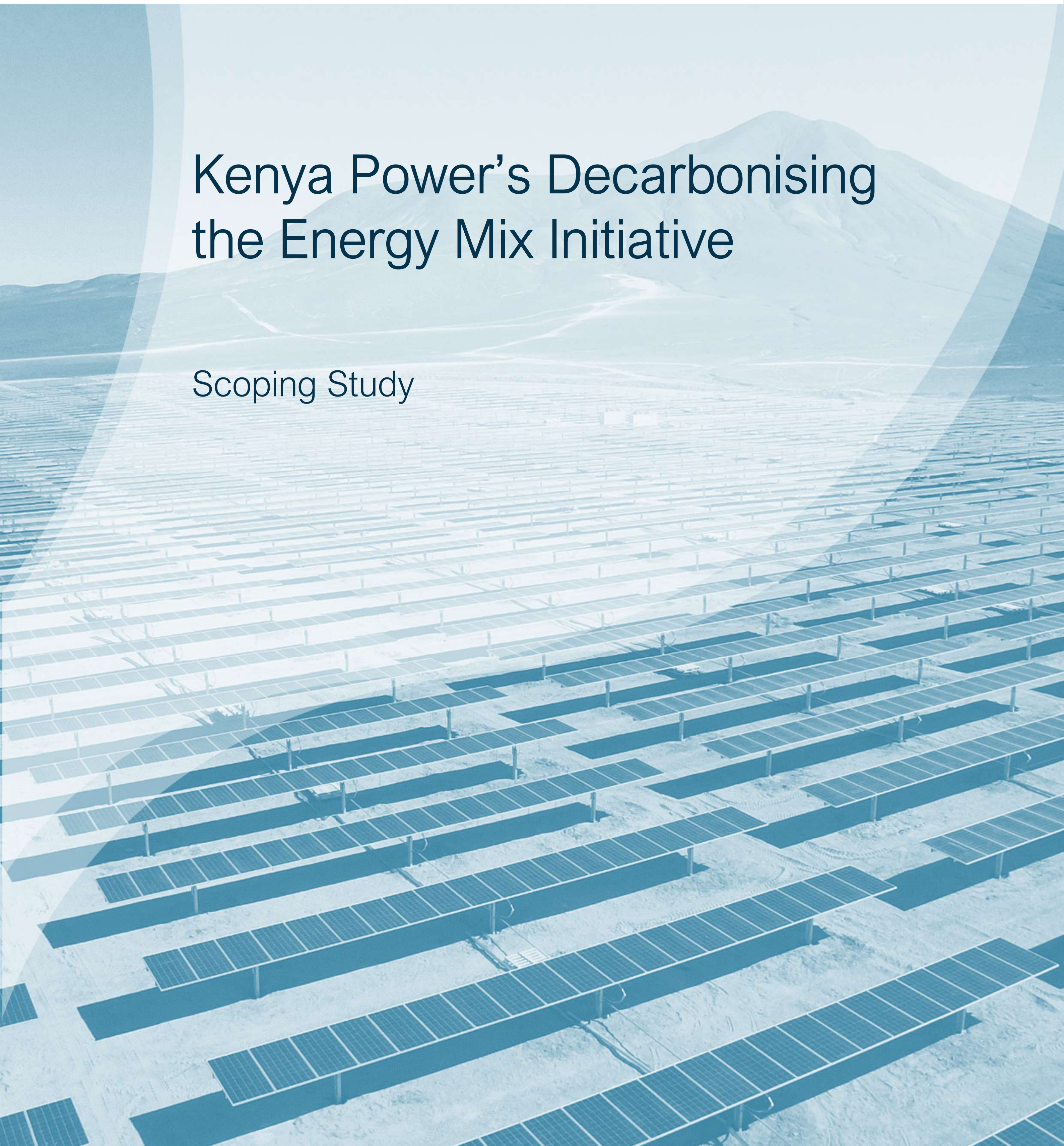

Kenya Power's Decarbonising the Energy Mix Initiative

Scoping Study

September | 2021

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Scoping Study

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EXECUTIVE SUMMARY

Technological innovations, cost declines and financial maturity of wind and solar are changing the way energy is produced around the globe and is leading to a growing participation of variable renewable energies (VRE). Kenya is not exempt from this trend and finds itself in an advantageous position having already supplied 87% of its electricity from renewable sources in 2019. Nevertheless, the inclusion of more VRE leads to new challenges that need to be addressed.

Kenya's power sector is expected to grow substantially due to demand growth and rising electricity access. While this poses challenges on the road to full decarbonisation, the situation in Kenya is advantageous and Kenya can profit from various positive preconditions. The country has one of the lowest carbon-intensive power systems in the region, mainly due to the large penetration of hydro and geothermal. The large share of these dispatchable renewable sources is one of their greatest assets to facilitate the integration of VRE. The country can furthermore benefit from high resources of wind (concentrated in the North-West) and solar PV (across the country) that are almost continuously available year-round. Although not necessarily centred around the main load centre, the geographical and seasonal distribution of these resources is well suited to optimise the use and upscale their participation. Furthermore, the planned grid expansion and interconnections with neighbouring countries can increase the flexibility in the system and allow for the integration of an even higher share of VRE. It is also important that planning in the region as a whole and in the individual countries is coordinated with regard to uptake of VRE.

Costs of wind and solar power are already substantially lower than those of fossil-based energy. Despite this, there are plans to build a large, 981 MW coal power plant. Although initially planned to respond to the future growth in demand, latest analyses have shown that the plant is largely oversized and will operate at very low capacity factors until the late 2030s. Other issues related to the coal plant arise concerning investments (numerous investors have pulled out), energy security (dependent on South African coal), economic effects (energy costs would rise substantially) and environmental effects (not compatible with Paris Climate Agreement).

This study is meant as a scoping study to support Kenya Power's *Decarbonise the Energy Mix* Initiative that is included in the company's Strategic Plan 2018-2023 by analysing potential challenges associated with power sector decarbonisation and suitable intervention options to overcome these challenges.

The *challenges* identified in this study can be attributed to the following five main **barriers**:

The **deployment of the Lamu coal power plant** would not only lead to an *oversupply of the power system but would also have negative effects on the flexibility of the system to cope with VRE* as it would limit their participation due to low ramp rates and high minimum loads. This inflexibility also leads to *inefficient and costly system operation* and would therefore put the *energy security and affordability of electricity supply at risk.* To compensate for the large inflexible asset *hydro resources would be misused and the system's vulnerability to drought increased.*

The **upscaling of renewable energy aligned with demand growth** requires continuous investments in *clean power capacity additions.* In line with the expansion of renewables, the grid needs to be reinforced to avoid *reaching capacity limits of transmission and distribution lines.*

Challenges related to the **operation of dispatchable renewable resources**, include the *vulnerability of the energy system and increased generation from expensive fossil fuels* in the dry months that occur due to the slight drop of renewable energy potential in this time. The *unexploited potential of hydropower* *with storage capacity,* including PHS and *the inflexibility of current geothermal plants as well as their utilisation as baseload* add to the issue.

The Kenyan power system has proven capable of providing certain levels of **flexibility** when 310 MW of wind power were smoothly added in 2019. The greater penetration of VRE will however *require even greater flexibility to balance supply and demand* reliably. The *limited monitoring and control of renewables* should be furthermore addressed to contribute to more flexible operations.

The **trend of an increasingly distributed power sector** will also take place in Kenya and *restructuring of power systems to respond to greater participation of Distributed Energy Resources (DER)* is needed. This can also help to address challenges related to the *perception of grid defection* and *reduced visibility and control of DER.*

Decarbonising the power sector has numerous co-benefits that go beyond the technical implications and the electricity sector. They can mainly be attributed to **economic**, **health-related impacts** related to lower levels of air pollution, and **environmental benefits** to slow down climate change.

In response to the identified challenges, this study concludes with 11 concrete recommendations for medium- and long-term policy measures and technical interventions to support Kenya in the process to decarbonise the country's energy sector.

To better understand the implications of the Lamu coal power plant on the operation of the energy system and assist in decision-making, Kenya Power should **carry out a broader analysis of the impacts of the Lamu project** in terms of system's efficiency, costs, sustainability and impacts in the utilisation of other plants.

Instrumental measures to keep the reliability of the system and enhance the ability to smartly integrate new sources into the system include the **reinforcement of the grid** as well as the **optimisation of load and network congestion management**. The system's efficiency and reliability as well as the integration of renewables into the system can further be improved by **more flexible operation of generation assets**. To encourage this, Kenya Power needs to evaluate changes at the policy level and market design. Furthermore, Kenya Power should **optimise the utilisation of renewable resources to improve system efficiency, flexibility and security**. This can for example be done by leveraging the complementarity of resources and maximising the value of storage in hydro reservoirs.

Fluctuations in the system can also be addressed with **improvements of monitoring and control practices**, which would additionally increase system reliability and facilitate larger integration of VRE and DER. **Incorporation of forecasting in operational practices** can further address these issues while additionally improving the predictability of the availability of renewable energy and minimising risks.

An **analysis and provision of technical validation for business models for DER** is another key foundation to establish ways to facilitate grid access to distributed actors. Kenya Power would not only benefit from a more levelled playing field for DER and more innovation but also directly from increased visibility and coordination of DER. Similarly, **the design of the tariff structure should be re-evaluated in the context of greater participation of DER** to reflect the changing role of the grid in a decentralised system and to encourage the demand to respond to system needs. In this way, Kenya Power can ensure revenues for grid cost recovery and simultaneously minimise further investments in the grid.

Smart metering and digitalisation solutions as well as **smart electrification to strengthen grid dependency** provide improved communication and monitoring that are key for Kenya Power to develop new business models that are in line with larger DER. This would also strengthen grid dependency and thus increase revenue streams.

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ABBREVIATIONS

AGC	Automatic Generation Control
CAGR	Compound Annual Growth Rate
CO_2	Carbon Dioxide
COP	Conference of the Parties
DER	Distributed Energy Resources
dRES	Dispatchable Renewable Energy Sources
EPRA	Energy and Petroleum Regulatory Authority
GHG	Greenhouse gas
GW	Gigawatt
GWh	Gigawatt hour
HVDC	High Voltage Direct Current
IPP	Independent Power Producers
KenGen	Kenya Electricity Generation Company
KPLC	Kenya Power and Lighting Company Plc
KPI	Key Performance Indicators
kV	Kilovolts
kWh	Kilowatt hour
LCOE	Levelised Cost of Electricity
LCPDP	Least Cost Power Development Plan
MW	Megawatt
PHS	Pumped Hydropower Storage
PPA	Power Purchase Agreement
RE	Renewable Energy
PV	Photovoltaic
USD	United States Dollar
VRE	Variable Renewable Energy

1 INTRODUCTION

The global energy sector is undergoing a rapid and radical transition of the way energy is produced, distributed and consumed. The shift is motivated by the urgency to ensure secure energy supply, achieve sustainable development and limit climate change. Technological innovation, the rapid decline in costs and rising investments in renewable energy and energy efficiency determine the pace and the direction of power sector decarbonisation.

