**EAST AFRICAN CIVIL SOCIETY FOR SUSTAINABLE ENERGY AND CLIMATE ACTION
(EASE&CA)**

PLAN FOR 100% RENEWABLE ENERGY SCENARIO IN KENYA BY 2050

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ACKNOWLEDGEMENT

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ABBREVIATIONS AND ACRONYMS

BAU	Business-As-Usual
CO_2e	Carbon Dioxide Equivalent
INFORSE	International Network For Sustainable Renewable Energy
GESIP	Green Economy Strategy and Implementation Plan
GHG	Green House Gas
CCAK	Clean Cook stove Alliance of Kenya
GW	Gigawatt
$MtCO_2e$	Metric tons of Carbon dioxide equivalent
ME&F	Ministry of Environment and Forestry
MEP	Ministry of Energy and Petroleum
MW	Megawatt
MRV	Measuring, Reporting and Verification
NCCAP	National Climate Change Action Plan
NDC	Nationally Determined Contribution
PA	Paris Agreement
SDGs	Sustainable Development Goals
KOSAP	Kenya off-Grid Solar Access Project
UNDP	United Nations Development Programme
GPOBA	Global Partnership of Output Based Aid
LMCP	Last Mile Connectivity Programme
NES	National Electrification Strategy
KenGen	Kenya Electricity Generation Company

EXECUTIVE SUMMARY

This report gives an overview of the Kenyan situation regarding energy supply and demand , and presents a scenario for how Kenya can move into a 100% renewable energy economy until 2050 and at the same time move from a lower middle income country into an upper middle income country as well as reduce biomass use for energy to sustainable levels. Kenya has vast potentials for renewable energy and has been ranked fifth globally in an annual Bloomberg index measuring investments and opportunities in clean energy, two facts that together give a good basis for realizing a development as described in the 100% renewable energy scenario in this report.

The report focuses on how to supply the energy for Kenya's development with renewable energy and how to Increase energy use with modern, energy efficient technologies. In addition to the scenario for transition to 100% renewable energy, the report also includes a business as usual scenario for how Kenya might develop without focus on renewable energy. A comparison of the cost of energy supply of the two scenarios shows an economic benefit of the renewable energy scenario.

The report explains specific proposals that lead to 100% renewable energy development. The results include strongly increased electricity production from renewables, the change of the total primary energy demand to 100% renewables, reduction of biomass use to be within sustainable levels of biomass production in Kenya, reduced emissions of CO_2, and estimates of costs of energy supply in the scenarios in 2030 and 2050. The most important specific proposals are:-

- Change to more efficient cooking, including efficient electric cooking and new highly efficient wood and charcoal stoves
- Change of transport gradually to electricity, hydrogen and new fuels (electrofuels)
- Make charcoal production much more efficient, increase conversion efficiency from wood to charcoal from around 10% today to 25%
- Expand windpower to 9,000 MWe
- Expand solar power to 17,000 MWe
- Expand geothermal power to 5,600 MWe
- Expand electric international interconnectors to 3,000 MWe capacity
- Use biomass power plants to balance demand and supply, in addition to existing hydro power

Further, the report presents the current situation and current official plans, including energy-related parts of Kenya's climate plans and NDC.

1.0 INTRODUCTION

Throughout the industrial era, mankind has used fossil fuels to meet his energy requirements. Coal, oil and natural gas have lit homes and powered machinery for more than two centuries, driving civilization forward. But as human development accelerated, the unsustainability of energy became apparent. Global fuel supplies deteriorated, the atmosphere became more polluted, and climate started to change. The search for renewable sources of energy began, to ensure a sustainable future.

Today, our civilization stands at a critical juncture. We are on the cusp of adopting clean energy at a scale never seen before. But for renewable power to continue its rapid advancement, the right decisions need to be taken.

When clean energy first made headway in the global scenario, questions were raised about how stable and scalable it was. At a macro level, unstable policies for powering future growth compromised development while costs for some renewable energy technologies, as solar power, were very high. Nevertheless, clean energy installations continued to grow, albeit slowly, until a dramatic leap a few years ago.

Today, a fifth of the world's electricity is produced by renewable energy. In 2016, there were 160 GW of clean energy installations globally. This is 10% more than in 2015, but they cost almost a quarter less. New solar power gave the biggest boost, providing half of all new capacity, followed by wind power, which provided a third, and hydropower, which gave 15%. It was the first year in history that added solar capacity outstripped any other electricity-producing technology. Several countries have set steep capacity installation targets over the next 10 to 15 years, following the climate COP21.

Energy is the lifeblood of all societies. But the production of energy from the burning of fossil fuels produces carbon dioxide emissions that are released into the atmosphere on a grand scale. The energy sector accounts for more than 70% of these emissions, which are driving climate change worldwide. Reducing CO_2 emissions from the energy sector has a direct and positive impact on climate protection. So there needs to be a transition from the current energy system that relies heavily on fossil fuels to a system that uses renewable energy sources that do not emit carbon, such as wind and solar. Also the use of biomass must be limited to be within the sustainable limits.

Provision of clean and sustainable energy is essential for the realization of Kenya's Vision 2030 and the Big Four and is considered as one of the infrastructure enablers of the socio-economic pillar of the Vision. The 2015 Energy and Petroleum Policy indicate that rapid growth in Kenya's economy over the past decade is partly attributed to increased investment in the energy sector, particularly in the electricity sub-sector. The government's four key pillars of economic growth and the Big Four manufacturing priority are energy-driven. Further, the development of renewable energy technologies represents a major opportunity for "Growth of green industry in manufacturing" in Kenya.

Kenya has been ranked fifth globally in an annual Bloomberg index measuring investments and opportunities in clean energy, underlining the country's position as the Centre of renewable energy in Africa. The Bloomberg NEF (BNEF) latest Climate scope report says that Kenya's rise for the first time in the global top five has been backed by the higher contribution of solar, wind and geothermal capacity into the energy mix. These three now account for up to 65 percent of the country's energy sources. This can be a major sector of industrial growth in Kenya if it can position itself to be a regional technology hub, whilst in the same regard, it can also be a significant missed opportunity, if not pursued.

1.1 Objective of the Study

The overall objectives of this study is to formulate a 100% renewable energy scenario and plan until 2050 for Kenya and analyse the cost of the plan in comparison with a development with less focus on renewable energy, a business as usual scenario. In order to realise that in a comprehensive manner, the report shall also

- Assess the current national energy situation,

- Assess the renewable energy and energy efficiency potentials,

- Assess the future demands with a continued economic growth in Kenya

- Compare renewable energy power solutions with non-renewable power solutions, including coal power and nuclear power

1.2 Methodology of the study

The study was conducted via literature review, data collection and energy modeling. The literature review involved available written national information such as reports, policy, strategies, plans, papers and others. As well as the incorporation of the key informants Interviews with government ministries, agencies, academia, private sectors and CSOs. The energy modeling included the use of INFORSE's spreadsheet model for development of energy balances 2000 – 2050 and the Energy Plan model with analysis of variations hour by hour of energy flows and of costs for the years 2030 and 2050.

2.0 ENERGY STATUS IN KENYA

The energy sector in Kenya is largely dominated by biomass (68% of the national energy consumption), electricity (9%) and imported petroleum (21%), with biomass (wood fuel, charcoal, and agricultural waste) providing the basic cooking and heating energy needs of the rural communities, urban poor and the informal sector. Indigenous energy production in Kenya is biomass (wood and agricultural waste), and electricity produced from hydropower, geothermal and other renewables (wind, biomass and solar). This is complemented by imported electricity, coal, crude oil and oil products.

In 2017, *Kenya's primary energy consumption was 23.8 million tons of oil equivalents (Mtoe) equal to 996 PJ. The division of the energy demand among main sectors is given in table 1*

Sectors	*Energy Consumption*
Residential	77% of final consumption
Transport	*14%*
Industry	*7%*
commercial and public	*1%*
Agriculture and forestry	*Less than 1%*

Table1. Division of Kenya's energy demand in sectors in 2017[1]

Kenya has made great progress towards universal electricity access. Where energy efficient appliances is facilitated by the government in rural areas and poor urban households thus significantly improving the uptake of clean cooking and heating energy sources. The total industry use of biomass is reducing significantly due to formalization of the sector and the incentives provided by the government.

In order to meet the growing energy needs of its citizens, the Kenyan government actively pursues new local and international technologies to expand and upgrade the transmission and distribution networks as well as promote the transition to a renewable based energy system to the citizens.

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1. Derived from IEA Statistics, www.iea.org. In the statistics, biomass use in commcercial sector is under residential sector

The deliberate policies and government's massive investment in the development of renewable sources of energy, such as geothermal, solar and wind among others, ensure the greening of Kenya's energy significantly, decreasing greenhouse gas emissions by 2030, compared with a business as usual (BAU) development.

The Government of Kenya is focused on sustaining a stable investment climate for private-sector expanding transmission and distribution networks to deliver power to customers, maintaining a creditworthy off-taker, maintaining cost-reflective tariffs, and reducing inefficiency in the sector to support more affordable end-user tariffs.

Status 2019

Electrification

In 2019, 75% of Kenyans had access to electricity *(according to Eng. Stephen Nzioka; Directorate of Renewable Energy, Ministry of Energy of Kenya, 2019*). The number of connected households tripled from 2.3 million in 2013 to 6.9 million in 2018. This has been achieved through a range of interventions by the government in collaboration with development partners.

These interventions include:-
  • Last Mile Connectivity Programme (LMCP)
  • Electrification of all public primary schools
  • Global Partnership of Output Based Aid (GPOBA)
  • Rural Electrification Programme (REP)
  • Kenya off-Grid Solar Access (KOSAP)

Kenya is poised to attain universal access to electricity by 2022. In December 2018, the National Electrification Strategy (NES) was launched to drive the country towards universal access by 2022, using both grid and off-grid solutions.

The NES envisages that:-
  • 2.7 million Grid connections will be made through grid densification and intensification.
  • Further 270,000 connections will be made through grid expansion within 15 km of the KPLC distribution system.
  • Some 34,000 connections will be made through 121 new solar mini-grids to serve housing clusters too far away from the network or too small to be connected to the national grid; and
  • About 1.9 million connections will be made through standalone solar systems.

The government has initiated the Kenya Off-grid Solar Access Project (KOSAP) for electrification of institutions far from grid using solar PV systems. An estimated 200,000 rural households in Kenya have solar home systems and annual PV sales in Kenya are between 25,000-30,000 PV modules. In comparison, the Kenya's Rural Electrification Fund, which costs all electricity consumers 5% of the value of their monthly electricity consumption (currently an estimated 16 million US$ annually), is responsible for 70,000 connections. With access to loans and fee-for-service arrangements, estimates suggest that the Solar Housing Systems (SHS) market could reach up to 50% or more of un-electrified rural homes. There are about 4 million households in rural Kenya alone which present a vast potential for this virtually untapped technology.

Cleaner cooking

- Kenya has an ambitious target of achieving 100% access to modern cooking services by 2030, including efficient cook stoves for wood and charcoal, household biogas, LPG stoves, and others.
- Government is running the development and promotion of efficient cook stoves for households and institutions.
- Government is collaborating with Clean Cook stove Alliance of Kenya (CCAK) to promote the development and dissemination of efficient cook stoves.
- A clean cooking component of the Kenya off-grid Solar Access project (KOSAP) seeks to disseminate 150,000 efficient cook stoves for households in selected 14 under-served counties.
- Cleaner cooking is an important parts of Kenya's climate plans and is included in the Kenya's National Determined Contributions (NDC) to the UNFCCC Paris Agreement (*see details in Annex 5.2*).

Renewables

- Renewable energy currently accounts for 70% of the installed power capacity including large hydro-power. It accounts for more than 70% of the power generation, but production varies from year to year with hydropower production that is low in dry years.
- Government is supporting a Solar PV electrification of public institutions, including health facilities. So far, 1,500 institutions have been electrified.
- Under the Feed-in-Tariff (FiT) policy, 278 renewable energy projects with a combined capacity of over 4.7 Gigawatts have been approved and are at various stages of implementation. This includes wind power, geothermal power, and solar PV power projects.

- Kenya recently commissioned three renewable power projects: 310 MW wind (Lake Turkana wind power project), 100 MW Kipeto (Kajiado) and 51 MW solar (Garissa).

Kenya with support from the World Bank is implementing the above-mentioned KOSAP project which targets to provide clean energy access to 14 under-served counties with renewable energy (solar home systems and clean biomass-based cooking solutions).

2.1 ESTIMATED RENEWABLE ENERGY POTENTIAL

Kenya has promising potential for power generation from renewable energy sources. Abundant solar, hydro, wind, biomass and geothermal resources which has led the government to seek the expansion of renewable energy generation to both urban and rural areas. Currently, the government has prioritized the development of geothermal and wind energy plants as well as solar-fed mini-grids for rural electrification.

2.1.1 Biogas

Biogas potential in Kenya has been identified in municipal waste, sisal and coffee production. The total electric capacity potential of all sources ranges from 29 to-131MW, generating 202 to 1,045GWh, which is about 1.3% to 5.9% of the total electricity purchased from the system. Biogas can also replace firewood and charcoal for cooking, which is mostly done with small-scale biogas plants. Biogas plants, including small plants for cooking, are included in Kenyan climate plans with up to 500,000 biogas stoves in operation by 2030[2]. Based on this, a conservative estimate of the biogas potential from wet biomass /as manure, wet organic waste) that has little value as direct fuel, is 16-20 PJ.

2.1.2 Biomass

Biomass fuels are the predominant source of primary energy in Kenya with wood-fuel (firewood and charcoal) and agricultural residues accounting for about 68% of the total primary energy consumption. About 55% of this is derived from farmlands in the form of woody biomass as well as crop residue and animal waste and the remaining 45% is derived from forests. In 2017 the consumption was 724 PJ. The sustainable potential of solid biomass has been estimated to 15 million tons per year, equal to 243 PJ with an expected energy content of 4.5 kWh/ton. With current official plans for energy forest plantations of 4.1 million ha (41,000 km^2), the potential will be increased. We conservatively

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[2] As part of plans for development and distribution of 1.5 million clean energy stoves in Kenya's National Climate Change Action Plan 2018 - 2020, Vol 3: Mitigation Technical Analysis Report see http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/10/8737_vol3.pdf

estimate the increase to be at least 35 PJ, giving a total sustainable potential of 278 PJ. If the liquid biofuels and biogas is added, the total, sustainable potential is around 300 PJ, with a conservative estimate of the biogas potential.

2.1.3 Wind Power

Kenya has promising **wind power** potential. In the windiest areas, where the annual capacity factor (CF) for wind turbines will be above 40%, the potential wind power production is estimated to 1,739 TWh/year. In areas with CF> 30%, the potential production is estimated to 4,446 TWh/year while if all areas with CF > 20% are included, the potential production is estimated to an impressive 22,476 TWh/year[3].

Presently, the Lake Turkana Wind Power Project (LTWP) and the Ngong Hills Wind Power Project are the only wind farms that are connected to the national grid, with capacities of 310 MW and 25.5 MW respectively. The LTWP is the largest wind power plant in Africa having achieved full commercial operation in March 2019. Kipeto project (Kajiado) will be second largest wind power project in Kenya. The project will supply 100MW of clean energy to the national grid as a significant contribution to Kenya's Vision 2030 and Big Four Agenda. The government of Kenya has estimated that 2 GW of wind capacity will be installed in Kenya by 2030.

Rift Valley has the two large windiest areas (average wind speeds above 9 m/s at 50 m high). The coast is also a place of interest though the wind resource is lower (average wind speeds about 5-7 m/s at 50 m high). About 25% of the country is compatible with current wind technology.

