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Towards 100% Renewable Energy Cities and Regions for Climate Change Mitigation in Kenya

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ABBREVIATIONS AND ACRONYMS

COD	Commercial Operation Date
CS	Cabinet Secretary
CSP	Concentrated Solar Power
ERB	Energy Regulatory Board
EPRA	Energy and Petroleum Authority
ERC	Energy Regulatory Corporation
FiT	Feed-in-tariff
GDC	Geothermal Development Company
GDP	Gross Domestic Product
GHGs	Greenhouse gases
GHI	Global Horizontal Irradiation
GoK	Government of Kenya
GWh	Gigawatt hour
IPP	Independent Power Producer
KenGen	Kenya Electricity Generating Company
KETRACO	Kenya Electricity Transmission Company
KenInvest	Kenya Investment Authority
KNES	Kenya National Electrification Strategy
KOSAP	Kenya Off-Grid Solar Access Project
KP	Kenya Power
KPLC	Kenya Power and Lighting Company
LCPDP	Least Cost Power Development Plan
Li-ion	Lithium-ion
MW	Megawatt
NuPEA	Nuclear Power and Energy Agency
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Systems
REREC	Rural Electrification and Renewable Energy Corporation

SREP	Scaling-up Renewable Energy Plan
TWh	Terawatt hours
USD	United States Dollar

EXECUTIVE SUMMARY

The Kenyan electricity supply industry has gone through several reforms particularly during the 1990s and early 2000s. These reforms have led to a relative stable and attractive power market to foreign investors. The electricity sector is unbundled with separate entities responsible for generation, transmission, distribution and retailing. The total installed on-grid capacity stood at 2,712 MW as of June, 2019. The generation mix includes hydropower (826 MW), geothermal (663 MW), thermal which comprises of diesel powered generators and heavy fuel oil (808 MW), Cogeneration from bagasse (28 MW), Solar PV (50.94 MW) and On-shore Wind (336 MW).
Of this electricity, 70.21% was generated locally using renewable energy sources, while 29.79% was generated using fossil fuels in the form of diesel plants. Strong policy and regulatory reforms have created a supportive environment for participation of independent power producers (IPPs) in the electricity sector. As of 2019, IPPs accounted for 1,020 MW of grid installed capacity, which equates to 25.5% of total energy mix.

Kenya wants to achieve universal access to electricity by 2022. This target is espoused in the 2018 Kenya National Electrification Strategy (KNES) and will be achieved through grid densification, intensification, and expansion as well as off-grid solutions. The strategy has a strong off-grid component and expects to provide approximately two million new connections by the year 2022.

There has been a positive growth on electricity consumption and it is attributed to increase in domestic connections and growth in the manufacturing sector. From the demand forecast, this is expected to grow and it will be driven by the on-going flagship Vision 2030 projects which are to be achieved through the third medium term plan (MTP3) - dubbed the Big Four Agenda - which targets manufacturing, housing and food security sectors. Electricity is a key enabler of this agenda.

Kenya is endowed with rich renewable energy resources like hydro, solar, wind and geothermal sources. The government promotes investments on renewable resources through the feed-in-tariff (FiT) policy as it intends to generate all of its electricity demand from renewable sources. This will result in affordable electricity due to less reliance on deploying expensive diesel generators that pollute the environment by increasing greenhouse gases emissions (GHGs).

Due to the intermittency of both solar and wind power, energy storage will play a critical role in ensuring that Kenya has safe, reliable power across the country. The Ministry of Energy (MoE) is collaborating with the African Development Bank (AfDB) to develop up to 10 MW of energy storage facilities, especially in off-grid areas, but there is need for a 'National Study' to identify and map out the potential and demand in energy storage, and a 'Sectoral Policy on Energy Power Storage' to effectively drive this technology in Kenya.

1. INTRODUCTION

1.1. Historical background and current situation of Kenya's power sector

The growth and expansion of Kenya's power sector industry dates back to 1922 when two power supply companies merged to form East African Power and Lighting Company (EAP&L)[1]. In 1954, Kenya Power Company (KPC) was formed as a subsidiary of EAP&L, whose mandate was construction of transmission lines to import power from Owen Falls in Uganda to Nairobi in Kenya. In 1983, EAP&L was renamed to Kenya Power and Lighting Company Limited (KPLC), which later rebranded and changed to Kenya Power; its current brand name since 2013.

As part of power sector reforms, the Government of Kenya (GoK) published a policy framework paper on economic reforms in 1996[2]. The intention of this paper was to initialize the unbundling and restructuring of the power sector, and promote participation of private investors. The government passed the Electric Power Act of 1997, which created Electricity Regulatory Board (ERB) as the sector regulator. It also unbundled the vertically integrated utility KPLC into Kenya Electricity Generating Company Limited (KenGen), a semi-public owned company responsible for the generation assets, and KPLC which remained responsible for all distribution and transmission of electricity. As a result of this 1997 Act, Independent Power Producers (IPPs) have been able to generate electricity and sell it to KPLC under negotiated Power Purchase Agreements (PPAs).

There have been continued reforms taking place in the power sector, especially with the adoption of 'Sessional Paper No. 4 on Energy' in 2004[3] and subsequent enactment of the Energy Act of 2006. The Paper also introduced feed-in-tariffs (FiTs) to promote renewable energy. This Act established the Rural Electrification Authority (REA) and restructured the Electricity Regulatory Board (ERB) to Energy Regulatory Commission (ERC) as a single regulatory body. Energy Act No. 12 of 2006 also established the Energy Tribunal that arbitrates disputes and appeals between parties involved in the energy sector. Sessional Paper No. 4 of 2004 on Energy provided for the establishment of the Geothermal Development Company (GDC) and Kenya Electricity Transmission Company (KETRACO). Legal Notice No. 131 of 2012 provided for the establishment of Kenya Nuclear Electricity Board (KNEB)[4].
More recently, the revised Energy Act, 2019[5] paved the way for the energy sector to take further steps towards its modernization and development. The Energy Act, 2019 has several amendments to the repealed Energy Act, 2006, intended to: consolidate the laws relating to energy, properly delineate the functions of the national and devolved levels of government in relation to energy, provide for the exploitation of renewable energy sources, regulate midstream and downstream petroleum and coal activity for the supply and use of electricity and other forms of electricity.

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[1] Mombasa Electric Power and Lighting Company and Nairobi Power and Lighting Syndicate (both established in 1908)
[2] Government of Kenya, with IMF and World Bank (1996), 'Kenya Economic Reforms for 1996-1998: The Policy Framework Paper', (https://www.imf.org/external/np/pfp/kenya/kenya.pdf), accessed 10th April 2020.
[3] Government of Kenya (2004), 'Sessional Paper No. 4 of 2004 on Energy' (http://www.erc.go.ke/images/Regulations/SESSIONAL%20PAPER%204%20ON%20ENERGY%202004.pdf), accessed 10th April 2020.
[4] www.nuclear.co.ke
[5] https://www.epra.go.ke/download/the-energy-act-2019/

The new Act has established several new "energy sector entities" that replaced those existing under the repealed laws and has gone further to restate and expand their mandates for them to properly discharge their functions. The Act led to restructuring of Energy Regulatory Commission (ERC) to Energy and Petroleum Regulatory Authority (EPRA); Rural Electrification Authority (REA) to Rural Electrification and Renewable Energy Corporation (REREC); Nuclear Power and Energy Agency (NuPEA) is the successor of Kenya Nuclear Electricity Board (KNEB); Energy and Petroleum Tribunal (EPT) is the successor of the Energy Tribunal.

Presently, Kenya's electricity sector remains unbundled in nature with separate entities responsible for power generation, transmission, distribution and retailing.
Key stakeholders/entities and their roles in the energy sector in Kenya are tabulated below (**Table 1)**.

Table 1: Key stakeholders in the energy sector[6][7]

Institution Level	**Institution**	**Role**
Lead Institution / National Government	**Ministry of Energy (MoE)**	The Ministry of Energy is the lead institution mandated with policy formulation and provides a long-term vision to all energy sector players. The Ministry oversees sectoral planning, electrification of rural areas and exploration of indigenous energy sources, promotes the development of renewable energy, and mobilizes financial resources for the public sector.
National Government	**Energy and Petroleum Regulatory Authority (EPRA)**	EPRA is responsible for regulating energy subsectors, providing consumer protection, ensuring reasonable return on developers' investments, overseeing licensing of power companies and reviewing and approving power purchase agreements (PPAs) and power tariffs.
	Rural Electrification and Renewable Energy Corporation (REREC)	REREC is responsible for implementing rural electrification through extension of the grid and off-grid projects, managing the Rural Electrification Programme Fund, establishing energy centers in counties, mobilizing funds in support of rural electrification projects, financing project preparation studies for rural electrification and recommending suitable policies to the government; developing, promoting and managing the use of all renewable energy and technologies excluding geothermal; and coordinating research in renewable energy.
	Renewable Energy Resources Advisory Committee (RERAC)	RERAC is an inter-ministerial committee intended to advise the Cabinet Secretary of Energy on matters concerning the allocation and licensing of renewable energy resources areas, management of water towers and catchment areas, development of multi-purpose projects, such as dams, and development and management of renewable energy resources.
	Kenya Electricity Generating Company	KenGen is the largest generating company and is majority Government owned. It is mandated with developing and managing

[6] Government of Kenya (2018*)*, Kenya National Electrification Strategy, Key Highlights.
[7] Energy Act, 2019

	(KenGen)	all public power generation facilities.
	Kenya Power and Lighting Company (KPLC)	KPLC is 51% Government owned and it owns and operates both the transmission and distribution networks throughout Kenya. KPLC is responsible for purchase of all bulk electricity and is the sole supplier to end use customers throughout the country. KPLC also operates the majority of the off-grid diesel power plants on behalf of the Rural Electrification Programme. It is the system operator and is responsible for generation scheduling and dispatch, frequency control, voltage control, outage management and system security
	Kenya Electricity Transmission Company (KETRACO)	KETRACO is 100% Government owned and owns, plans, designs, builds, operates and maintains high voltage electricity transmission lines (132kV and above) and associated substations.
	Nuclear Power and Energy Agency (NuPEA)	NuPEA is the implementing agency mandated with development of a comprehensive legal and regulatory framework for nuclear electricity generation and use in Kenya. It carries out research, development, and dissemination activities in the energy and nuclear power sector, and develops the human resource capacity to ensure Kenya has the requisite manpower to successfully establish and maintain a nuclear power programme.
	Geothermal Development Company (GDC)	GDC is a fully Government owned special purpose vehicle (SPV) that undertakes surface exploration, appraisal and production drilling, manages proven steam fields, and enters into steam sales agreements with investors in the geothermal power sector.
County Governments	**47 County Governments**	County Governments prepare their respective County Energy Plans in respect of energy requirements for the Cabinet Secretary of Energy. Some of these counties provide supplementary funding to rural electrification projects within their counties.
Private Electricity Suppliers	**Independent Power Producers (IPPs)**	IPPs are private investors in the power sector. They are involved in power generation either at large-scale or in development of renewable energy projects under the Feed-in-Tariff Policy.
	Private Companies	Private companies involved in Off-grid solutions provide mini-grids and standalone renewable energy systems to energy consumers.
	Emergency Power Producers (EPPs)	EPPs are private companies that have quick, readily deployable energy on demand in times of an emergency. They use fossil fuels generators "on demand" for short-term supply as a basis. They are firms like Aggreko, Ibera Africa, Gulf and others.
Independent Entities	**Energy and Petroleum Tribunal (EPT)**	This is an independent legal entity that arbitrates disputes and appeals between parties in the power sector.

2. KENYA ENERGY LANDSCAPE

2.1. Current energy portfolio in Kenya

In 2019, Kenya's installed power generation capacity was 2,712 MW, up from 2,629 MW in 2018, representing a 3% growth (up from 0.8% in 2017). This additional 361 MW capacity includes 310 MW from Lake Turkana Wind Power (LWTP) Farm which was commissioned in September 2018[8] and 50MW Garissa Solar Power developed by Rural Electrification and Renewable Energy Corporation (REREC), commissioned in November 2018[9].

Electricity generated increased to 11,493 GWh in 2019, up from 10,702 GWh in 2018, representing a 6.9% increase (up from 4.9% in 2018). This marked positive growth in power generated and is a result of growth in the commercial/industrial electricity consumption.