In Kenya, renewable generation accounted for 87% of the total electricity supply in 2019. While hydropower and geothermal already constitute the core of the existing system, the main drivers for the increased share of variable renewable energy have been economic considerations as solar and wind are becoming increasingly cheaper and more practical than fossil fuels. Due to the country's substantial renewable energy resources it has the potential to bypass fossil fuel-driven economic development. For this to materialise, the country must reconsider its plans to build new coal-fired power plants and shall prepare for the smooth integration of large amounts of variable renewable energy capacities into its existing power system. These variable sources have specific features that differ from those of dispatchable energy sources, posing new and fundamental challenges to the operation and governance of a power system.

It is important that these challenges and their temporal sequence are recognised and understood by key stakeholders in the Kenyan power sector in order to identify adequate and timely measures to address them. One key actor is Kenya Power, which transmits, distributes and retails electricity to customers throughout Kenya.

Kenya Power's Corporate Strategic Plan 2018-2023 is the company's roadmap for the years to come and is therefore important to set the course to cope with the challenges but also to seize the opportunities related to new developments in the power sector. Examples from around the globe have shown that power sector decarbonisation processes are accompanied by rapid cost reductions in supply and demand-side technologies, increasing digitalisation, the promotion of system resilience, and the expansion of energy access through innovative technology and market solutions (OECD/IEA, 2018).

The objectives of the **Scoping Study** are to identify a suitable and realistic approach for Kenya Power to address the issue of decarbonisation, to determine the possible impacts on Kenya's power system, and to provide insights into potential challenges related to the decarbonisation of the power sector as well as possible intervention options.

In order to fulfil these objectives, the study first examines Kenya Power's Strategic Plan and the *Decarbonising the Energy Mix Initiative*, including the expected consequences of power sector decarbonisation on Kenya Power's operation (Chapter 2). In a second step, the study takes stock of the current situation of Kenya's power sector and analyses current and subsequent phases of power sector decarbonisation, including main challenges related to 'decarbonising the energy mix' (Chapter 3). The study concludes with a summary of the findings and an outline of concrete recommendations for medium- and long-term policy measures and technical interventions to support power sector decarbonisation in Kenya (Chapter 4).

Based on the identification of necessary interventions for power sector decarbonisation in the Scoping Study and on feedback provided by Kenya Power, an **Implementation Plan** will be developed (planned for Q1-Q2 2021). While the structure and content of the implementation plan will be agreed in close collaboration with the Kenya Power team, the aim would be to classify individual intervention options according to their relevance and feasibility and to present concrete implementation proposals.

2 KENYA POWER'S STRATEGIC PLAN AND DECARBONISING THE ENERGY MIX INITIATIVE

The **Kenya Power and Lighting Company Plc** (henceforth referred to as Kenya Power) is established as a limited liability company and its original mandate is the production, supply and sale of electricity. However, the mandate to produce electricity has since been taken over by Kenya Electricity Generation Company (KenGen) - which was formed in 1998 - as well as by Independent Power Producers (IPP).

The business model of Kenya Power is a regulated, centralised distribution model in which bulk power is purchased from KenGen and IPPs and electricity is retailed to customers located across the country. Most of the revenues are derived from the sale of power to end customers through regulated tariffs.

Kenya Power is a listed company with approximately 49.9% of its shares publicly traded on the Nairobi Securities Exchange and the remaining 50.1% of its shares are owned by the Government of Kenya. The main law governing Kenya Power's operations and the energy sector as a whole is the Energy Act 2019. The Energy and Petroleum Regulatory Authority (EPRA), established under this Act regulates the activities of Kenya Power to ensure compliance with the law and other legal requirements.

2.1 Kenya Power 2018-2023 Strategic Plan

In this chapter Kenya Power's Strategic Plan is introduced with an emphasis on the initiative to decarbonise the energy mix.

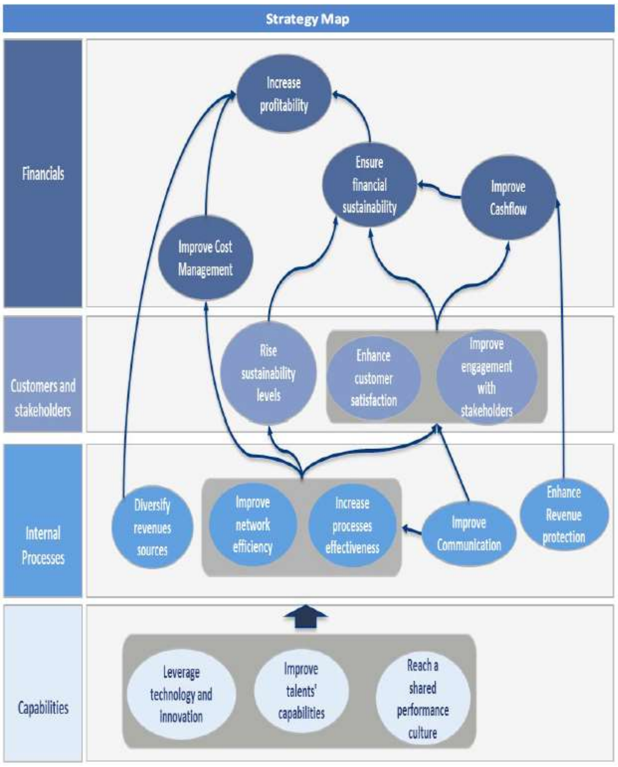
Kenya Power's five-year Corporate Strategic Plan 2018/19-2022/23 (henceforth referred to as Strategic Plan) is the company's roadmap that outlines priority areas with desirable and measurable goals for guiding decision-making and operations of the company (Kenya Power, 2018). The Strategic Plan builds on the Corporate Strategic Plan 2016/17-2021/22, which was revised after two years as the environment in which the company operates has witnessed several key changes. After consideration of new opportunities and risks to the company's business, several changes have been made to the vision, mission and core values of the company with the aim to *strategically position the company at the centre of social economic development in Kenya by providing quality and reliable power supply*. In addition, four thematic pillars have been identified on which the company aims to focus on during the five-year period: Financial sustainability, customer satisfaction, people, and power supply management (Figure 1).

Figure 1: KPLC Corporate Strategic Plan 2018/19 – 2022/23 - Overview

Vision	**Energy Solutions Provider of Choice**			
Mission	"Powering people for better lives by innovatively securing Business Sustainability"			
Strategic Themes	**Financial Sustainability**	**Customer Satisfaction**	**Our People**	**Power Supply Management**
Strategic Results	A business that generates sustainable profits while balancing its social role	To be the energy supplier of choice and to have satisfied customers	Be the employer of choice	Achieve universal access to power that is reliable, robust, cost effective and safe
Values	**Customer First, One team, Passion, Accountability, Excellence, Integrity**			

The Strategic Plan contains 15 strategic objectives which are assigned to four *perspectives* (financial, customer and stakeholders, internal processes, and capabilities). It is implemented through 31 *corporate strategic initiatives* and measured using 33 Key Performance Indicators (KPI) (Figure 2). The strategic initiatives are projects that need to be implemented in order to achieve the objectives and comply with the defined targets.

Figure 2: Structure of KPLC's Strategic Plan



Objectives	Key KPIs	Initiatives
Increase profitability	• Profit before Tax (PBT) • Earnings per share (EPS) • Price-Earnings ratio (PER)	• None (overall result for financial performance)
Ensure financial sustainability	• Power sold increase Y-o-Y • Total revenues increase Y-o-Y • Average revenue per customer (RPC)	• Grow, retain and get back large customers • Adapt organization and tools to our customers and create a commercial mindset • Increase revenues from the low-end customers
Improve cashflow	• Receivables • Cash collection rate • Debt to Equity rate	• Improve performance of collections • Improve procurement terms
Improve cost management	• T&D costs / Revenues • Average cost of purchased power	• Reduce Capex expenses • Subcontract T&D activities • Decarbonize the energy mix • Increase part of cheap power in the mix • Reduce cost of manpower
Enhance customer satisfaction	• Customer satisfaction index • Customers' complaint rate	• Reduce sources of customer's non-satisfaction • Improve management and resolution of complaints
Improve engagement with stakeholders	• Number of projects supported by communities • # of proposals accepted by regulators	• Build a stakeholders' ecosystem • Spread KPLC's voice
Rise sustainability levels	• CSR Rating	• Improve corporate reputation
Diversify Revenues sources	• % of non-core revenues vs total revenues	• Develop non-core sources of revenues
Improve network efficiency	• CAIDI • SAIFI • Technical losses • Savings due to DSM	• Extend maintenance and upgrades of T&D infrastructure • Optimize network, load management and redundancies • Extend the use of DSM
Improve process effectiveness	• Index of a select # of KPIs linked to Key processes	• Perform reengineering of key processes • Build advanced data analytics capabilities
Improve Communication	• Internal communication index • Corporate social responsibility score	• Improve internal communication • Become a reference in CSR
Enhance Revenue Protection	• Commercial losses • Billing rate (postpaid)	• Know and reduce commercial losses level
Leverage technology, and innovation	• Innovation / technology index	• Implement digital customer field service technologies • Nurture innovation and entrepreneurship • Launch pilot systems for innovative utility management systems • Create an integrated smart-grid program
Improve talent Capability	• Productivity index - as perceived	• Provide an attractive and rewarding work environment
Enhance a shared performance culture	• Values and culture buy-in index	• Embed KPLC culture and values in the day-to-day management • Develop teamwork spirit

2.2 Decarbonising the Energy Mix Initiative

This chapter shows how a decarbonisation of the energy mix can have positive impacts on other objectives of Kenya Power's Strategic Plan.

As can be observed in Figure 2, the *Decarbonise the Energy Mix* Initiative is one of the initiatives that should support fulfilling the Strategic Plan's objective of improving cost-management (part of the financial perspective) with the corresponding KPIs being Transmission & Distribution costs and revenues[1] as well as the average cost of purchased power[2].

With this initiative, Kenya Power "shall aim to rebalance its energy mix towards less carbon-emitting sources, by favouring hydro, wind and solar generation sources and lowering the share of fuel, diesel and other thermal sources, whenever the balance of system allows it" (Kenya Power, 2018).