Some 80-100 small wind turbines (0.4 – 6 kW) have been installed to date, often as part of a Photovoltaic (PV)-Wind hybrid system with battery storage.

For this scenario, we will consider a potential of 500 GW wind power with an average capacity factor of 40%, equal to 3500 full load hours (with 3500 full load hours, each kW of wind power will produce 3500 kWh electricity /year). The 500 GW can then produce 1740 TWh electricity/year (6300 PJ/year).

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[3] Wind data from JRC Technical Report "Energy projections for African countries", Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12391-0, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118432/jrc118432_jrc118432_reviewed_by_ipo.pdf

10.4 Wind power density
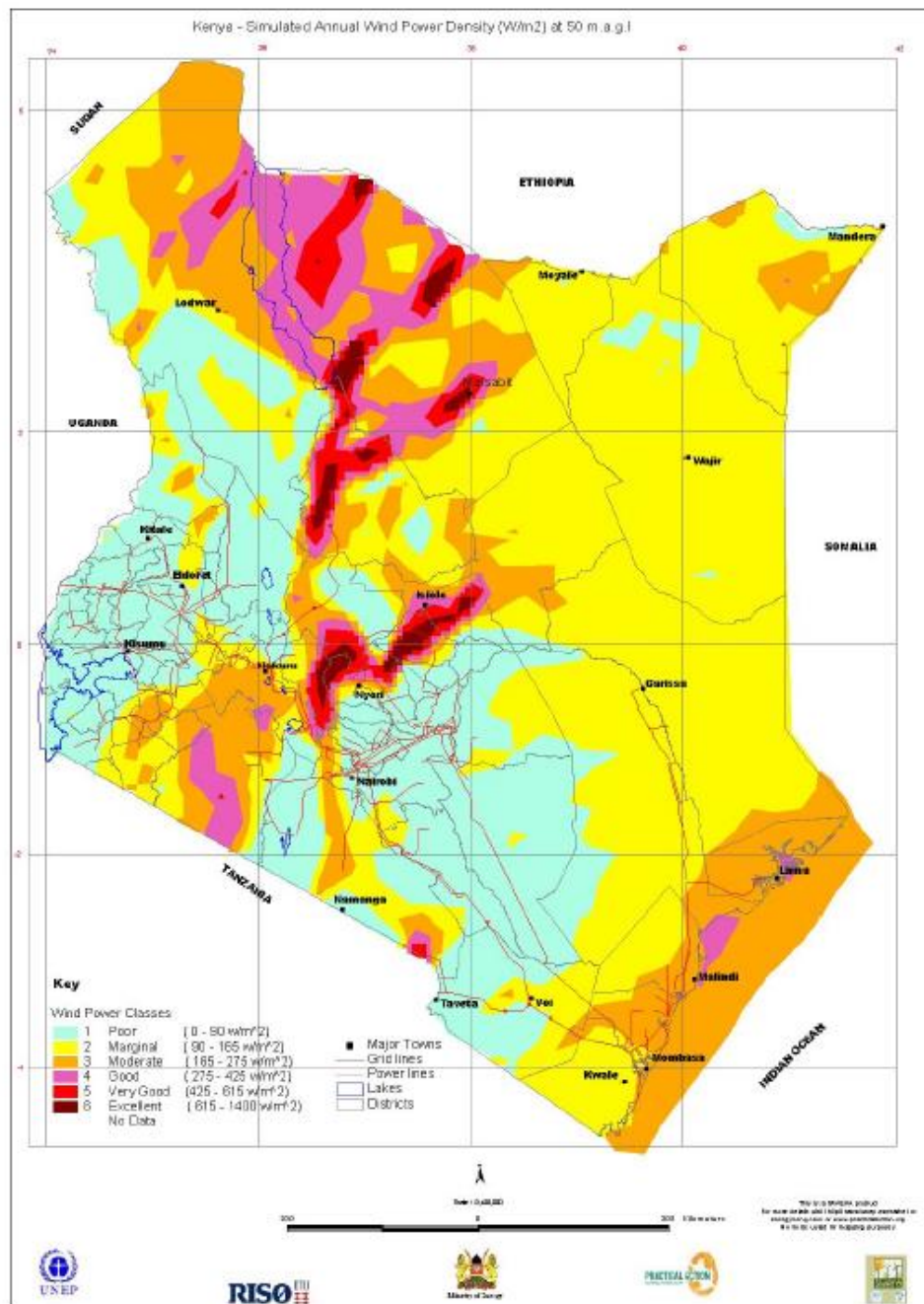
Figure 17: Map showing simulated annual wind power density at 50 m above ground

2.1.4 Solar Energy

Kenya has great potential for the use of solar energy throughout the year because of its location near the equator with 4-6kWh/m2/day of insolation. Following the Energy (Solar

Water Heating) Regulations from 2012, there has been a surge in solar usage.

For this scenario we will consider a potential of 10 m^2/person of solar PV panels equal to 500 million m^2. With an efficiency of 15%, this is equal to 75 GW solar power and with an average of 1800 kWh/m2 of annual insolation, the solar power production potential is 135 TWh (500 PJ). The theoretical potential is much larger. In addition to solar power, there is also a large potential for solar heating
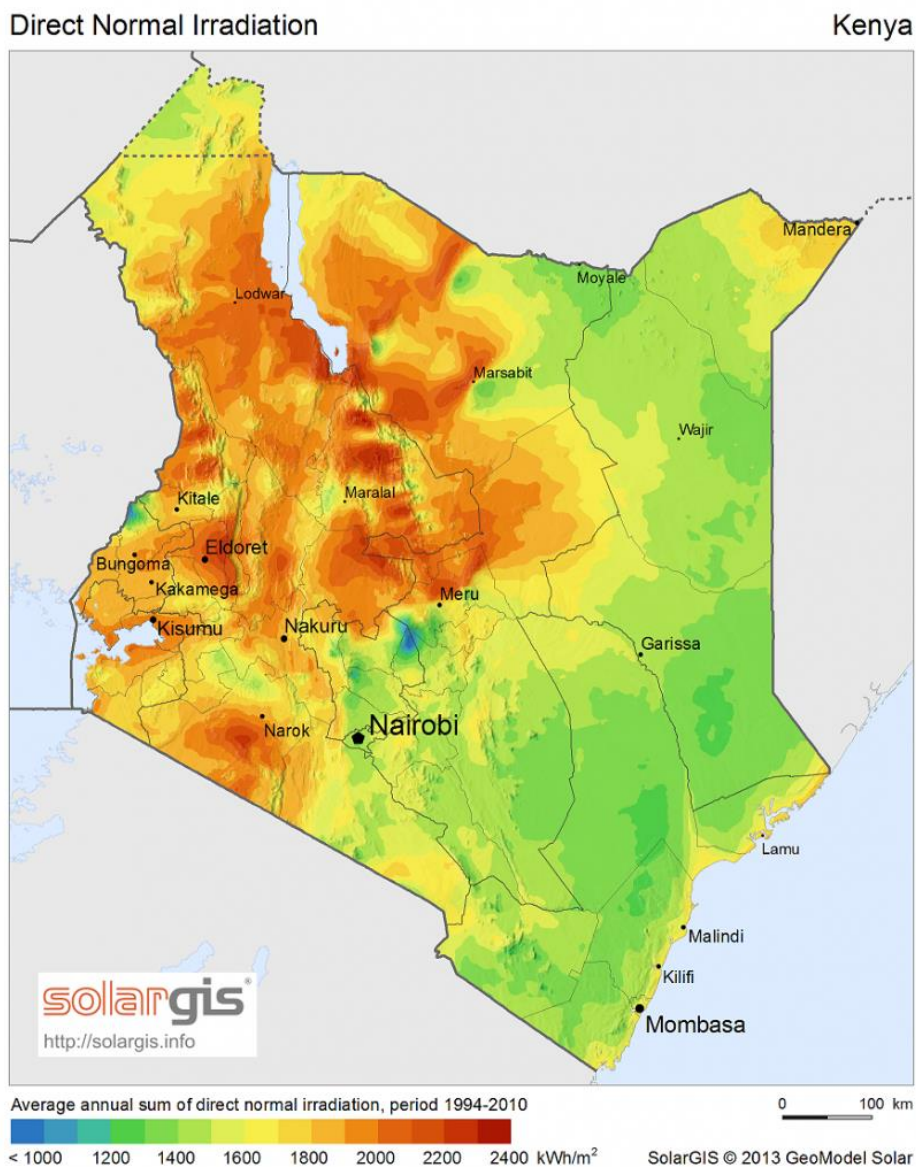
Source: GeoModel Solar

2.1.5 Geothermal energy potential

Currently, 80% of Kenya Electricity Generation Company's (KenGen) energy portfolio is geothermal and hydro. In 2018, contribution from geothermal resources increased by 4%

to 47% of the total energy purchased byKP , easing overreliance on hydropower generation and mitigating increase in electricity costs by minimizing dispatch of expensive thermal power.

Kenya is endowed with **geothermal resources**, mainly in the Rift Valley. Geothermal and wind energy have comparably low electricity production costs. Conservative estimates suggest geothermal potential in the Kenyan Rift Valley at 2,000 MW, whereas the total national potential is put at between 7,000 and 10,000 MW.

For this scenario, we will use a potential of 8500 MW, which with 95% capacity factor[4] gives a production potential of 66 TWh.

2.1.6 Hydroelectricity

Kenya has a well-developed hydro power sector with installed capacity of 823 MW and a capacity in the dams of 730 GWh. In 2017 the hydro power production was 4.45 TWh

Plans for expansion of hydropower until 2030 are 300 MW of small hydro.

The Kenyan Government is strongly pushing for a shift to other alternative resources of electricity generation because of the unforeseeable variations of hydro-power between wet and dry years.

Kenya has an estimated hydropower potential of up to 6,000 MW comprising large hydro (sites with capacity of more than 10MW)[5] and also a potential of small hydro, but several of the potential some sites are expensive to develop and/or development of hydro power at the sites have considerable environmental issues.

For this scenario we include the existing hydro power capacity and 300 MW planned expansion of small hydro.

2.2 FUTURE ENERGY EFFICIENCY AND ENERGY DEMANDS

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[4] According to Energypedia fossil fuel power generation capacity (oil-fired) was 32.5% of total capacity, cited in 2018 in https://www.standardmedia.co.ke/article/2001290115/fact-checker-just-how-much-is-kenya-s-electricity-capacity.

[5] National Energy Policy October 2018.pdf
https://kplc.co.ke/img/full/BL4PdOqKtxFT_National%20Energy%20Policy%20October%20%202018.pdf

For a prosperous development of Kenya, strong development of productive sectors is needed together with human development. To support the development; it is important that increasing supply of affordable and reliable energy is available. The basis for the scenarios in this report is that the demands for energy services will increase in line with population increases and with a development of Kenya from a lower middle income country to a higher middle income country until 2050. The increases in population and Gross Domestic Product (GDP) is shown in table 2

Kenya development assumptions	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population (millions)	29.5	33.6	38.8	43.6	48.6	53.9	59.4	65.1	71.6	77.9	83.9
GDP (billion USD)	12.7	18.7	40	64.0	97.6	128	169	224	295	390	514

Table 2 Kenya development assumptions for scenarios, statistics until 2020, projections until 2050, see Annex 2 for basis for the assumptions.

Based on the development assumptions and assumptions of increase in energy efficiency, the energy demands are estimated for the following sectors:-

i.   Household cooking demands
ii. Household light and electricity
iii. Service, cooking demand
iv. Service, light and electricity
v.   Industry, fuel demand
vi. Industry, electricity demand
vii. Transport
viii. Other demands

For each sector, the energy demand is estimated as the multiplication of demand for the energy service (as cooked meals, persons and goods transported etc.) and the energy efficiency of the sector. For each sector, the demand for the energy service is estimated using historical data since 2000 from International Energy Agency (IEA)[6] combined with the development assumptions in Table 2.

2.2.1 Household cooking demands

Household cooking demands are today responsible for two-third of Kenya's primary

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6. See calculations in Annex 1 and IEA data in https://www.iea.org/data-and-statistics/data tables? country=KENYA

energy supply, including direct use of wood and other biomass, as well as charcoal production for cooking. Of the biomass demand, households are responsible for 90% of the demand for wood and residues, and also for two-thirds of the charcoal demands, see Annex 1. While the cooking will increase with increasing population, there are large potentials to increase efficiency of cooking, thereby lowering the energy demand for cooking.

The improvement of efficiency has already started with improved cook stoves, where Kenya have been in front for decades, but there are still large potentials for increasing the efficiency with massive dissemination of improved cook stoves, new, high-efficient cook stoves, super-efficient electric cooking, biogas, and more efficient charcoal production. These five solutions are all included in this scenario. Some other solutions are not included, as wood briquettes (that are not well known in East Africa), LPG gas (that perpetuate the reliance in fossil fuels and are hard to afford for most of the population), and ethanol (that has low energy efficiency in production).

The efficiency assumptions of the five prioritized solutions are:-

- Efficient cook stoves with efficiencies around 25%, which is twice as good as traditional fires and "jikos",
- High-efficient cook stoves for wood and charcoal with efficiencies of 50%. This is a new technology, which is now produced and available in a few places in East Africa[7]
- Super-efficient electric cooking with insulated, computer-controlled pressure cookers that can cook with only 10% of the energy needed from traditional fires, partly because the cooking time can be reduced with the pressure cookers. They are now promoted in Tanzania[8], as well as in countries in Europe, including Denmark and in Asia. They need electricity, however.
- Biogas that can replace cooking with wood and charcoal with cleaner, sustainable options, where dung and other feedstock for the biogas are abundant.
- Efficient charcoal production. The efficiency of traditional charcoal production is very low, 8-12%[9]. We use 10% as basis for the years 2000 – 2020 as improved charcoal production is not widespread in Kenya. With new, high-yield, low-emission systems, conversion efficiencies can be increased to 25-33%. We assume that charcoal

[7]. According to Biogas Energy Status in Kenya, Samuel Matoke, State Department of Lifestock, Kenya http://www.fao.org/fileadmin/user_upload/energy/investa/presentations/PPT_Matoke.pdf

D[7] See IEA statistics for Kenya, https://www.iea.org/countries/kenya

[8] See model available in Tanzania at https://sescom.co.tz/about-us/14-electric-pressure-cooker

[8]Biogas-Ministry of Energy
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwjln crhwvnoAhUJ3hoKHWAuDzUQFjABegQIARAB&url=http%3A%2F%2Fenergy.go.ke%2F%3Fp%3D912&usg=AOvVaw 2Xg9CCQgGrfcWEQfVdGk58

production will gradually be changed to these new technologies until 2050, increasing average efficiency to 25% in 2050.

There were 22,000 biogas plants in Kenya around 2015 of which 90% (20,000) were domestic[10]. The sector is developing and according to IEA statistics, the Kenyan biogas production increased 20% 2015-2017. Thus we expect that both number of household biogas plants and biogas use has increased 50% in the period 2015-2020.

Kenyan LPG use for cooking is increasing, but according to IEA statistics the LPG demand was only 0.7% of cooking energy demand at the latest year with available data (2017), and thus we have not included it.

With the Kenyan Climate Action Plan and NDC, introduction of improved cook stoves and biogas is already included. We assume that these parts of the NDC are realized, that the development is continued in the following NDCs, and that it will also include high - efficiency cook stoves and super-efficient electric cooking.