In 2019, the energy generation mix remained relatively stable with contribution from geothermal sources reducing from 47% (2018) to 43.79%. Hydro contribution rose to 32.55% in 2019, up from 30.12% in 2018. Overall, hydro increased from 3.2 GWh in 2018 to 3.7GWh in 2019, representing a 14% increase. This is a result of increased rainfall in 2019 which boosted generation from most of the hydroelectric dams. Thermal power plants contribution decreased from 20.6% in 2018 to 11.29% in 2019 as a result of more renewable energy connections to the grid.

Total generation from wind power rose significantly from 25.5 GWh in 2018 to 1,192 GWh in 2019 marking a 97.9% increase, which in-turn accounted for 10.4% of the total energy mix in the country[10]. Solar power annual generation on the other hand rose from 0.15 GWh in 2018 to 60.15 GWh in 2019 translating to 99.8% increment (up from less than 1% in 2018), representing 0.52% of the total energy mix. These sources of renewable energy mitigated the increase in electricity costs by minimizing dispatch of expensive thermal sources.

Peak power demand, registered on the national grid, grew by 5.8% from 1,802 MW in 2018 to 1,912 MW in 2019. The growth in power demand was largely driven by the increased number of customers and growing consumption in the commercial and industrial sectors **(Table 5).**

Total installed capacity from IPPs rose to 1,020 MW in 2019, up from 709 MW the previous year, which equates to a 30.5% increase. The total energy generated increased from 2.49 GWh in 2018 to 2.9 GWh in 2019 - accounting for 25.5% of the total energy mix.

A detailed statistical breakdown of the contribution for various sources of energy in the generation mix is presented in **Table 2, 3 and 4** below for the different sources.

[8] https://ltwp.co.ke/overview/
[9] https://www.rerec.co.ke/index.php?option=com_content&view=article&id=53&Itemid=234 (Accessed on 10th April, 2020).
[10] This is as a result of injecting 310 MW from Lake Turkana Wind Power into the national grid.

Table 2: Power system operation statistics for the last 7 years[11]

COMPANY	Capacity (MW) as at 30.06.2019		Energy generated in GWh						
	Installed	Effective[12]	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
KenGen									
Hydro									
Tana	20.0	20.0	108	69	108	109	71	96	96
Kamburu	94.2	90.0	520	421	358	434	384	321	399
Gitaru	225.0	216.0	1,036	830	710	862	775	724	869
Kindaruma	72.0	70.5	252	201	165	208	183	179	193
Masinga	40.0	40.0	148	206	138	127	169	107	199
Kiambere	168.0	164.0	1,129	979	718	996	938	751	1,026
Turkwel	106.0	105.0	545	719	551	426	402	458	545
Sondu Miriu	60.0	60.0	393	351	376	419	282	388	258
Sangóro	21.0	20.0	110	109	125	140	90	129	82
Small Hydros	11.7	11.2	57	59	60	63	44	33	42
Hydro Total	**818**	**797**	**4,298**	**3,944**	**3,308**	**3,784**	**3,339**	**3,186**	**3,707**
Thermal									
Kipevu I Diesel	74	60	185.2	219.9	156.5	128.6	211.3	238.3	197
Kipevu III Diesel	120.0	115.0	320.7	524.2	299.0	181.4	512.1	583.8	490
Embakasi GT	30.0	28.0	27.3	41.3	4.1	0.6	0.2	0.0	0.0
Muhoroni GT	30.0	27.0	-	-	-	-	108.0	65.5	67.0
Garissa & Lamu	-	-	26.9	27.6	11.7	12.4	-	0.0	0.0
Garissa Temporary Plant (Aggreko)	-	-	-	-	21.0	18.6	-	-	0.0
Thermal Total	**254**	**231**	**560**	**813**	**492**	**342**	**83**	**888**	**754**
Geothermal									
Olkaria I	45.0	44.0	369	352	333	331	195	247	285
Olkaria II	105.0	101.0	696	712	756	814	791	832	796
Eburru Hill	2.54	2.2	9	7	11	10	0	6	10
Olkaria Mobile Wellheads	80.6	77.8	23	53	196	357	472	518	492
Olkaria IV	140.0	140.0	0.0	32	1,064	976	852	1,132	1,095
Olkaria I 4 & 5	140.0	140.0	0.0	0.0	744	1,055	968	1,133	1,096
Geothermal Total	**513**	**505**	**1,096**	**1,156**	**3,104**	**3,542**	**3,279**	**3,868**	**3,747**
Wind									
Ngong	25.5	25.5	13.9	17.6	37.7	56.7	63.2	47.5	67.4
KenGen Total	**1,610**	**1,558**	**5,968**	**5,931**	**6,943**	**7,725**	**7,513**	**7,987**	**8,276**
Government of Kenya, Rural Electrification Programme									
Thermal	31.4	21.3	26.0	29.8	35.1	39.9	40.8	46.9	57.6
Solar	0.69	0.62	0.6	0.8	0.9	0.8	0.5	0.0	0.06
Wind	0.660	0.494	0.7	0.4	0.0	0.000	0.003	0.124	0.0
Total Off-grid	**27**	**18**	**27**	**31**	**36**	**41**	**41**	**47**	**58**

[11] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2018/2019
[12] Contracted output from the station under normal operating conditions

Independent Power Producers (IPPs)									
Iberafrica I&II	108.5	102.5	592	550	198	128	252	186	74
Tsavo	74.0	74.0	178	454	233	70	168	215	131
Thika Power	87.0	87.0	-	454	233	70	168	215	107
Biojule Kenya Limited	2.0	2.0	-	-	-	0.0	0.7	0.4	0.3
Mumias - Cogeneration	26.0	21.5	71	57	14	0.0	0.0	4	0.0
OrPower 4 - Geothermal I, II, III and IV	150	150	503	851	955	1066	1172	1,186	1,285
Rabai Power	90.0	90.0	443	633	609	536	606	562	120
Imenti Tea Factory (Feed-in Plant)	0.283	0.283	0.7	0.1	0.5	0.7	0.3	0.6	0.3
Gikira small hydro	0.514	0.514	-	0.4	1.6	1.9	0.9	1.4	1.1
Triumph Diesel	83.0	83.0	-	-	4.8	81.8	83	28	16
Gulf Power	80.32	80.32	-	-	60	8	61	80	37
Regen-Teremi	5.0	5.0	-	-	-	-	1	18	20
Gura hydro	2.0	2.0	-	-	-	-	-	17	12
Chania hydro	0.50	0.50	-	-	-	-	-	0.8	0.3
Strathmore University	0.25	0.25						0.2	0.15
Lake Turkana Wind Power	310.0	300.0	-	-	-	-	-	-	1,124
IPPs Total	**1,020**	**999**	**1,788**	**2,698**	**2,160**	**1,934**	**2,466**	**2,495**	**2,930**
Emergency Power Producers(EPP)									
Aggreko Power	0	0.0	261	94	63	50	0.0	0.0	0.0
EPP Total	**0**	**0**	**261**	**94**	**63**	**50**	**0.0**	**0.0**	**0.0**
Garissa Solar									
REREC Garissa	50	50	-	-	-	-	-	-	60
Garissa solar total	**50**	**50**	**-**	**-**	**-**	**-**	**-**	**-**	**60**
Imports									
UETCL	-	-	41	83	76	65	180	168	168
TANESCO	-	-	1.2	1.3	0.6	0.0	0.0	0.0	0.0
EEPCO-Moyale	-	-	-	2.1	2.8	2.6	3.4	3	1.8
Total Imports	**-**	**-**	**42**	**87**	**79**	**67**	**184**	**171**	**170**
SYSTEM TOTAL	**2,712**	**2,629**	**8,087**	**8,840**	**9,280**	**9,817**	**10,205**	**10,702**	**11,493**

Table 3: Installed and effective capacity (MW) in 2019[13]

Technology	Capacity (MW) at 30.06.2019			
	Installed	Effective	Installed	Effective
Hydro	826	805	30.46%	30.62%
Geothermal	663	655	24.44%	24.91%
Thermal	808	769	29.79%	29.26%
Cogeneration	28.0	23.5	1.03%	0.89%
Solar	50.94	50.87	1.88%	1.93%
Wind	336	326	12.39%	12.38%
Total	**2,712**	**2,629**	**100%**	**100%**

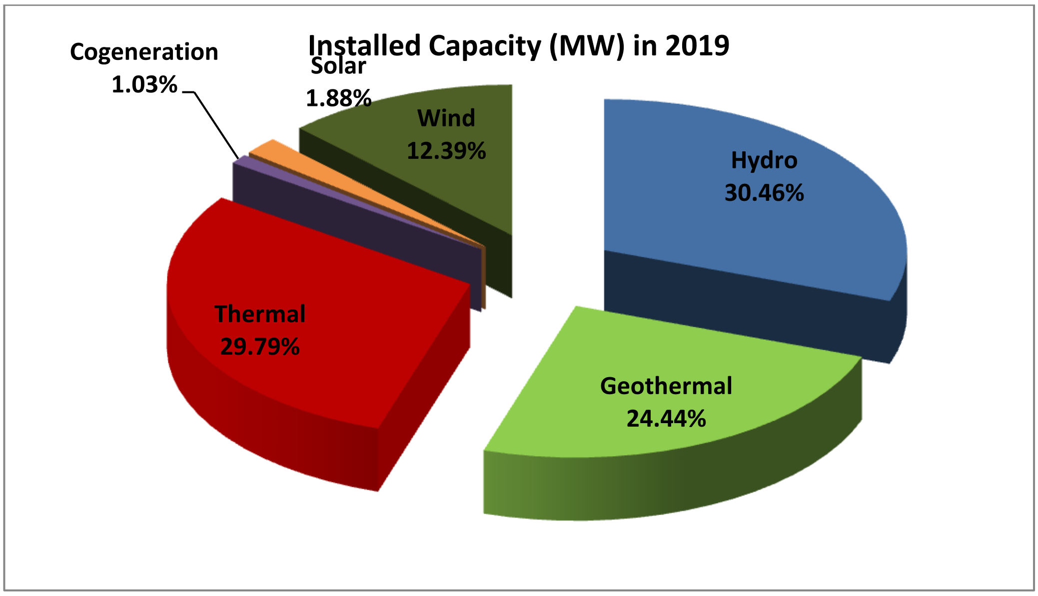

Figure 1: Installed capacity (MW) in 2019

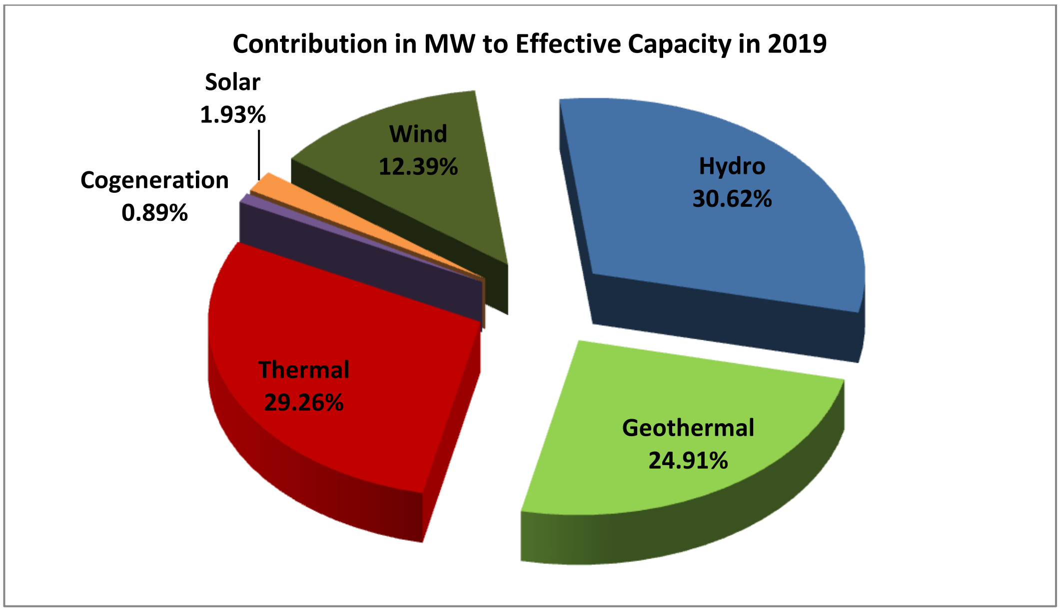

Figure 2: Effective capacity (MW) in 2019

[13] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2018/2019

Table 4: Generation mix in GWh in 2018/19[14]

Technology	Capacity (GWh)	Percentage %
Hydro	3,741	32.55%
Geothermal	5,033	43.79%
Thermal	1,298	11.29%
Cogeneration	0.27	0.00%
Solar	60	0.52%
Wind	1,192	10.37%
Imports	170	1.48%
Total	**11,493**	**100%**