Interlinkages with other objectives of the Strategic Plan

Our analysis shows that a successful implementation of the *Decarbonising the Energy Mix* Initiative can improve Kenya Power's strategic positioning in numerous ways. Table 1 shows the extent to which power sector decarbonisation can contribute to the achievement of other objectives of the Strategic Plan. As can be observed below power sector decarbonisation has positive effects on each of the four

[1] This ration is the costs that are necessary to build and maintain the T&D network compared with the total revenue of Kenya Power. T&D costs and revenues are both taken from the Profit and Loss (P&L) statement.

[2] The average cost of power reflects how cheap or how expensive Kenya Power bought its power from KenGen, the IPPs or from PPAs. This cost includes power costs and other charges (e.g. capacity charges). Average cost of power is the weighted sum of power multiplied by its unit cost divided by the total quantity of power bought in GWh.

perspectives of the Strategic Plan, well beyond 'improving cost management', the goal to which the initiative was originally assigned.

Table 1: Interlinkages with other objectives of the Strategic Plan

PERSPECTIVES	OBJECTIVES	IMPACTS FROM DECARBONISING THE ENERGY MIX
FINANCIALS	Increase profitability Ensure financial sustainability Improve cashflow Improve cost management	• Reduced dependency on fossil fuel-based power generation leads to lower power purchase costs to Kenya Power • Renewable energy is the cost-effective alternative to expand the system, reflected in lower generation costs and tariffs • Energy transition leads to the emergence of new services, new business models and new revenue streams (improve cash flows and profitability) • Mitigate risk of stranded assets: Renewable energy-based system ensures long-term financial sustainability • Energy transition with increased and active participation of consumers creates dependency on the grid, protecting the revenue streams
CUSTOMER AND STAKEHOLDERS	Enhance customer satisfaction Improve engagement with stakeholders Rise sustainability levels	• Facilitate the emergence of business models for consumers (increase satisfaction and dependency on the grid) • Encourage active participation of customers and other stakeholders (improved engagement and higher dependency on the grid)
INTERNAL PROCESSES	Diversify revenue sources Improve network efficiency Improve process effectiveness Improve communication Enhance revenue protection	• Energy transition is accompanied by innovation, leading to the emergence of new services and new business models (diversify revenue sources) • Energy transition requires smarter and pro-active operation of the grid, which lead to significant improvements in network efficiency • Digitalisation is one of the drivers of the energy transition, which comes with other co-benefits such as improved communications, improved data management and efficient operation
CAPABILITIES	Leverage technology and innovation Improve talent capability Enhance a shared performance culture	• Innovation is the engine of the energy transition. Embarking on the decarbonisation process will boost technology innovation in technologies, business models, operation and talent capabilities

2.3 Expected consequences of power sector decarbonisation

The purpose of this chapter is to summarise the various statements made in the Strategic Plan on the possible effects of power sector decarbonisation.

Decarbonising the power sector or increasing the share of VRE in the system is addressed in several parts of the Strategic Plan and presented as a challenge in the vast majority of cases. In the following, the various statements made in the plan on the possible effects of power sector decarbonisation are summarised.

It is worth noting that our analysis of the challenges and opportunities related to decarbonising Kenya's power sector, that can be found in Chapter 3.2.2, is independent of this. Chapter 2.4 contains a critical reflection of the expected consequences summarised in this chapter.

The various challenges mentioned in the Strategic Plan can be grouped into three main areas of expected consequences of power sector decarbonisation (Table 2).

Table 2: Expected consequences of power sector decarbonisation

	AREA	DESCRIPTION	REFERENCE
	Technical challenges	Increase of renewable generation sources disrupt the order and hierarchy in the system causing **grid management challenges**	New trends (section 5.1.5 in the Strategic Plan)
	Economic challenges	Lower costs of renewables result in **lost revenues for utilities**	New trends (section 5.1.5); External analysis (section 5.1.3)
	Business model challenges	Low costs of renewables and available decentralised generation leads to **grid defection**	New trends (section 5.1.5); Internal analysis (section 5.1.2)

The *technical challenges* mentioned in the Strategic Plan relate to the decentralisation of the grid and energy sources. It is argued that the increased participation of private generators (IPPs) and small local community producers and the increase of renewable generation sources obsolete the historical hierarchy and order in the grid and that this causes challenges for the grid operator to manage the grid properly, balance supply with demand and use the least-cost generation options (Kenya Power, 2018).

The *economic challenges* are brought in relation to the emergence of renewables. It is pointed out in the Strategic Plan that the cost of renewable energy is steadily falling and therefore the bulk of the new generation coming onto the market is made up of renewables, mostly solar and wind. The lower costs for renewable energy generation sources, particularly for PV solar, make it easier for some customers to generate their own electricity without being dependent on the grid as before. This is considered a major challenge for utility companies as they would lose revenue and increasing their investments in the grid at the same time (Kenya Power, 2018).

The *business model challenge* is linked to the perception of grid defection caused by the low costs of renewables, combined with available and cheap storage systems and available decentralised generation (Kenya Power, 2018).

Three additional developments mentioned in the Strategic Plan that can lead to challenges in the power sector are linked to *manage increasing intermittency from renewables, more thermal generation (coal and gas) expected to be brought to the market* as well as to *recurrent droughts with corresponding negative impacts on hydropower production* (Kenya Power, 2018). The potential consequences of these developments are aligned with our analysis of the challenges and opportunities of decarbonising Kenya's power sector, which are described in more detail in Chapter 3.2.2.

2.4 Critical reflections of the expected consequences of decarbonisation

This chapter provides critical reflections on the expected consequences of the decarbonisation process in Kenya as presented in the Strategic Plan (see previous chapter) and explains why they are not the main focus in our analysis of challenges in Chapter 3.2.2.

The expected consequences of increasing the share of VRE regarding *grid management* (technical challenges), the fear of *grid defection* (business model challenges) and with it a *loss of revenue* (economic challenges) can actually be considered as opportunities to adapt current understanding of the system and adopt more efficient operations and strategies that would lead to net gains to Kenya Power if embraced early on (Table 3).

Table 3: Critical reflections of the expected consequences of decarbonisation

AREA	CRITICAL REFLECTION
 **TECHNICAL CHALLENGES**	The change in the hierarchy of the grid due to the increasing participation of VRE (through IPPs or small local community producers) do not limit the ability of Kenya Power to manage the grid and use the least-cost generation options. On the contrary, Kenya already counts on low-cost, clean, and flexible generation that would allow to manage the grid with higher participation of VRE while keeping the balance of supply-demand and reducing total system costs. The need to cope with greater intermittency and uncertainty from VRE in the medium- and long-term (see Chapter 3.2.2, *flexibility needs*), brings the opportunity to enhance current practices in system operation and efficient use of existing assets. This can lead to numerous benefits beyond enabling penetration of VRE, such as reduced operational costs, improved system reliability, better information management and creation of additional services.

ECONOMIC CHALLENGES

Decentralised and distributed generation is inevitable with decreasing energy costs for renewable energy sources. However, this does not imply economic losses for Kenya Power if the business models are adapted accordingly. Increased participation of cheaper renewable energy coming to the market reduces the costs of power purchase from fossil thermal generation to Kenya Power, improving its economic competitiveness and enabling more affordable electricity tariffs. To avoid the risk of lower revenues due to reduced energy sales, the tariff design should reflect the changing structure in the system, where the grid remains important not only to provide energy but mainly to guarantee the reliability of supply.

An active and smart participation of prosumers (e.g. through price signals) can be translated to lower investment costs to Kenya Power. For instance, by shedding peak load that defers grid investments in the long run. The active participation of the demand (e.g. prosumers) opens the door to new and innovative services for which Kenya Power is the enabler. Their adequate understanding and monetisation can generate additional revenue streams.

BUSINESS MODEL CHALLENGES

The risk of *grid defection* is more prominent in a system resisting the inevitable penetration of distributed renewables and more active role of demand, and with a regulatory design and tariff structure that is not adapted to the new paradigm. If Kenya Power embraces the transition, taking a more active role and enabling and managing the participation of prosumers, it can convert the risk of *grid defection* into an opportunity to strengthen *grid dependency* for consumers. Kenya Power can leverage from the growing participation of decentralised generation and developments in digitalisation to establish new business models where the grid is the enabler, which can lock users to the grid (*grid dependency*). This does not necessarily imply a need to increase the system's capacity to deliver enough power at peak demand if efficient signals to shape the behaviour of the prosumers are implemented (such as dynamic time-of-use tariffs presenting higher electricity tariffs in peak hours and thus incentivising the use of batteries with solar systems) and generation assets are used optimally (such as PHS).

In the energy transition, the value of the grid shifts from an asset that transports electricity to the infrastructure that provides reliability in security of supply and allows the emergence of new services and actors. Regulation, market design and tariff structure should adapt to monetise from the new added values and create new revenue streams to Kenya Power.

On the contrary, if the transition is actively impeded (e.g. by charging artificial costs for rooftop installations, putting burdens in their participation, etc.) the future risks of grid defection will amplify as the benefit of being independent from the grid would be even bigger. The increasing electrification of end-use sectors is another trend of the energy transition that counteracts the risk of *grid defection*.

The reflections on some of the challenges described by Kenya Power in its 2018-2023 Strategic Plan show that many of the implications of decarbonisation (see Chapter 2.3) are *challenges* that can be overcome with improvements of current practices or can be turned around and create added value for Kenya Power. Kenya Power, as the operator of the grid, has the unique opportunity to adapt the grid to the needs of the future and as such strengthen its position as a leader in Kenya's energy sector.

Nevertheless, the energy transition towards higher shares of VRE in the power system comes with other challenges along the process in the short and long-term in terms of system operation and changing structures, which may have an impact on the operations and business model of Kenya Power. Chapter 3 presents an analysis of the Kenyan power system to identify key challenges in the process of energy transition.