The Kenya Climate Action Plan 2018-2022 includes distribution of 4 million improved cook stoves. This is equal to 1 million stoves per year. We assume that 80% are replacing inefficient stoves while 20% are replacing worn out improved cook stoves, giving a net increase of 800.000 efficient stoves per year, a large increase from historical figures of 124,000 stoves/year[11], as we estimate above.

We assume that the distribution takes effect from 2020, and that the rate of 1 million improved stoves is maintained after 2022 (800,000 net increase) until the use of traditional, fires and jikos is not more than 5%. We assume that after 2022, an increasing fraction will be the high-efficient stoves; leading to almost all cook stoves will be high-efficiency in 2050.

The Kenya's Climate Action Plan 2018-2022 and the Kenya's first NDC (2016) includes that biogas stoves are increased from around 30,000 today to 250,000 in 2022 and 500,000 in 2030. We assume that this is realized and that the level of 500,000 stoves is maintained.

As a new measure, we propose super- efficient electric cooking, starting with 700.000 of these pressure cookers until 2025 and gradually increasing to cover 25% of household

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[10] Kenya's National Climate Change Action Plan 2018 - 2020, Vol 3: Mitigation Technical Analysis Report, note 68, see http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/10/8737_vol3.pdf
[10] Winrock International, E+Co, and Practical Action. 2011. The Kenyan Household Cookstoves Sector: Current State and Future Opportunities.

cooking needs in 2050. They will replace most of charcoal use, LPG, and gradually also partly wood and other biomass.

This development will give large efficiency increases in cooking, leading to 77% increase in cooking efficiency in the period 2000 – 2050, meaning that cooking one meal in 2050 will use 23% of the energy that it used in 2000. Some of the energy will come from renewable electricity.

The effect of the increased efficiency on cooking energy demand is illustrated in Graph 1 and the details are given in Annex 1.
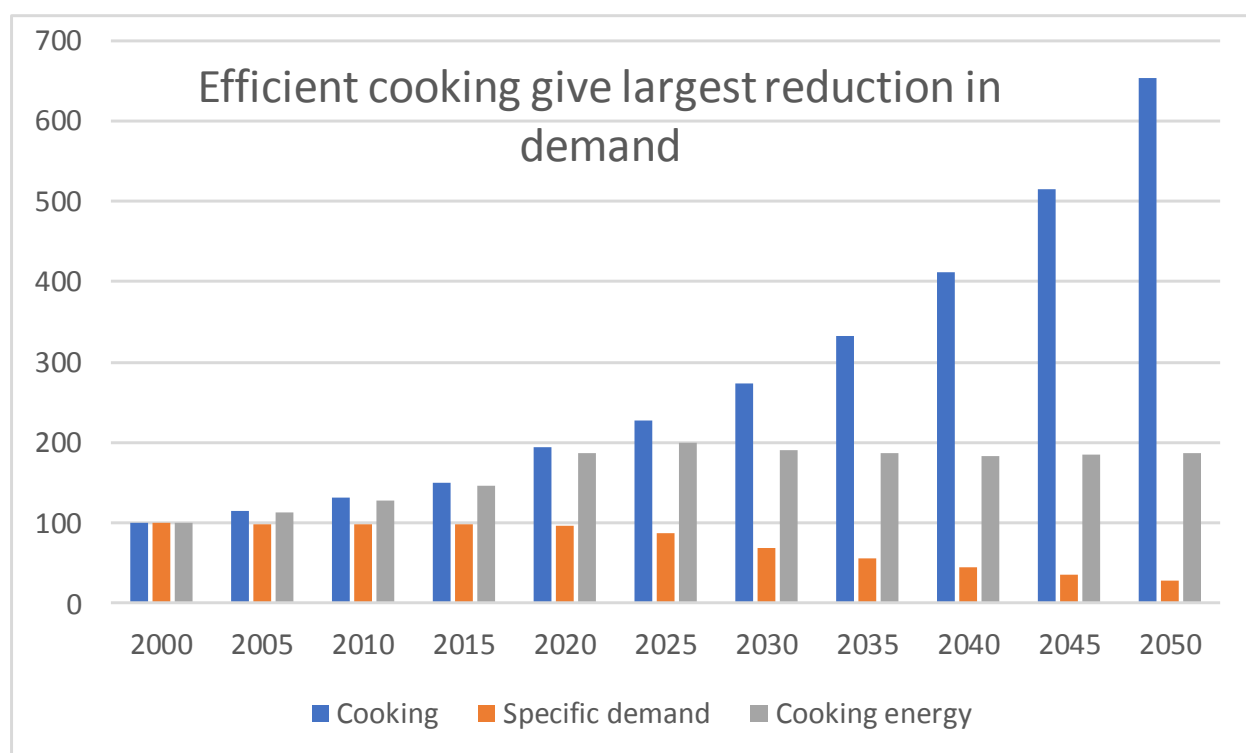
Graph1. Development relative to 2000 of cooking (meals cooked) and final energy demand for cooking 2000 – 2050 with transition to very efficient stoves and smart (electric) cooking.
Own calculations as explained in Annex 1

With the implementation of these proposals, we estimate an increase in energy efficiency in cooking of 77%, 2000 – 2020, equal to a reduction in the energy demand for an average meal to 23% of the year 2000-level.

Illustrations of some of the technologies to realise the high increase in cooking efficiency

Improved cook stove with chimney, efficiency 20-30%

New generation cook stove, above 50% efficiency. The picture shows an institutional model with efficiency above 54%, see https://sescom.co.tz/about-us/19-improved-and-modern-institutional-firewood-stoves-seta-is

"Smart cookers" that can reach 80-90% efficiency and also give short cooking time with the pressure cooking effect. In total they are 10times as efficient as traditional fires. The cookers can cook and fry lightly with high efficiency, also food that does not need long cooking time, as ugali. Read about its use the Ecook Book, online https://tatedo.or.tz/mecs-latest/39-ecook-book

In addition to use of biomass, Kenyan households also use kerosene, for cooking as well as for light. The consumption was 16 PJ in 2015 and 19 PJ in 2020 (estimated) equal to 5% of household energy demand. In the

100% renewable energy scenario, we assume the kerosene consumption to be reduced to 9 PJ in 2030 and 0 in 2050. The kerosene will be replaced by electricity, primarily.

For the BAU scenario, we assume the same development of improved cook stoves as in the renewable energy scenario, but not the introduction of super-efficient electric cooking, which is not part of the current plans in Kenya. Instead we assume that use of charcoal will continue with the same fraction of household fuel use as today and the use of fossil fuel, kerosene and LPG, will also continue with the same fraction as today. Probably LPG would then replace kerosene.

We will use the fractions in Annex 1; table A3 to divide biomass use between sectors, while the total biomass use will be according to IEA data for 2000 – 2015 and for 2020 using the trend 2015-2017 of IEA data.

Solid biomass use in households after 2020 is estimated based on the assumption that cooking demands are following population size. With the increase in efficiency, the energy demand for cooking will not follow population size. Instead it will follow population size multiplied by specific demands. The demand for biomass for cooking will also be lower because of an estimated change to super-efficient electric cooking of 25% of the cooking in the renewable energy scenario- This gives the cooking demand and the biomass demand for cooking in the table 4, relative to year 2000.

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cooking demand	100	112	129	148	165	182	201	221	242	264	284
Solid biomass share of cooking	99%	99%	99%	99%	98%	93%	87%	82%	77%	72%	73%
Cooking with solid biomass	100	112	129	148	164	170	174	181	187	191	206
Solid biomass demand for cooking	100	110	126	143	158	140	132	112	91	70	57

Table 4: Demand for cooking and for biomass for cooking with estimated development of specific energy demand for cooking, relative to year 2000, renewable energy scenario. See calculations in Annex 1.

To test the validity of the assumption of correlation between cooking demand and population, a correlation is calculated for the years 2000 – 2020, where cooking demands and population are from independent sources. The correlation coefficient is 99.9%[12] ,

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[12] An estimate published in 2011 is that around 35% of households own an improved cookstove, i.e. there are around 3.5 mio. Improved cookstoves. This is an increase from one million in 1990, equal to an increase

which shows a very high degree of correlation. An important result shown in table 4 is that the biomass demand for cooking is lower in 2050 than in previous years, in spite of higher cooking demands.

In addition to the efficiency of cooking, also the efficiency of charcoal production is increased in the scenario, from present 10%, to 15% in 2030 and to 25% in 2050. This requires a transformation of the charcoal sector to advanced charcoal production. This can be done on larger plants, but it is also possible to increase efficiency to above 25% with mobile units that can be carried on standard trailers[13].

We assume the same energy efficiency increase in charcoal production in the renewable energy scenario and in the BAU scenario.

With the combination of efficient cooking, efficient charcoal production and shift to super-efficient electric cooking (primarily replacing charcoal with super-efficient electric cooking), biomass consumption for cooking can be reduced from 570 PJ today, inclusive wood for charcoal to 152 PJ by 2050.

2.2.2 Household light and electricity

Electricity use is rapidly increasing in Kenya, mainly with increasing wealth. With efficient lamps (as LED), electric light is possible with affordable levels of energy consumption for many Kenyans. In addition to increased wealth, electricity is also replacing kerosene for light. The household electricity demand has increased from 3 PJ in 2000 to 12 PJ in 2020 (estimate based on development until 2017), an increase well above the population growth. At the same time, the efficiency of electricity use has increased with efficient lamps and efficient equipment. While the average efficiency increase is not fully documented, we assume for this scenario that the efficiency has increased 42% from 2000 to 2020 and that efficiency will continue to increase with 15% each 5 year.

With these assumptions, end-use efficiency of electricity will be 5 times higher in 2050 than in 2000. This is equivalent to the efficiency increase from traditional, incandescent lamps to the modern LED lamps available today.

The demand for electricity in households has increased 6-fold in the period 2000 – 2020. With the assumption of 41% efficiency increase, this is equal to a 10-fold increase in the demand for light electricity services in the period. Based in these trends, we assume that

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of 124,000 per year. The estimate is in the publication "The Kenyan Household Cookstoves Sector: Current State and Future Opportunities" by Winrock International, E+Co, and Practical Action. 2011.
[12]. Correlation coefficient, calculated with excel "correlation" function

demand for light and electricity services in households will increase with population growth and in addition with 84% of GDP growth. With this assumption, we get the developments of light and electricity service demands, of specific electricity use, and of electricity demands in households relative to year 2000, shown in table 5

Households	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Light, other electricity service demand	100	155	312	490	729	950	1240	1619	2114	2760	3604
Electricity, specific demand	100	92	73	61	58	49	42	36	30	26	20
Electricity demand	100	142	228	299	423	468	520	577	640	710	721

Table 5, light and other electricity service demand in households, specific demand and electricity demand in households relative to the year 2000

To test the correlation between population growth, 84% of GDP growth, and the demand increase for light and electricity services for the years 2000 – 2020, we calculate the correlation. The correlation coefficient is 99.9%[14], showing a very high correlation.

The development of electricity service demand, efficiency, and basic electricity demand are the same for the renewable energy scenario and the BAU scenario.

In the renewable energy scenario is in addition electricity demand for cooking, which is in addition to the demand shown in table 8. This gives a total annual electricity demand in the households of 10.6 TWh (38 PJ) in the renewable scenario.

2.2.3 Service sector, cooking demand

The development of the service sector has been faster than the development of the population and more linked to GDP than to the population. We estimate that the growth in the service sector cooking demand increases with around 14% of the GDP increase. For the efficiency and the change to super-efficient electric cooking, we assume the same development as for the household sector. This gives a development of cooking and fuel

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[14] The Energy Plan model is a software to calculate the energy balance of a country hour by hour during a year. It is developed by Aalborg University, Denmark and comes with libraries of examples, technology catalogue and others, It is available from www-energyplan.eu

demands shown in table 6.

Service sector	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cooking demand	100	115	131	150	194	228	273	333	412	516	653
Share wood	73%	73%	73%	73%	73%	69%	66%	63%	59%	56%	56%
Share, charcoal	27%	27%	27%	27%	27%	26%	24%	22%	21%	19%	19%
Share super-efficient electric cooking	0	0	0	0	0	5%	10%	15%	20%	25%	25%
Efficiency, biomass	14%	14%	14%	14%	14%	17%	18%	22%	28%	37%	49%
Biomass demand	100	113	128	145	186	178	187	175	161	143	135

Table 6, service sector cooking demand, cooking efficiencies and biomass demand for cooking, relative to year 2000

The table shows that while the cooking demand can triple from 2020 to 2050, end-use biomass demand can be reduced. When, in addition, charcoal production efficiency is increased, the primary biomass demand will decrease even further.
This gives an annual biomass demand in the service sector of 8.3 TWh (40 PJ) in 2050 of which 10 PJ is charcoal.

Above assumptions are for the renewable energy scenario. For the BAU scenario, we expect the same efficiency increases for biomass use and charcoal production, but no change to super-efficient electric cooking.

2.2.4 Service sector, light and electricity demand

In the service sector electricity demand is increasing fast, from 1.4 PJ in 2000 to 4.9 PJ in 2020 (estimated). We expect that this increase is mainly driven by the increase in the GDP. In parallel, we assume that energy efficiency is increasing as in the household sector. Thus, the demand for light and other electricity services are increasing even more.

With the same efficiency increase for electricity use in the service sector as in the household sector, the increase in electricity services correlates well with 75% of the increase in GDP for the period 2000 – 2030. We assume that this correlation remains.
The resulting demands are shown in table 7.

Service sector	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Light and	100	148	322	491	604	785	102	1348	177	232	306

electricity service demand							8		1	8	4
Electricity, specific demand	100	92	73	61	58	49	42	36	30	26	20
Electricity demand	100	136	235	299	350	387	431	480	536	599	613

Table 7 Service sector demands for electricity services and for electricity, relative to year 2000

A test of the correlation between development of the electricity service demand in the service sector and 75% of the GDP shows a correlation coefficient of 98.4%, showing a high correlation. This gives an annual electricity demand in the service sector of 3.6 TWh (10 PJ) in 2050 without electricity for cooking. When electricity for cooking is added, the demand is 13 PJ.

The assumed development of electricity is the same for the renewable energy scenario and the BAU scenario with the exception that electric cooking is not included in the BAU scenario.

2.2.5 Industry, fuel demand

The use of industrial fuel (coal, oil, and biomass) in industry has increased from 20 PJ in 2000 to 43 PJ in 2020 (estimated). In parallel, there has been an increase in energy efficiency, which we estimate to 28% in the period, equal to an annual increase of 1.6%. After 2020, we assume a higher efficiency increase of 2%/year equal to 10% per 5 year, because of actions to increase energy efficiency. In addition, it is assumed that industrial fuel use is gradually replaced with heat pumps and direct electric heating with an average coefficient of performance of 3 (heat pumps and electric heating combined). *It is assumed that remaining fossil fuel use is replaced with biomass and solar heating.*

With the assumption of 28% increase in energy efficiency 2000 - 2020, the increase of fuel-based energy service demand correlates relatively well with 30% of the increase in GDP for the period 2000 - 2020. The correlation coefficient is 94.3%, which is a reasonably good correlation. This gives an annual biomass demand in the industrial sector 0.65 TWh (2.4 PJ) in 2050.

The assumed development of fuel use in the BAU scenario is with same efficiency increase as in the renewable energy scenario, but with no change to heat pumps and with no conversion from fossil fuels to biomass.

2.2.6 Industry, electricity demand

The use of electricity in industry has increased from 7.5 PJ in 2000 to 17 PJ in 2020

(estimated). In parallel, the end-use efficiency has increased, but not as much as in the household sector, where the LED lamps have revolutionized energy use for light. Instead we assume a 32% efficiency increase, equal to 2%/year. After 2020, we assume a higher efficiency increase of 2.5% per year equal to 12% per 5 year because of actions to increase efficiency.