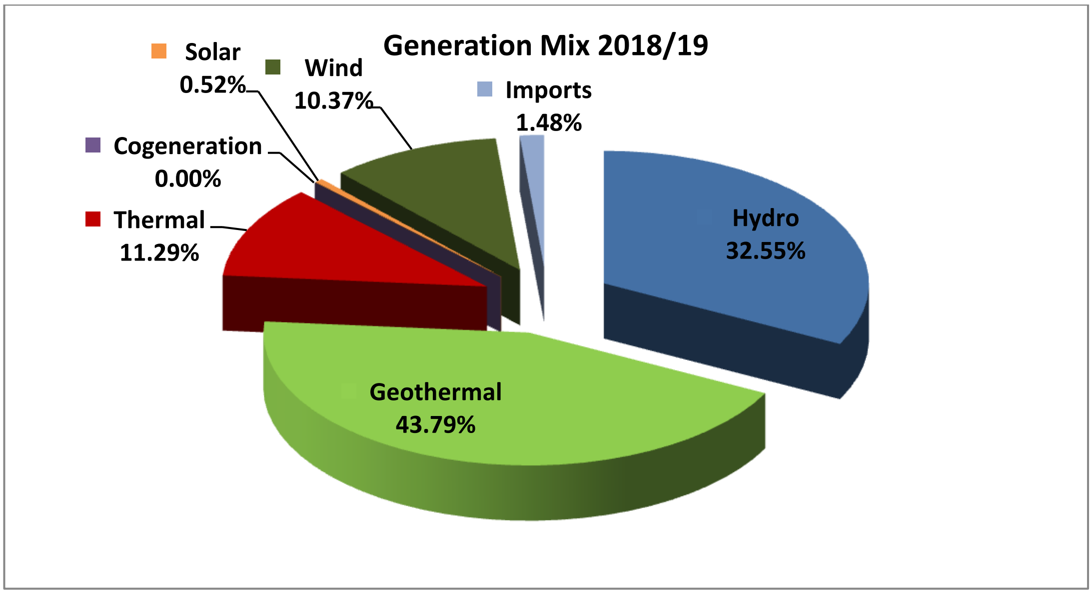

Figure 3: Electricity generation mix in 2019

Table 5: Peak demand from 2008 to 2019[15]

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Peak demand (MW)	1,044	1,072	1,107	1,194	1,236	1,354	1,468	1,512	1,586	1,656	1,802	1,912

[14] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2018/2019
[15] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037

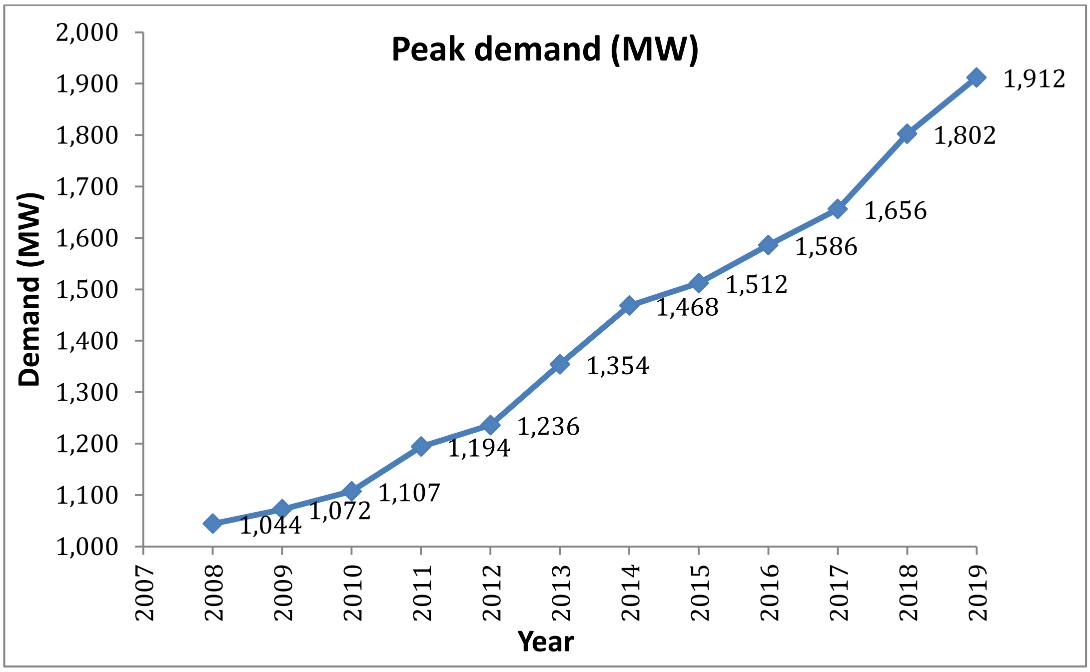

Figure 4: Peak demand (MW) from 2007 to 2019

2.2. Potential 'prosumers' in Kenya

Prosumers of renewable are operators that produce a portion of their onsite power needs from renewable energy technologies and sell the excess electricity to the national/local grid or local community. This includes renewable energy sources for heating and cooling needs, as well as electricity generation. It also includes the use of certain bio-energy resources such as those from forestry, meat processing, agriculture, as well as the waste management sector.

In Kenya, industrial prosumers have the potential to contribute significantly to social inclusiveness of industrial development, as the possibility of a self-supplied low-cost energy option allows local households in rural communities to maximize their productivity and add value to their products. Industrial prosumers can give rise to decentralized energy system providers.
In Kenya, IPPs play a key role in this and prosumers who currently supply excess power generated to the national grid are:

- ✓ Imenti Tea Factory owned by Kenya Tea Development Authority (KTDA) that has an installed capacity of 0.283 MW and supplied 0.3 GWh to the grid in 2019;
- ✓ Strathmore Solar owned by Strathmore University with an installed capacity of 0.25 MW and supplied 0.15 GWh to the grid in 2019;
- ✓ Mumias Sugar Company does cogeneration from bagasse to fully support its requirements and injects the surplus electricity to national grid. It has an installed capacity of 26MW and uses 12 MW for factory needs and domestic use in the staff quarters[16].

Some of the 'big' customers for Kenya Power that were not satisfied with high energy costs have resorted to generating their own electricity at site for their consumption through embedded power in the form of solar PV systems. Malls, flower farms, factories, tea estates and universities are taking

[16] http://www.iwmi.cgiar.org/Publications/Books/PDF/resource_recovery_from_waste-238-247.pdf

up embedded solar systems because they are reliable, they help control costs, they meet growing consumer demand for green power and they increase productivity. Selected embedded solar PV projects in Kenya include: Dormans Coffee, Tatu City (1.0MW), Galleria Mall (0.56MW), Bidco Thika (1.2MW), Waridi Flowers (0.22MW), Penta Flowers (0.25MW), Kilaguni Serena (0.3MW), International School of Kenya (0.15MW) and Two Rivers Mall (1.3MW).

In Kenya, agro-industrial prosumers in areas without grid electricity access can act as rural energy entrepreneurs, adding electricity to their product line by generating additional revenue while offering local energy benefits to the surrounding community. EPRA estimates that Kenya-based sugar millers in the Western region can generate a total of 150MW to the grid by 2022. The State is offering feed-in-tariff US10 cents per kilowatt hour to boost the struggling sugar industry to expand their income generation portfolio. This move is also aimed at stopping expensive importation of power from Uganda and may potentially decommission the costly thermal back-up plant in Muhoroni[17]. Tea growing and production industry not connected to the national grid is another potential sector where prosumers can actively take part. In addition, Kenya generates a lot of waste (industrial, agricultural and domestic) that could be harnessed to generate electricity.

Barriers to entry of potential prosumers

Some of the barriers to potential prosumers into the Kenyan energy landscape include:

I. Lack of policies governing the sale of excess energy;
II. Opposition from incumbent energy system owners; and
III. Limited local capacities on renewable energy technologies.

[17] https://www.standardmedia.co.ke/business/article/2001330064/state-eyes-150mw-electricity-generation-from-sugar-factories

3. RENEWABLE ENERGY RESOURCES POTENTIAL IN KENYA

Kenya has a promising potential of generating its power from the renewable energy resources it is endowed with. The country has abundant solar, hydro, geothermal, wind and biomass resources that can be harnessed. This has led the government to focus on the expansion of renewable energy generation, supported by the reduction in the contribution of thermal power plants to the country's total energy mix. Through the government-supported Least Cost approach, the development of geothermal, wind energy plants as well as solar-fed mini-grids intended for rural electrification has been prioritized.

3.1. Hydropower energy

Kenya has a significant hydropower potential that is estimated in the range of 3,000 – 6,000 MW. Currently, 3,741 MW of hydropower has been exploited, consisting of both small and large installations owned and operated by national power generation utility KenGen. Most of this potential is situated within the country's six main drainage basins. The implementation of some of these schemes is undertaken by both the Government and IPPs.

It is estimated that the undeveloped large hydroelectric power potential of economic significance equates to 1,449 MW, of which 1,249 MW (or approximately 86%) is suitable for large projects whose capacity is 30 MW or above. Small, mini and micro hydroelectric systems (with capacities of less than 10 MW) are estimated to have a generation potential of 3,000 MW. As of 2019, small hydropower schemes run by KenGen had an installed total capacity of 11.7 MW, while those run by private developers was 8.3 MW. In 2019, the existing hydropower plants contributed 32.55% of the annual generation mix. Average energy production from these potential projects is estimated to be at least 5,605GWh per annum. This hydroelectric potential is located in five geographical regions of Kenya's six major drainage basins. Of these, 151 MW has been identified in Lake Victoria North basin, 178 MW in Lake Victoria South basin, 305 MW in Rift Valley basin, 790 MW is Tana River basin and 60 MW in Athi River basin as shown in **Table 6** below.

Table 6: Hydropower potential of major catchment areas[18]

Catchment area	Area (Km^2)	Major Rivers	Identified hydropower potential (MW)
Lake Victoria North	18,374	Nzoia R., Yala R.	151
Lake Victoria South	31,734	Nyando R., Sondu R., Kuja R., Mara R.	178
Rift Valley	130,452	Turkwel R., Kerio R., Ewaso Ng'iro South R.	305
Tana	126,026	Tana R.	790
Athi	58,639	Athi R., Lumi R.	60
Ewaso Ng'iro North	210,226	Ewaso Ng'iro North R., Daua R.	0
TOTAL	**575,451**		**1,484**

[18] Power Generation and Transmission Master Plan, Kenya Long Term Plan 2015 - 2035 – Vol I

There is a growing awareness of the possibilities that small hydropower might offer in terms of vast generation options. Several studies and investigations have been carried out in order to verify this. However, so far only a few small hydropower schemes have been realized, either as part of the national grid supply or as stand-alone systems for agro-industrial establishments, as is the case with tea growing and production farms in Kenya. The economic risk in undertaking hydropower projects can be large, because they are capital intensive. There is uncertainty with regard to power prices in the future, and the costs of building and producing hydropower vary significantly from power plant to power plant, depending on variables such as the size and location of the plant. Additionally, a small generator requires approximately as many people to operate as a large one, although larger hydropower plants normally have a lower cost per kilowatt. Another key risk related to a hydro-dominated power system, like Kenya's, is its vulnerability to large variations in rainfall and climate change. This has proven to be a challenge in the recent past, with the failure of long rains that resulted in power and energy shortfalls.

Beyond the existing schemes, Kenya still has substantial hydropower potential. This is reflected by current plans to develop large hydro projects in Karura and High Grand Falls (both in the Tana catchment area), Nandi Forest (in the Lake Victoria North catchment area) and Magwagwa (in the Lake Victoria South catchment area), and Arror (in the Rift Valley area). This development could lead to additional hydropower capacity of over 800 MW in the long-term.
There is a large pipeline of small hydropower projects under the FiT scheme. Feasibility studies of smaller hydropower projects are still on-going.

3.2. Geothermal energy

The Great Rift Valley of section of Kenya is endowed with rich geothermal resources. A map showing potential prospects locations in Kenya is shown in **Figure 5** below.

