public facilities does not necessarily translate into improved access to electricity in neighboring areas. Access to electricity still remains a major issue of concern for Kenya, where 27.63 million people still lack such access. Access to electricity can be obtained by two means: access to the electricity grid and access to off-grid solutions.

There are contending hypotheses on which electricity access-related independent variable (availability or affordability) has a stronger explanatory power with regard to connected and unconnected households. A study conducted by a team of engineers from MIT found that a significant number of households in western Kenya remained unconnected, even though there

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[49] A series of conversations with M-Kopa representatives by the IESE research team.

[50] According to some sources consulted, the subsidized KSh 15,000 connection fee is rarely all that is charged and connection costs are significantly higher most of the time.

[51] Ana Pueyo, Simon Bawakyillenuo and Helen Osiolo, *Cost and Returns of Renewable Energy in Sub-Saharan Africa: A Comparison of Kenya and Ghana* (Brighton: Institute of Development Studies, April 2016), p. 43.

[52] KPLC, "Kenya Power Confirms 5.9 Million Customers Connected to the Grid," March 20, 2017, http://www.kplc.co.ke/content/item/1951/kenya-power-confirms-5.9-million-customers-connected-to-the-grid, accessed May 14, 2017.

were electricity lines nearby.[53] It is technically easier to supply a connection to a building that is close to a transformer, which suggests that the connectivity rate would be higher among households that are close to a transformer. However, empirical evidence indicates otherwise.

If we take a closer look at Kenya, exploring data on the poverty rate and electrification rate disaggregated at county level (see Figure 17), we find a strong association between poverty levels and access to electricity. The counties that had higher poverty rates were those where we found lower electrification rates. This is the case for Turkana, Mandera, Wajir, Tana River, and West Pokot.

According to the African Development Bank's Last Mile Connectivity Project, KPLC has the potential to connect 472,000 households at an overall cost of $686 million, which is around $1,453 per household.

A study conducted by the World Bank argues:

> "The affordability threshold is typically defined as spending on subsistence power needs of between 3 and 5 percent of the total household budget. [...] By looking at the distribution of household budgets, one can calculate the percentage of households for which subsistence consumption priced at full economic cost would absorb more than 5 percent of their budgets and thus prove unaffordable."[54]

The study maintains that the average electricity tariffs "would only be affordable for 25 percent of households that remain unconnected to the grid. Tariffs consistent with full recovery of economic costs would be affordable for 70 percent of the population."[55]

Poor reliability is a barrier for the incorporation and use of electricity. Although power outages have decreased since the unbundling of the sector, they remain common in many parts of the country. Moreover, some of the electricity generating infrastructure and devices fail to comply with quality tests and so are used for only a short time before being rendered useless. This causes a lack of faith in electricity projects and electrical appliances in Kenya, leading people to opt for what they see as more "stable" sources of energy, such as polluting solid biomass.

The real challenge is to give greater coverage through the network in a more efficient manner that will decrease connection costs while ensuring the recovery of the investment. At the same time, it is necessary to establish a protocol or methodology that will determine the most cost-effective type of technology to provide access to electricity according to location (distance from the point where electricity is generated), population density, household size, income level of the area's residents, etc. The transparency and standardization of these criteria would send a clear signal to investors and customers alike.

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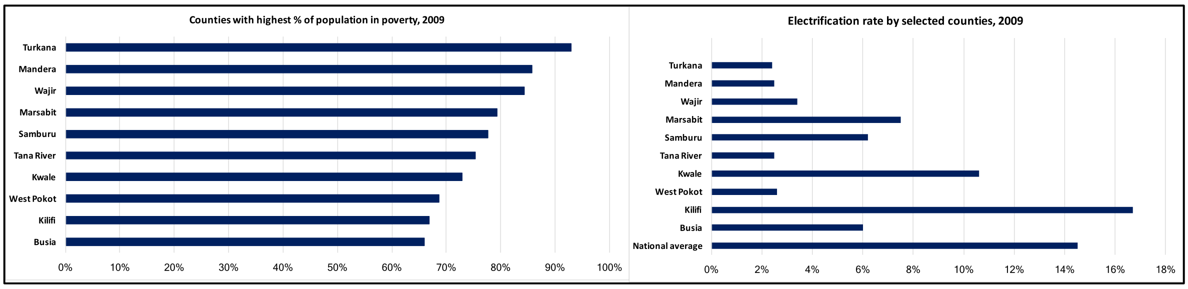
[53] Kenneth Lee et al., "Electrification for 'Under Grid' Households in Rural Kenya," *Development Engineering* 1 (June 2016): pp. 26-35.

[54] Cecilia Briceño-Garmendia and Maria Shkaratan, *Power Tariffs: Caught Between Cost Recovery and Affordability*, Policy Working Paper 5904 (The World Bank, Africa Region, Sustainable Development Unit, December 2011), p. 29.

[55] Ibid., p. ii ("Abstract").