3 POWER SECTOR DECARBONISATION IN KENYA

3.1 Characteristics of the power sector in Kenya

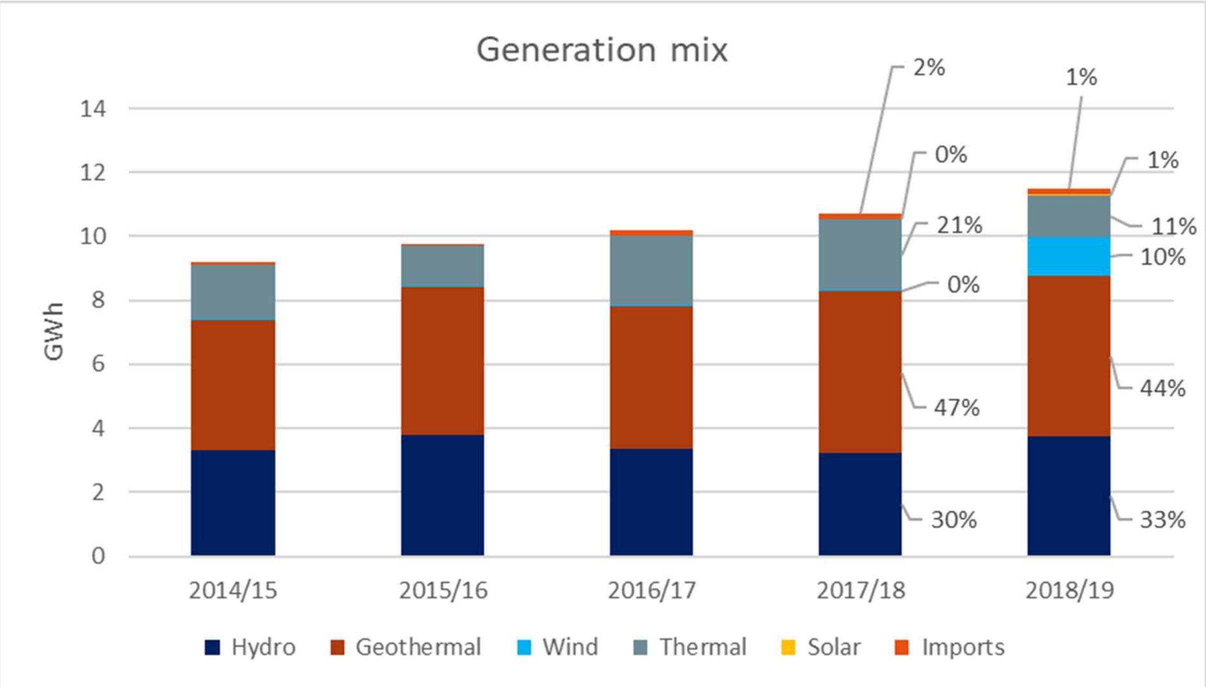
This chapter analyses the current situation of power sector decarbonisation in Kenya by providing an overview of the power sector and examining country-specific characteristics.

Generation mix

The significant participation of dispatchable renewable resources (i.e. hydro and geothermal) is the biggest asset of the Kenyan power system to integrate higher shares of variable renewable energy (VRE).

The Kenyan power system is characterised by its hydro-thermal configuration, with a substantial participation of dispatchable renewable resources. Geothermal and large hydropower plants each account for 29% of total installed capacity in the system and represented 44% and 33% of total generation in 2019, respectively (Government of Kenya, 2020). Before 2018, power generation from fossil fuels, notably from diesel-fired power plants, was used to cover the remaining generation needs with an annual participation ranging between 10% and 20% responding to the annual growth in demand and the fluctuations of water availability. However, with the installation of 310 MW of wind power capacity in Lake Turkana in 2019, this technology significantly increased its participation in total generation from less than 1% in 2018 to 10% in 2019, displacing fossil fuel generation. In 2019, renewable generation accounted for 87% of the total electricity supply (Figure 3) (Government of Kenya, 2020).

Figure 3: Kenya's Generation Mix



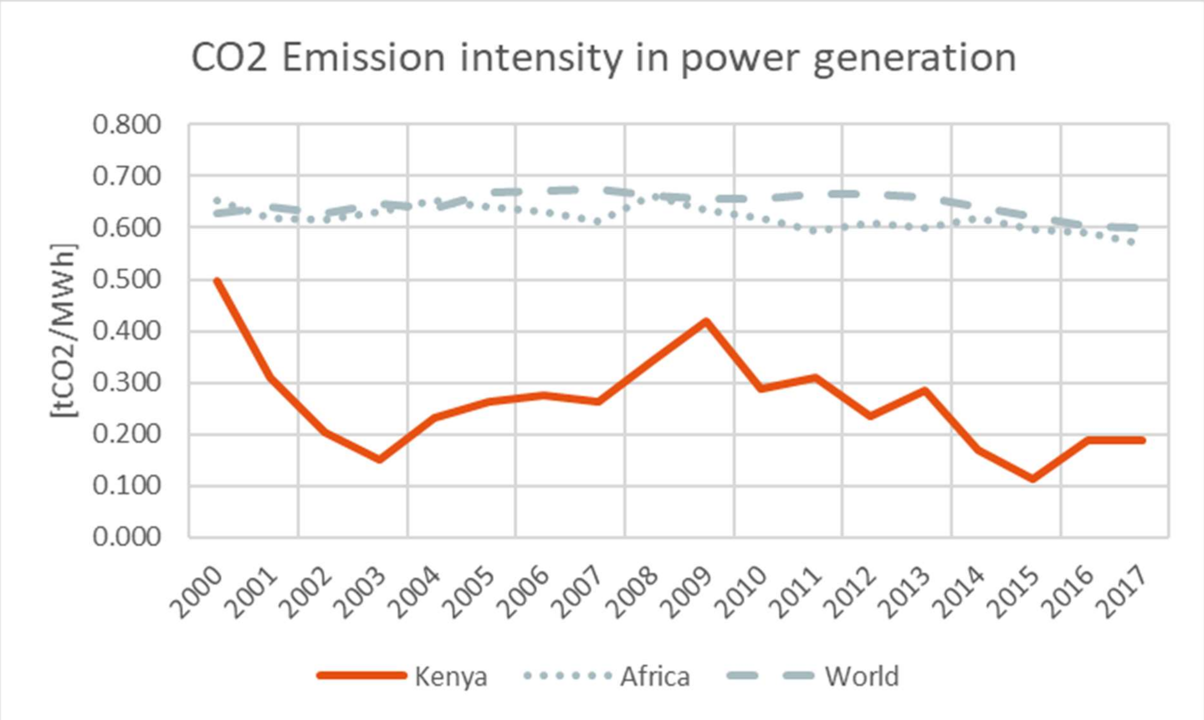
Source: (Government of Kenya, 2020)

Carbon intensity of the power system

The renewable energy-based generation mix has enabled Kenya to have one of the lowest carbon-intensive power systems in the region.

The abundant water and geothermal resources in the country have allowed Kenya to develop a power system around these technologies, reaching CO_2 emissions intensity per unit of electricity generated considerably lower than global and African averages (Figure 4). The variation in emissions intensity is largely explained by the annual fluctuation of water availability, as was evidenced in 2009 when the prolonged drought led to reduced hydropower generation and consequently an increase in emission intensity.

Figure 4: CO_2 Emission Intensity in Kenya



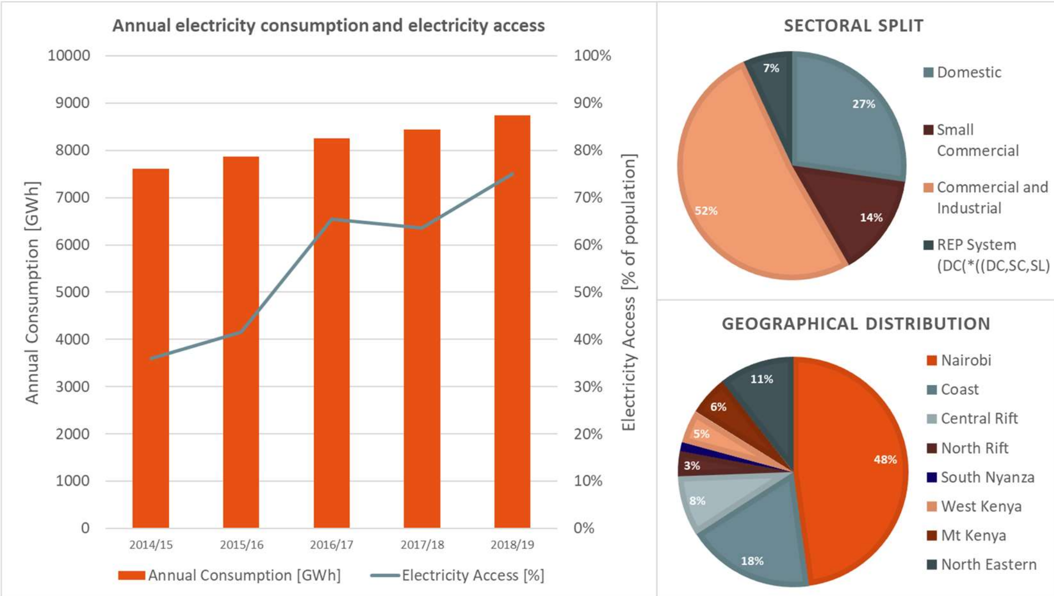
Source: (IEA, 2019)

Power system growth

The Kenyan power system is in expansion, driven by demand growth and rising electricity access.

Electricity consumption has increased at CAGR of around 4% in the last 5 years, partly driven by the increasing number of users getting access to electricity. By 2018, 75% of the population had access to electricity, compared to 36% in 2014 (World Bank, 2020a). The accelerated access to electricity led to approximately 21% increase in annual consumption in the same period. In 2018, more than half of the electricity consumption came from the commercial and industry sectors. Around 48% of the demand is concentrated around Nairobi, followed by 18% of the consumption in coastal regions (Figure 5).