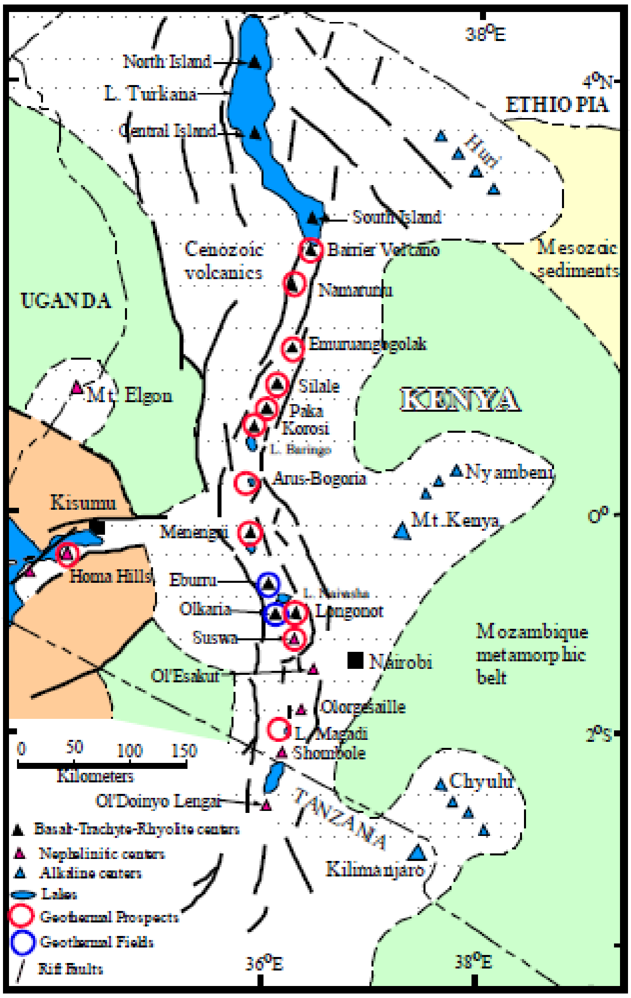

Figure 5: Geothermal prospects locations in Kenya[19]

Region	Potential (MW)
I. RIFT REGION	
1. Central Rift	
a) Menengai	1,600 MW
b) Eburru	250 MW
c) Arus Bogoria	400 MW
Sub-total	**2,250 MW**
2. South Rift	
a) Olkaria	2,000 MW
b) Longonot	750 MW
c) Suswa	600 MW
d) Lake Magadi	100 MW
Sub-total	**3,450 MW**
3. North Rift	
a) Lake Baringo	200 MW
b) Korosi	450 MW
c) Paka	500 MW
d) Silali	1,200 MW
e) Emuruangogolak	650 MW
f) Namarunu	400 MW
g) Barrier	450 MW
Sub-total	**3,850 MW**
II. NYANZA REGION	
a) Homa Hills	100 MW
b) Akira	350 MW
Sub-total	**450 MW**
TOTAL POTENTIAL	**10,000 MW**

Table 7: Geothermal potential in Kenya[20]

In Kenya, 16 high temperature potential sites occur along the Rift Valley. Other locations include Homa Hills and Akira in Nyanza. Geothermal resource potential is estimated at 10,000 MW **(Table 7)** along the Kenyan Rift Valley. Nakuru County is endowed with the majority of geothermal resources; Olkaria, Menengai, Ebbru and Suswa are all in Nakuru County. Currently geothermal power is only being harnessed in the Olkaria, Menengai and Eburru fields. In the medium- and long-term, new geothermal reservoirs, such as Suswa, Longonot, Akiira and Baringo Silali are planned to be developed. Other potential geothermal prospects within the Kenya Rift that have not been studied in great depth include Emuruangogolak, Arus, Badlands, Namarunu, Chepchuk, Magadi and Barrier[21].

Presently, geothermal resources account for 663 MW of the total installed generation capacity. KenGen accounts for 513 MW of the total installed capacity and its plants are equipped with single-

[19] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037
[20] Ibid
[21] Ibid

flash steam technology, while the remainder is owned by IPPs which use binary steam-cycle technology. Geothermal power plants run as base load due to the low short-run marginal costs.

It can be expected that geothermal power will play an essential role in the future Kenyan power system. Good knowledge and expertise in geothermal exploration, drilling, power plant implementation and operation is already present in the country. However, drilling risks, high upfront costs and a rather long implementation period have to be taken into account in the planning stage.

Geothermal power provides reliable base load power at low operating cost. Single flash technology, which is mainly being utilized in Kenya today, is restricted in providing flexible power due to technical reasons. Binary systems however, are able to be operated very flexibly. With regard to future geothermal expansion and considering the power system needs (load following, regulation control), it is recommended that the opportunity to use binary technology is explored and deployed.

3.3. Wind energy

Kenya has vast unexploited wind energy resource. Wind energy is considered to be the most mature in terms of commercial development in Kenya, compared to other renewable energy resources. In the recent years, there has been a sharp decrease in wind energy development costs.

Experience in using wind for power generation in Kenya is steadily growing and this is demonstrated most notably with the commissioning and operation of the 310 MW Lake Turkana Wind Power Farm in Loiyangalani, Marsabit County. It comprises of three hundred and sixty turbines each with a name plate capacity of 850 kW[22]. The best potential locations for wind power generation are located in Samburu, Laikipia, Meru, Nyeri and Nyandarua and Kajiado counties. Other potential areas of interest are Lamu, off shore Malindi, Loitokitok at the foot of Kilimanjaro and Narok plateau. On average, the country has an area of approximately 90,000 square kilometers[23] that has excellent wind speeds of 6 m/s and above that is suitable for wind power generation.

Wind turbines do not produce power constantly and, at their rated power (which is only achieved at higher wind speeds); capacity factors are typically in the range of 20% to 55%. Due to the intermittent nature of energy generated from wind sources, investment in battery storage is highly encouraged for investors contemplating joining the Kenyan market. A wind energy data analysis and development programme conducted in 2013 by WinDForce Management Services Pvt. Ltd[24] indicates a total technical potential of 4,600 MW of which 2,036 MW is expected to be installed by 2030[25]. Local production and marketing of small wind generators has started, and a few pilot projects are under consideration. However, thus far only a few small and isolated wind generators are in operation.

[22] https://www.power-technology.com/projects/lake-turkana-wind-power-project-loyangalani/
[23] This is a portion of the entire country suitable for wind power generation.
[24] Wind sector prospectus for Kenya
[25] https://www.renewableenergy.go.ke/asset_uplds/files/Wind%20Sector%20Prospectus%20Kenya.pdf

3.4. Solar Energy

Kenya has high insolation rates and solar power is largely regarded as an option for rural electrification and decentralized applications. Over time, there has been an increase in installation of domestic solar systems for lighting and heating purposes. Commercial and industrial applications such as flower and vegetable farms, malls have already pioneered and installed captive renewable energy systems to contribute to the power supply on their premises. Another interesting upcoming market is for solar energy for productive use such as domestic and commercial solar water heaters, solar water pumps, solar based refrigeration and solar drying. The use of these technologies is not yet widespread but demand appears to be high.

3.4.1 Solar photovoltaic (PV)

Photovoltaic (PV) devices convert solar energy directly into electrical energy. The amount of energy that can be produced is proportional to the amount of solar energy available on a specific site. PV has a seasonal variation in electricity production, with the peaks generally following months with the highest solar irradiation. Due to the stable climate, PV systems operating along the equator typically have a fairly consistent exploitable solar potential throughout the year. In favourable regions, the global horizontal irradiation (GHI) is up to 22,400 kilowatt hour per meter squared per year (kWh/m²/year).

As a result of its position across the equator (4.5° South and 5° North), Kenya is endowed with very high solar resources. Kenya experiences high insolation rates, averaging five to seven hours of peak sunshine and an average daily insolation rate of 4 to 6 kWh/m^2. As a result of dispersion and conversion efficiency of solar photovoltaic (PV) modules, 10 to 14% of this energy can be converted into electricity. This translates to an approximate energy generation of 23,046 TWh/year for PV installations. Therefore, Kenya has the potential to generate all its electricity needs from solar resources.

In Kenya, PV stand-alone systems for households and public institutions have been subsidized. The Government has zero-rated the import duty and removed Value Added Tax (VAT) on renewable energy equipment and accessories.
The government is planning to install an additional 500 MW and 300,000 domestic solar systems by 2030. Commercial and industrial applications are becoming increasingly important. Flower and vegetable farms have already pioneered and installed captive renewable energy systems to contribute to power supply on their premises[26].
In addition, hybrid PV-diesel island grids are multiplying: 18 MW of existing diesel-run stations will be retrofitted for the use of solar power in the next few years.

3.4.2 Concentrated Solar Power (CSP)

Concentrated Solar Power (CSP) plants are thermal power plants that collect solar energy by using mirrors to concentrate direct sunlight onto a receiver. The receiver collects and transfers the solar thermal energy to a heat transfer fluid which can be used to generate electricity in a steam turbine. CSP plants typically include a thermal energy storage system. This allows for dispatchable

[26] https://www.get-invest.eu/market-information/kenya/renewable-energy-potential/

electricity generation, including possible generation during night time and periods with passing clouds.

Presently, Kenya does not have any CSP generation facility and its potential is not addressed in the medium and long term expansion planning. However, it is strongly recommended to closely monitor the global development of the technology in future years.

3.4.3 Solar water heater systems (SWH)

Water heating for domestic, residential and commercial establishments using electricity consumes a lot of energy which is expensive. As a result, to reduce energy bills and have an efficient and economical way of heating water at home, most Kenyans are now adopting the use of solar water heating systems (SWH). This has promoted the use of clean energy and reduction in energy related costs.
The most common types of solar water heating systems in the Kenyan market include: Flat plate collector solar system and Evacuated tube collected solar system.

3.4.3.1 Flat plate collector solar system

The Flat plate collectors are the common systems in domestic and residential homes in Kenya. It comprises of a rectangular frame with a transparent, glass/ plastic front cover that allows solar energy to pass through to a dark solar absorber which has a row of pipes filled with water or a heat transfer fluid flowing through. The frame has an insulated casing[27].

3.4.3.2 SWH market analysis

These SWH systems are sold by EPRA approved distributors and installed by licensed technicians. The market price for solar water heater panels in Kenya is Ksh. 50,000 (USD 500) to Ksh. 150,000 (USD 1,500) for domestic residential houses and Ksh. 600,000 to 2 million for commercial and industrial establishments[28][29].

There are about 77,000 SWH (equivalent to 457,076 m^2 of collector area) in the Kenyan market as of April 2017. The market currently supports an estimated 960 direct and indirect jobs. The untapped market including domestic, commercial, institutional and industrial is conservatively estimated to be 2 million units[30].

3.4.3.3 SWH market barriers

The main barriers hindering the uptake of SWH in Kenya include: inadequate technical skills, high upfront costs, lack of innovative business models, limited financing options, unclear policy requirements, intermittent supply of water, disjointed institutional mandate, inadequate technical

[27] https://www.solarthermalworld.org/sites/default/files/news/file/2018-10-31/study_of_the_swh_industry_-_kenya_high_res_final.pdf
[28] https://solarshop.co.ke/solar-water-heaters/
[29] https://www.davisandshirtliff.com/shop/index.php?route=product/category&path=18_63
[30] https://www.solarthermalworld.org/sites/default/files/news/file/2018-10-31/study_of_the_swh_industry_-_kenya_high_res_final.pdf

standards, limited enforcement capacities among mandated institutions, low quality products and services and the owner-occupier mismatch[31].

3.4.3.4 The Energy (Solar Water Heating) Regulations, 2012

The regulation requires that all domestic dwellings or residential houses with 3+ bedrooms, commercial buildings, health institutions and educational institutions with hot water (60^0C) requirements of a capacity exceeding 100 litres per day shall install and use solar water heating (SWH) systems[32].
Non-compliance to this regulation renders one liable to a fine not exceeding one million Kenya shillings and/or imprisonment for a term not exceeding one year[33].

In 2018 following public outcry that the regulation will increase costs for landlords and tenants and undermine access to affordable housing which is part of the Big Four agenda, the parliament repealed this law. Parliament annulled this punitive fine on solar water heating systems on account of there being a contravention to the section of the Statutory Instruments Act (SI Act)[34].

EPRA dropped the water SWH law requiring building owners to install solar water heating systems and is reworking on the regulation to omit residential homeowners. This is a reprieve to real estate developers, homeowners and institutions which can now choose whether or not to install the system. The Draft Energy (Solar Photovoltaic Systems Regulations 2019) would only be specified to commercial building owners[35].