Figure 15

Poverty rate and electrification rate (% of households) by county in Kenya, 2009

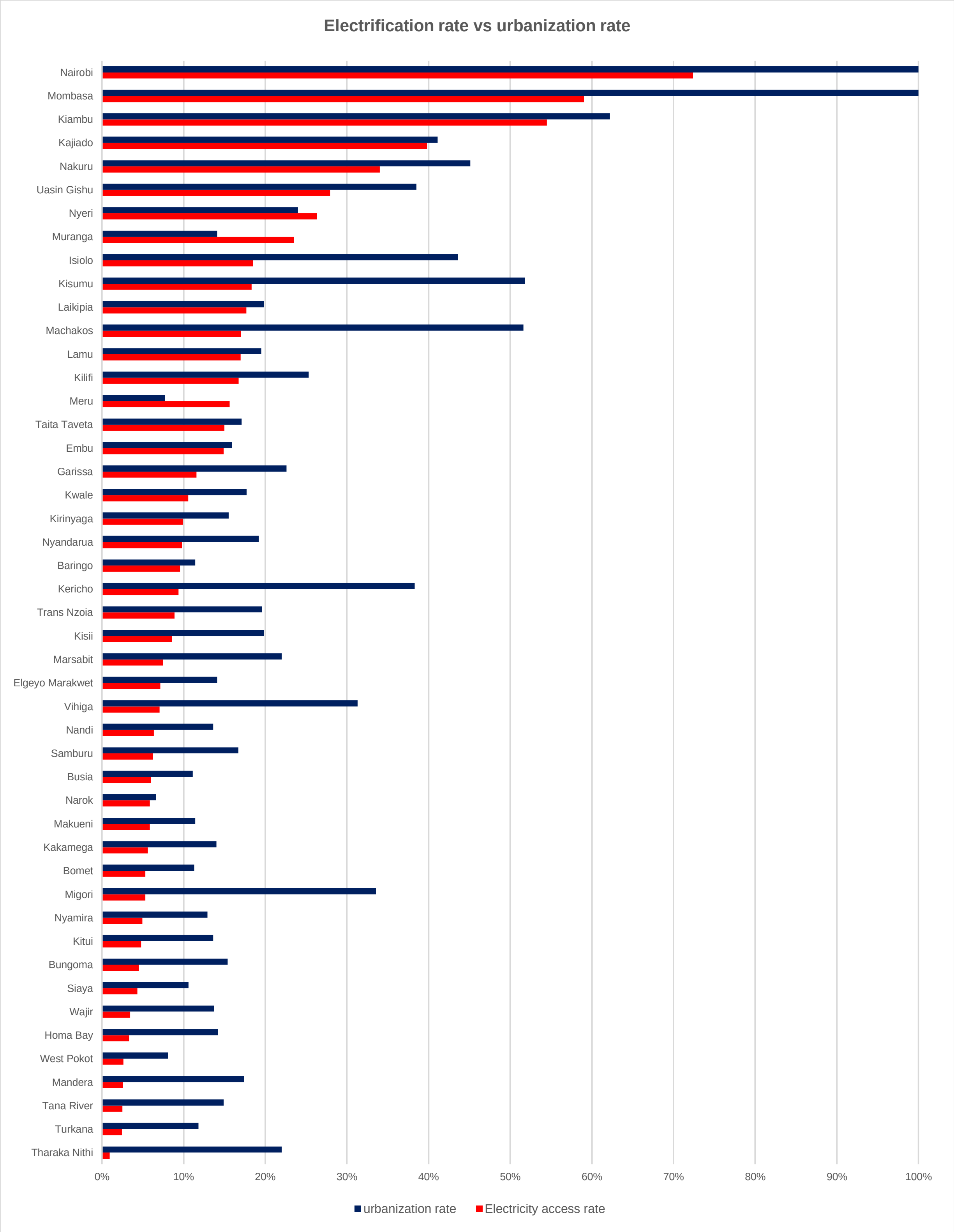


Source: Prepared by the authors, based on data from the Kenya National Bureau of Statistics (http://statistics.knbs.or.ke/nada/index.php/catalog/55/study-description).

As we can observe in Figure 16, the penetration rate of electricity in Kenya's central region is very high compared to the national average. Whether someone is on the grid or not has a geographical element in Kenya. Counties with higher concentrations of urban population – which we have called urbanization rates, measured as percentages of the population living in urban areas – tend to have higher electrification rates, measured as percentages of households with electricity.

Figure 16

Percentage of households with access to electricity vs. urbanization rate by county in Kenya, 2009

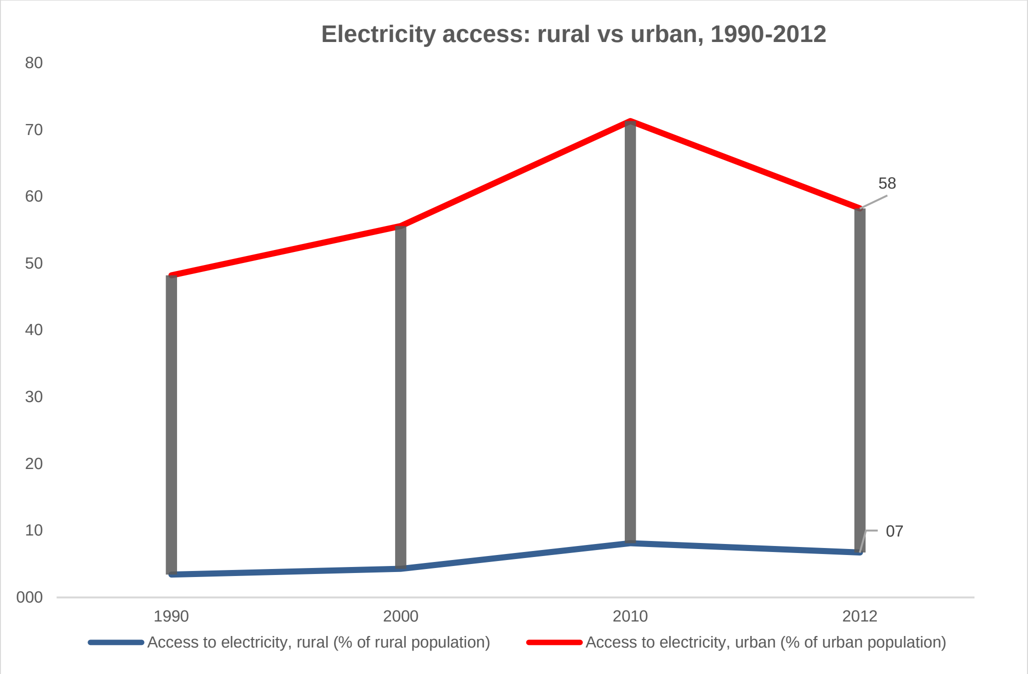


Source: Prepared by the authors, based on data from Kenya National Bureau of Statistics (http://statistics.knbs.or.ke/nada/index.php/catalog/55/study-description).

Figure 17 shows the geographic component of electricity access in Kenya. We can observe a large gap in access to electricity between urban and rural areas, to the detriment of the latter.

Figure 17

Access to electricity in urban and rural areas in Kenya, 1990-2012

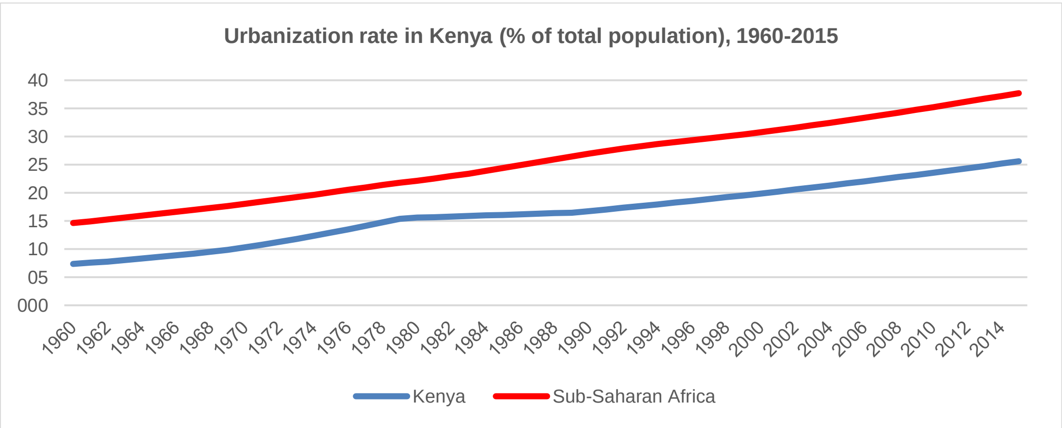


Source: Prepared by the authors, based on data from the World Bank's World Development Indicators (http://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?contextual=default&locations=KE).

A comparison of Figure 18 and Figure 19 makes the electricity gap suffered by rural areas of Kenya even more salient when it becomes clear that even Kenya's urbanization rate is well below the average urbanization rate of sub-Saharan Africa. More than 70% of Kenya's population lives in rural areas.