With the assumption of 32% efficiency increase, the increase of electric energy service demand correlates well with 35% of the increase in GDP for the period 2000 – 2020. The correlation coefficient is 98.4%, which is a good correlation.

This gives an annual electricity demand in the industrial sector 19.6 TWh (70 PJ) in 2050, including electricity use for heat pumps and direct electric heating to replace most heating with fossil fuels.

The assumed development of electricity use in the BAU scenario is the same as in the renewable energy scenario, except that there is no change from fuels for heating to heat pumps and electricity.

2.2.7 Transport demands

The energy demand for transport has increased strongly from 40 PJ in 2000 to 177 PJ in 2020 (estimated). The technology has not changed much since the year 2000 and therefore we assume that efficiency has not changed much. Thus, the transport demand has increased as much as the transport energy use. Increase in transport demand correlates well with the population increase combined with 43% of the GDP increase 2000-2020.

Today the transport energy is fossil fuels in the form of diesel and petrol. In the **renewable energy scenario** this will gradually be replaced with electricity and hydrogen (H_2) and hydrogen-based alternative fuels. In the renewable energy scenario, all hydrogen is produced from renewable electricity while no hydrogen is included in the BAU scenario. The alternative fuels, called "electro fuels", are fuels made from electricity via the production of Hydrogen. The simplest of these are methanol that can be produced from hydrogen and CO_2.

With the shift to electric vehicles, efficiency will be around 5 times higher than for petrol and diesel cars. For hydrogen and electro-fuels, where traditional combustion engines

can be replaced by fuel cells and electric motors, efficiency is around 2.5 times higher than for petrol and diesel cars. With ¾ of the transport changed to electricity and ¼ to fuel cell vehicles, and in parallel the general efficiency increase is 15% 2020 - 2050, the energy to move one passenger or one ton of goods one km can be reduced to 22% in 2050 of what it is in the year 2000. The development is shown in table 8

Transport	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport demand	100	106	185	300	457	575	733	936	1200	1541	1983
Fossil transport share	100%	100%	100%	100%	100%	100%	89%	69%	42%	18%	0%
Bio. transport share	0%	0%	0%	0%	0.2%	0.4%	0.6%	0.7%	0.8%	0.7%	0.6%
El.transport share	0%	0%	0%	0%	0%	0%	10%	25%	45%	57%	75%
H2 transport share	0%	0%	0%	0%	0%	0%	0%	5%	12%	24%	24%
Transport, specific demand	100	100	100	100	99	94	82	66	48	34	22
Fossil fuel for transport	100	106	185	300	449	536	538	429	243	94	0
Electricity for transport	0	0	0	0	0	0	10	32	61	90	108

Table 8, Transport demands (movement of persons and goods) and energy demands for the renewable energy scenario, relative to the year 2000. The electricity use includes electricity to produce H_2 for transport with an efficiency of 73%. For electricity for transport, the basis (100) is the fossil energy consumption in the year 2000

The correlation between increase in transport demand and increase in population + 43% of increase in GDP is 99.3%, which shows a very good correlation. In the renewable energy scenario in 2050, the annual electricity use for transport is 43 TWh (157 PJ) and the hydrogen + electrofuels demand is 13.7 TWh (49 PJ).

For the BAU scenario, there is not included introduction of electric or hydrogen vehicles for road transport while it is included that rail transport will be electrified. In this way 2% of the transport energy will be changed to electricity and 98% will remain fossil fuel. The efficiency of transport is assumed to increase 30% with more efficient vehicles.

To illustrate the strong increase in energy use for transport and how the change to

electricity can mitigate that, graph 1 shows increase in energy for transport in the BAU scenario while graph 2 shows increase in energy for road transport in the renewable energy scenario. Road transport consumes 96% of the energy for inland transport in 2050, even with an assumption of increased use of railways.
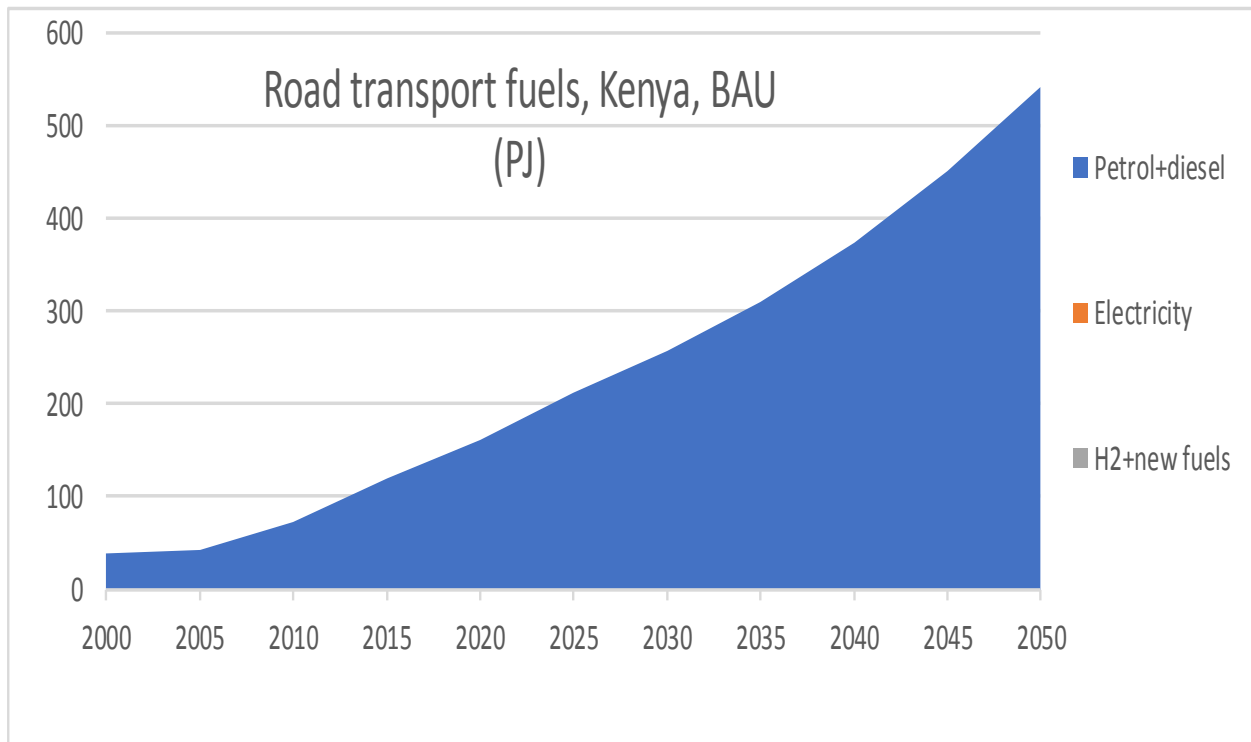
Graph 1: Road transport energy demand in BAU scenario
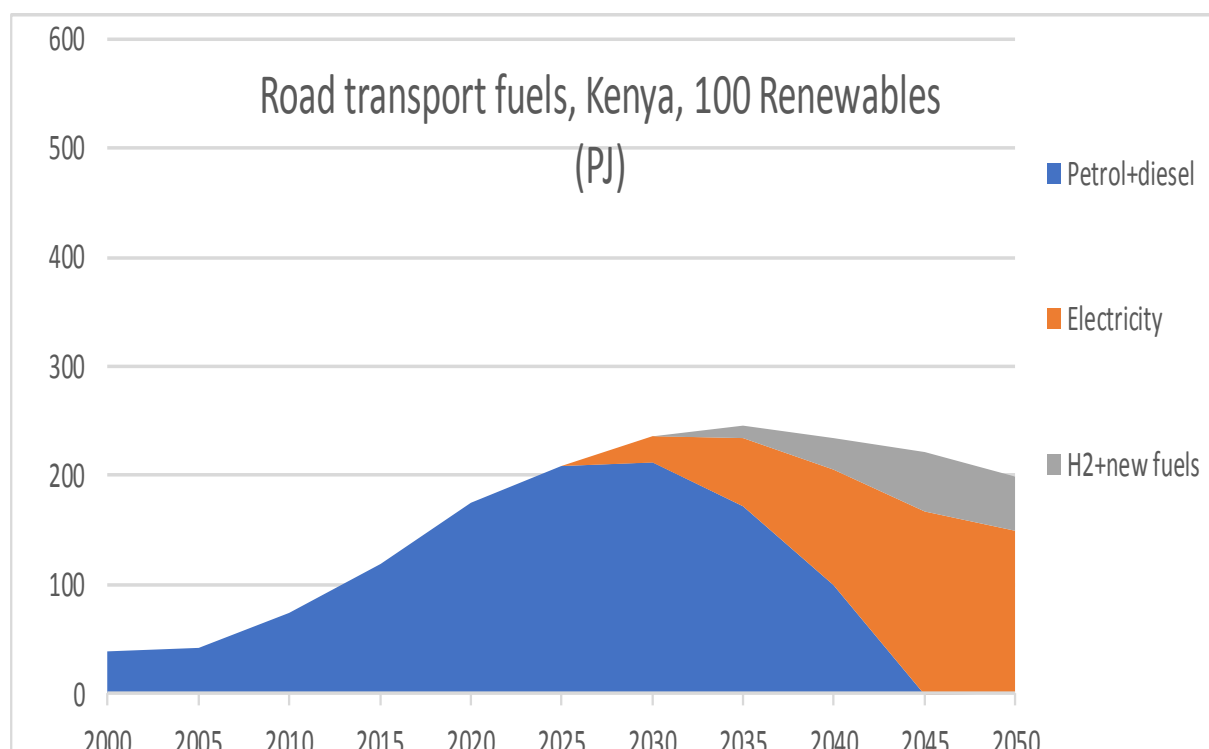
Graph:2: Road transport energy demand in renewable energy scenario

2.2.8 Other demands

The scenarios include other, smaller demands:

- Energy consumption in oil supply including what refineries consume themselves is 1.6 PJ in 2020, which is expected to reduce in 0 in 2050 in the renewable energy scenario and increase to 4 PJ in 2050 in the BAU sector with the increased oil use
- Electric grid losses are 6.7 PJ in 2020 and they are expected to increase to 50 PJ in 2050 with the increased electricity supply in the renewable energy scenario and to 14 PJ in the BAU scenario
- Agricultural energy use of 1.26 PJ in 2020 is included in the scenarios, and its energy efficiency is expected to increase similar to the industrial sector. Its influence of total consumption is minimal.
- Solar heating is included for household and service sector demands other than cooking, increasing from 1.4 PJ in 2020 to 5 PJ in both scenarios. It is also included in the industrial sector with 2 PJ in 2050 in both scenarios.
- There is a production of 0.3 PJ of liquid biofuels in 2020 which is expected to increase to 1.5 PJ in 2030 and 3 PJ in 2050 in the renewable energy scenario, while it is

expected to increase to only 1.5 PJ in the BAU scenario in 2050. It is all used in the road transport.

- Use of oil for non-energy purposes was 6 PJ in 2017. This is not included in the scenarios
- Aviation fuel consumption is not included in the scenarios. It was 30 PJ in 2017.

2.2.9 Total Final Energy demand

Combining the consumption of the above end-use sectors, we get the total final (end-use) energy demand.
The final energy demands divided in sectors are shown in graph 3 and graph 4 for the two scenarios. Observe the different scales.
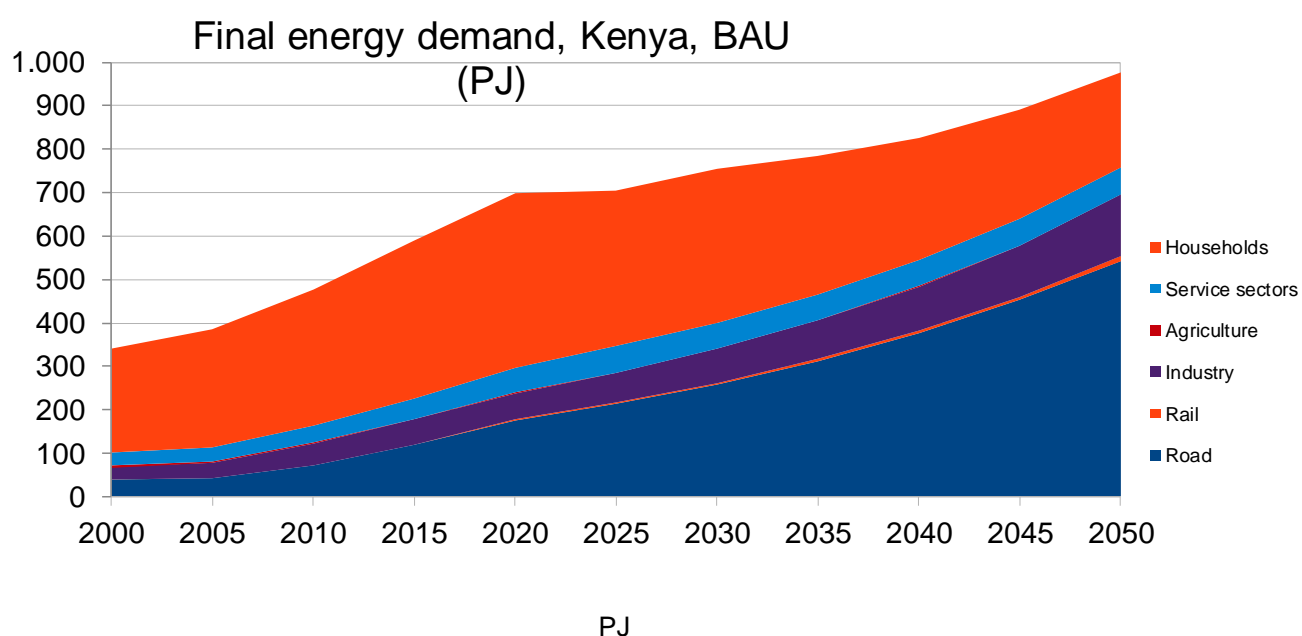
Graph 3. Final energy demand in the BAU scenario, based on assumptions in this chapter and in Annex 1
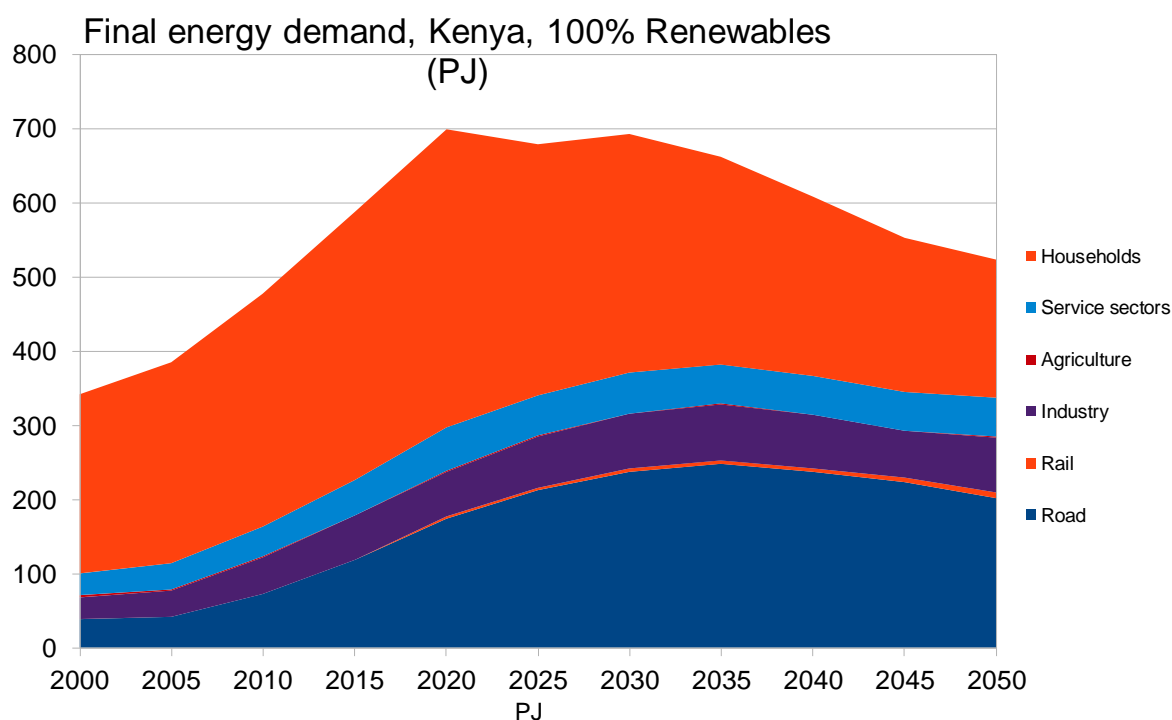
Graph:4: Final energy demand in the renewable energy scenario, based on assumptions in this chapter and in Annex 1

Comparing the graph 3 and graph 4, it is very visible how transport is gradually becoming more important in the energy balance, in particular in the BAU scenario. In the BAU scenario this implies a strong reliance on fossil fuels.