Figure 5: Demand growth and geographical and sectoral breakdown



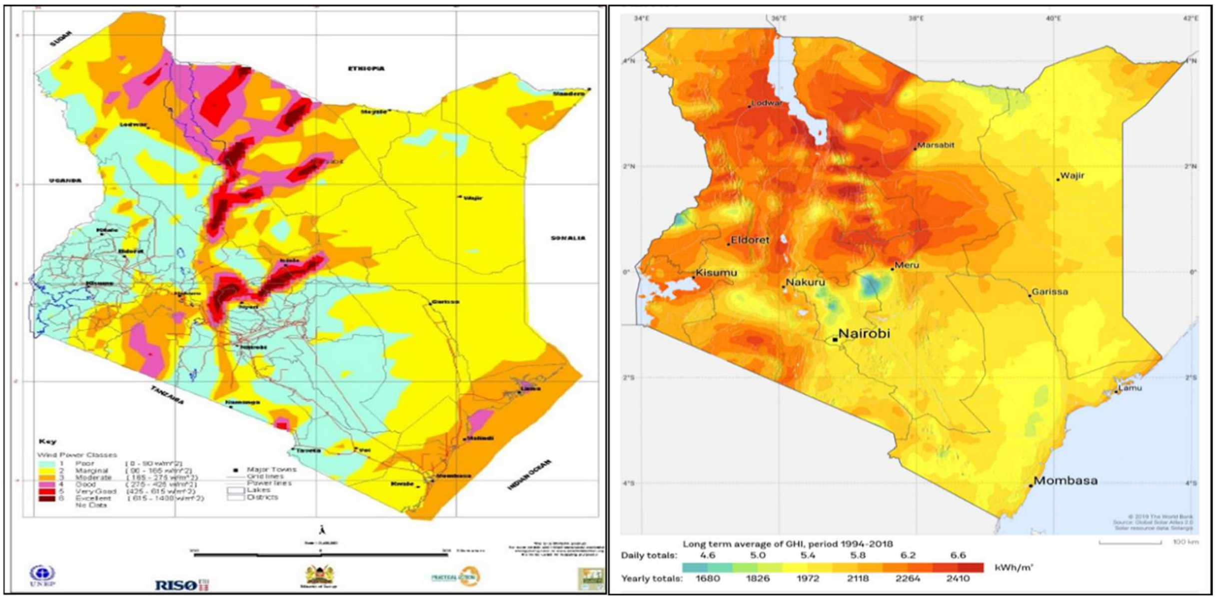
Source: (Government of Kenya, 2020; World Bank, 2020b)

Renewable resource availability

Kenya can benefit from the geographical distribution of the renewable resources and their availability throughout the year, optimising their use and upscaling their participation

Besides geothermal, hydro, and the installation of 310 MW of wind in 2019, only negligible amounts of renewable resources have been deployed. Kenya has rich solar resources across the country as well as strong wind resources in the North-West around Lake Turkana (Figure 6). Although distant from the main load centres, the richest solar and wind resources are concentrated roughly in the same area with potential access to the grid through the 400kV line that connects Lake Turkana with Nairobi. Also, studies indicate that there are suitable places for pumped hydro storage in the North-Western part of the country (Government of Kenya, 2020).

Figure 6: Renewable Energy Resources in Kenya (left: wind power, right: solar irradiation)



Source: (Government of Kenya, 2020)

The availability of Kenya's renewable energy resources varies across regions and throughout the year. The most stable renewable energy source is geothermal, which is characterised by its ability to provide a stable output of energy. Due to its equatorial location, Kenya's sunshine hours are also relatively stable across seasons. The irradiation of the sun is however also influenced by diffusion which slightly differs across the regions with some having higher values around December/January and others in May to July. On an overall average, however, the irradiation is stable across the year. The North-Western area of Kenya that has high wind resources has shown to generate most wind power in October to December and from March to April (Kenya Power, 2020). Although not fluctuating significantly throughout the year, the lowest capacity factors are encountered in the dry months between June and September (*Renewables.ninja*, 2019). The most fluctuating renewable source in Kenya is hydropower, which is directly influenced by the wet seasons that occur in March/April to May/June and in October to November/December. In the dry periods between January and February and June and September hardly any rain falls, which highlights the importance of using hydropower with reservoirs to be able to store water for longer periods.

In Kenya, although having good resources available year-round, a small bottleneck for renewable energy could thus occur in the dry seasons.

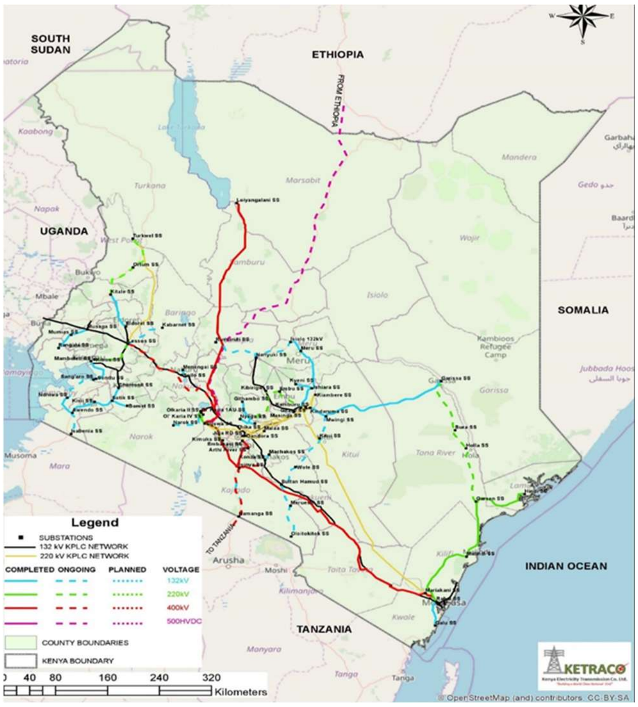
Grid expansion

The planned grid expansion and interconnections with neighbouring countries increase the flexibility in the system to integrate higher shares of renewables.

The existing transmission and distribution network is developed in the South-West of the country around Nairobi, the main load centre. The grid is characterised by its radial configuration expanding to the main energy sources (hydro and geothermal in the West and wind in the North-West) and to other major load centres in the South-East. The remarkable expansion of the grid in the last 6 years, with an annual average growth of 10%, is mainly driven by the increasing demand and growing electrification access rates. The further expansion of the grid is central to achieve the goal to attain universal access to electricity by 2022. Currently, the Kenyan national grid is interconnected with Uganda via a 132kV transmission line and with the other neighbouring countries via distribution lines.

The construction of a 500kV high voltage direct current (HVDC) overhead transmission line between Ethiopia and Kenya is underway and is expected to be completed in 2021. The line will be able to transfer 2 GW of electricity, which is higher than Kenya's current peak load of 1.91 GW (Government of Kenya, 2020). Other interconnection projects include two 220kV lines connecting to Tanzania and Uganda, which are at advanced stages of construction (Figure 7).

Figure 7: Kenya's Transmission Grid



Source: (Government of Kenya, 2020)

Role of utilities

The dominance of utilities in the power system place them at the centre of the decarbonisation process in the country

The electricity system in Kenya is largely dominated by a small number of large players that generate and distribute energy. KenGen, the largest energy generator in Kenya, produces 72% of Kenya's electricity and owns 63% of its generation mix and Kenya Power is in charge of the transmission, distribution and retail of electricity in the country (Kenya Power, 2020). Their large market shares put these utilities in uniquely powerful positions to play a leading role in the implementation of decarbonisation processes in the country.

KenGen's generation fleet is composed of 85% renewable energy of which 47% is hydro, 37% is geothermal and 1% is wind (based on generation data from KPLC from 30.06.2020). Having large shares of dispatchable power, KenGen is in an advantageous position as it technically able to more easily increase the penetration of other VRE without losing important participation with their hydro and geothermal energy assets.

3.2 Power sector decarbonisation process in Kenya

This section entails an analysis of the current and subsequent phase of power sector decarbonisation which allows for understanding, structuring and addressing a number of challenges resulting from increased variable renewable energy sources penetration in the country's power system. Particular attention is paid to the effects of decarbonisation for the system operator.

The sustained cost reductions, financial maturity and policy development around renewable energy will continue to lead the growing participation of wind and solar globally. Kenya, with its abundant wind and solar resources, is not exempt from this trend. The increasing participation of renewables in the Kenyan power system will continue to displace more expensive fossil fuel-based electricity generation. The reduced costs of power purchase from fossil thermal generation and the economic competitiveness of renewables can be reflected in significantly lower costs to Kenya Power and more affordable electricity tariffs, if the expansion is managed well and stranded capacity can be avoided.

3.2.1 Current state and path to decarbonisation

With the high shares of established hydro and geothermal power, the recently connected wind park in Lake Turkana, as well as small shares of solar and biomass, 87% of Kenya's electricity generation and 74% of the installed capacity are already renewable. Kenya therefore has relatively small shares of fossil fuels and thus great preconditions for full decarbonisation.

Kenya's energy sector is forecasted to grow mainly driven by constantly increasing demand. The electricity consumption is expected to grow substantially and almost triple (compared to current levels) to 21,414 GWh by 2030. However, the demand is not growing as quickly as anticipated as projections of yearly electricity demand growth had to be revised downwards from originally 6.7% (2017 to 2037) to 5.7% (2019 to 2039) (Reference Expansion Plan, Government of Kenya, 2020).

This growth emphasises the importance to incrementally add new sources of VRE to maintain the favourable renewable energy penetration. This also makes sense economically as the costs of such energy sources have decreased substantially over the last decade: in Kenya the weighted average cost of power of PV is currently USD 0.06/kWh while those of onshore wind are USD 0.1/kWh, both much lower than thermal energy that still costs USD 0.161/kWh (Okoth, 2020). Costs for both are expected to continue to decrease which makes them not only economically competitive with thermal energy but the cheaper option. Therefore, the planned additions by 2026 include substantial shares of VRE, mainly 651 MW of wind and 852 MW of solar PV as well as more renewables through 1,368 MW geothermal and 167 MW hydropower (Reference Expansion Plan in Government of Kenya, 2020).

Besides renewables, coal is also considered an important fuel in Kenya's energy expansion plans. Kenya is planning to build the 981 MW (3x327 MW) Lamu power plant, which will be the first coal-fired power station in East Africa. The originally anticipated high demand was a main argument to build the Lamu coal plant. However, from a current demand perspective it is not needed anymore, as is evidenced in its projected capacity factors that are as low as 0% in the first two years after construction and, in the best-case, will still be below 15% in 2037, according to the LCPDP 2019-2039 (Government of Kenya, 2020). The Lamu plant's commissioning date has been pushed back numerous and is now expected to come online in 2027 the earliest (Government of Kenya, 2020).

Although PPAs for the coal power plant have already been awarded, the plant is still subject to much controversy and its status is uncertain. The Environmental Impact Assessment has been withdrawn, the plant has not yet secured a partial risk guarantee, and major players such as the African Development Bank, a potential investor, and General Electric (GE), who was meant to build and maintain the plant, announced their withdrawal from newly built coal power plants (Business Daily Africa, 2020; Matters Engineering, 2020; Winning, 2019). In addition, the plant is expected to run (at least at first) on imported coal from South Africa, which raises concerns about energy security. Other issues include resettlement plans for future mining activities, considerable pollution and its lack of compatibility with the Paris Climate Agreement, which does not only prohibit the addition of new coal power plants but calls for a complete coal phase out by 2040.

The construction of the plant leads to immense stranded asset risks and simultaneously increasing electricity tariffs. The system LCOE is expected to peak at USD 0.184/kWh in 2027, up from USD 0.086/kWh in 2019. The installed capacity would then be 7465 MW, more than 150% higher than the expected peak load (Government of Kenya, 2020). The commission of the new Lamu power plant is therefore not only not in line with Paris Climate targets but will also have negative economic effects.