Figure 18

Urbanization rate in Kenya and sub-Saharan Africa, 1960-2015



Source: Prepared by the authors, based on data from the World Bank's World Development Indicators (http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=KE).

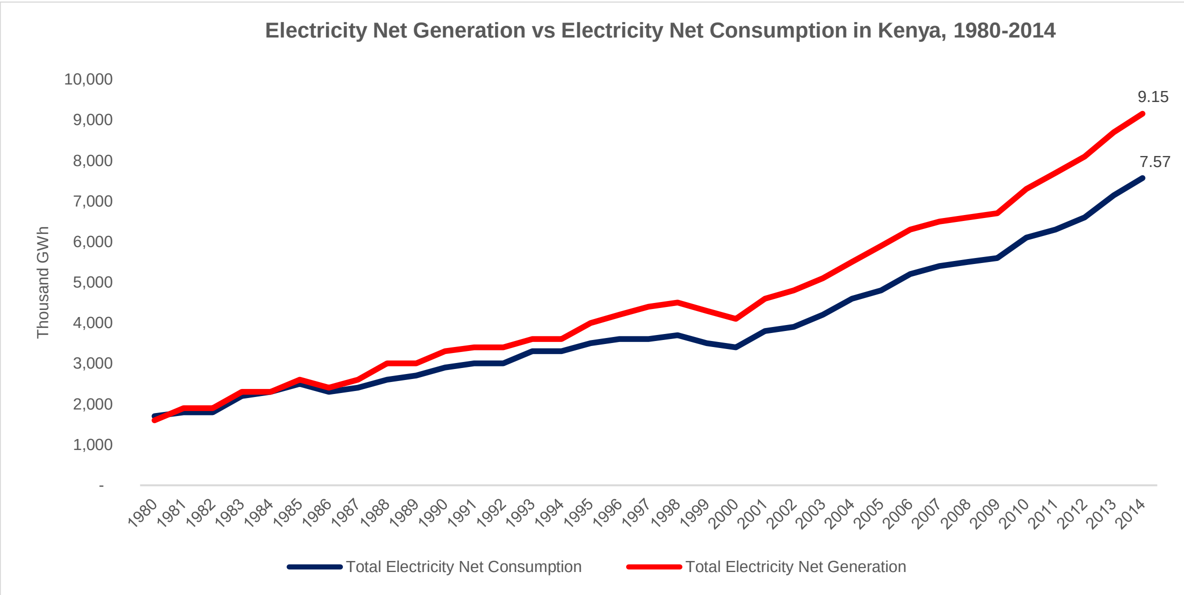
Between 1990 and 2015 Kenya experienced an annualized urbanization rate of 4.36%. However, the urbanization rate in the country is below the trend for sub-Saharan Africa. As shown in Figure 20, in Kenya 25.62% of people were living in cities in 2015 compared to 37.74% of people living in cities in sub-Saharan Africa as a whole. The International Energy Agency has said that mini-grid and off-grid systems provide electricity to 70% of those gaining access in rural areas in sub-Saharan Africa. However, according to the agency's forecast for the electrification rate in sub-Saharan Africa, more than half a billion people, mainly in rural areas, will be without electricity in 2040.[56]

Transmission and Distribution Losses

The balance between electricity generation and electricity consumption accounts for transmission and distribution losses and, to a lesser extent, for electricity exports, mainly to Uganda. Figure 19 shows power generation and power consumption in Kenya between 1980 and 2014. We can observe how, over time, generation outpaces consumption, which – with constant transmission and distribution losses – yields a higher reserve margin.

Figure 19

Power generation and consumption in Kenya, 1980-2014



Source: Prepared by the authors, based on data from the U.S. Energy Information Administration, International Energy Statistics, electricity, Kenya (https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000007vo70000fvu&c=000000000000000000000004&ct=0&tl_id=2-A&vs=INTL.2-12-KEN-BKWH.A&cy=2014&vo=0&v=H&start=1980&end=2015).

[56] International Energy Agency, *Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa*, World Energy Outlook Special Report (Paris, 2014), p. 13.

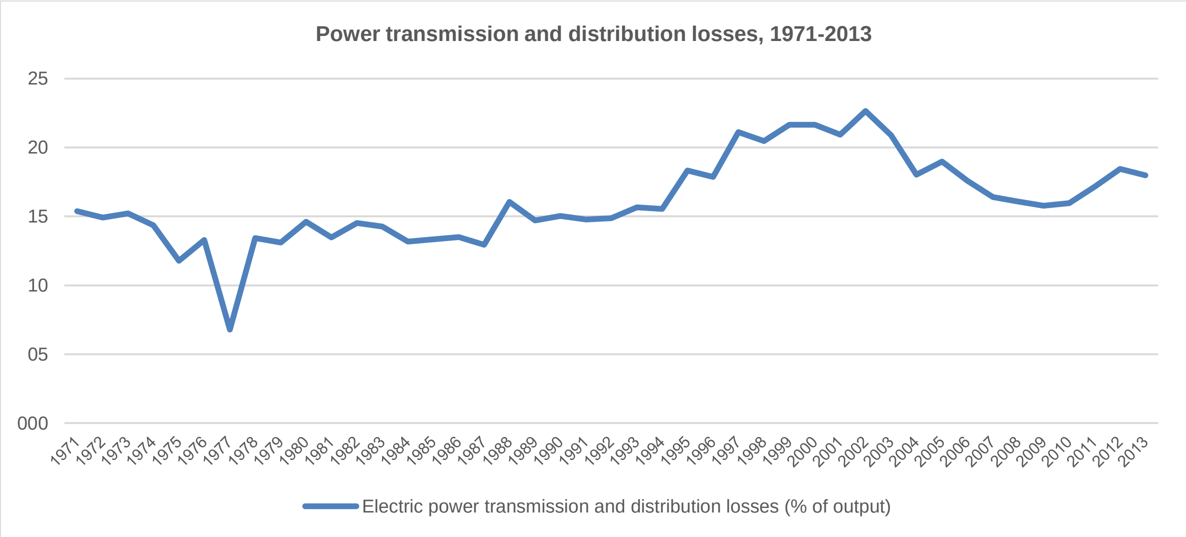
Figure 20 shows power transmission and distribution losses in Kenya between 1971 and 2013 as a percentage of net power generation.

> "Electric power transmission and distribution losses (% of output) in Kenya [were] 17.98 as of 2013. Its highest value over the past 42 years was 22.65 in 2002, while its lowest value was 6.79 in 1977. Definition: Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage."[57]

In 2013, power and distribution losses accounted for 17.98% of net electricity generation (8.7 thousand GWh), which means that 1.56 thousand GWh was lost. Assuming 100 kWh as the average residential power consumption level per month,[58] the electricity lost would have been enough to supply 1.3 million households (15% of all households in the country[59]) for a year.