It is also visible how the strong actions to increase energy efficiency in cooking are expected to limit final energy already from 2025, specifically the use of biomass.

The figures behind graph 3 and graph 4 are given in Annex 1.

For the planning of the energy supply system, it is important to divide the final energy demand in energy forms. This division is shown for the renewable energy scenario in graph 5, while the figures behind are given in Annex 1.

End-use energy use, Kenya Renewable Energy Scenario (PJ)

Legend: Electricity, Hydrogen, Charcoal, Wood, oth.bio, Biogas, Oil, Coal
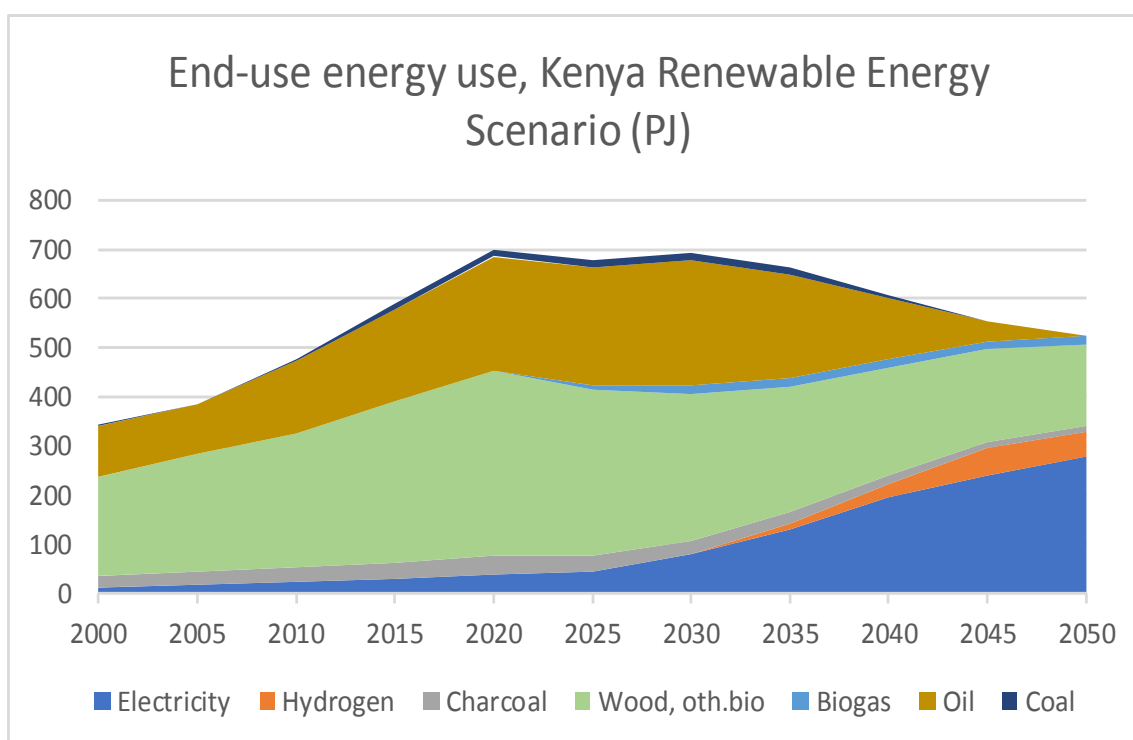
Graph 5: Development of final (end-use) energy demand in the renewable energy scenario. Hydrogen also includes electro fuels. The graph 5 clearly shows how the strong energy efficiency in cooking drives down biomass use while the change to efficient use of electricity replaces both biomass and fossil fuels in ways that reduce the total end-use energy consumption.

*In **the BAU scenario**, there is no conversion to electric cooking and very limited conversion to electric transport. Also the use of hydrogen is not included in the BAU.*

The main differences are then for end-use consumption in the BAU scenario:
- Electricity use is only increasing to 76 PJ in 2050 (278 PJ in renewable energy scenario).
- Charcoal use is decreasing to 27 PJ in 2050 (13 PJ in renewable energy scenario).
- Wood and biomass use is decreasing to 194 PJ in 2050 (166 PJ in renewable energy scenario).
- Biogas is 16 PJ in 2050, similar to the renewable energy scenario
- Oil use is increasing to 600 PJ in 2050, from 210 PJ in 2020 (it is 0 in 2050 in the renewable energy scenario
- Coal use is increasing to 32 PJ in 2050 from 13.5 PJ in 2020 (it is 0 in 2050 in the renewable energy scenario).

3.0 THE SCENARIOS AND THE RENEWABLE ENERGY USE

With above scenarios for final energy use, energy demands for all can be met, increasingly with domestic supplies. There will also be a diversified energy mix to reduce over-reliance on hydro and petroleum sources of energy.

We expect a development with increase in wind power, solar power, and geothermal power as well as a reduction in biomass use to reach sustainable levels, and a stable hydro-power production, but with reduced contribution to total supply. Power production is increased to meet power demands while biomass production is reduced with reducing demands because of high efficiency.

In the following, we explain how we constructed scenarios to meet the final energy demands, and the developments of renewable energy needed to meet the demands. The main elements in the modelling process are:

The modelling is made with INFORSE's spread sheet model with energy balances for each 5 year until 2050 and with the Energy Plan model for the years 2030 and 2050. The method for development of the scenarios is:

- The spread sheet models are first developed for the two scenarios,
- Then energy demand and supply data from the spread sheets are used to generate the Energy Plan models,
- With the Energy Plan models it is ensured that there is hourly balance of demand and supply in every hour of the year.
- Then the spread sheets are adjusted to follow the annual energy balances from Energy Plan.
- The hourly distributions of solar and wind are from the Energy Plan 14.2 library, *see energyplan.eu*
- The hourly distribution of electricity demands is from a study at Lappeenranta University of Technology[15]
- The economic parameters for technologies and fuels were developed from the Energy Plan technology Catalogue and other sources, see data and calculations in Annex 3
- The economic calculations are made with an interest rate of 10%.

The electric interconnector capacity with neighbouring countries is expected to be

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[15] Abdulganiyu, I. O. (2017). Possibilities and barriers for increasing renewable power generation in kenya and tanzania. Technical report, Lappeenranta University of Technology., Finland

increased to 1000 MW in 2030 and 3000 MW in 2050.

Because of the variations in solar and wind power production, hydro power and biomass power is used to make demand and supply meet on an hourly basis together with use of interconnectors.

The scenarios are using a combination of renewable energy for large – scale power production, as the least cost option. Since other options are also considered in Kenya, we have compared six different options for large-scale power supply in 3.1

Following the comparison in 3.1, is the renewable energy demands needed shown in graph 6 and detailed in 3.2 – 3.4. Other scenario results are in chapter 4.

Energy Type	Existing capacity (2019)	Capacity 2030	Capacity 2050
Solar	400 MW PV incl small solar +2500 m^2 solar heaters	3330 MW PV incl. small, 2 mill. m^2 solar heaters	17330 MW PV incl. small, 2 mill. m^2 solar heaters
Biogas/biomass	30,000 bio digesters for cooking 4.7 mill improved stoves	250,000 bio digesters for cooking, 12.6 mill. improved cookstoves*	500,000 bio digester for cooking, 15.6 mill. improved cookstoves*
Geothermal Energy	801 MW	2931 MW	5566 MW
Hydro power	+823 MW	1123 MW	1123 MW
Wind power	+350 MW	1500 MW	9000 MW

Graph 6 Renewable Energy in 100% renewable energy scenario
* Of the improved cookstoves, 0.5 million shall be high-efficient cookstoves in 2030 and 15.5 million in 2050. In addition, the scenario includes 1.5 million super-efficient electric cookers in 2030 and 5.4 million in 2050 (Need more clarification)

3.1 Large-Scale Power Supply Options

In this report, we compare two scenarios that both have renewable energies as the main power supply options. Given the increasing power demand in Kenya, also other options

are available, primarily for centralized power supply. Therefore, in this chapter we compare the main options for supplying centralized "bulk" power from large-scale power supply- The main options are:

- Wind power that Kenya has very good conditions for, as described in 2.1.3. In the scenarios, we take into account the variations in wind power in Kenya, modeling of power system, where wind power production is combined with other power supplies to ensure uninterrupted supply. In this comparison is used wind power with 3500 full load hours, which is also used in the scenarios

- Solar power that Kenya also has very good conditions for, as described in 2.1.4. In the scenarios, we take into account the variations of solar power in the modeling, as we do for wind power. In this comparison is used 1800 full load hours, which is also used in the scenarios.

- Geothermal power, where Kenya has a large and unique potential, as described in 2.1.5

- Hydro power, where the theoretical potential is large, but costs and sustainability issues limit the potential severely, as described in 2.1.6. In addition, Kenya already has substantial development of hydro power and given the fluctuations of rivers from year to year, the current strategy is to rely less on hydro power in the future. Therefore, we will not include large-scale hydro power in the comparison in this chapter, and major expansion of hydro power is not included in the scenarios

- Biomass power including solid biomass and biogas has some potential in Kenya; but given that a large part of current biomass use in Kenya is unsustainable, it is not likely to be covering a large part of the power demand in Kenya. It is, however, included to cover peak power demand in the renewable energy scenario. Given that this peak power is not comparable with the large-scale electricity supply on from the other supply options, it is not included in this comparison. in the renewable energy scenario (see chapter 4), the biomass electricity production is increased to 0.8 TWh (2.8 PJ) in 2045 and 2.3 TWh (8 PJ) in 2050, but this is only 2% of power demand and therefore it is not comparable to the other power supply options in this comparison. The increase of biomass use for power from 2045 in the scenario is within the sustainable limits of biomass use, given the reduction in biomass use for cooking in the scenario.

- Coal power has been suggested for Kenya and is included in this comparison with a large-scale plant, 400 MW or larger. Smaller coal power plants will be more expensive. The very central character of coal power makes it difficult to include coal power without risk of expensive over capacity that will make the economic case less favorable for coal relative to this comparison. Also the environmental problems with coal power make them less favorable, which is not shown in the comparison below.

- Oil power, a fuel oil power plant is included for comparison as such plants have been used in Kenya for large-scale power supply in years with low rainfall. In this comparison is used a plant with an internal combustions engine of 10 MW that can burn fuel oil that is considerably cheaper than diesel oil used for the more efficient combined cycle gas turbines. The heavy fuel oil plants are more polluting and are as such not recommended.
- Nuclear power has been suggested for Kenya and is included in this comparison with a large plant, 1000 MW or larger. Smaller nuclear power plants, included suggestions of small modular reactors, will be producing more expensive power. Since very few new nuclear power plants are under construction and since they typically are troubled by delays and cost overruns, the costs of a nuclear power plant have considerable uncertainties. Therefore, we include two cost alternatives:
  - The costs of a realized power plant, the Olkilutoto Power Plant in Finland that is planned to open in 2021
  - Costs according to the EU Joint Research Center Technology Catalogue 2014[16].

With the technology costs and fuel costs in Annex 3, the power costs from the six large-scale power options described above (not including hydro power and biomass power as indicated above) are given in graph 7 and 8. Graph 7 shows results with an interest rate of 10% and graph 8 with 5%. Both are made with present (year 2020) costs of technologies and fuel.

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[16] See https://publications.jrc.ec.europa.eu/repository/bitstream/JRC92496/ldna26950enn.pdf

Bulk power costs, 2020, 10% interest rate, USD/MWh
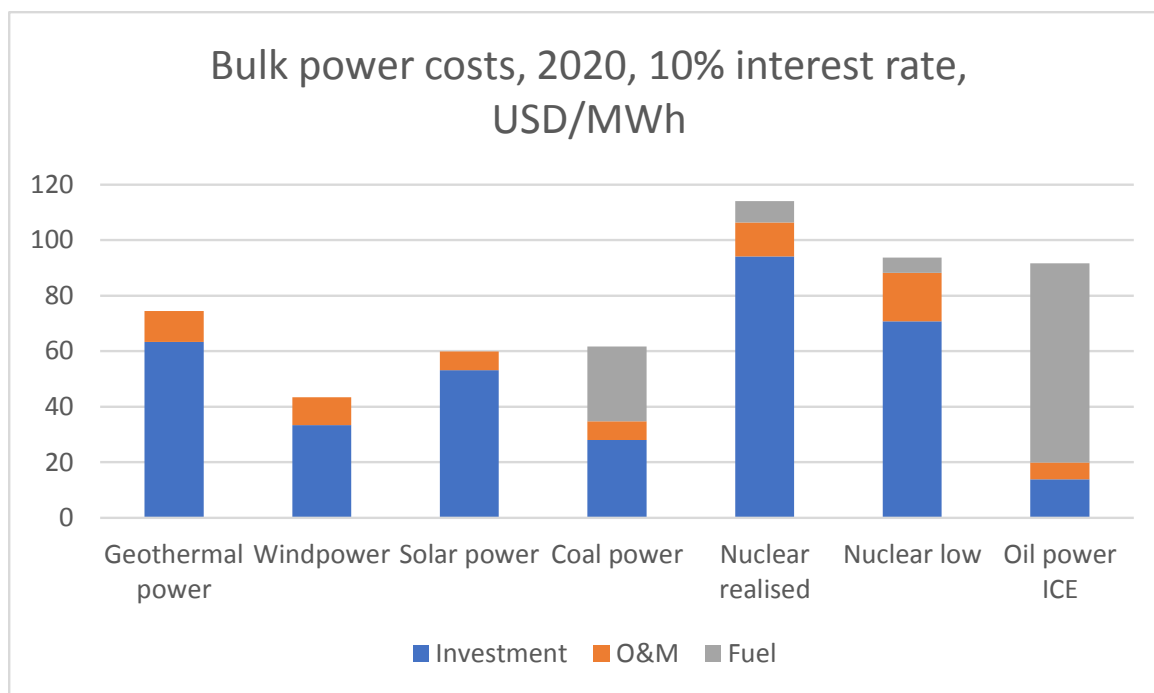
Graph 7. Power costs of six large-scale power supply options for Kenya with high (10%) interest rate and current costs of fuels and technologies

Bulk power, 2020, 5% interest rate, USD/MWh
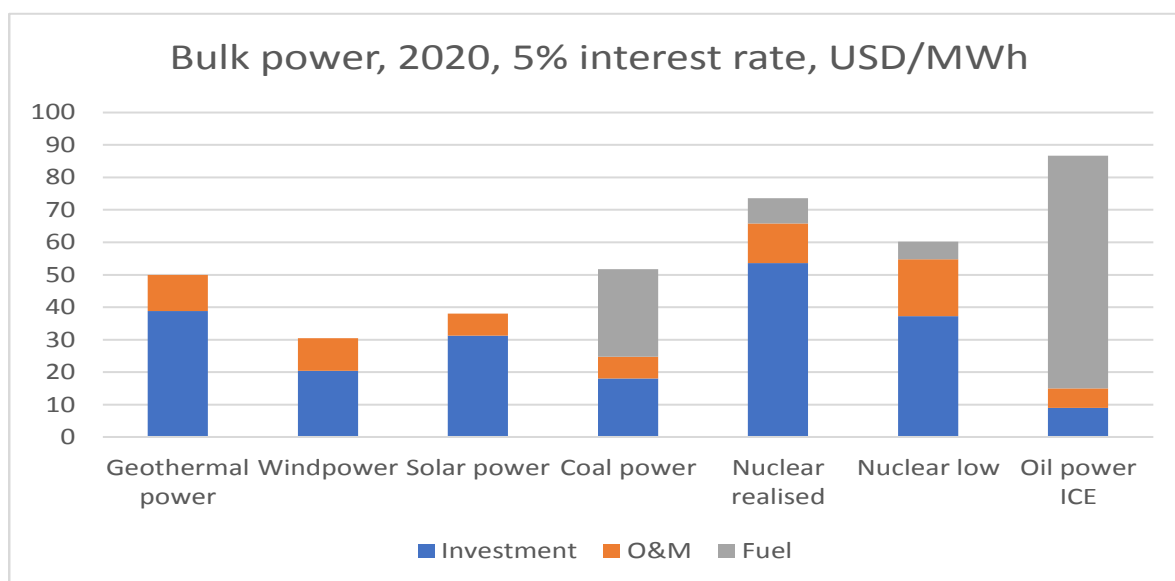
Graph 8 Power costs of six large-scale power supply options for Kenya with low (5% interest rate and current costs of fuels and technologies.