3.4.4 Innovative finance mechanism for solar home systems

3.4.4.1 Pay-As-You-Go

Pay-as-you-go (PAYG) is an innovative business model that harnesses technology to provide 'one-stop-shop' solutions for consumer finance and renewable energy products. PAYG is a technology-driven method that allows consumers to pay the least amount for a given energy system or pay a fee for the service of using the system. It uses information technology to enable remote activation with payment receipt[36]. PAYG solar home system (SHS) companies typically provide basic lighting and mobile phone charging services. It has since been replicated by M-KOPA and Angaza Limited due to its wider acceptability in the market. The technology is playing an important role in expanding access to electricity services to remote and low-income populations.

The standalone solar home system comes with an energy storage battery, a charge controller, solar panel and light emitting diode (LED) bulbs, and a mobile charger. Larger systems (typically 50W and above) can potentially connect direct current (DC) appliances such as a television and

[31] EDD Advisory Limited, 2017 – Study of the Solar water heating industry in Kenya.
[32] http://www.kpda.or.ke/documents/Policies/The%20Energy%20Solar%20Water%20Heating%20Regulations,%202012.pdf
[33] Government of Kenya (2012) The Energy (Solar Water Heating) Regulations, 2012. GoK
[34] Nation Media Group - https://www.nation.co.ke/business/MPs-quash-punitive-law-on-failure-to-install-solar-water-heaters/996-4699326-8goj2d/index.html
[35] The Star Newspaper - https://www.the-star.co.ke/business/2020-01-26-epra-reviews-solar-water-heating-law-homeowners-to-be-spared/
[36] Alstone, P., D. Gershenson, D. N. Turman-Bryant, D. Kammen, and A. Jacobson. 2015. Off-Grid Power and Connectivity Pay-as-You-Go Financing Digital Supply Chains for Pico Solar. Lighting Global Market Research Report.

refrigerator. Households with SHSs have reported lower kerosene usage, which in-turn lowers GHG emissions (both from carbon dioxide and black soot). Other benefits include increased household disposable income due to reduced spending on kerosene and candles; health benefits from reduced in-door pollution and increased evening study hours for school children[37].

This business model and addresses key challenges of extending end-user finance and collecting of payments from remote customers, who often have erratic and limited cash flow, through a "payment by installments" software application that protects the service provider and ensures paid for services to the consumer. Pioneering PAYG companies have successfully raised grant, equity, and more recently, debt finance to pilot, develop, and scale their businesses. This has been raised exclusively from international investors. There has been hesitance from local financial institutions to finance these PAYG customers, as they perceive PAYG companies as early-stage risky businesses and are unfamiliar with the technology, as well as the creditworthiness of rural consumers.

The absence of local capital sources to some extent explains the fact that almost all the successful PAYG companies are foreign-owned and -managed. Market leaders such as Azuri, M-KOPA, Mobisol, D.Light, Sumac have begun expanding into regional markets. For these companies to scale up and have a broader impact in the sector, there is need to raise more capital from donors and DFIs and introduce products that have larger energy generating capacities, if they are to provide more than basic lighting and mobile charging services.

Technological barriers to the PAYG business are falling and the sector is likely to see the entry of a larger number of companies, but access to finance remains a key entry barrier, particularly for locally owned and managed companies. Finance is most critically needed to build out marketing, sales, and service infrastructure and to provide customers with financing. New entrants in the PAYG sector will lead to increased competition and lower prices and allow products and services that offer higher levels of electricity access at affordable prices

[37] Kaufman, R., R. Duke, R. Hansen, J. Rogers, R. Schartz, and M. Trexler. 2000. Rural Electrification with Solar Energy as a Climate Protection Strategy. Renewable Energy Policy Project

4. ELECTRICITY DEMAND IN KENYA

4.1. Electricity demand and Customer Characteristics

The demand for electricity has shown an upward trend in the last 5 years. While the demand was 7,655 GWh in 2014/15 it increased to 8,769 GWh in 2017/19. This represents an average annual percentage increase of 3.92%, with the highest growth recorded in 2014/15 (5.7%) as evidenced in **Table 7** below.

Table 7: Consumption in GWh for various categories of consumers/customers 2014/15 – 2018/19[38]

Tariff	Types of customers covered by this tariff	Consumption in GWh				
		2014/15	**2015/16**	**2016/17**	**2017/18**	**2018/19**
DC	Domestic	1,866	2,007	2,138	2,335	2,366
SC	Small Commercial	1,143	1,153	1,201	1,222	1,250
CI	Commercial and Industrial	4,030	4,104	4,266	4,225	4,462
IT	Off-peak	15	26	41	33	N/A
SL	Street lighting	35	40	55	66	68
	REP System (DC, SC,SL)	525	537	549	554	595
	Export to Uganda	38	43	20	22	27
	Export to TANESCO	2	2	2	1	0.01
	TOTAL	**7,655**	**7,912**	**8,272**	**8,459**	**8,769**
	% INCREASE P.A.	**5.70%**	**3.40%**	**4.50%**	**2.30%**	**3.70%**

There has been a positive growth among all consumer categories and this is largely attributed to the increased effort in attaining universal access to electricity by 2022[39]. The total number of customers increased to 7,067,861 in 2019 from 6,761,090 in 2018 representing a 4.5% growth as shown in **Table 8** below[40].

Table 8: Total number of customers covered by all tariff categories[41]

	Year and Number of Customers					
	2013/14	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
TOTAL (KPLC)	2,239,431	2,908,714	3,918,355	4,912,772	5,428,989	5,658,605
TOTAL (REP)	528,552	703,190	972,018	1,269,510	1,332,101	1,409,256
GROSS TOTAL	**2,767,983**	**3,611,904**	**4,890,373**	**6,182,282**	**6,761,090**	**7,067,861**
% INCREASE P.A.	**18.7%**	**30.5%**	**35.4%**	**26.4%**	**9.4%**	**4.5%**

Commercial and Industrial consumer category remains the largest consumers of electricity generated and this can be attributed to growth in the manufacturing sector and large commercial establishments in the economy driven by the growth in the gross domestic product (GDP).

[38] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2018/2019
[39] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.
[40] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2018/2019
[41] Ibid

4.2. Increasing customer connection

4.2.1 Last Mile Connectivity Project

In 2017/18, a total of 578,808 new customers were connected to the grid, growing the overall customer base by 9.4 percent to 6,761,090 million. This was attributed to the government funded Last Mile Connectivity Project (LCMP) which was launched in 2015 to scale up connectivity in rural and peri-urban areas by providing a subsidy for grid extension to enable customers to access to electricity supply at an affordable cost. As a result, the national electricity access from both grid and off-grid solution as at end of June 2018 had risen to 73% compared to 29% five years ago.

4.2.2 Kenya Off-grid Solar Access Project (KOSAP)

The Kenya Off-Grid Solar Access Project (KOSAP)[42] is a flagship electrification project by the Ministry of Energy, financed by the World Bank. In partnership with World Bank, Kenya has committed 150Million USD towards KOSAP for six years, expected to be completed in 2023[43].The project aims to provide affordable electricity to 14 least electrified counties targeting 1.3 million households in northeastern and northern Kenya. The project will go a long way in contributing to the KNES targeted universal access to electricity by 2022[44]. This project is important towards achievement of Vision 2030[45].

Through KOSAP, Kenya Power aims at connecting 277,000 households, 1,097 community facilities and 380 boreholes using solar mini-grids. The K-OSAP project is at the development phase and will be implemented in 14 least electrified counties in the country[46]. These counties are: West Pokot, Turkana, Samburu, Marsabit, Isiolo, Mandera, Wajir, Garrisa, Tana River, Lamu, Kilifi, Kwale, Taita Taveta and Narok. The project is jointly implemented by Ministry of Energy, KPLC and REREC[47].

The project aims to encourage solar service providers to expand their services from more urban areas to underserved counties; KOSAP will provide incentives including a results-based financing facility. This financing facility will compensate the providers through competitive awards for initial, ongoing incremental, and opportunity costs associated with service expansion[48].

4.3. Electricity demand forecast

Electricity demand forecast is carried out and updated bi-annually through the Least Cost Power Development Plan (LCPDP)[49] by the relevant stakeholders[50] in the power sector, whose main

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[42] Ministry of Energy, (2019) – “The Kenya Off-grid Solar Access Project (K-OSAP)” https://kosapfm.org/about
[43] www.president.go.ke
[44] Ministry of Energy, “The Kenya Off-Grid Solar Access Project (K-OSAP)”
[45] Kenya Vision 2030, “Kenya Vision 2030”
[46] Kenya Power and Lighting Company Limited - Annual Report and Financial Statements 2017/2018
[47] www.energy.go.ke
[48] World Bank, Kenya: Off-Grid Solar Access Project for Underserved Counties. http://projects.worldbank.org/P160009?lang=en (accessed 27th February 2020)
[49] The Least Cost Power Development Plan is a Kenya Energy Sector Report intended to guide the sector on sector status, generation expansion opportunities and transmission infrastructure target network expansion as well as resource requirements for the expansion programme.

objective is to develop an accurate and acceptable assessment of future electricity demand for an optimal power expansion plan. It is updated biennially, with the most recent demand forecast carried out in 2017 to cover the next 20 years (2017 – 2037); the report was made public in June 2018[51].

Specific objectives of the electricity demand forecast is to:

I. Analyse the current and future context of the economy and the power sector;
II. Update some of the assumptions used in the previous demand assessment forecast;
III. Review key demand driving factors from the previous plans;
IV. Update the status of the flagship projects.

4.3.1 Energy Demand forecasting methodology

The objective of a demand forecast is to provide a sound basis for the power system expansion planning. A critical analysis and a selection of suitable scenarios reduce the impact of forecast uncertainty on the planning results. These results will reduce the risk of costly over- or under-estimating the size of the power system.

The above objective is partly achieved through a sensitivity analysis by investigating a suitable range of scenarios. The three scenarios include:

- **Reference scenario:** This is the best-case scenario and applies key assumptions for a probable development based on the historic development and actual plans (technical, demographic and economic issues diligently assessed).

- **High scenario:** normative scenario; This scenario applies the wide range of ambitious government plans such as achieving 100% electricity connectivity level by 2022 and implementation of Vision 2030 growth projection through flagship projects.

- **Low scenario:** This scenario presents a low growth trajectory in which most of the government plans and projects are not implemented as planned. It is assumed that in this scenario, economic development will be at the existing rate with no expected increase during the planning period.

4.3.2 Energy demand structure

The forecasting approach followed the existing tariff categories and usage levels:

a) Domestic consumption: this includes KPLC, off peak tariff and REP domestic consumers;
b) Small commercial consumption: this includes small commercial and off-peak tariff small commercial consumers;
c) Commercial and Industrial consumption: this represents large power consumers in tariff categories;
d) Street lighting.

[50] EPRA, KPLC, KenGen, REREC, GDC, KETRACO and NuPEA
[51] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.

4.4. Main drivers of the projected demand

The demand for electricity in Kenya has been increasing over time. Key driving factors of demand considered are:

- **Demographic pattern of Kenya**: This includes population growth. It has an explicit effect on domestic consumption and connectivity level;
- **Urbanization**; this includes the growth of urban cenres which have an impact on the demand for electricity and connectivity levels;
- **GDP growth**: directly impacts on household's income and activity of the productive sector translated into electricity consumption of commercial and industrial customers. Electricity consumption has a direct correlation to the GDP.
- **Vision 2030 Flagship projects**: These projects have an impact on GDP growth and contribute to demand growth based on their specific load requirements. The impact of these projects have, however, been tempered with reality that not all the proposed projects will be realized in the time they are planned for; hence only those foreseen to happen in the near future have been considered.

In calculating the expected projected demand over the next seventeen years, three growth scenarios have been used namely: reference, high and low.

4.4.1 Demographic patterns

Over the past 20 years, Kenya's population has doubled with a marked improvement in life expectancy. Although Kenya's extreme growth is expected to slow in the coming years, it will still be significant. The current growth rate of change of 2.52% annually is predicted to drop to 2.2% by 2030. Human population grew to 47.6 million in 2019 up from 46.5 million in 2018[52]. The population is expected to grow from 47.6 million to 66.9 million in 2030[53].

As the population grows so does the need for services and one of them being need for energy at different levels. Due to this factor alone, the uptake of solar energy through use of solar PV panels in off-grid rural regions of Kenya has been rising. This coupled with the evolving need for power for long hours especially for school going cadre that need longer studying hours has created the need for energy storage to enable consumers extend working hours into the night.

Population growth has an impact on the consumption and connectivity levels of electricity. In Kenya, based on historical analysis, power consumption is expected to grow between 1.0 to 1.2 times the GDP growth[54].