Figure 20

Transmission and distribution losses in Kenya, 1971-2013



Source: Prepared by the authors, based on data from the World Bank's World Development Indicators (http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?locations=KE-AD).

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[57] Index Mundi, "Kenya – Electric Power Transmission and Distribution Losses," http://www.indexmundi.com/facts/kenya/electric-power-transmission-and-distribution-losses, accessed February 23, 2017. Based on data from the International Energy Agency.

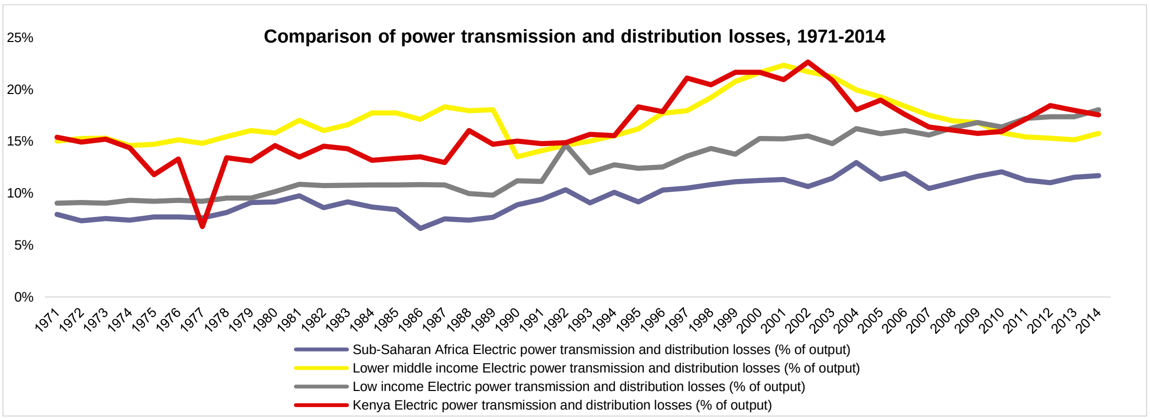
[58] Cecilia Briceño-Garmendia and Maria Shkaratan, *Power Tariffs: Caught Between Cost Recovery and Affordability*, Policy Working Paper 5904 (The World Bank, Africa Region, Sustainable Development Unit, December 2011), p. 15.

[59] Based on official population data from 2009, when 8,767,954 households were registered in Kenya.

Figure 21 compares transmission and distribution losses in Kenya with the trend in sub-Saharan Africa – low-income as well as lower middle-income countries. We can observe how the trend in Kenya lies between the boundaries of low-income and lower middle-income countries. In terms of power transmission and distribution losses, Kenya arguably belongs somewhere in between low-income and lower middle-income countries.

Figure 21

Comparison of power transmission and distribution losses, 1971-2014



Source: Prepared by the authors, based on World Bank data (http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?locations=KE-AD).

Power Outages

The electricity market in Kenya is largely comprised of renewable sources. Hydro is still the largest single source of generation capacity among renewable and nonrenewable sources. Hydroelectric plants' dependence on rainfall to generate electricity in a country highly exposed to major drought have made the Kenyan power system extremely vulnerable to frequent intermittency problems. The resulting power shortages, outages and blackouts, with strict power rationing as a consequence, have led to drastic losses across sectors. Table 3 shows selected indicators as proxies for the impact of Kenya's power system on overall company performance for the year 2013. It is worth highlighting the losses suffered by private companies in the country as a proportion of annual sales. Companies reported losses in the order of 6% of annual sales due to electrical outages.

Table 3

Impact of power on company performance from selected indicators, 2013

Impact of electricity on business environment in Kenya, 2013

Indicator	Units	2013
Number of electrical outages in a typical year	Number	6.3
Duration of a typical electrical outage	Hours	5.0
Losses due to electrical outages	% of annual sales	5.6
Percent of firms owning or sharing a private generator	%	57.4
Proportion of electricity from a private generator	%	7.8
Percent of firms identifying electricity as a major constraint	%	22.2

Source: The authors, based on the World Bank's Enterprise Surveys data, Infrastructure (http://www.enterprisesurveys.org/data/exploretopics/infrastructure).

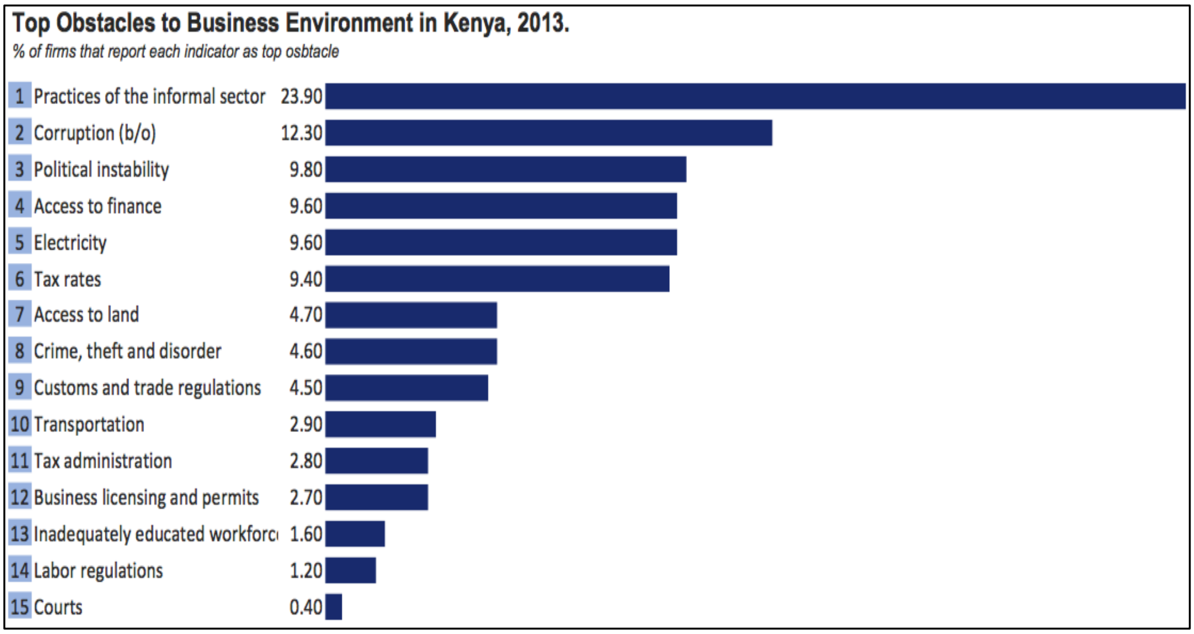
Over time, firms have developed coping mechanisms to deal with the frequent outages. In the same surveys conducted by the World Bank, 57% of firms acknowledged sharing electricity generators to hedge against outages. The same firms said the electricity supplied by these emergency generators made up 7.8% of the firms' electricity consumption.