The graphs clearly show that nuclear power is much more expensive than other power options. Only with a low interest rate, it can compete with oil power. This is in line with

other studies, including a study on the least cost power options for Kenya[17]. Since this study on Kenya least cost power options was published, costs of solar power and wind power has decreased considerably.

While the graphs 7 and 8 give an overview with current costs of technologies, forecasts are that solar power will reduce at least 25% in investment costs over the coming 20 years while other technology costs will reduce maybe 10%. This is likely to make solar power the cheapest form of power in Kenya.

There are always some uncertainties of costs. For this comparison, it is important to note that the solar and wind conditions chosen are averages of good conditions. In the best local conditions in Kenya, the economy is better, both of wind power and solar power.

The comparison of graphs 7 and 8 show that with low interest rates, all the renewables options are cheaper than even coal power that is the cheapest of the non-renewable alternatives (when the problems of the large-scale is not taken into account). Comparing the graphs also show how important the interest rate is for the power production costs, with for instance solar power reducing from 60 US$/MWh to below 40 USD/MWh with the reduction from 10% interest to 5% interest. This shows how important it is that power investments are made with low interest financing. Thus, the use of climate financing with low interest for renewable power should be used as much as possible.

The graph 9 shows the difference in costs of wind power with respectively 10% and 5% interest rate.

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[17] Kenya Least Cost Power Development Plan 2011-2031 identifies nuclear together with coal power as the more expensive than other power options, being windpower, geothermal power and a large hydro-power project. Assuming the large increase in demand for power, the plan includes, however, nuclear power at a later stage when the cheaper options have been exhausted. Sine this study was made in particular solar power and also windpower have reduced in price, making other alternatives, as nuclear power less competitive. See plan at
https://www.renewableenergy.go.ke/downloads/studies/LCPDP-2011-2030-Study.pdf
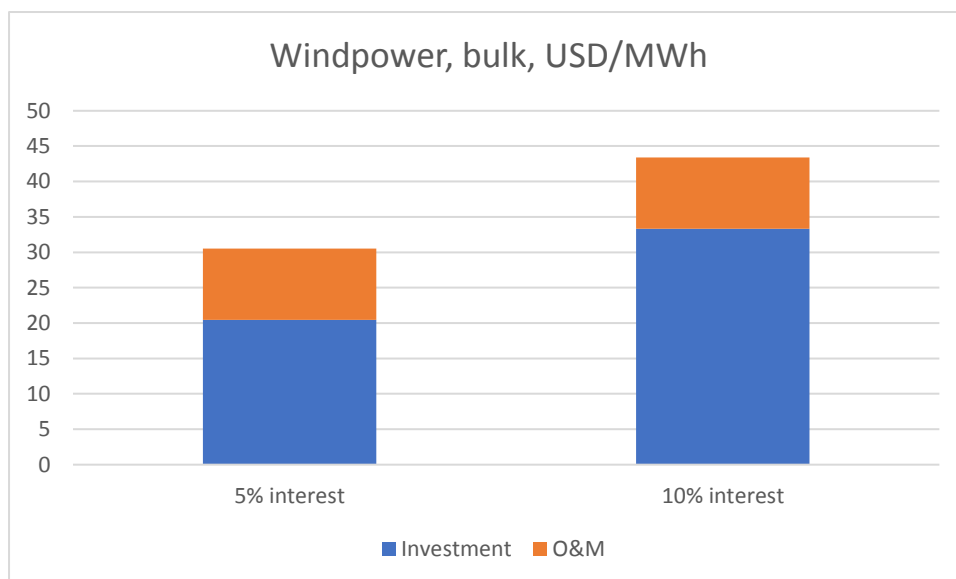
Graph 9, costs of power production from wind power with 5% and 10% interest rates, 2020 technology costs.

The graph 9 underlines the importance of low-interest financing for renewable energy.

No power supply option is optimal as the only power supply, and to identify the actual cost of power supply, it is necessary to calculate how to supply power in each hour of the year, with the variations in demand and in renewable supply. We do that in this study with the Energy Plan model. For Kenya it is also important to include decentralized power as it is not economic to supply the entire country with a centralized grid

In conclusion, the cheapest power options for large-scale power production are today wind power, solar power and then geothermal power, while the most expensive are nuclear power or oil power, depending on the interest rate for the financing. In future it is likely that solar power will be the cheapest. For large-scale power production, we include the cheapest power supply options in the form of renewable energy in the models in this study.

3.2 Development of wind power

Wind power is increased to meet the increasing power demand. In the scenarios, the power demand is not increasing as fast until 2030 as in official forecasts, and development is therefore slower. The development of wind power in the scenarios and in official plans is shown in table 12

Wind power (MW)	2020	2025	2030	2035	2040	2045	2050
Renewable scenario	350	550	1500	3000	5000	8000	9000
BAU scenario	350	450	800	9500	1150	1500	1850
National strategies	350	800	2000-3000				

Table 9. Wind power development in Kenya in the renewable energy scenario, in the BAU scenario, and in the proposed Renewables Additions 2018- 2022 (for 2025), and 2014 Draft National Strategy, renewable energy expansion plans until 2030.

With this expansion and with 3500 full load hours, wind energy production will reach 23.3. TWh = 85 PJ in 2050 in the renewable energy scenario. This is less than 2% of the potential of 1740 TWh identified in chapter 2.1.

3.3 Development of solar power

Solar is increased to meet the increasing power demand. In the scenarios, the development is faster than in the official forecasts from 2025 to 2030 because we estimated that a higher development of solar has a better economy. The development of solar power in the scenarios and in official strategies is shown in table 13.

Solar power (MW)	2020	2025	2030	2035	2040	2045	2050
Renewable scenario	400	430	3330	5330	9330	14330	17330
BAU scenario	400	430	990	4030	5830	10230	14930
National strategies	400	430	500				

Table10. Solar power development in Kenya in the renewable energy scenario, in the BAU scenario, and in the 10 Year Power Sector Expansion Plan, 2014- 2024 (for 2025), and 2014 Draft National Strategy, renewable energy expansion plans until 2030.

With the expansion to 17,330 MW solar power in 2050 in the renewable energy scenario and with 1800 full load hours, the solar power production will be 31 TWh equal to 112 PJ. This is just ¼ of the potential identified in chapter 2.1

3.4 Development of geothermal power

Geothermal power is increased to meet the increasing power demand. In the scenarios, the demand of power is not increasing as fast as in official forecasts, and development is therefore slower. The development of geothermal power in the scenarios and in official strategies is shown in table 14

Geothermal power (MW)	2020	2025	2030	2035	2040	2045	2050
Renewable scenario	801	972	1486	2931	4631	5226	5566
BAU scenario	801	938	938	938	998	998	1083
National strategies	801	1486	6000				

Table11. Geothermal power development in Kenya in the renewable energy scenario, in the BAU scenario, and in the proposed Renewables Additions 2018- 2022 (for 2025), and 2014 Draft National Strategy, renewable energy expansion plans until 2030.

With the expansion to 5566 MW geothermal power in 2050 in the renewable energy scenario and with 95% capacity factor, the geothermal power production will be 46 TWh equal to 167 PJ. This is 2/3 of the potential identified in chapter 2.1.

4.0 ENERGY BALANCES, CO$_2$ EMISSIONS AND ECONOMY

4. 1 Electricity Sector

The scenario results for the electricity sector shows that in the BAU scenario there is steady growth in the electricity use that easily can be met with renewable energy while in the renewable energy scenario there is a strong increase in electricity use, which can also be met without problems with the large potentials for wind, solar and geothermal power in Kenya. See graph 10 and graph 11

Electricity production, Kenya, BAU (PJ)
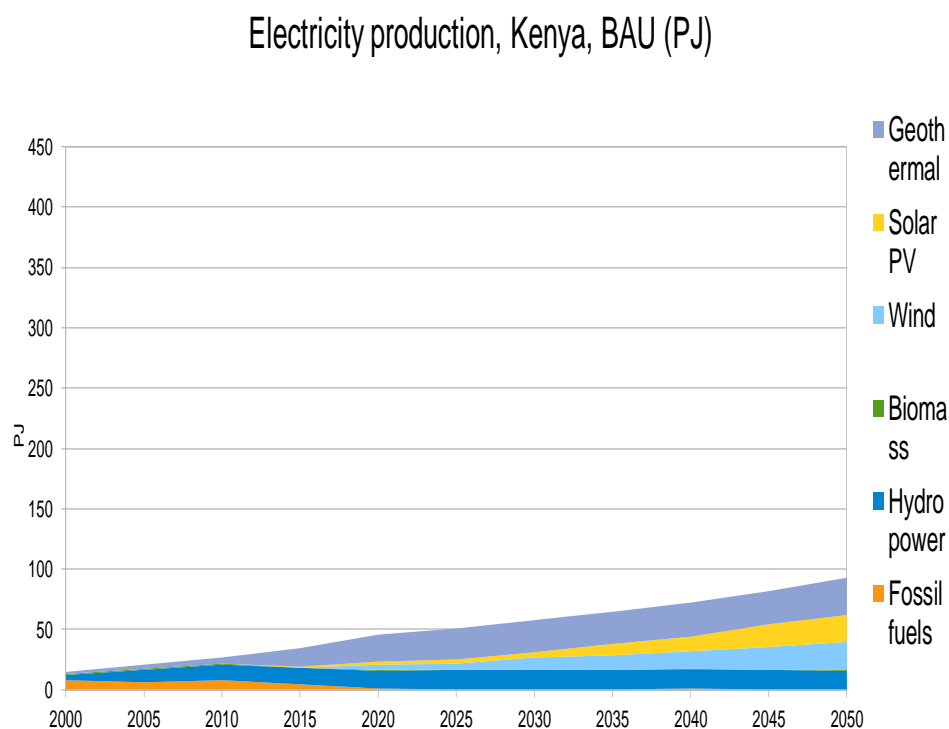
Graph 10 Electricity productions in the BAU scenario

Electricity production, Kenya, 100% Renewables (PJ)
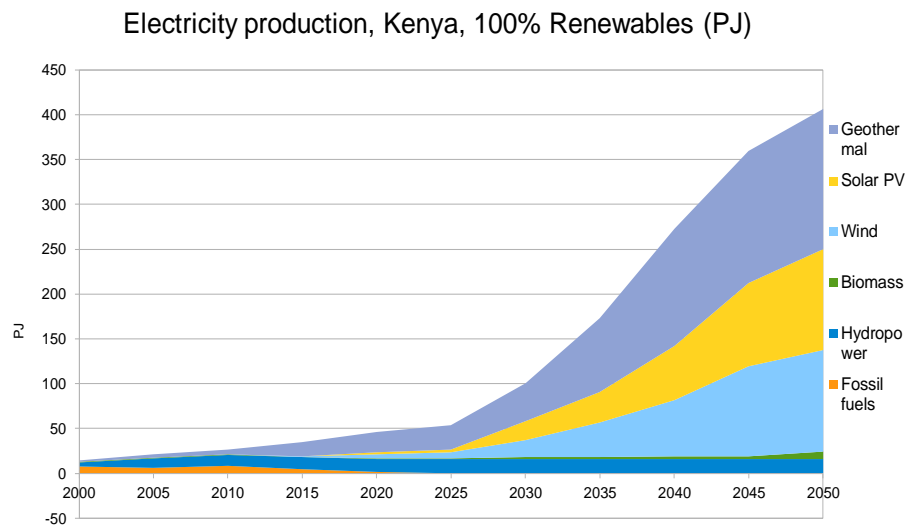
Graph 11, Electricity production in the renewable scenario

4.2 Total, primary energy demand

The total primary energy demand is increasing as shown on graph 12 for the renewable energy scenario.
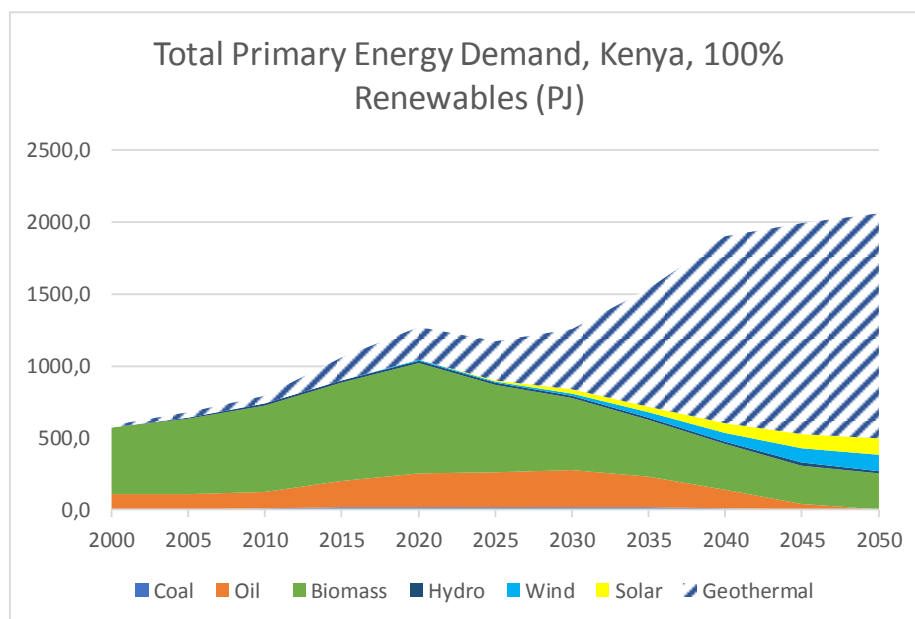
Graph 12 Primary energy demand in the renewable energy scenario.