3.2.2 Existing barriers in the process towards decarbonisation

The existing structure and the energy resources available have enabled Kenya to smoothly reach 10% of the generation mix with wind power, contributing to the 87% share of renewables in the mix in 2018/2019. However, some considerations must be made to continue decarbonising the power system or at least to maintain such high levels of renewable penetration in the future (Table 4).

Table 4: Main barriers[3] towards decarbonisation and corresponding key challenges

Barrier towards decarbonisation	***Timeframe***	***Key challenges***
Lamu power plant	Short-term (decision to install the plant)	Sub-optimal oversupply
		Inflexible generation to cope with VRE
		Inefficient and costly system operation
		Risk on energy security and affordability of electricity supply
		Misuse of hydro resources and increased vulnerability to droughts
Upscale renewable energy aligned with demand growth	Along the process (follow demand growth)	Substantial clean power capacity additions required
		Reach capacity limits of transmission and distribution lines
Operation of dRES and role of hydro as storage	Medium- to long-term	Vulnerability in dry seasons and increased generation from expensive fossil fuels
		Unexploited potential of hydropower with storage capacity
		Inflexibility of geothermal plants, used as baseload
Flexibility needs	Long-term	Need for greater flexibility to balance supply-demand
		Limited monitoring and control of renewables
Future of distributed energy resources	Long-term	Restructuring of power systems to respond to greater participation of DER
		Perception of grid only as assets to allow energy flow (grid defection)
		Reduced visibility and control of DER

[3] In addition, the following barriers were mentioned during the workshop (see Annex): energy constraints that are currently taking place and make KPLC consider battery storage in addition to hydro storage to improve efficiency, security and sustainability and inadequacies in the planning and implementation of the power system (generation/transmission).

The negative impact of Lamu coal power plant in the integration of renewables

Key challenges:
- Sub-optimal oversupply
- Inflexible generation to cope with VRE
- Inefficient and costly system operation
- Greater risks on energy security and affordability of electricity supply
- Misuse of hydro resources and increased vulnerability to droughts

The major barrier in the process towards decarbonisation lies on the unfold of the Lamu coal power plant. The coal project has several known negative effects such as significant increase in carbon emissions in the power sector, health-related impacts, and economic non-viability (IEEFA, 2019; Kahlen, 2019). The installation of the Lamu plant would lead to an **oversupplied power system**, which is reflected in very high risks of stranded assets, low capacity factors and higher electricity tariff to consumers. But probably the most important effect of the Lamu coal power plant in the decarbonisation of the system in the long-run is its negative impact on the integration of variable renewables in the system.

Coal power plants are largely **inflexible generation assets** compared to any other thermal power generation (excluding nuclear). Their low ramp rates and their usually high minimum loads (i.e. their technical constraint to generate at a minimum load of 30%-50% of their nominal capacity) reduce the bandwidth of their operation, limiting the flexibility they can provide to the system. These characteristics hinder the penetration of VRE, which require flexible assets to balance the increasing variability and uncertainty in the system (Energiewende, 2017).

The installation of such inflexible asset in Kenya could limit the participation of renewables. A coal power plant of that magnitude limits the capacity of the system to absorb variability, leading to curtailment of renewable generation at earlier phases of the energy transition (i.e. at lower shares of VRE penetration). Considering the remarkable hydropower generation in the system, which are largely flexible, the installation of the Lamu power plant would be a step back in the integration of variable renewables in the system.

A sizable presence of inflexible assets in power systems typically lead to **inefficient and costly system operation**. Given the fluctuation of supply and demand, inflexible systems have to resort to costly reserves allocation and suboptimal dispatch of power plants to compensate for the flexibility needs. These inefficiencies are reflected as higher operational costs and more expensive electricity bills, significantly impacting Kenya Power's business model. Likewise, a greater dependency on fossil fuel-based power generation leads to higher power purchase costs to Kenya Power and higher electricity bills. A shift towards fossil fuel-based power generation makes Kenya more exposed to fluctuations of international fossil fuel prices, **putting at risk the energy security and the affordability of electricity** supply in the country.

Finally, the installation of a coal power plant also has negative impacts on the utilisation of hydropower assets. The inflexibility of the Lamu power plant will need to be compensated with a more flexible operation of hydropower plants, leading to inefficient operation of hydro plants, **misuse of hydro resources and making the system more vulnerable to droughts**.

Upscale renewables aligned with the demand growth

Key challenges:
- Substantial clean power capacity additions required
- Reach capacity limits of transmission and distribution lines

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The significant demand growth expected in the future, led by efforts to reach universal electricity access and increasing industrialisation and urbanisation trends, requires **substantial clean power capacity additions** in order to maintain the same levels of penetration in the generation mix. Hence, progress in power system decarbonisation requires continuous annual investments in renewable capacity that leads to higher electricity generation from renewable sources than the annual demand growth.

The growing demand will also lead to increasing electricity flows in the grid which will eventually lead to **reaching the capacity limits of the transmission and distribution lines**. Consequently, an expanding system with growing demand such as in Kenya must be accompanied by investments in grid capacity expansion and reinforcement. Whereas this trend is mainly driven by demand growth and not by the decarbonisation process, it significantly contributes to improving the flexibility in the system and facilitating the integration of higher shares of variable renewables.

Power flows do not increase evenly throughout the network. The geographical distribution of renewable resources and demand growth must be considered when expanding the grid. The accelerated deployment of renewable power installations in resource-rich areas of the country (e.g. North-West of the country around Lake Turkana) and the growing demand in main load centres (e.g. Nairobi) is expected to lead to congestions in the corridor connecting these two regions. The full deployment and integration of renewables in Kenya requires adequate planning and grid reinforcement in North-West–Nairobi corridor in the medium to long-term.

Operation of dispatchable renewable resources (i.e. hydro and geothermal) and the role of hydro as storage to integrate VRE

Key challenges:
- Vulnerability in dry seasons and increased generation from expensive fossil fuels
- unexploited potential of hydropower with storage capacity
- Inflexibility of geothermal plants, used as baseload

The slight drop in renewable energy potential in January to March and June to September, leads to an increase in electricity generation from fossil fuels. The latter is to compensate for the reduction in electricity production from hydro resources before and during the dry seasons, in order to keep the reservoirs within the levels required to ensure the reliability of the system. The focus should therefore lie on the expansion of wind and solar that present relatively stable resource availability throughout the year, which allows storing more water in the reservoirs to modulate throughout the year and use in later times when it is more valuable, while reducing the generation from expensive fossil fuels. The optimal coordination of the potential and profiles of renewable resources (hydro, geothermal, wind and solar) is a cost-effective solution to **reduce the vulnerability to dry seasons while increasing the participation of renewables**, reduce emissions and minimise total system costs.

In Kenya there is vast potential for further exploitation of hydropower estimated between 3,000 MW and 6,000 MW, of which roughly 1,500 MW count as *identified potential* (Government of Kenya, 2020). Many possible projects would be of relatively large sizes starting at 30 MW and going as high as 500 MW, like the planned project at High Grand Falls. Studies have further shown that there is also a potential for Pumped Hydropower Storage (PHS). The optimal operation and planning of the **unexploited potential of hydropower with storage capacity**, including PHS, has an even greater value in the context of higher penetration of VRE.

Through an optimal operation of dispatchable renewable resources in coordination with the rest of the system, hydropower energy and its storage capacity will be utilised when it is more valuable for the system, this is when electricity generation is more expensive or during peak demand. As a result, shortcomings in times when VRE output is slightly lower can be avoided and the utilisation of thermal energy generation can be reduced and directed mainly to support to meeting the peak demand. If additional VRE and dispatchable renewable capacity is installed to cope with increasing demand, the existing thermal fleet is enough to support in meeting the peak demand and less new thermal additions are needed in the future.

Geothermal plants currently operate with the single flash steam technology, which is technically **not able to produce flexible power and is only used to generate baseload power**. With the growing energy demand and the expected expansion of geothermal, it is therefore very important that binary steam cycle systems are implemented for future use as they are much more flexible and therefore better compatible with variable renewable energies. Today most of the existing binary plants are operated by independent power producers.

Flexibility needs: existing Kenyan system is able to cope with its integration

Key challenges:
- Need for greater flexibility to balance supply-demand
- Limited monitoring and control of renewables

Looking ahead in the decarbonisation process in Kenya, the increased participation of VRE resources will gradually require **greater flexibility from the system to balance the supply and demand of electricity** in a reliable manner. Although the need for flexibility is oftentimes perceived as the main challenge to integrate VRE, measures and solutions are readily available in existing power systems.

For instance, the existing generation fleet in Kenya can provide the flexibility needed for the first shares of VRE in the system as was evidenced in 2019 with 10% penetration of wind and can continue increasing without major problems. Being at the centre of a regional grid integration, Kenya can also leverage its advantageous position with regards to grid interconnection with neighbouring countries. The substantial transmission capacity allows to take advantage of geographical complementarities of renewables and to be able to balance the system (i.e. export electricity when there is a surplus of VRE generation and import when there is low availability). Grid expansion plays a central role in the integration of VRE, as does the facilitation of deployment of renewable energy at the distribution level.

Wider use of battery storage systems could be another solutions to increase system flexibility. Batteries can be of utility scale (large storage capacity, usually connected to the transmission or distribution grid), or behind-the-meter (smaller storage capacity, often for commercial or residential use). The most used and commercially available battery storage technologies are made of lithium-ion, a material with great conditions to absorb, store and release electricity. The advantage of battery storage over e.g. PHS is that they have no geographical constraint and can more flexibly be sized, and can therefore be placed wherever flexibility is needed.

Moreover, an improvement of current practices such as efficient system operation[4], flexible operation of geothermal plants, advanced market designs and optimised hydro-thermal coordination can untap additional flexibility potential in the system to continue increasing the participation of renewables.

As the share of VRE increases, further measures implemented in other countries can also be incorporated in the Kenyan context and contribute to addressing the challenges associated with the **limited monitoring and control of renewable resources** in the system. Kenya can learn from best practices in other countries that have gone through similar or deeper challenges to respond to increasing uncertainty and variability from VRE. These practices include the following measures:

- Use Automatic Generation Control (AGC) in system operation,
- develop Control Centres dedicated to the control and monitoring of renewables,
- incorporate forecasting in system operation and planning,
- efficient reserves allocation,
- encourage active participation of the demand and
- integrate locational signals in operational practices and investment decisions.

The existing Kenyan system is able to cope with the integration of first shares of VRE. Deeper challenges may become visible only with substantially higher shares of VRE (e.g. more than 40%-50%). This means that even if it is relevant to start planning for deeper structural changes in the long-run, renewables should continue developing in the short and medium-term.