By virtue of its versatility of use and its being crucial to economic growth, electricity is the energy service most sought by Kenyans. Access to it is typically associated with improved quality of life. Even though Kenya's economy has been growing at approximately 5.1% per year over the past 10 years, growth has been constrained by an insufficient supply of electricity.

According to the World Bank's Enterprise Surveys 2013 (see Figure 22), 10% of surveyed firms in Kenya said electricity was the top obstacle in the business environment and 22.2% of firms said electricity was a major constraint. Although significant progress has been made in expanding generation capacity, the Kenyan electricity system continues to face key challenges, such as the diversification of the electricity mix, the reduction in connection payments and electricity price drops.

Figure 22

Business environment in Kenya, 2013



Source: World Bank's Enterprise Surveys 2013 (http://www.enterprisesurveys.org/data/exploretopics/corruption%23--13).

Concluding Remarks

The two guiding electricity policies in the country (Kenya Vision 2030 and the Least Cost Development Plan), if implemented, would leave the country with excess capacity, which would translate into higher electricity prices for end consumers.

Prioritizing the electricity access challenge would unlock the array of benefits that come with higher electricity consumption: Δ Electricity access → Δ Power consumption / capita → Δ GDP & Δ HDI (Human Development Index).

Investment Opportunities

We acknowledge Kenya's movement toward a greener future in harnessing renewable resources in its energy mix. The government is actively looking for ways to facilitate investment in green energy generating systems through the Green Climate Fund, an instrument created by the United Nations Framework Convention on Climate Change (UNFCCC) in 2010, aimed at supporting a paradigmatic shift in the global response to climate change. Through the fund, the United Nations allocates its resources to low-emission and climate-resilient projects and programs in developing countries, paying particular attention to the needs of societies that are highly vulnerable to the effects of climate change.

At the 2016 annual meeting of the African Development Bank Group, Rwandan president Paul Kagame stated that Africa was tired of poverty and darkness. He emphasized that the only solution would be through investment in industrialization projects, such as the 30 MW project between Kenya and Rwanda, which had been halted due to the lack of a transmission line between the two countries. The development bank aims to add 160 GW of power to the grid, connect 130 million people to the grid and connect 75 million people to off-grid systems between 2016 and 2026. Investors, therefore, can consider getting support from the bank while investing in various areas of the electrical sector in Kenya.

Grid Power System

Building of Power Infrastructure

Infrastructure development is as critical to delivering growth and reducing poverty as it is to addressing broader development goals. Africa's largest infrastructure deficit is found in the power sector.

Building regional infrastructure would not only help to improve trade but would also contribute to regional trust and security. In 2014, Kenya signed a five-year contract to export 30 MW of power to Rwanda. The power was to be bought and sold for $0.014 per kilowatt and the price was to be reviewed every two years. The agreement was part of a regional initiative to improve the power grid along the Northern Corridor and its aim was to increase Rwanda's electricity generation capacity by 263%, from 155 MW to 563 MW by 2017. This was rendered impossible due to the lack of a transmission line between the two countries.

The African Development Bank Group has supported electricity companies, such as Eskom in South Africa, to obtain loans to improve electricity transmission. In Kenya, KETRACO is looking to implement various priority projects, totaling roughly 5,000 km of transmission lines. Funding is necessary to implement a number of them, so this is a possible area for investment.

Lack of community consent has caused delays in setting up power infrastructure, such as the 482 km Mombasa-Nairobi transmission line. It is behind schedule because of Kajiado landowners' refusal to relinquish their land for the line. Lack of consent led to the cancellation of the Kinangop Wind Park project early in 2016, causing a delay in wind power generation.

Investing in Net Metering

Net metering is an energy-efficiency policy instrument that provides incentives for the local generation of electricity, while bringing billing savings to customer-generators of electricity.

Section 190 of the 2015 Energy Act provides for net metering, whereby a consumer who owns an electric power generator of a capacity not exceeding 1 MW may apply to enter into an agreement to operate a net-metering system with KPLC.

Small renewable energy systems can be purchased by individuals for the purpose of net metering. This opportunity will greatly benefit both the investor and consumer, as one will earn a profit while the other will gain access to cheaper electricity.

Kenya could learn a great deal from California, the United States' leading market for the installation of solar PV generation, which has 1,400 MW of PV installations operating in the homes or businesses of 134,000 Californians. Net-metering policies in the United States have facilitated the expansion of renewable energy through on-site or distributed generation. Since Kenya is focused on generating electricity through renewable energy, this might be one of the solutions to the country's power deficit.

However, net metering is capital-intensive. For instance, to produce 0.6 MW in Nairobi using solar PV panels, investment capital of about $1.3 million was required in the case of Strathmore University.

Investing in Training and Capacity Building

Consumers have greater trust when there is a presence of technicians who are well-versed in trouble-shooting and ancillary services and in the repair and maintenance of energy technology. In Kenya, the pool of well-trained technicians tends to be concentrated in the major cities of Nairobi and Mombasa. Hence, it is difficult to get someone to service the technologies in rural areas of the country in the event of power failure. There are 31 technical training institutes in 19 of Kenya's 47 counties and four national polytechnics, as well as the Kenya Technical Trainers College and technical universities in four counties, but these are not enough to service national energy needs.

Pooling funds to train and build the capacity of local people to deal with technological issues and to service energy machinery offers an opportunity for profit, due to the fact that these skilled technicians are severely lacking in Kenya.

Cleaner and Cheaper Electricity Technologies

It is possible to operate the existing infrastructure for electricity generation using cheaper and cleaner fuels. Large diesel generators can be modified easily to run on methanol. This has been done around the world already. Methanol is cheaper than diesel and can be produced easily from natural gas or biomass.

Small gasoline and diesel generators could be converted to run on ethanol or methanol or a mix of carbons from village-scale biofuel machines. Village-scale, off-grid solar solutions are already being implemented in many places. In Rwanda, Ignite Power is bringing solar power to 250,000 new consumers.

There are a number of clear investment opportunities in this area, including the following:

Photovoltaic Electricity

Solar-based electricity is an attractive alternative to grid power for rural electrification and decentralized applications. The Kenyan government has come up with tax incentives to promote the development of PV stand-alone systems for households and public institutions. This is a system that is appropriate for the supply of electricity through mini-grids, especially to off-grid gated community housing developments, rural schools, hospitals and public institutions generally.

Solar PV is a very interesting investment area in Kenya. The insolation rate is even higher than in countries where solar PV is one of the major sources of power generation capacity. There are densely populated areas located far from the grid reach. However, the financial viability of solar PV projects is driven largely by the decision of large banks regarding whether or not to support specific projects according to their associated risks.