4.4.2 Urbanization

Kenya has witnessed rapid urbanization since independence and coupled with a well-educated population, this has attracted local and multinational industrial revolution in the country that is

[52] Kenya National Bureau of Statistics - https://www.knbs.or.ke/
[53] Kenya Population - https://www.worldometers.info/demographics/kenya-demographics/
[54] Power Africa 2015 – Development of Kenya's Power Sector 2015 – 2020 https://www.usaid.gov/powerafrica/kenya

largely around the urban centres. This in essence has resulted to a rural-urban migration and industrial growth around the centres. This has had two-fold effect on electricity demand.
First, there has been an increasing demand for energy to drive the growth under the commercial and industrial (C&I) sector which in turn has attracted high power tariffs for the industries. Some consumers therefore in clamour for lower costs of power and increased energy efficiency have resorted to adopting renewable energy, energy storage and energy efficiency measures that drive the market for RE technology.
Secondly, there is a critical mass of workforce that work in the C&I related sector that are low income earners who due to high cost of power result into RE sources of power before they are able to afford grid tied supply. This demand is directly attributed to urbanization in which the current urban population is 27.5% of the total population recorded in 2019 National Census. The rate of urbanization in Kenya stands at 4.23% and 50% of the population is projected to be urbanized by the year 2030[55][56].

4.4.3 Gross Domestic Product Growth

The real Gross Domestic Product (GDP) is estimated to have expanded by 5.4% in 2019 compared to a growth of 6.3% in 2019. Over the past 5 years, the GDP has grown at an average of 5.62%. The growth has been attributed to an overall growth in almost all the sectors of the economy from agriculture, manufacturing, mining, transport and storage, electricity supply etc.[57].
The economy is expected to grow by 6.9% and 7.0% in 2021/22 and 2022/23 financial years[58]. The growth for 2020/21 has been disrupted by the Coronavirus disease (Covid – 19). Most of the economic activities have **so** far been slowed down by restrictions resulting from containment and cessation of sections of the population, the nationwide curfew and stoppage of international passenger travel[59].
Kenya had a gross national income (GNI) per capita of USD 1,280 in 2018 putting it in the ranks of lower middle-income countries. The GDP and the GNI combined together bring another driver for renewable energy consumption because a critical mass of the population have disposable income to spend on utilities like power and other areas that improve the quality of populations livelihoods[60].

In 2019, the manufacturing sector's real value added grew by 3.2% compared to a revised growth of 4.3% in 2018. The sector's volume of output expanded by 2.0% in 2019. The growth was on account of increase in production of motor vehicles, trailers and semi-trailers; plastics; animal and vegetables fats and oils; and pharmaceuticals sub-sectors[61].

In Nairobi City County, the number of completed public residential buildings in 2019 was 530 with a total of 5,134 housing units were under construction by the National Housing Corporation and the

[55] Institute of Economic Affairs 2017 - https://www.ieakenya.or.ke/downloads.php?page=1536232616.pdf
[56] https://www.indexmundi.com/kenya/urbanization.html
[57] Kenya National Bureau of Statistics Economic Survey 2020 - https://www.knbs.or.ke/?wpdmpro=economic-survey-2020
[58] Budget Policy Statement 2018 – Kenya Institute for Public Policy Research and Analysis (www.kippra.or.ke)
[59] Kenya National Bureau of Statistics Economic Survey 2020 - https://www.knbs.or.ke/?wpdmpro=economic-survey-2020
[60] https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=KE
[61] Kenya National Bureau of Statistics Economic Survey 2020 - https://www.knbs.or.ke/?wpdmpro=economic-survey-2020

State Department of Housing of which (4,700) of housing units commenced in 2019. Once completed, a majority of these houses will be connected with electricity thereby increasing its demand[62].

This demand for housing has been accelerated by devolution through the formation of County governments in which employees were transferred to these devolved units countrywide from the central government. Improvements in road networks in these devolved units summed up with growth in housing demand has resulted in creation of urban centres through urbanization which has resulted in an increase in electricity demand.

4.4.4 Future economic outlook: Vision 2030

The foundation upon which to build a prosperous Kenya is based on Vision 2030's blueprint. Kenya Vision 2030 was launched in 2008 as Kenya's development blueprint covering the period 2008 to 2030. It was aimed at making Kenya a newly industrializing, middle income country, providing high quality life for all its citizens by the year 2030. The Vision was developed through an all-inclusive stakeholder consultative process, involving Kenyans from all parts of the country. The Third mid-term plan (2018 – 2022) of Vision 2030 will be implemented through **The Big Four Agenda** whose key highlights are listed below[63]:

1. **Manufacturing** - Expanding the manufacturing sector through the blue economy, agro processing, textiles and leather. The government also committed to support growth of manufacturing by introducing Time of Use (ToU) of tariffs shifting of demand from peak to off-peak periods and thereby increasing consumption due to lower off-peak tariff and creating an additional 1,000 small micro-finance enterprises;
2. **Food security** - This will be achieved through encouraging and facilitating large-scale commercial agriculture through irrigation and other technologies;
3. **Housing** - To address shortage of affordable housing, the Government plans to facilitate provision of 500,000 housing units by 2022. Additionally, the State Department for Housing, Urban Development and Public works will construct 7,394 housing units for the National Police Service Commission and 4,900 units for public officers;
4. **Universal Health Coverage -** by reducing the cost and ensuring universal access to quality healthcare by 2022.

Growth in manufacturing, food security and housing sectors would lead to increased business opportunities. Connectivity to competitively-priced, reliable and safe electricity and ease of access to electricity will promote business growth and achievement of the Big Four Agenda.

Vision 2030 recognizes energy as one of the key enablers of sustained economic growth and a key foundation of Kenya's envisaged national transformation. The vision identifies projects that have a significant bearing on future GDP growth as well as an effective spike in energy demand **(Table 9).**

Table 9: Flagship projects and their respective assumptions[64]

Project	Reference scenario				High scenario			
	First year of	Initial load	Year of total load	Total load (MW)	**First year of**	Initial load	**Year of total**	Total load

[62] Ibid
[63] Eye on the Big Four: Budget Watch for 2018/19 and the Medium Term www.parliament.go.ke
[64] www.vision2030.go.ke

	operation	(MW)			operation	(MW)	load	(MW)
Electrified mass rapid transit system for Nairobi	**2024**	15	2030	50	**2022**	15	**2027**	50
Electrified standard gauge railway Mombasa - Nairobi	**2022**	98	2030	130	**2021**	100	**2028**	300
Electrified standard gauge railway Nairobi - Malaba	**2026**	61.74	2035	61.74	**2024**	63	**2032**	189
Electrified LAPSSET standard gauge railway	-	-	-	-	**2035**	30	**2037**	30
Oil pipeline and Port Terminal (LAPSSET)	**2025**	50	2037	150	**2022**	50	**2032**	150
Refinery and Petrochemical Industries (LAPSSET)	**2028**	25	2037	100	**2025**	50	**2030**	200
Konza Techno City	**2024**	2	2037	190	**2022**	2	**2034**	200
Special Economic Zones	**2021**	5	2037	110	**2020**	30	**2028**	110
Integrated Steel Mill					**2030**	100	**2035**	200

4.5. Demand forecast results

The forecast results developed for the peak load (MW) and energy consumption (GWh) for the long-term period 2017 (base year) to 2037 are presented in this section based on the three defined scenarios:

4.5.1 Electricity consumption and peak load for reference, high and low scenarios

Annual electricity demand and peak load are expected to grow for all scenarios over the forecasting and planning period. For the **reference scenario**, the gross electricity consumption grows from 10,465 GWh in 2017 to 14,334 GWh and 39,187 GWh in 2022 and 2037 respectively as shown in **Table 10.** This represents an average annual growth of 6.7% per annum.

Table 10: Energy Demand by scenarios (with flagships Vision 2030 projects)[65]

	Low scenario			Reference scenario			High scenario			Losses (Reference Scenario)
Year	**GWh**	**Growth**	**MW**	**GWh**	**Growth**	**MW**	**GWh**	**Growth**	**MW**	**%**
2017	10,465	4.9%	1,754	10,465	4.9%	1,754	10,465	4.9%	1,754	19.0%
2018	11,032	5.4%	1,842	11,169	6.7%	1,866	11,470	9.6%	1,917	18.5%
2019	11,530	4.5%	1,928	11,820	5.8%	1,978	12,464	8.7%	2,088	18.0%
2020	12,071	4.7%	2,021	12,546	6.1%	2,103	13,676	9.7%	2,293	17.6%
2021	12,612	4.5%	2,114	13,312	6.1%	2,234	14,900	9.0%	2,516	17.0%
2022	13,156	4.3%	2,207	14,334	7.7%	2,421	16,456	10.4%	2,766	16.5%
2023	13,810	5.0%	2,319	15,293	6.7%	2,586	17,989	9.3%	3,027	16.5%
2024	14,503	5.0%	2,438	16,327	6.8%	2,764	19,799	10.1%	3,342	16.6%
2025	15,229	5.0%	2,563	17,750	8.7%	2,989	22,056	11.4%	3,705	16.6%
2026	15,982	4.9%	2,692	19,098	7.6%	3,224	24,295	10.1%	4,078	16.6%
2027	16,780	5.0%	2,829	20,393	6.8%	3,441	26,572	9.4%	4,450	16.6%
2028	17,627	5.0%	2,975	22,082	8.3%	3,720	29,043	9.3%	4,854	16.6%
2029	18,525	5.1%	3,129	23,593	6.8%	3,974	31,509	8.5%	5,261	16.6%
2030	19,475	5.1%	3,293	25,195	6.8%	4,244	34,847	10.6%	5,780	16.6%
2031	20,482	5.2%	3,466	26,864	6.6%	4,525	37,632	8.0%	6,251	16.6%
2032	21,552	5.2%	3,651	28,640	6.6%	4,826	40,587	7.9%	6,752	16.6%
2033	22,798	5.8%	3,872	30,529	6.6%	5,148	43,635	7.5%	7,272	16.6%

[65] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.

2034	24,008	5.3%	4,081	32,542	6.6%	5,491	46,954	7.6%	7,842	16.6%
2035	25,297	5.4%	4,305	34,691	6.6%	5,859	50,595	7.8%	8,468	16.6%
2036	26,561	5.0%	4,523	36,848	6.2%	6,232	54,105	6.9%	9,094	16.6%
2037	27,945	5.2%	4,763	39,187	6.3%	6,638	57,990	7.2%	9,790	16.6%

Electricity demand is expected to grow to 9,790 MW in 2037 which is more than five times the peak demand of 1,754MW in 2017 in the **high scenario**. This is as a result of utilization of the load that is achieved through implementation of less challenged (easily implemented) planned Vision 2030 flagship projects. In this scenario the energy consumed grows from 10,465 GWh in 2017 to 57,990 GWh in 2037 which is approximately 8.8% growth per year.

In the **low scenario**, the electricity consumption growth is gradual over the planning period averaging 5% per annum. The energy consumed increases to 27,945 GWh by the year 2037 from 10,465 GWh in 2017.

These results from the three forecast scenarios are summarised in **Table 11** below.

Table 11: Summary of demand forecast results (MW)[66]

Scenario	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2028**	**2030**	**2033**	**2035**	**2037**
Low	1,754	1,842	1,928	2,021	2,114	2,207	2,319	2,438	2,563	2,975	3,293	3,872	4,305	4,763
Reference	1,754	1,866	1,978	2,103	2,234	2,421	2,586	2,764	2,989	3,720	4,244	5,148	5,859	6,638
Vision	1,754	1,917	2,088	2,293	2,516	2,766	3,027	3,342	3,705	4,854	5,780	7,272	8,468	9,790

[66] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.

5. TOWARDS 100% RENEWABLE ENERGY TRANSITION

5.1. Power generation expansion planning in Kenya

Kenya is endowed with plentiful indigenous renewable energy resources. The Scaling-up of Renewable Energy Plan (SREP) identifies the need to accelerate the development of renewable energy projects[67]. This vision for green energy is further emphasized in the Government's Vision 2030, which identifies reliable, clean and affordable energy as a foundation for Kenya's long-term economic and social development.
In Kenya, the electricity generation expansion is achieved through the national generator KenGen, IPPs, steam development by GDC and power import contracts with Uganda and Ethiopia. The current energy mix has reduced contribution generation from thermal sources as attention shifts to renewable energy sources.

A summary of committed projects for the period 2020-2024 is presented in **Table 12**. These are projects with approved PPA and Commercial Operation Date (COD), and those making significant progress in implementation or prioritized in the strategic plans of KenGen and GDC. These projects are to be developed through public or private companies.