The future trend of distributed energy resources and their role in the decarbonisation process

Key challenges:
- Restructuring of power systems to respond to greater participation of DER
- Perception of grid only as assets to allow energy flow (grid defection)
- Reduced visibility and control of DER

On the demand side, a prominent participation of distributed energy resources (DER) and a more active role of consumers in the power sector is gaining ground globally and it is also expected that the same will happen in Kenya. This trend is mainly driven by six factors: the need to provide universal electricity access, more affordable clean technologies available to consumers, the modularity of renewable resources allowing the decentralisation of electricity generation, increased digitalisation of the power sector, increased electrification of end-use sectors as vehicle to decarbonisation and the emergence of new business models for on-grid and off-grid services (e.g. pay-as-you-go, solar home systems).

Given the above-mentioned drivers, the deployment of DER can be considered an unstoppable trend. While this trend requires **gradual restructuring of power system operation and planning**, taking advantage of all these resources and implementing smart management approaches is key to a successful transition and decarbonisation. The traditional connect-and-forget approach would create more challenges than solutions. In fact, a proactive approach to integrate and take advantage of DER's characteristics will not only facilitate the energy transition but could potentially lead to monetizable

[4] Efficient system operation includes generation control (AGC), better forecasting and its incorporation in system operation, use of dedicated control centres, better monitoring and communication, digitalisation, efficient reserves sizing and allocation, etc.

benefits to Kenya Power such as the provision of additional services, defer grid investment costs and create a dependency on the grid (as opposed to grid defection).

In the process of the energy transition towards a more decarbonised, electrified and decentralised system, the grid – and therefore the utilities that own and control it – **should be understood not only as assets that allow the flow of energy** but also as the backbone that allows the exchange of services and information across a wide range of actors. The central role of the grid in facilitating this transition plus the growing electrification of end-use sectors create a stronger dependency of the users to the grid, which should be understood by utilities like Kenya Power to reformulate their business model and monetise from it.

By proactively managing and planning greater participation of DER, power utilities and system operators such as Kenya Power can exploit the flexibility potentials in the demand side, facilitating the integration of higher shares of renewables in the power sector, and create business models around DER's dependency on the grid.

Initial solutions to **increase visibility and control of distributed energy resources** to anticipate disruptions and facilitate their seamless growth include the improvement of forecasting, enabling the participation of aggregators and the implementation of advanced monitoring and control techniques. In more advanced stages of DER penetration, the regulation and the power sector structure (e.g. market design, regulation framework, structure of tariffs, etc.) should also adapt in order to allow regulators, system operators and utilities to anticipate changes that can be initially perceived as challenges and turn them into strengths.

3.3 Co-benefits of power sector decarbonisation

This section assesses additional economic, health-related, and environmental benefits of the power sector decarbonisation process in Kenya. This is done with a focus on geothermal and coal-based power generation, as they are the main energy sources considered to provide baseload power in the future.

Policies that primarily aim at addressing challenges in the electricity sector can go beyond impacts on energy access and security and positively contribute to the achievement of other sustainable development-related objectives that are important to society, such as food security, human health, employment creation, and environmental services. In this context, the benefits of policies that go beyond their original purpose are labelled "co-benefits" or sustainable development impacts. The integration of multiple objectives in policies can strengthen public support for such policies and increase the cost-effectiveness of their implementation.

There are a number of co-benefits of decarbonising the power sector. In fact, social and economic co-benefits have become key drivers of the global transition towards the new renewable energy world. Some of the co-benefits attributed to the decarbonisation of the power sector and which are frequently stated in literature (e.g. IASS, 2017) are linked to its contribution to

- providing secure and affordable power for all,
- mitigating conflicts over scarce resources,
- promoting the national economy, local businesses, and jobs,
- increasing people's health and wellbeing,

- unburdening governments and freeing resources, as well as
- empowering local communities and citizens.

This section focuses on the economic, health-related, and environmental impacts of the power sector decarbonisation process, using the comparison of geothermal and coal-based power generation to illustrate the impact on Kenya's development. These two generation technologies are chosen as they are the two main sources considered for future baseload electricity supply options in Kenya, each representing a distinct electricity supply expansion pathway.

Economic (incl. employment and investment) impacts

Investment in electricity generation results in the immediate creation of *direct and indirect employment* opportunities, as well as wider economic effects, during a project's construction and operation phases. A direct comparison of both generation technologies with regard to their impact on job creation shows that geothermal power generation creates three times more domestic employment per MW of new capacity than coal-based power generation. The main reason for these results are the different local shares in the value chain for these two technologies. While geothermal power has a long history in Kenya and expertise is locally available and sourced, coal development would heavily rely on the foreign labour force, both for construction and operation and maintenance of the plant (Kahlen, 2019).

Air pollution and health impacts

Electricity generation technologies also differ in terms of their impact on *air pollution and human health.* The energy sector in general, including both production and use, is the largest source of man-made air pollution emissions. Geothermal and coal-fired power plant emissions differ significantly, not only in terms of GHG emissions (see impacts on climate change below), but also in other air pollutants such as particulate matter, sulphur dioxide, and nitrogen oxides. Geothermal power plants emit less than 1% of the air pollutants emitted by coal-fired power plants of equal capacity. The construction and operation of the proposed coal-fired power plants in Kenya would be a major source of air pollution in the country, with significant impacts on human health. A quantitative analysis of the health impacts has shown that up to 2065, roughly 1,620 Kenyans would have died prematurely from the associated air pollution if both coal plants in Lamu and Kitui were to be built (Kahlen, 2019). These health impacts are further associated with significant costs for the healthcare system.

Climate change impacts

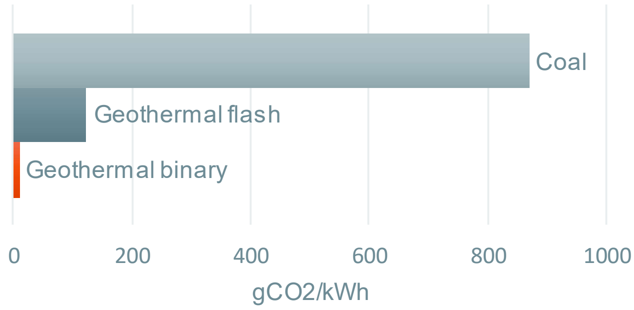
Apart from these important effects on sustainable development, the energy sector is at the core of global efforts to combat climate change. Around two thirds of global greenhouse gases (GHG) and 90% of carbon dioxide (CO_2) emissions stem from energy production and use (OECD/IEA, 2018). The trend towards electrification of other end-use sectors increases the urgency to decarbonise the power sector. Hence, the transition to a cleaner and more efficient energy system is key for achieving the global goal of the Paris Agreement to limit global temperature rise to well below 2°C, aiming at 1.5°C. Key for a comprehensive transformation of the energy system is the decarbonisation of the power sector (Rogelj et al., 2015).

Thus, the power sector decarbonisation is an important element for Kenya to reach its climate commitments under the Paris Agreement. Having agreed to peak GHG emissions as soon as possible and to achieve net-zero emissions in the second half of the century, compliance with the Agreement will require all Parties to restrict short-term investments in fossil fuel power generation technologies to the absolute minimum required, and to transition to a 100% renewable energy-based electricity supply sector in the medium- to long-term. Recognising this need, 50 of the Parties most vulnerable to climate change impacts, including Kenya, vowed at COP22 in November 2016 to strive towards 100% renewable energy by 2050 (Climate Vulnerable Forum, 2016).

The main measure required to contribute to Kenya's climate change targets and ensure decarbonisation of the power sector would be the restricted use or avoided installation of new coal and additional natural gas capacity. This can be achieved through further expansion of other electricity supply options – such as renewable energy sources – and/ or energy efficiency improvements.

Even though geothermal power is a renewable energy source, geothermal-based electricity generation can result in GHG emissions. However, these emissions are minor in comparison to those from traditional non-renewable baseload generation facilities, such as coal-fired power plants, since there is no combustion process involved (Figure 8).

Figure 8: Comparison of global emission factor estimates for geothermal binary and flash technology and coal-based power generation



Source: (Bertani & Thain, 2002; Schloemer et al., 2014)

4 APPROPRIATE INTERVENTION OPTIONS

This concluding section presents an overview of recommended interventions to support Kenya Power to overcome the previously identified challenges that arise when decarbonising the country's energy mix.

The analysis of the current status of the Kenyan power system and the subsequent phases in the decarbonisation process (Chapter 3.2) served as a basis to identify key challenges that should be addressed in the short- to medium-term or anticipated for the long-term. Table 5 illustrates an overview of intervention options to support Kenya Power to overcome those challenges. The intervention options respond to the challenges identified in Chapter 3 and a compilation of relevant practices found in literature (De Vivero et al., 2019; IRENA, 2019).

Table 5: Intervention options to move forward in the decarbonisation process

		Lamu power plant					Upscale renewable energy aligned with demand grow		Operation of dRES and role of hydro as storage			Flexibility need		Future of distributed energy resources		
Intervention option	***Time-frame***	***Key challenges*** *Sub-optimal oversupply*	*Inflexible generation to cope with VRE*	*Inefficient and costly system operation*	*Risk on energy security and affordability of electricity supply*	*Misuse of hydro resources and increased vulnerability to droughts*	*Substantial clean power capacity additions required*	*Reach capacity limits of transmission and distribution lines*	*Vulnerability in dry seasons and increased generation from expensive fossil fuels*	*Unexploited potential of hydropower with storage capacity*	*Inflexibility of geothermal plants, used as baseload*	*Need for greater flexibility to balance supply-demand*	*Limited monitoring and control of renewables*	*Gradual restructuring of power systems to respond to greater participation of DER*	*Perception of grid only as assets to allow energy flow (grid defection)*	*Reduced visibility and control of DER*
Broaden the analysis of the impacts of the Lamu project	*Short-term*	x	x	x	x	x										
Encourage flexibility of generation assets	*Along the process*		x	x			x				x	x				
Optimise the utilisation of renewable resources to improve system efficiency, flexibility and security	*Medium-term*		x			x			x	x	x					
Improve monitoring and control practices	*Medium-term*		x	x							x	x	X			
Incorporate forecasting in operational practices	*Medium-term*						x			x			x			
Reinforce the grid	*Along the process*							x		x		x				

Intervention option	Time-frame	Key challenges: Lamu power plant					Upscale renewable energy aligned with demand grow		Operation of dRES and role of hydro as storage			Flexibility need		Future of distributed energy resources		
		Sub-optimal oversupply	*Inflexible generation to cope with VRE*	*Inefficient and costly system operation*	*Risk on energy security and affordability of electricity supply*	*Misuse of hydro resources and increased vulnerability to droughts*	*Substantial clean power capacity additions required*	*Reach capacity limits of transmission and distribution lines*	*Vulnerability in dry seasons and increased generation from expensive fossil fuels*	*Unexploited potential of hydropower with storage capacity*	*Inflexibility of geothermal plants, used as baseload*	*Need for greater flexibility to balance supply-demand*	*Limited monitoring and control of renewables*	*Gradual restructuring of power systems to respond to greater participation of DER*	*Perception of grid only as assets to allow energy flow (grid defection)*	*Reduced visibility and control of DER*
Optimise network congestion management	*Along the process*							x				x				
Analyse and provide technical validation for business models for DER	*Medium- to long-term*						x						x	x	x	x
Re-evaluate the design of the tariff in the context of greater participation of DER	*Medium- to long-term*													x	x	
Deploy smart meters and digitalisation solutions	*Long-term*												x	x	x	x
Strengthen grid dependency through smart electrification	*Long-term*													x	x	x

Broaden the analysis of the impacts of the Lamu coal-fired power plant

Although the macro implications of installing the coal-fired Lamu power plant have been thoroughly discussed, its implications on the operation of the system are less understood. Kenya Power should carry out a broader analysis of the impacts of the Lamu project in terms of the system's efficiency, costs, sustainability and impacts in the utilisation of other plants. This analysis should enable Kenya Power to understand the impact that the Lamu coal plant would have on its operations and take a position regarding the installation of the plant.