> "[...] some new markets are starting to install measurable capacities of solar PV, both on- and off-grid. South Africa, for example, installed about 0.8 GW in 2014 to rank ninth globally for capacity added; most of this added capacity was in large parks and the result of South Africa's tender programme. Kenya has focused on increasing off-grid solar in isolated areas, with large plants (several MW) also under development, and Rwanda commissioned a solar PV farm (8.5 MW) in 2014 that represents 7% of national installed power capacity."[60]

In Kenya, there are a number of organizations with rooftop PV systems, including Williamson Tea Factory (1 MW), the United Nations Environment Programme headquarters (0.5 MW) and Strathmore University (0.6 MW). The university's system was set up by the Strathmore Energy Research Centre (SERC) with the aim of creating a greener university by meeting all its power needs from this green source. The 0.6 MW solar PV rooftop system was implemented with an investment of $1.3 million and consisted of 2,400 solar panels, 1,200 optimizers and 30 inverters with a lifespan of at least 20 years. The resulting installation generated more power than the university could consume, which led to a net-metering arrangement with KPLC, whereby the latter buys the excess 0.25 MW of electricity at KSh12.36 ($0.12) per kWh of solar electricity delivered to the national grid for a period of 20 years.

SERC has also been able to achieve solar grid parity – that is, producing solar power that is cheaper than the power produced by the national grid. In the event that an investor is able to identify a market for the electricity, solar energy is a lucrative area for investment as it is inherently free and therefore cheaper than sources such as thermal. SERC, for instance, sells its solar electricity at $0.12 per kWh, while KPLC sells its electricity at $0.216 per kWh. As a result, SERC has been able to close a deal to produce and sell its cheaper electricity to three Serena hotels in the near future.

There are complex regulatory requirements, as at least nine different government bodies are involved in the renewable energy licensing process, with a total of 15 different clearances needed. This makes it difficult for companies to comply with renewable energy standards, however much they would like to do so. Moreover, the information about each of the clearances is scattered and

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[60] Renewable Energy Policy Network for the 21st Century, *Renewables 2015: Global Status Report*, p. 60.

often difficult to find. SERC, for instance, started producing 0.6 MW of solar electricity in June 2014 but it was not until October 2015 that it managed to sign a power purchase agreement to sell 0.25 MW to KPLC. The waiting period, which was almost a year and a half in this case, could pose a problem for investors as they would have to continue funding the not-yet-profitable solar grids while they waited to sign a power purchase agreement. This could render them bankrupt, as it would involve spending without receiving any returns for a long period of time.

Solar Home Systems and Pico-PV Systems

Solar home systems (10 W to 500 W[61]) generally consist of a solar module and a battery, along with a charge control device so that direct current (DC) power is available during dark and cloudy periods. These systems provide electricity to off-grid households for lighting, radios, television, refrigeration and Internet access. This size of system can be used for nondomestic applications such as telecommunications, water pumping, navigational aids, health clinics, educational facilities and community centers. For higher power demands (such as 500 W to 1,000 W), larger solar panels, additional battery capacity and inverters to supply alternating current (AC) power may be needed. The advantages of these bigger systems lie in their ability to power more sophisticated electrical appliances. The world's largest market for solar home systems is Bangladesh, where it has grown at an astounding compound annual growth rate of 60% during the past decade, reaching total sales of three million systems.

In Kenya, Mobisol and M-Kopa[62] offer innovative payment mechanisms such as pay-as-you-go (PAYG), which is by instalments. Customers pay a small deposit for a solar charger kit, a portable system and a control unit that can be used for powering LED lights and charging devices, then they pay installments until eventually they own the solar system. The market for PAYG solar continued to grow in 2015. Since 87% of direct investment in off-grid solar companies in 2014 and 2015 went to pay-as-you-go companies, there is a clear investment opportunity here.

On the other hand, pico-PV systems are the smallest distributed solar PV systems (1 to 10 W_p or watt-peak)[63] which can power small lights, low-power appliances and mobile phone charging stations. These systems typically decrease in size as the efficiency of appliances that utilize the generated power improve. Investment in appliances with improved efficiency represents a promising niche for investors.

Pico-PV systems can replace kerosene lamps, candles and battery-powered flashlights and are the most widely used renewable energy technology by far. Among the companies that produce the systems are d.light, Greenlight Planet and Barefoot Power.

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61 Power conversion of 1 W = 1 / 10^3 kW = 1 / 10^6 MW.

62 According to the REN21 2016 report, M-Kopa raised $31.5 million in 2015 for off-grid renewable energy projects. Source: Renewable Energy Policy Network for the 21st Century, *Renewables 2016: Global Status Report* (Paris: REN21 Secretariat, 2016).

63 A pico-PV system is a small PV system with a power output of 1 W to 10 W, mainly used for lighting. The "pico" here is distinct from the metric system unit prefix "pico" (symbol p), denoting one trillionth, a factor of 10^{-12}. The abbreviation W_p stands for watt-peak capacity, which is the nominal capacity, or the capacity that is realized under agreed standard test conditions – Wikipedia, "Nominal Power (Photovoltaic)," https://en.wikipedia.org/wiki/Nominal_power_(photovoltaic). W_p is not the regular power output but rather the maximum capacity of a module under optimal conditions.

Pico-PV systems yield high savings for consumers, who can save up to 70% of what they spent on kerosene by using pico-PV instead. This area of investment could have many customers, given the savings.

At the moment, pico-PV systems can play only a niche role for specific purposes. Rural inhabitants usually prefer a grid connection so they can plug in more "power-hungry" appliances such as TV sets.

Waste-to-Electricity Conversion

Waste can be converted into electricity using a number of methods, such as incineration, gasification, landfill biogas combustion, gas supply through a pipeline system and anaerobic digestion. Energy recovery[64] from waste is important due mainly to the significantly reduced waste volume for landfill, the reduction of total greenhouse gas emissions and the potential for the generation of electricity or the cogeneration of electricity and heat, which would benefit Kenya as a large part of the population still has no access to the electricity grid. Kenya has a sugarcane industry that also fuels "co-generation plants with bagasse."[65]

Methane, for example, can be produced from solid waste through anaerobic digestion, which is the slow decomposition of biologically active organic matter in an oxygen-free environment. This gas is used to produce methanol, which, in turn, can be used to produce electricity. Investment in trash-to-methanol conversion could be lucrative as methanol is more environmentally friendly than diesel, and its "low heating value, low lubricity, and low flash point make it a superior turbine fuel compared to natural gas and distillate, which can translate to lower emissions, improved heat rate, and higher power output."[66] "In 2014 Kenya began to construct its first grid-connected biomethane plant, which was expected to begin producing power in 2015."[67]

A challenge facing Kenya's current waste disposal system is that, even though each county government is to designate waste disposal sites for its own territory, there is either a lack of availability of public land for this purpose or the communities neighboring the land oppose it being turned into a dump. Together with high poverty levels, this has led to dumps being created in environmentally sensitive areas, such as riverbanks, forests and wetlands. Another challenge is limited awareness and knowledge of the importance of a clean and healthy environment, and this has led to poor handling of waste at the household level. There is also a failure on the part of Kenyans to take individual responsibility, which has contributed to poor environmental practices, such as littering, illegal dumping and open burning.