The main increase is because of the increased use of geothermal power, where the efficiency from the energy in the underground steam to the electricity output is only 10%[18]. Of the total primary energy consumption in 2050 of 2000 PJ, 1400 PJ are losses in the geothermal power production. These losses are not harmful, but this low-temperature heat is hard to use, as there is no need for the waste heat in the sites, where the geothermal power stations are located.

4.3. Biomass sustainability

One objective of a scenario for transition to sustainable energy is to reduce biomass use to a sustainable level. While the sustainable level is not a fixed value, we have used the potential of 300 PJ as discussed in chapter 2.1. In the renewable energy scenario, this level is reached in 2050, as shown in graph 13.
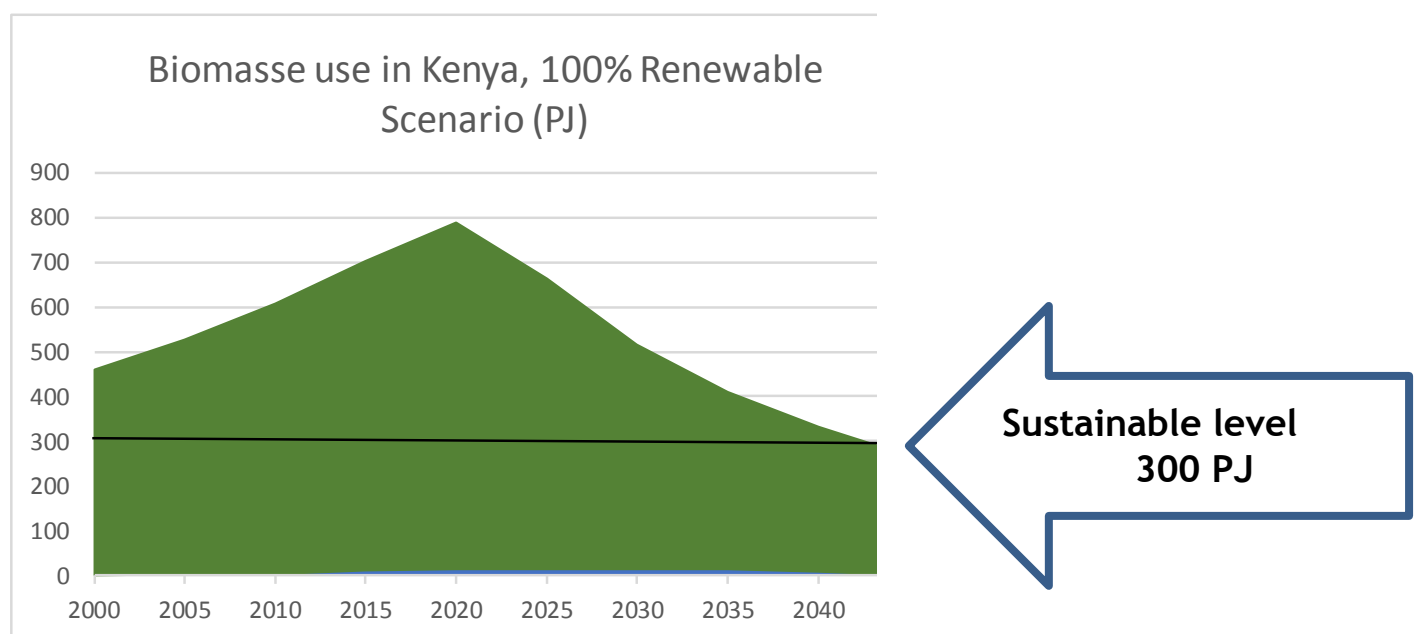
Graph 13 Biomass use (all) in renewable energy scenario

As shown on graph 13, the biomass use is high in 2020 but with the current plans for higher efficiency in cooking in Kenya and with the adoption of the scenario, the use can reduce rapidly and at 2050 the use of biomass will be sustainable at 300PJ.

In the BAU scenario, biomass use is also reduced, but only to 322 PJ.

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[18] 10% efficiency for geothermal power in Kenya is the efficiency used in the IEA statistics used for the scenarios, from www.iea.org

4.4 CO_2 emissions from Energy

With the phase out of fossil fuel use, the CO_2 emissions from fossil fuel use will also be phased out. In the renewable energy scenario, also the CO_2 emissions from unsustainable biomass use can be phased out. In the BAU scenario, the CO_2 emissions from fossil use will increase, but the CO_2 emissions from unsustainable biomass use will be reduced.

The development of CO_2 emissions from fossil fuel use is shown in graph 14 and graph 15 for the two scenarios.
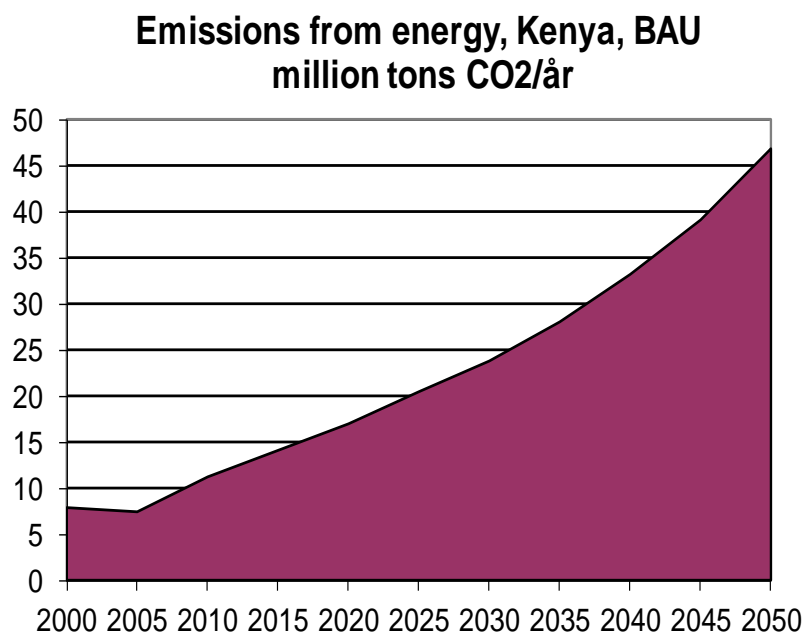
Graph 14 CO_2 emissions from fossil fuel use, BAU scenario

Emissions from energy, Kenya, 100% Renewables, million tons CO2/år
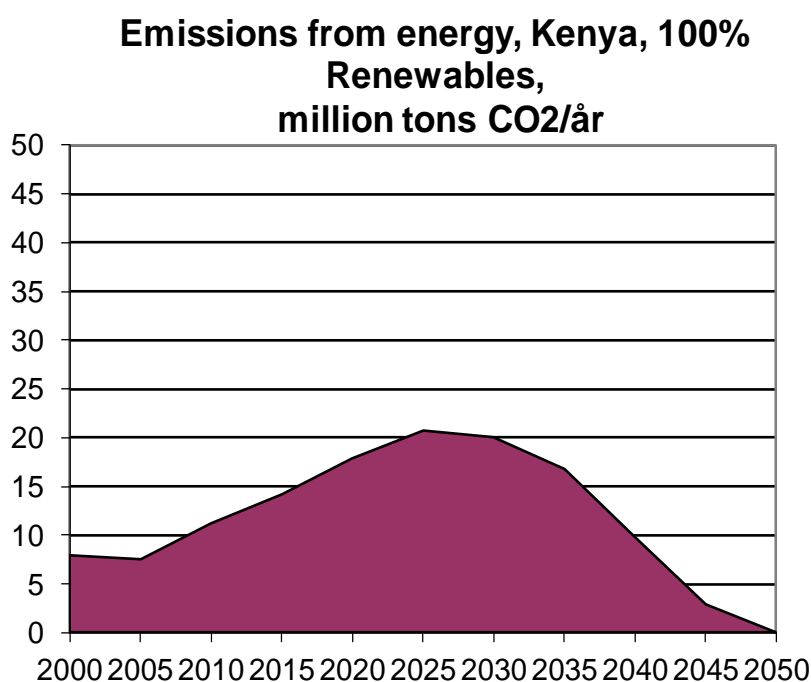
Graph 15 CO$_2$ emissions from fossil fuel use, renewable energy scenario

The graphs show that there will be reduced emissions as from 2025 if the renewable scenario is adopted and implementation is made according to the scenario. With this promotion of clean and sustainable energy solutions, it is likely to have zero CO$_2$ emissions by 2050.

While the renewable energy scenario can lead to CO$_2$ neutrality from energy by 2050, it is not necessarily leading to greenhouse gas neutrality, as there are other greenhouse gases than CO$_2$ and as there are non-energy emissions of CO$_2$, for instance from agriculture.

4.5 Scenario Economies

With the detailed modeling of the scenarios for 2030 and 2050 with Energy Plan, also costs are calculated for these two years. The results in the form of total costs divided in fuel costs, investment costs (annual payments on investments + interest rates) and other costs (mainly operating and maintenance costs) are given in graph 16 and graph 17.
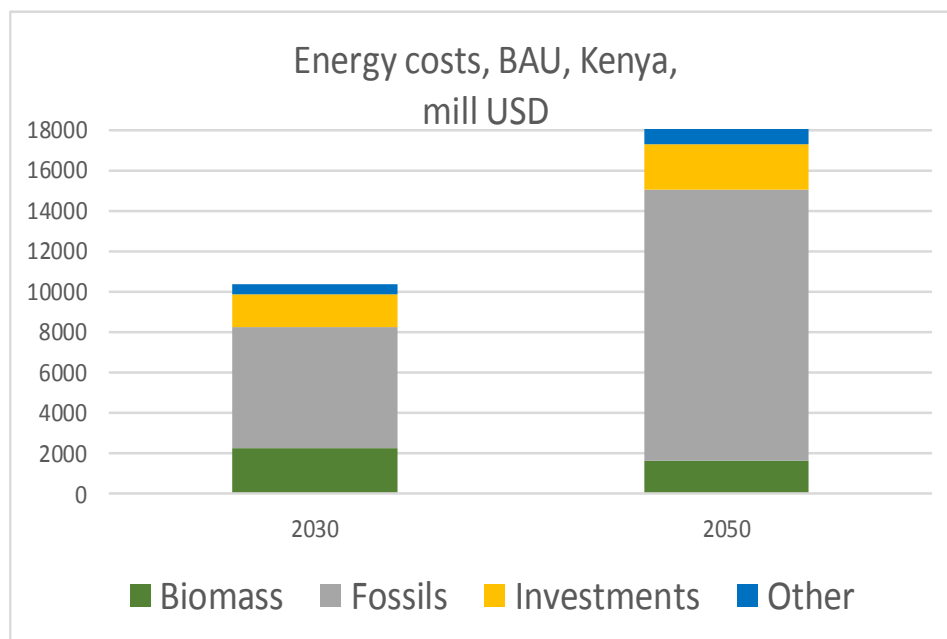
Graph 16 Costs of energy supply in 2030 and 2050, BAU scenario
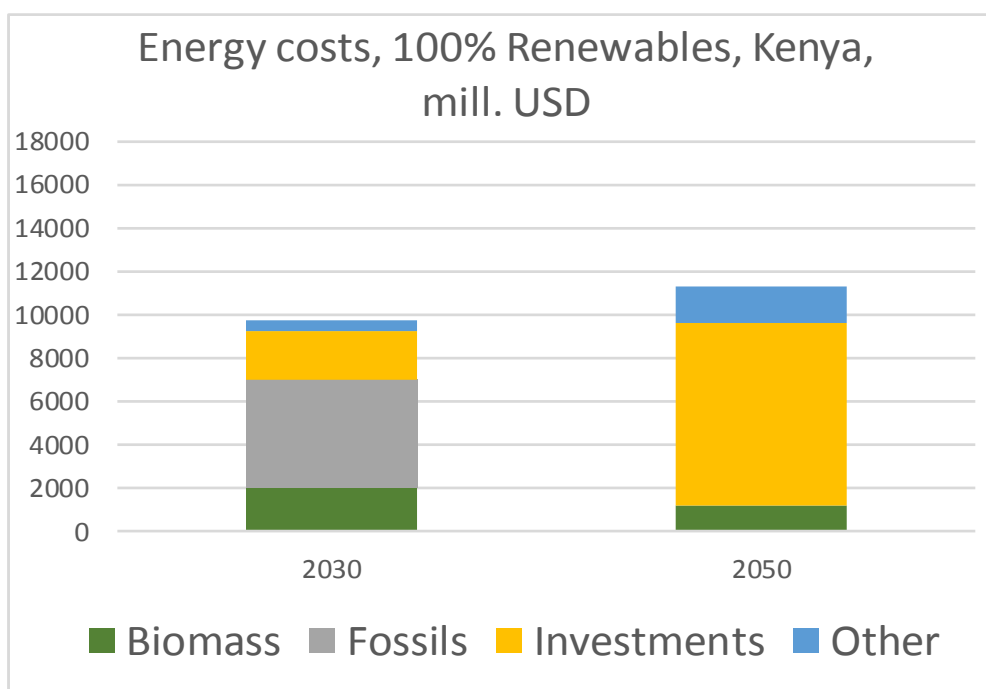
Graph 17

Costs of energy supply in 2030 and 2050, renewable energy scenario

The graphs show that energy supply is cheaper in the renewable energy scenario compared with the BAU (Business As Usual) scenario. The difference is particular high for 2050, where energy supply costs in the renewable energy scenario are only 2/3 of the costs of the BAU scenario.

The costs only include energy supply costs, but not end-use equipments as efficient stoves and electric vehicles. Many experts estimate that electric vehicles will have same costs as fossil fuel vehicles within a decade, but today they are more expensive.
The costs also does not include costs of electric networks, except for costs of electricity losses and of investments in electric interconnectors.

Costs estimates are sensitive to all inputs. One important input is the interest rate, and as most costs of the renewable energy scenario in 2050 are investment costs, the interest rate of 10% is important for the costs of the investments. If interest fall, as they have done in Europe and USA, the renewable energy scenario will be considerably cheaper.

Another important input is the fuel costs. The fuel costs are given in Annex 3. Some costs in 2050 are:

- Diesel oil 17.7 USD/GJ at refinery and 19.8 USD/GJ at gas stations, equal to a crude oil price around 54 USD/barrel[19]

- Wood for energy 3 USD/GJ at source and 6 USD/GJ at household user, equal to around 35 K.Sh/kg at source and 70 KSh/kg at household

Given the large economic benefits of the renewable energy scenario, smaller variations in the fuel prices will not change the conclusion that the renewable energy scenario will be the cheapest, in particular after 2030.

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[19] Calculated with the assumption that diesel prices are twice the price of crude oil, and with the conversion of 1 barrel of oil = 6.12 GJ

5.0 ACTORS and RECOMMENDATIONS

5.1 The Scenario actors

In both scenarios, key individuals, groups, and/or institutions play different roles. The choices they make or the decisions they take often determine the kind of future we are likely to face.

These actors include:-

Government – is a critical in player policy formulation and implementation as well as ownership and service provision of energy sector. The future outcomes are fundamentally based on the policy decisions made, the regulatory framework set, the management of ownership and service provision in the energy sector. The level of government financing of projects will also determine the future.