Encourage flexibility of generation assets

Generation assets can be incentivised to operate more flexibly through adjustments in the market design to send efficient economic signals to generation units or creating new flexible products (e.g. reserves, ramping products). The flexible operation of generation assets would benefit Kenya Power by improving the system's efficiency and reliability, while facilitating the integration of renewables into the system. Kenya Power plays a central role to evaluate the changes needed at the policy level to encourage flexibility. For instance, understanding and evaluating the implications of new market designs to incentivise flexibility on the operations and business model of Kenya Power.

Optimise the utilisation of renewable resources to improve system efficiency, flexibility and security

Additionally, by encouraging the optimal utilisation of renewable resources, leveraging from resources' complementarities, and maximising the value of storage in hydro reservoirs, Kenya Power can further improve the efficiency, flexibility and security of the system.

Improve monitoring and control practices

By improving monitoring and control practices, Kenya Power would be better positioned to respond to fluctuations in the system, while increasing its reliability and facilitating the integration of VRE and DER. Kenya Power can improve monitoring and control practices by requesting generation units to be equipped with AGC or enhance the control centres to be able to monitor generation units and major loads in real time.

Incorporate forecasting in operational practices

The incorporation of forecast in operational practices would allow Kenya Power to improve predictability of renewable energy availability in the short term, minimising the uncertainty risk and keeping reliability standards while increasing the participation of renewables. Kenya Power can do this in coordination with renewable energy plant developers and meteorology service providers. It is important that if forecast practices are already in place, e.g. requested through PPAs, they are used in the efficient operation of the entire system for example to size and allocate operational reserves or to anticipate congestions and RE curtailments.

Reinforce the grid

The reinforcement of the grid (e.g. replacing old equipment, building new lines, increasing the capacity of existing lines or increasing redundancies) is one of the key interventions to keep the reliability of the system in the context of increasing demand and greater participation of renewable and distributed energy sources. A strong and robust grid is one of the main flexibility assets to integrate higher shares of VRE.

Optimise network congestion management

Similarly to the grid reinforcement, the optimisation of load and network congestion management are instrumental measures to keep the reliability of the system and smartly integrate new sources into the system.

Analyse and provide technical validation for business models for DER

This would be instrumental to provide a foundation to establish policies that facilitate the entry of new actors in the system while keeping alignment with Kenya Power's objectives and relevance in the system (e.g. maintaining the grid as a key enabler). By enabling the access of DER to the grid and supporting a technical analysis that leads to enabling policies and a regulatory framework, Kenya Power would contribute to level the playing field for DER and encourage innovation in the sector. In turn, Kenya Power would benefit from increased visibility and coordination of DER.

Re-evaluate the design of the tariff in the context of greater participation of DER

Time-varying tariffs enable customers to adjust their electricity consumption voluntarily (either through automation or manually) to reduce energy expenses. Time-varying tariffs can be determined based on the power system balance or short-term wholesale market price signals. This measure can reduce the peak demand and therefore reduce investments needed in the grid reinforcement. Similarly, to avoid grid defection, the tariff structure should be adapted, reflecting the changing role of the grid infrastructure from transporting electricity from generation to consumer, to ensuring reliability and security of supply for a consumer with on-site generation. In this sense, the demand charge in the tariffs should be adjusted from being volumetric to being a fixed charge that reflects the peak load a consumer uses from the grid.

Therefore, by adopting a fixed demand charge and a time-varying electricity charge in the tariff, Kenya Power can ensure the revenues for grid cost recovery while also minimising further investments in the grid.

Deploy smart meters and digitalisation solutions

Wider usage of smart meters and sensors, the application of the Internet of Things and digitalisation have created opportunities to better operate and provide new services to the system. Digital technologies would support Kenya Power in several ways, including: better monitoring of assets and their performance; more refined operations and control closer to real-time; and the emergence of new business models on the consumer and prosumer side. The growing relevance of digitalisation is also due to advancements in decentralisation, with the deployment of large numbers of new small generators, mainly rooftop PV. Enhanced communication and better control over the assets connected to the grid are key for Kenya Power to successfully embark on this transition. Particular programs to deploy smart meters can be put in place.

Strengthen grid dependency through smart electrification

By encouraging and facilitating the electrification of end-uses of energy (e.g. transportation, industry, etc.), Kenya Power can smartly integrate new users to the grid, increase electricity sales, offer additional services and strengthen the dependency of users on the grid to supply their energy needs. All this would be reflected in increased revenue streams.

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6 ANNEX

The Scoping Study has been presented to members of the KPLC team during a two-hour online workshop that took place on May 20, 2021.

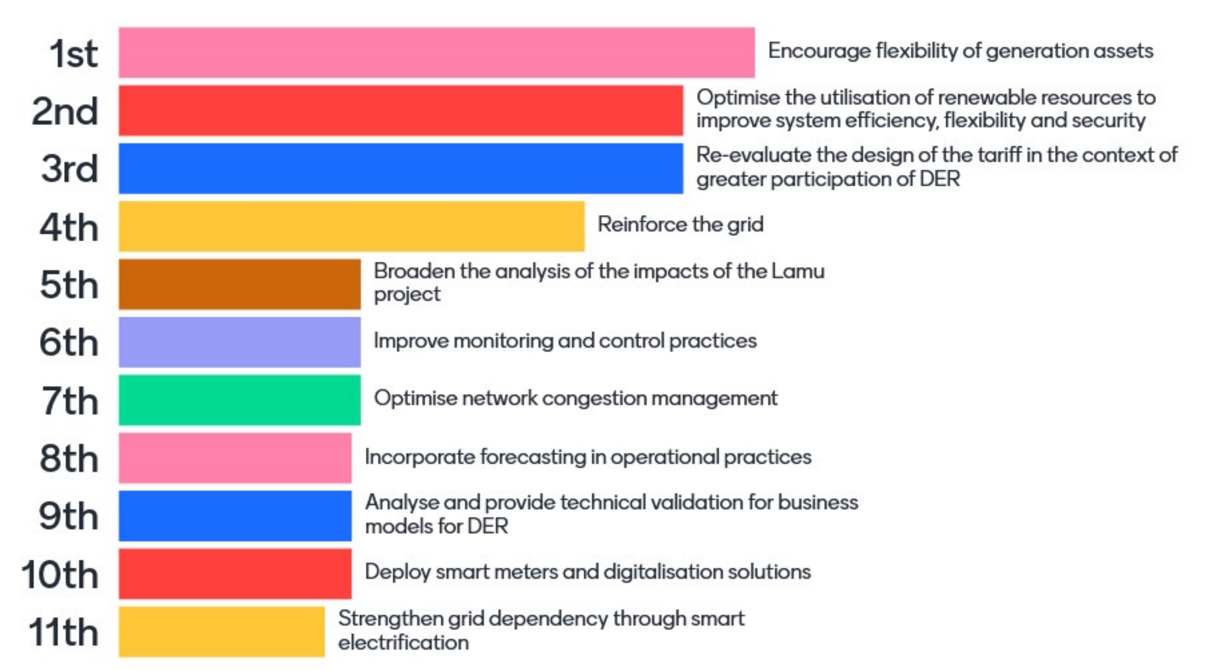
The objectives of the workshop were to present the results of the Scoping Study, obtain feedback from a wider audience at Kenya Power and jointly discuss about suitable intervention options and practical implications for their implementation.

As part of the discussions, a live poll allowed participants to indicate which of the intervention options presented in the study they thought were the five most relevant for Kenya Power in the process of decarbonising the energy mix.

According to the respondents, there are four intervention options that stand out in terms of relevance for KPLC: to encourage flexibility of generation assets, to optimise the utilisation of renewable resources to improve system efficiency, flexibility and security, to re-evaluate the design of the tariff in the context of greater participation of DER and to reinforce the grid.

The full results can be seen in Figure 9 below.

Figure 9: Intervention options – results of an online poll



(Results of a live online poll through menti.com with nine respondents)

In addition, the discussion at the workshop has led to an emphasis on other intervention options that have not been specifically identified as such in the study. They include:

- Assuring that the planning process works well and is used
- Having a system reliability in charge, who would also be doing the planning
- Having plans that need to capture issues of spinning capacity to accommodate the intermittent energy sources
- Ensuring that the intermittent have controlled/firm output requirements in their operations

The 11 intervention options described in Chapter 4 include several examples, but these are by no means exhaustive. On the contrary, this report intentionally focused on more generic intervention options where all of the above points fall into, without specifically having been described. These points are all equally relevant as the described examples and fall into one or even multiple intervention option categories:

- Better planning processes falls under intervention options *Broaden the analysis of the impacts of the Lamu project, encourage flexibility of generation* assets, *reinforce the grid* and *strengthen grid dependency through smart electrification.*
- Systems reliability is included under *improve monitoring and control practices, incorporate forecasting in operational practices, reinforce the grid* and *optimise network congestion management*.
- Spinning capacity falls under the intervention option *encourage flexibility of generation assets*.
- Firm output capacity is implied in the intervention option *optimise the utilisation of renewable resources to improve system efficiency, flexibility and security.*

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