The main guiding principle of Kenya's National Waste Management Strategy of 2015, developed by the National Environment Management Authority, is the zero waste principle, whereby waste

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64 "**Energy recovery** includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub-system of the overall system with another. The energy can be in any form in either subsystem, but most energy recovery systems exchange thermal energy in either sensible or latent form. In some circumstances the use of an enabling technology [...] is necessary to make energy recovery practicable. One example is waste heat from air conditioning machinery stored in a buffer tank to aid in night time heating." Source: Wikipedia, "Energy Recovery," https://en.wikipedia.org/wiki/Energy_recovery, accessed February 23, 2017.

65 Renewable Energy Policy Network for the 21st Century, *Renewables 2015: Global Status Report*, p. 34.

66 Methanol Institute, "Power Generation," http://www.methanol.org/power-generation/. Accessed on February 23, 2017.

67 Ibid., p. 48.

is a resource that can be harnessed to create wealth and employment and reduce environmental pollution. The strategy's long-term goal is to recover about 80% of waste (through recycling, composting and waste to energy) by 2030, with 20% going to a sanitary landfill (inert material). Its medium-term goal is to recover 50% of waste (through recycling, composting and waste to energy) by 2025, with 50% going to semi-aerobic landfill. The strategy's short-term goal is to recover 30% of waste (through recycling and composting) in key urban areas by 2020, with 70% being disposed of through controlled dumping (tipping, compacting and covering).

To achieve its objectives, the authority intends to promote public-private partnerships in waste management, especially for the promotion of resource recovery through energy generation, waste segregation at source, and waste as an income-generating venture, so this could be a lucrative area for investment.

Modern Biomass Conversion Into Electricity

The rapid increase in the volume and types of agricultural biomass waste, as a result of intensive agriculture in the wake of population growth and improved living standards, is becoming a burgeoning problem, as rotten waste agricultural biomass emits methane and leachate, while open burning by farmers to clear land generates carbon dioxide (CO_2) and other pollutants. Hence, improper management of waste agricultural biomass is worsening climate change, water and soil contamination, and local air pollution. Furthermore, this waste is of great value with respect to material and energy recovery.

Globally, modern biomass has been acknowledged as a positive alternative source of energy because it is renewable, cheaper, readily available and can be CO_2 neutral. Unlike other renewable energy sources such as solar and wind, modern biomass can be converted to liquid, solid and gas through an array of biomass conversion technologies. It is suitable not only for heat and electricity generation but also for transportation fuels. However, there are findings that show that transforming biomass into electricity "is more beneficial than turning it into transportation fuels."[68]

Kenya, as an agricultural country, generates substantial quantities of agricultural biomass waste every year. This waste could be converted into electricity, especially through direct combustion, gasification, pyrolysis or anaerobic digestion processes, which provides an investment opportunity.

Biomass utilization is hindered severely by its associated cost and the complexity of its logistics as biomass is bulky and, to develop the necessary capacity, dispersed geographical generation points must be coordinated.

Moreover, the quality of biomass depends on the weather, and the seasonal nature of agricultural crops poses unique challenges for biomass supply chain management.

Biofuel Production

Biomass can be converted directly into liquid fuels called biofuels, which can reduce pollution, alleviate the burden on foreign exchange caused by importing oil byproducts, improve on the balance of trade and create employment. Since modern biomass has been considered 80% more efficient at producing electricity than as a transport fuel option, biofuels derived from biomass

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[68] Tyler Hamilton, "Biofuels vs. Biomass Electricity," *MIT Technology Review*, May 8, 2009, https://www.technologyreview.com/s/413406/biofuels-vs-biomass-electricity/.

can be expected to perform just as well. Therefore, investing in biofuel production for electricity generation rather than for transport use could be more profitable from an investment perspective. There is a modest level of bio-power production in Kenya, where some sugarcane mills produce electricity from bagasse in cogeneration facilities for their own use and sell excess electricity to the national grid.[69]

According to the Organisation for Economic Co-operation and Development (OECD) and the United Nations Food and Agriculture Organization (FAO), demand has increased for biofuel feedstock and, since Kenya is making efforts to use green energy, investing in biomass digesters to produce biofuels may be a profitable area for investment in the energy sector.

Worldwide, there has been a move away from first-generation biofuels, which use corn sugar and vegetable oils as feedstock and are blended partly with conventional fuel, toward second-generation biofuels, which are considered to be more environmentally friendly due to the use of abundant and cheap plant waste biomass. The feedstock for second-generation biofuels includes agricultural residue – such as wheat straw, forest residue, aquatic biomass, skins and pulp from fruit pressing, water hyacinth, castor oil, jatropha, cottonseed and croton – which is all unfit for human consumption.

Water Hyacinth in Lake Victoria

Investing in the use of water hyacinth plants in Lake Victoria to generate power could prove to be a profitable investment venture. Water hyacinth is a good source for biofuel production and its profile compared well with that of conventional feedstock, such as cow dung. Investing in such a project will contribute to both business profits and social benefits, as the use of water hyacinth will provide energy and improve the health of neighboring communities. For a 2 MW biogas digester with an investment of $8.8 million and maintenance and operational expenses at 5% of the investment, the internal rate of return would be 16.24%.

Off-Grid Power System

Given the low level of electricity connectivity in the country, Kenya is aware that the most effective way of providing power to everybody entails harnessing the available off-grid electricity generating resources.

Investing in Hybridizing Mini-Grids

Mini-grids are isolated grids, usually in places that are far from the national power grid, which is often the main source of electricity for both commercial and residential use. In Kenya, the largest mini-grids have a capacity of 1 MW. They differ from solar home systems as they have a central point for generation but consumption takes place in different places. A solar home system is independent – generation and consumption happen in the same place.

Generation costs can be reduced by hybridizing these mini-grids – that is, cogenerating[70] thermal energy along with solar PV or other renewable power sources. Investments can be made to hybridize the mini-grids developed by the REA to make electricity cheaper. Connection fees to

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[69] Renewable Energy Policy Network for the 21st Century, *Renewables 2015: Global Status Report*, p. 44.

[70] Cogeneration or combined heat and power (CHP) is the simultaneous generation of electricity and heat, or the conversion of waste heat into electricity.

electricity grids can therefore be reduced further from the current subsidized level of KSh15,000, which still proves to be too expensive for many. Companies such as M-Kopa, which allows for electricity to be paid for in installments, have tried to ease this burden for Kenyans but M-Kopa targets only people in rural areas and does not cater to those living in slums. In Budalangi, a local community set up a mini-grid and started supplying electricity to residents even before getting approval from the ERC as there was an urgent need for electricity. This demonstrates that an urgent need for power creates an investment opportunity in Kenya.

Power in Lokichogio is being sold for $1 per kWh, which is excessive compared to the $0.17 per kWh being paid in middle-income households connected to the grid. The power provided is generated from diesel, which is very expensive. The lack of options in this area provides a perfect investment opportunity to set up cogeneration mini-grids with, for example, both solar and diesel energy, which would sell electricity more cheaply and consequently attract customers.