Table 12: Committed and candidate generation projects and estimated CODs[68]

Estimated COD	Plant name	Type	Capacity [MW]
2020	Menengai 1 Phase I - Stage 1	Geothermal	103
2020	Olkaria 1 - Unit 6	Geothermal	70
2020	Olkaria 1 - Unit 2 Rehabilitation	Geothermal	17
2020	Olkaria 1 - Unit 3 Rehabilitation	Geothermal	17
2020	Kipeto - Phase I	Wind	50
2020	Kipeto - Phase II	Wind	50
2020	Alten, Malindi, Selenkei	PV	120
2020	Quaint Energy, Kenergy	PV	50
2021	Olkaria Topping	Geothermal	47
2021	Ngong 1 - Phase III	Wind	10
2021	Chania Green	Wind	50
2021	Aperture	Wind	50
2021	Eldosol	PV	40
2021	Makindu Dafre Rareh	PV	30
2021	Gitaru solar	PV	40
2022	Olkaria 6 PPP	Geothermal	140
2022	Menengai I - Stage 2	Geothermal	60
2022	Prunus	Wind	51
2022	Meru Phase I	Wind	80
2022	Ol-Danyat Energy	Wind	10
2022	Electrawinds Bahari	Wind	50
2022	Hanan, Greenmillenia, Kensen	PV	90
2023	OrPower4 Plant 4	Geothermal	61
2023	Olkaria 7	Geothermal	140
2023	Eburru 2	Geothermal	25
2023	GDC Wellheads	Geothermal	30
2023	Wellhead leasing	Generic back-up	50

[67] https://www.renewableenergy.go.ke/downloads/policydocs/Updated_SREP_Draft_Investment_Plan_May_2011.pdf
[68] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.

		capacity	
2023	Karura	Hydropower	89
2023	Electrawinds Bahari Phase 2	Wind	40
2023	Sayor, Izera, Solar joule	PV	30
2023	Belgen, Tarita Green Energy Elgeyo	PV	80
2024	Lamu Unit 1	Coal	327
2024	Lamu Unit 2	Coal	327
2024	Lamu Unit 3	Coal	327
2024	Olkaria 8	Geothermal	140
2024	Menengai III	Geothermal	100
2024	Baringo Silali - Paka I	Geothermal	100
2024	Marine Power Akiira Stage 1	Geothermal	70
2024	Meru Phase II	Wind	100
2024	Tarita Green Energy Isiolo, Kengreen	PV	50
2024	Asachi, Astonfield Sosian, Sunpower	PV	81
TOTAL			**3,392**

Kenya's first 1,050 MW Lamu Coal fired power plant was supposed to be commissioned in 2024 from **Table 12** above, but this project has encountered several setbacks towards its development. In June, 2019, the National Energy Tribunal (NET) revoked its environmental licence from the National Environment Management Authority citing omission of engineering plans and details of the plant from public participation exercise and it not being aligned with the Climate Change Act. The planned project is also close to a UNESCO World Heritage Site. This shows the government's commitment towards generating 100% of its energy needs from available renewable sources.

5.2. Opportunities in RES in Kenya

As the country is on an ambitious path to generate all its power needs from its rich renewable energy sources it is endowed with, there are various opportunities that these renewable energy systems (RES) will provide. Adoption of RES will facilitate the establishment of satellite locations where carbon free pockets or habitats can be created to cater for fresh food storage before marketing, light agribusiness processing and value addition, remote light technical based ventures like fabrication, apparel and health facilities. Another opportunity will be in major urban habitat zones where the approach is to identify and focus on enhancing renewables technology such as solar street lighting for security, as well as light consumer uptake in the informal and semi-formal locations of the urban centers. This is expected to accelerate achievement of the United Nations Sustainable Development Goals specifically "Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all" and "Goal 11: Make cities inclusive, safe, resilient and sustainable".

5.3. Energy Act, 2019 and Renewable energy

The new enacted Energy Act 2019 places priority on the development of renewable energy resources in the country.

The Energy Act, 2019[69] Part IV, Section 74 sub-section 1-3 on Renewable energy mandated the Cabinet Secretary (CS) of energy to carry out the following within 12 months of coming into force of this Act. It requires the CS to:

a) Commence a countrywide survey and a resource assessment of all renewable energy resources;
b) Prepare a renewable energy resources inventory and resource map in respect of each renewable energy resource area and thereafter prepare updates biennially which shall be published in the Gazette;
c) Prepare the renewable energy resources inventory and resource map.

The Act further mandates the CS Energy to promote the development and use of renewable energy technologies, including but not limited to biomass, biodiesel, bioethanol, charcoal, fuelwood, solar, wind, tidal waves, hydropower, biogas and municipal waste.

5.4. Decommissioning programme for existing plants

Kenya plans to have all its energy derived from renewable sources and this has been backed by the stipulations of the new Energy Act 2019 on renewable energy. The long-term plan is to decommission all thermal plants that are expensive and release GHGs into the environment. The plants being decommissioned will be replaced by renewable energy plants from solar, wind, hydro and geothermal sources that are less costly and environmentally friendly.

Table 13 shows the retirement schedule for existing power plants. A total of 1,091 MW including all existing thermal power plants are expected to be decommissioned by 2036.

Table 13: Decommissioning Schedule for existing power plants[70].

Year considered for decommissioning	Plant name	Type	Net capacity (MW)
2019	Olkaria 1 Unit 1	Geothermal	15
2019	Iberafrica 1[71]	Diesel engines	56
2019	Olkaria 1 Unit 2	Geothermal	15
2020	Olkaria 1 Unit 3	Geothermal	15
2021	Embakasi GT 1	Gas turbines (gasoil)	27
2021	Embakasi GT 2	Gas turbines (gasoil)	27
2021	Tsavo	Diesel engines	74
2023	Kipevu 1	Diesel engines	60
2028	Ngong 1, Phase I	Wind	5
2029	Olkaria 3 Unit 16 (OrPower4)	Geothermal	48
2030	Rabai Diesel (CCICE)	Diesel engines	90
2031	Kipevu 3	Diesel engines	115
2033	Olkaria 2	Geothermal	105
2034	Olkaria 3 Unit 79 (OrPower4)	Geothermal	62
2034	Iberafrica 2	Diesel engines	52.5
2034	Thika (CCICE)	Diesel engines	87

[69] Energy Act, 2019
[70] Updated Least Cost Power Development Plan (LCPDP), Study Period 2017 – 2037.

2034	Athi River Gulf	Diesel engines	80
2035	Triumph (Kitengela)	Diesel engines	83
2035	Ngong 1, Phase II	Wind	20
2036	KenGen Olkaria Wellheads I & Eburru	Geothermal	55
Total decommissioned			**1,091**

5.5. Promoting RE investments

5.5.1 Scaling-up Renewable Energy Plan

The Country also has in place the Investment Plan for Scaling-Up Renewable Energy (SREP), which is under implementation. The SREP aims at supporting Kenya initiatives towards a low greenhouse gas (GHG) emission development pathway by harnessing renewable energy sources (RES) in the country. It has a specific focus on decentralized energy systems, especially mini-grids and solar systems.

5.5.2 Feed-in-Tariff Policy

To promote investment in RE the country has developed and put in place a Feed-in-Tariff (FiT) framework[72]. This policy was first issued in March 2008 and has been revised twice to respond to stakeholder experiences: firstly, in January 2010 and secondly in December 2012. This instrument aims at promoting generation of grid-connected electricity from RES (wind power, biomass, small hydro, solar, biogas and geothermal) and specifies the contents of a Standardised PPA for up to and above 10 MW plants **(Table 14 and 15)**. Once a PPA is established, the tariff is secured for 20 years.

Table 14: FiT values for Small RE projects with installed capacity up to 10 MW[73]

Technology	Installed capacity (MW)	Standard FiT (USD/kWh)	Percentage escalable portion of the tariff	Min capacity (MW)	Max capacity (MW
Wind	0.5-10	0.11	12%	0.5	10
Hydro*	0.5	0.105	8%	0.5	10
	10	0.0825	8%	0.5	10
Biomass	0.5-10	0.10	15%	0.5	10
Biogas	0.2-10	0.10	15%	0.2	10
Solar (Grid)	0.5-10	0.12	8%	0.5	10
Solar (Off grid)	0.5-10	0.20	8%	0.5	1

Table 15: FiT values for Large RE projects with installed capacity above 10 MW[74]

Technology	Installed capacity (MW)	Standard FiT (USD/kWh)	Percentage escalable portion of the tariff	Min capacity (MW)	Max capacity (MW
Wind	10.1-50	0.11	12%	10.1	50
Geothermal	35-70	0.088	20% for first 12 years	35	70

[72] FiT Policy; Kenya Ministry of Energy, 2012
[73] Ministry of Energy and Petroleum, 2020
[74] Ibid

Hydro			and 15% after		
	10.1-20	0.0825	8%	10.1	20
Biomass	10.1-40	0.10	15%	10.1	40
Solar (Grid)	10.1-40	0.12	12%	10.1	40
Wind	10.1-50	0.11	12%	10.1	50

Some of the main advantages of FiTs are that:

a) They limit the investment risk for the power producers[75];
b) They only cost money to ratepayers if projects are in operation;
c) They lower transaction costs,
d) They settle uncertainties related to grid access and interconnection;
e) They enhance market access, and
f) They encourage the use of technologies at different stages of maturity[76].

[75] This risk is shifted to other participants, such as ratepayers or taxpayers.
[76] Couture, Toby D., Cory, Karlynn, Kreycik, Claire, Williams, Emily, 2010. A policymaker's guide to Feed-in-Tariff policy design. NREL. www.nrel.gov/docs/fy10osti/44849.pdf

6. ENERGY STORAGE TECHNOLOGY

Batteries are devices that store electricity in chemical form and convert this stored chemical energy into electrical energy when required. Battery storage systems are modular in nature and can be connected or disconnected to meet capacity and load requirements. They are connected to a power source that is responsible for charging the battery for usage during power outages or periods of peak demand. While the utility grid is the source of power for most domestic and industrial consumers, renewable power **sources** such as solar photo voltaic (PV) and wind generators are coupled with battery storage systems which store the excess generation during periods of low demand[77].

Large scale penetration and expansion of energy storage in Kenya will play a crucial role in ensuring the country has clean, safe and reliable power[78]. It is envisaged that off-grid systems comprise the largest market in Kenya, largely driven by rural electrification efforts by the government, which aims for 100% electrification by 2022 in its mid-term plan of Vision 2030 (implemented through the Big Four Agenda).

In Kenya, the majority of storage batteries are utilised in off-grid PV systems, which require batteries to store electricity generated during the day for use at night. The existing operational grid-connected wind power projects in Kenya[79] supply directly to the grid and use it as storage. Energy storage has been utilised in Stand-alone solar PV systems and are custom-designed to satisfy energy and power demands for specified loads. These systems are mainly for institutions such as schools and health centres. This technology has also been used for solar street lighting systems especially in off-gird and remote towns in the country.
Mini-grid solar systems are high capacity and custom-designed systems that meet the energy and power demands for a group of consumers. Mini-grid solar systems are usually operated in hybrid modes with other power generators such as wind or diesel generators and storage batteries are at times included in a number of them to enhance quality, adequacy and reliability of supply[80].
Battery energy storage technologies utilised in the Kenyan are explained below.

6.1. Battery technology in Kenya

6.1.1 Lead-based Batteries

Lead acid batteries cost is relatively low and provide an acceptable form of energy storage. As a result of this, currently it dominates the storage market in Kenya.

- **Application:** Auto batteries, back-up power, uninterrupted power supply (UPS), and grid energy storage.
- **Types:** Advanced lead acid, hybrid lead acid, lead carbon, and valve-regulated lead acid.

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[77] Frost and Sullivan – Future and Impact of Power Storage in Sub-Saharan Africa, 2017
[78] https://www.navigantresearch.com/news-and-views/how-energy-storage-plays-a-role-in-kenyas-longterm-electricity-goals
[79] Lake Turkana Wind Power and Ngong Wind farm projects
[80] Energy and Petroleum Regulatory Authority (2018), Final Report: Consultancy services for a study on Solar Photovoltaic industry in Kenya. https://www.kenyacic.org/sites/default/files/research/Solar%20Photovoltaic%20Industry%20Baseline%20Study-%20Draft%20October%202018.pdf

- **Cost:** The local market price ranges from USD 45 (Ksh. 4,500) for a 12V 18AH to USD 850 (Ksh. 85,000) for a 2V 1,250AH solar storage battery[81].

Lead acid is the most established battery technology. These batteries are of varying capacities and voltages and can be made with flat or tabular plates. They can also be packaged to use liquid acid (flooded) or immobilized acid (sealed) in form of a gel[82].