Concluding Remarks

There is momentum for investment opportunities in the electricity subindustry in Kenya, especially in power generation, before it takes off and barriers emerge to entry.

These investment opportunities arise from unreliable power supply sources, a lack of available power where there is demand, and prohibitively expensive electricity bills compared to neighboring countries such as Ethiopia.

Conclusions and Recommendations

The reforms that Kenya has undergone since the 1990s have not been translated into greater diversification of electricity supply from power generating companies, a more reliable electricity supply system, and lower electricity prices for end consumers. There are several challenges to be resolved:

1. Access to electricity:
    a. Some 60% of the population still has no access to electricity. The figure is much lower in rural areas, where 6.7% of the population lacks electricity access.
    b. With only $9 a month available to spend on energy consumption, 50% of unconnected households do not reach the minimum boundary at which access to electricity can be granted, which is $14.50 a month for home solar systems.
2. Transmission and distribution losses[71] account for 1.56 thousand GWh per year, enough to provide electricity to 1.3 million households for a year.
3. The frequency of power outages and blackouts causes companies to register losses equivalent to 5.6% of their annual sales.

Kenya is one of the countries in sub-Saharan Africa with the most extensive experience in IPP projects. However, efforts to liberalize the electricity generation system have not been translated into greater competitiveness and lower electricity tariffs.

[71] These also account for authorities' failure to collect electricity bills.

Nevertheless, several factors combine to create an investment opportunity – the legal and regulatory framework, the present structure of the power supply system, the priority of the energy sector in the national industrialization strategy, the fact Kenya is becoming a middle-income country, and the emphasis of multilateral donors on ending energy poverty.

Moreover, Kenya has proven its commitment to honoring public-private partnerships in the energy sector. We acknowledge there is momentum for investment in the country's power subindustry, especially in power generation and movable technologies that can reach those counties and households still outside the grid's reach. New entrants in the off-grid system are benefiting from easy access to financing and high returns on investment. Therefore, the Kenyan electricity market's challenges represent a lucrative opportunity for private investors. This is the most opportune time to create a renewable energy innovation or to invest in the sector as it will soon boom and entry to the market will be restricted.

We recommend that the Kenyan government do the following:

1. Simplify the complex regulatory requirements in any processes in the energy sector to enable existing companies to comply easily with the standards set and, in addition, to attract more investment in the sector.

2. Assess the experience of independent power producers. What is important is not the number of IPPs but how the IPPs help create a more resilient and cost-competitive electricity market in Kenya, thus ensuring lower power generation costs, a more reliable power supply and guarantees on the weighted average cost of capital (WACC) to enable IPPs to compete with KenGen. The challenge ahead is to create the conditions to attract cost-competitive IPPs.

3. Procure power competitively, according to order of merit and not as the result of direct agreements. There is evidence that, when power is procured competitively, IPPs have generally delivered power at lower costs and their contracts have held up better compared to directly negotiated power purchase agreements.

4. Map the population with no access to electricity, segment households according to income level and available income for energy consumption, and determine the most cost-efficient technology to provide access to electricity to different households according to their resources and needs. Special attention should be given to households that have $9 a month or less to spend on energy as otherwise they are likely to remain deprived of access to electricity.

5. Elaborate protocols to standardize the most cost-efficient technology or technologies to provide unconnected households with access to electricity, taking into account location, the condition of the infrastructure, income level, household size, population density, etc.

6. Assess and improve the engagement of local communities and landowners in all phases of new project infrastructure, from analysis to implementation and final evaluation. This is necessary because lack of community consent is a significant barrier to the take-up and use of electricity and because it causes delays in setting up power infrastructure.

Appendix 1

Levelized Cost of Electricity (LCOE) by Source

		Capacity factor	Investment costs ($/kW)	O&M costs (% capex/year)†	Sensitivity to investment costs		Sensitivity to capacity factor	
					LCOE (cents/kWh)	Equity IRR	LCOE (cents/kWh)	Equity IRR
Solar PV	**Kenya**	20%	2,150	1%	15*	5%*		
	Africa	22%	3,472	N/A	18	2%		
	International	20%	1,306-5,425	1.05%	11	16%		
Onshore wind	**Kenya**	45%	2,538.8	3.25%	10.3*	15%*	10*	
	Africa	32%	2,368.4	3%	9.7**	18%**	14.5**	
	International	30%	1,787.3 (USA)	0.8%	5.7***	55%***	14.5**	
2Hydro (large)	**Kenya**	55%	3,829	N/A	11*	5%*		
	Africa	N/A	2,538.8	N/A	6**	22%**		
	International	50%	1,004.7-3,516.4	1.4%	N/A	N/A		
Hydro (small)	**Kenya**	50%	2,589	2.8%				
	Africa	N/A	2,645	N/A				
	International	N/A	1,005-3,516	1.5%-2.5%				
Geothermal (conventional)				$65/kW (fixed) = 1.67%	5.4*	30%*		
	Kenya	92%	3,901	$0.0116/kWh (var.)	7.8**	17%**		
	Africa	N/A	N/A	N/A				
	International	90%	2,419	3%-6%				

† O&M costs as a percentage of investment costs

Assuming WACC at 10%. The average financing cost for IPPs is 11% and WACC for KenGen is about 5%.

Solar PV	Sensitivity to investment costs	* Assuming the Kenyan average investment cost of solar PV is $2,150 per kW ** Assuming the African average investment cost of solar PV is $2,580 per kW *** Assuming the international lower-bound cost of solar PV is $1,505 per kW
Solar PV	Sensitivity to capacity factor	A sensitivity analysis of solar PV capacity factors shows that, at current tariffs and financing costs, projects in Kenya would be financially viable only for capacity factors of 30% or more. Solar PV is still not financially viable with the current price set at $0.12 per kWh in Kenya's feed-in tariffs. A price of $0.18 per kWh would make solar PV projects financially viable in Kenya.
Wind	Sensitivity to investment costs	* Assuming the Kenyan average investment cost of wind is $2,539 per kW ** Assuming the African average investment cost of wind is $2,285 per kW *** Assuming the international lower-bound cost of wind is $1,523 per kW
Wind	Sensitivity to capacity factor	* Assuming an average capacity factor of 45% for Kenya's best locations ** Assuming an average capacity factor of 30% for most locations in Africa and internationally
Hydro	Sensitivity to investment costs	* Assuming the Kenyan average investment cost of large hydro is $3,829 per kW ** Assuming the African average investment cost in large hydro is $2,297 per kW
Geothermal	Sensitivity to investment costs	* At KenGen's very low financing cost ** At the higher financing cost of IPPs

Source: Based on data and analysis from Ana Pueyo, Simon Bawakyillenuo and Helen Osiolo, *Cost and Returns of Renewable Energy in Sub Saharan Africa: A Comparison of Kenya and Ghana* (Brighton: Institute of Development Studies, April 2016).