The performance of lead acid batteries is relatively efficient with round trip efficiency (RTE)[83] of 70 – 90%. The battery has a life span of 5 to 15 years, has fair cycle life[84], its reliable and readily available. Recent design modifications and addition of some elements to the plates has enhanced the battery's cycle life and efficiency.

Disadvantages of the lead acid battery is that it is characterized by a slow charge regime, low weight to energy ratio, low power and energy density, relatively short cycle life and high maintenance requirements[85]. Proper disposal of lead-acid batteries can be problematic, leading to the possibility of severe contamination of the environment and even fatal poisoning of individuals.

6.1.1.1 Sample projects utilizing Lead acid battery storage in Kenya[86]

- ✓ 60 kW Solar PV Diesel hybrid plant at Biyamadhow market in Wajir County, owned by REREC;
- ✓ 30 kW Hybrid Solar PV generation plant at Eldas Power Station, Wajir County, owned by REREC;
- ✓ 47 kW Solar PV System in Kakuma Refugee camp, Turkana County;
- ✓ 60 kW Grid tied Solar generation plant at Lodwar power station, in Turkana County, owned by Kenya Power;
- ✓ 60 kW Solar power PV system in Tambuzi flower farm, Nanyuki, Laikipia County;
- ✓ 54 kW Solar PV System installation at Kenya Commercial Bank Branch in Telek, Maasai Mara, Narok County;
- ✓ 350 kW Grid tied Solar PV system at Mitchell Cotts Limited warehouse in Embakasi, Nairobi County;
- ✓ Numerous solarized boreholes in the Country.

The above projects have been implemented by PowerPoint Systems E.A Limited and Associated Battery Manufacturers (ABM) marketed under the brand name Chloride Exide.

The Kenyan market is generally dominated by lead acid battery options as the preferred storage for off-grid systems. Lead acid dominates with a prevalence rate of 95%. The sealed battery dominates the market at 89% prevalence rate.

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[81] The prices were obtained from interviews with Sales representatives from PowerPoint Systems E.A Ltd and ABM Chloride Exide on 15th May, 2020.

[82] https://www.energysage.com/solar/solar-energy-storage/what-are-the-best-batteries-for-solar-panels/

[83] RTE is the ratio of energy put in to energy retrieved from storage in MWh.

[84] Cycle life is the number of complete charge/discharge cycles that the battery is able to support before that capacity falls under 80% of its original capacity.

[85] Frost and Sullivan (2017) – Future and Impact of Power Storage in Sub-Saharan Africa, https://www.prnewswire.com/news-releases/future-and-impact-of-power-storage-in-sub-saharan-africa-2017-300576920.html

[86] These projects were compiled from one-on-one interviews with Sales representatives from PowerPoint Systems E.A Ltd and ABM Chloride Exide on 15th May, 2020.

Figure 6: Sample photos of Lead-acid batteries in the Kenyan market

Various types of ABM Chloride Exide Batteries

2V 1250 AH Hoppecke brand Lead acid-battery – PowerPoint Systems E.A Limited

12V 18AH Valve regulated sealed Lead-acid battery - PowerPoint Systems E.A Limited (Ritar Brand)

12V 200AH Valve regulated sealed Lead-acid battery - PowerPoint Systems E.A Limited (Ritar Brand)

6.1.2 Lithium-based Batteries

Lithium-ion (li-ion) batteries were commercialized in the early 1990s and have widespread application in consumer electronics as a result of the need for high energy density.

- **Application:** Consumer electronics, electric vehicles, frequency and voltage regulation, RE integration and large-scale energy storage.
- **Types:** Lithium iron phosphate, lithium ion titanate, lithium manganese oxide, lithium nickel cobalt aluminum, lithium nickel manganese cobalt, and lithium polymer.
- **Cost:** The global market price for this battery is from USD 600 to USD 2500 per kWh.

Li-ion battery technology has a very high efficiency with an RTE close to 100%. They have high power and energy densities; high cycle life and long-life span of service and high voltages. They are highly scalable and can be adapted to any voltage, power and energy requirement.
However, the downside of Li-ion batteries is they are costly; contain toxic, volatile and flammable fluids and lithium as a metal is a finite resource. The battery is also subject to overheating and negative effects of overcharging and over-discharging.

6.1.2.1 Lithium-ion batteries market penetration

At the moment, some lithium ion batteries are used in solar home systems. More households will shift to these batteries as they have a more reliable electricity provision when faced with load shedding and black outs.

REREC are in the process of putting up a 280kW Solar PV – Diesel hybrid generation plant in Buna trading center in off-grid County of Wajir. Solar batteries back-up intended for use will be either a deep-cycle regulated lead-acid batteries or lithium ion batteries.

It is worth-noting that Nickel based batteries are not in use in Kenyan projects currently. A check with REREC cites approval by EPRA for the technology has not been granted to allow large scale use of nickel based battery storage technology in the RE projects[87].

6.1.3 Battery storage summary

In conclusion, the combination of performance, price and availability makes lead acid batteries the most suitable and predominant battery technology for off-grid PV applications in Kenya. The only manufacturer of Lead acid solar batteries in Kenya is ABM under the brand name Chloride Exide. This battery is cost effective, reliable and long-lasting. This battery has been used for powering individual homes and lighting and/or powering the community in off-grid regions[88]. The threat facing this battery manufacturing industry in Kenya is scarcity of raw materials as a result of smuggling of lead into Uganda and influx of low cost batteries imported from other countries[89].

Although lead acid batteries are the most popular in Kenya, Lithium-ion batteries are gaining market share because they are light in weight, last longer and have a high discharge and charge rate compared to lead acid batteries.

6.2. On-going studies on Battery storage potential[90]

There are three companies that are doing preliminary studies on Energy storage in Kenya. These studies are on-going and site specific due to investment interests in these areas and none of the studies findings has been publicly published. These companies are:

[87] This information is from an interview with an official from REREC in Nairobi conducted on 8th June, 2020.
[88] https://www.abmeastafrica.com/our-products
[89] https://www.standardmedia.co.ke/business/article/2001268683/why-battery-manufacturing-industry-is-at-risk
[90] This information was compiled from an interview with a Kenya Power Officer in the Planning and Research Department.

I. Xago Africa has a 40 MW Solar PV project near Ranga'ala in Siaya County where they intend to incorporate storage. The objective of this study is assessing the energy storage prospects for the grid.
II. Energy Storage Africa (ESA) is carrying out a study on the storage potential for a project in Suswa region in Narok County of Kenya.
III. BioTherm Energy (Pty) Ltd under Kipeto Wind Project in collaboration with Power Engineers and Customised Energy Solutions (CES) are carrying out a study on battery storage for the 100 MW Kipeto wind project in Kiserian, Kajiado County, Kenya.

It suffices to note that the energy storage market in Kenya is still at its infancy stages and studies have to be conducted countrywide to map out the energy storage potential regions. The Ministry of Energy has been very supportive in terms of granting the above companies to carry out their preliminary studies.

6.3. Opportunities for energy storage in Kenya

Storage of power through the use of battery energy storage systems is critical as the moves towards 100% generation from renewable energy sources for all its electricity requirements. While the foremost application of battery storage would be in renewable energy-based off-grid power generating systems for rural electrification and uninterrupted access to electricity, batteries are set to play a major role in powering telecommunication towers and providing a clean and sustainable source of power to off-grid lodges and luxury resorts, which rely on diesel powered generators that are environmentally unfriendly and not aligned with the country's climatic agenda of reducing its GHG emissions.

The future of battery storage systems across residential, commercial and industrial application in Kenya is very promising and remains largely untapped. Due to reducing cost of renewable energy technologies such as solar PV and wind, some industries, commercial establishments and mining processes are pursuing renewable generation to meet their power requirements in order to achieve business sustainability, decrease operational expenditures and boost their profit margins. A continuous supply of power from renewables can only be assured through incorporation of battery storage systems in the set up.

6.3.1 Market drivers for energy storage

Some of the drivers for successful implementation of the battery storage technology are listed below:

I. Remote/rural power systems and the rising trend of mini-grids;
   - Off-grid systems carry the largest market opportunity in Kenya, primarily driven by village electrification efforts;
   - Rural RE connected business establishments creates jobs, while using off-grid RE saves rural households between USD 43 -100per annum. Mini-grids facilitate the use of irrigation pump and other commercial and agro-processing appliances such as

cold storages, poultry lighting and eggs incubation, which boosts income generation and job creation[91][92];

- In Kenya, the health sector is a devolved function. Some counties that are rural have no access to a stable power source and so energy storage is key to enable them run essential medical services and equipment, like X-Ray machines, Intensive Care Units (ICU) units, diagnostics and others seamlessly with no interruptions. For this reason, rural, off-grid communities provide a perfect market for energy storage opportunities.

II. Integration of RE into the grid;
   - Increases efficiency and stability of the national grid;
   - Reduces energy waste, through grid optimization by storing and releasing energy when needed;
   - Reduces reliance on expensive, dirty fossil fuels;

III. Transport industry;
   - Hybrid fuel saving cars that utilize the battery storage, such as the Honda Insight, Toyota Prius and other battery powered hybrid motor cars available in Kenya;
   - Electrification of the Standard Gauge Railway (SGR) and heating of the Lamu Port and Lamu Southern Sudan – Ethiopia Transport (LAPSSET) corridor oil pipeline across its entire installation. Approximately 300 MW of energy is needed to power these projects. It is also an indicator that there is a huge demand for enough firm power to sustain operations in these applications.

IV. Industrial activity that requires reliable supply of electricity.
   - Refrigeration, agribusiness value addition, garments making and fabrication.

6.3.2 Market restraints for energy storage

The adoption of battery storage systems is not without its own challenges and these restraints include;

I. Lack of sufficient studies on energy storage potential;
II. Lack of affordable financing;
III. Lack of a tariff category in the existing tariff structure;
IV. Utility-scale battery storage is still expensive;
V. Limited local expertise and familiarity with battery storage technology.

6.4. Flexible market entry strategy

The key strategy to entering the Kenyan market for energy storage players is to focus on lowering the costs for integrated storage solutions. The players should be able to develop a flexible market entry strategy and to make a compelling business case even if the price should decrease. It is also important for storage players to adjust to specific customer and grid needs across the value chain.

[91] https://microgridknowledge.com/kenya-off-grid-minigrids/
[92] Power Africa Off-Grid Project 2019 – Kenya Off-Grid Solar Market Assessment

7. CONCLUSION

The Kenya energy supply sector is unbundled in nature and over the years has undergone some regulatory reforms making it attractive to the participation of IPPs. Through a feed-in-tariff policy and a Standardised PPA, the sector has attracted foreign investors. Kenya is on an ambitious plan of universal electricity access by 2022; this will be made possible by grid densification, intensification and expansion, in particular opening up the rural, off-grid regions through mini-grids and storage systems. The Big Four agenda of Vision 2030 is also expected to elevate Kenya to a middle-income economy, with projects such as electrification of the standard gauge railway and heating of the LAPSSET oil pipeline expected to spur the demand for electricity. In conjunction with the World Bank, the country is implementing the KOSAP project that aims to connect fourteen counties that are energy deprived.

Plans are underway to generate 100% of electricity from abundant renewable energy resources in the country. The commitment to this has been exhibited by decommissioning some of the expensive thermal plants, and the generation expansion plan does not include any fossil fuel sources. This will reduce the emission of GHGs responsible for climate change. In the rural areas, with over-reliance of kerosene for basic lighting, an innovative pay-as-you-go was invented and has enabled most rural homes off the grid to access energy through solar home systems. Prosumers in the agro-industrial sector have the potential to electrify households and businesses in rural areas, and boost their revenues by supplying excess power to the grid.

The demand in electricity and number of connections is on the rise and this is attributed to the increasing domestic consumption and growth of the manufacturing and industrial sector. To boost this, a time-of-use tariff was introduced by the government to enable manufacturers to take advantage of production during the off-peak hours.

Energy generation from solar and wind sources is characterized by intermittency - battery energy storage is the solution to this. Energy storage stores energy and releases it depending on demand, thereby stabilizing the grid. Energy storage can be utilised in off-grid rural power supply systems, the transport sector, integration into the renewable energy grid and for industrial activities that require uninterruptible supply of electricity. This energy storage systems technology is being adopted in the country, but there is need for a national study to analyze the potential, demand and draft a sector policy on energy policy to regulate and effectively drive this technology. Lack of affordable financing and limited local technological expertise remains to be some of restraints into the renewable energy storage market in Kenya.

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