The private sector – plays the crucial role of providing independent energy supply, equipment, and others. Their role could grow overtime in power generation, distribution and supply, but if the business environment is not conducive, they could slow down their investments or relocate to more business friendly environments. They also determine levels of energy cost based on level of competition. It can also be a conservative factor, clinging to fossil fuels in spite of better alternatives.

Ordinary citizens –form part of the end users of the energy supply. They are important players in increasing or reducing CO_2 emissions based on their cultural habits, choice of energy and spending patterns on energy.

Development partners – are critical in financing energy projects. The outcome is based on whether they give the resources or not as well as the conditionality attached to their resources.

Technical experts – will determine research and innovation as well as transfer of technologies. They also give guidance to the governments.
Foreign investors – provide capital, but also repatriation of resources. They can provide competition, which can help in regulation of market prices, but they can also monopolize sectors.

Global policy makers – set global rules on environmental standards and climate strategies, which determine country investments and directions.

County governments – are crucial in local implementation and in ensuring level of energy access to citizens. They are therefore critical in determining the level of equity in access to various forms of energy.

5.1.1 The working terrain
Source: Scenarios participants (Institute of Economic Affairs (IEA), 2015)
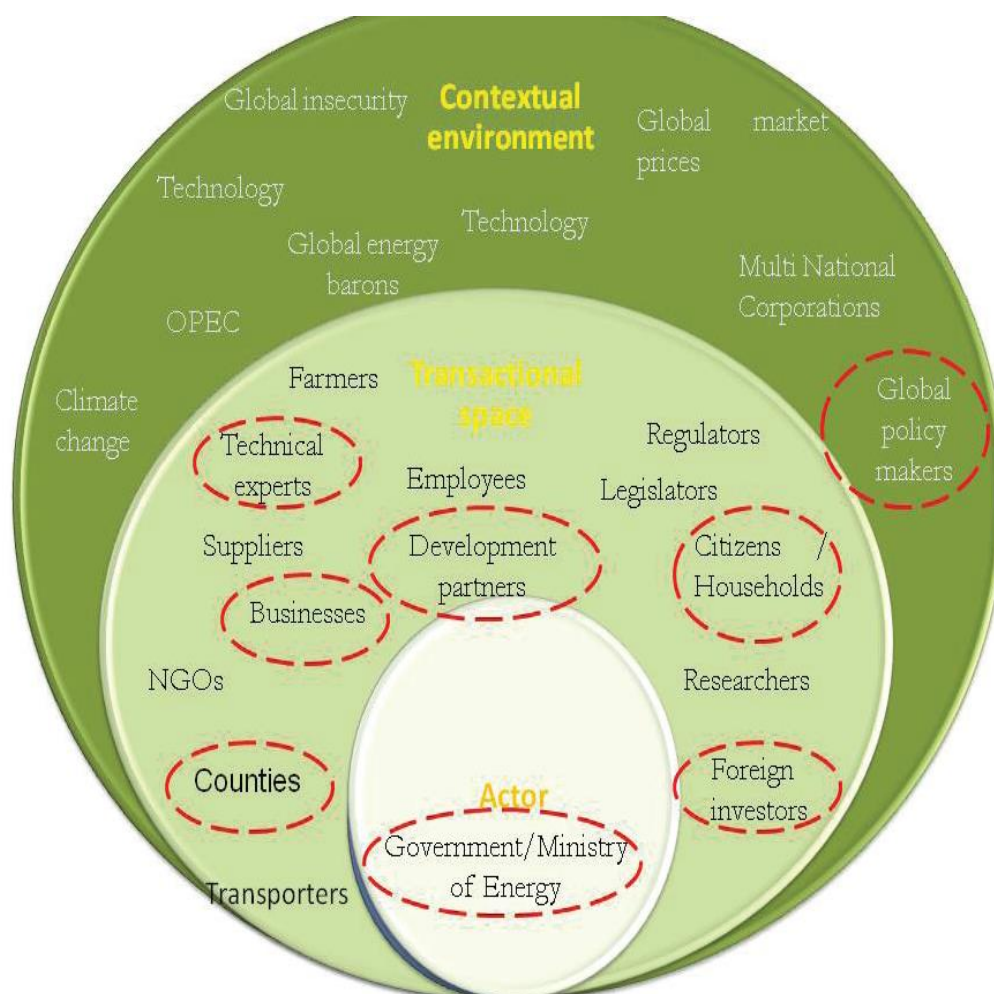
5.2 Policy Recommendations

Policies and strategic choices are crucial, if Kenya is to realize the renewable energy scenario in accordance, following from the vision 2030, the constitution, and the greening policy framework. Following are the recommendations:-

1) Energy expansion is crucial if the country is to provide all with energy access and provide energy for developments that can improve the country's economic performance.

2) Investing in modern energy solutions with energy efficiency and cleaner, renewable energy should be priorities. There should be high priority on efficient cooking, but all sectors must be in the scope for increased energy efficiency.

3) Diversifying the energy mix into different renewables to reduce over-reliance on finite resources like hydro-generation and petroleum sources of energy without creating new dependencies on energy imports.

4) Fully exploiting clean and renewable energy sources that are locally available like geothermal, wind and solar.

5) Fully exploit energy efficiency potentials in all sectors with capacity building on energy efficiency, regulation, and energy audits in domestic, service, and industrial sectors.

6) Managing the cost of energy through optimal combination of energy efficiency and affordable renewable energy should be a priority. Expensive energy solutions as nuclear power should be avoided.

7) Make biomass use for energy sustainable with a combination of efficient biomass use, efficient charcoal production, increased supply with plantations etc. and change to affordable alternatives based on renewable energy as they become available. This shall include better enforcement of the legal and regulatory framework for sustainable production, distribution and marketing of biomass as well as stronger promotion of sustainable afforestation programmes.

8) Make transport energy sustainable with use of electric transport, based on renewable electricity.

9) Raising public awareness of more efficient energy use, including energy efficiency measures, local use of renewable energy, and new technology developments. There is a need to raise awareness of the potentials and benefits of renewable energy, including biogas and solar energy for electricity and heat.

10) Reducing the geo-political tensions with regional neighbors and carefully/transparently negotiating bilateral and multi-lateral agreements with them to ensure mutual benefit and successful regional integration and cooperation, also on sustainable energy, allowing a larger market for renewable energy and energy efficiency.

11) Involving local communities and county governments along the entire energy chain as well as transparent and accountable management of resources for the mutual benefit of all to reduce tensions and enhance ownership of projects. Local communities must be included in decisions on siting of renewable energy installations (solar, wind, geothermal, hydro), and have benefits that at least compensate for the change in land-use that affects them. The benefits should be long-lasting and can include job opportunities, affordable power supply, and infrastructure as better water supply. Renewable energy installations shall create local development.

12) Gender mainstreaming in the implementation of energy projects and programs.

13) Deliberately creating local capacity on all levels in the new energy areas to create employment and reduce foreign domination of labor in the sector. This shall include increasing the expertise in Kenya in geothermal energy, windpower, and biogas.

14) Develop Investment cost Frameworks to guide private sector investment in DREs; especially for high capital intensive like mini-grids and grid extension for rural electrification. There is also need to review the existing policies and provisions to protect the private sectors in energy sector from exploitation in energy research, innovations, production and benefits by the government as a way to facilitate sustainable partnerships.

15) Improving regulatory compliance of existing provisions as well as formulation of legal and regulatory framework of energy technologies and resources. This include regulatory compliance of natural gas and oil resources to be able to effectively manage extraction and exploitation, have clear revenue distribution, eradicate corruption, and set sunset dates in line with the Paris Agreement and the renewable energy scenario. It also includes enforcement of standards and regulations for renewable energy, in particular solar technologies, to avoid sub-standard equipment.

16) Fiscal investment in greening of the economy to reduce the impact of climate change and environmental degradation.

17) Security of the infrastructures: The sector to work closely and create liaison between the respective parastatals security, national security apparatus and local citizens to monitor the street lighting network and address arising challenges that affect the sector infrastructure. The sector to undertake automation of the street lights with a complete central monitoring system and securing memoranda of understanding and Maintenance Agreements with county governments.

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Annex 1
Assumptions for the calculation of demands

A1.1 Demands for Cooking

The Kenya's Climate Change Action Plan 2018-2022 and the Kenya's first NDC (2016) includes that biogas stoves are increased from around 30,000 today to 250,000 in 2022 and 500,000 in 2030. We assume that this is realized and that the level of 500,000 stoves is maintained.

As new measures, we propose:

- Super- efficient electric cooking with efficiencies ten times traditional fires. The introduction will start with 700.000 of these pressure cookers until 2025 and gradually increasing to cover 25% of household cooking needs in 2050. They will replace most of charcoal use, LPG, and gradually also part wood and other biomass.

- High-efficiency biomass stoves with efficiencies of 50% in average, 4 times higher than traditional fires. The introduction will start with 100,000 of these stoves until 2025 and 500,000 until 2030. They will later replace almost all other biomass stoves.

This gives the development of cooking and charcoal efficiency as well as fuel use in table A1

Household cooking	2000	2005	2010	*2015*	*2020*	2025	2030	2035	2040	2045	2050
Household number, mill.	7,6	8,6	9,9	11,2	12,5	13,8	15,2	16,7	18,4	20,0	21,5
Cooking demand	100	112	129	148	165	182	201	221	242	264	284
Improved cook stoves (standard), mill.	2,2	2,9	3,5	4,1	4,7	8,6	12,1	9,9	5,9	2,6	0,1
Improved cook stoves (standard) %	30%	33%	35%	37%	38%	62%	65%	59%	32%	13%	1%
High-efficiency cook stoves, mill.	0	0	0	0	0	0,1	0,5	3	7,5	11,5	15,5
High-efficiency cook stoves,%	0%	0%	0%	0%	0%	1%	3%	18%	41%	58%	72%
Biogas cooking (families), mill	0	0	0,01	0,02	0,03	0,25	0,5	0,5	0,5	0,5	0,5
Biogas cooking	0%	0%	0,10	0,18	0,24	1,8%	3,3%	3,0%	2,7%	2,5%	2,3%

(families), %			%	%	%						
Super-efficient electric cooking, number	0	0	0	0	0	0,7	1,5	2,5	3,7	5,0	5,4
Super-efficient electric cooking, %	0%	0%	0%	0%	0%	5%	10%	15%	20%	25%	25%
Traditional cooking, %	70%	67%	65%	63%	62%	30%	18%	5%	4%	2%	0%
Average efficiency, all	14%	14%	14%	14%	14%	17%	20%	26%	33%	45%	58%
Specific demand, 2000 basis	100%	98%	97%	97%	96%	78%	68%	53%	41%	30%	23%
Average, efficiency, solid biomass	14%	14%	14%	14%	14%	17%	18%	22%	28%	37%	49%
Specific demand, 2000 basis, solid biomass	100%	98%	98%	97%	96%	82%	76%	62%	49%	37%	28%

Table A1, development of main cooking types and cooking efficiency with above assumptions for the 100% renewable energy scenario

From table A1 can be calculated share of cooking with solid biomass as the development of the volume of cooking with biomass relative to year 2000 multiplied with the specific efficiency of biomass. In this way is calculated the biomass demand for household cooking relative to the year 2000. See results in table A2.

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Solid biomass share of cooking	99%	99%	99%	99%	98%	93%	87%	82%	77%	72%	73%
Cooking with solid biomass	100	112	129	148	164	170	174	181	187	191	206
Solid biomass demand for cooking	100	110	126	143	158	140	132	112	91	70	57

Table A2: demand for cooking and for biomass for cooking with estimated development of specific energy demand for

A1.2. Biomass Demand Distribution on Sectors

Annual statistics from IEA give the total end-use of biomass, but not the division between sectors: households, service sector, and industry. This division is derived from a specific study on this, based in data from the year 2000.

In table A3, the division is given between households and cottage industries for the year 2000

	Firewood (Tons/yr)	Wood for Charcoal (tons/yr)	Wood Waste (tonnes/yr)	Farm Residue (tonnes/yr)	Kerosene (litres/yr)	LPG (kg/yr)	Electricity (Kwh/yr)
Rural Household	14,065,004	7,624,935	136,459	2,649,981	172,761,463	1,406,270	93,376,810
Urban Household	358,709	6,020,663	83,863	12,832	150,707,171	16,883,884	723,013,990
Cottage Industry	467,145	2,860,900			2,142,950	7,021,875	353,558,397
TOTAL	14,890,858	16,506,498	220,321	2,662,813	325,611,584	25,312,028	1,169,949,197

Table A3 Annual consumption of various energy types in households and cottage industries (2000)[20]

To this should be added consumption in industry and commercial sectors given in table A2 below, data from the same study;

Annual fuel wood and charcoal consumption by cottage industries Industry	Quantity of fuel wood in tonnes/year	Quantity of charcoal in tonnes/year
Brick making	55,772	-
Tobacco	78,365	-
Milk processing	4,900	540
Fishing and fish smoking	17,960	-
Jaggary	180,000	-
Bakeries	20,665	622
Restaurants/kiosks	1,276,155	428,025
Tea Industry	155,000	-
Total	**1,788,817**	**429,187**

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[20] Source: Republic of Kenya (2002) Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small Scale Industries and Service Establishments. Ministry of Energy, Nairobi, Kenya.

Table A4, Annual fuel wood and charcoal consumption by cottage industries and industries[21]

Based on these data, we calculate the division of biomass use in industry, service sector and households. The results for charcoal and for other biomass are given in table A3 (table A3 is also in the main report). For the calculation for the figures in table A3, the following conversion factors are used:-

- Between wood for charcoal and charcoal, the factor is 10%, i.e. only 10% of the energy and the mass of wood for charcoal are becoming mass and energy in the charcoal, the rest is lost in the process.[22]
- Between residues and wood, the factor is 75%, i.e. the energy content per ton of residues is 75% of the energy content of wood.

Division of biomass	Wood, wood waste and agriculture residues		Charcoal	Sector composition	
	in tons/year	in percentage	In tons/year	In per-Centage	
Industry	136.082	0,7%	540	0,03%	Brick making
Service sector	1.763.965	9,5%	714.737	34%	Bakeries, restaurants and kiosks, cottage industry
Households	16.641.145	89,8%	1.364.560	66%	Rural and urban households
Total	18.541.192	100,0%	2.079.837	100%	

Table A5, division of solid biomass use across end-use sectors

We will use the fractions in table A5 to divide biomass use between sectors, while the total biomass use will be according to IEA data for 2000 – 2015 and for 2020 using the trend 2015-2017 of IEA data. The IEA divides solid biomass use in end-use of solid biomass and solid biomass for "Other transformation", which is charcoal production. In addition, a small fraction (0.2%) is used for electricity production according to IEA.

A1.3 Development of Final Energy Demand

Based on assumptions in this annex and in chapter 2, the final energy demand is calculated for the scenarios. The results are given in table A6 and A7 divided in sectors

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[21] Source: Republic of Kenya (2002), op.cit.
[22] Charcoal data are from energypedia, see https://energypedia.info/wiki/Charcoal_Production

for the two scenarios. For the renewable energy scenario, final energy demand is also divided in energy carriers, in table A8

Consumption'	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Road	39	42	73	119	175	213	237	248	237	224	202
Rail	1	0	0	0	3	4	4	5	5	6	7
Industry	28	36	49	59	61	68	74	75	71	62	75
Construction	0	0	0	0	0	0	0	0	0	0	0
Agriculture	3	1	1	1	1	1	1	1	1	1	1
Service sectors	30	34	41	47	58	54	55	53	52	51	53
Households	242	272	313	362	402	340	321	280	241	209	186
Total	342	386	477	589	699	677	694	662	608	553	523

Table A6, final energy demand divided in sectors, renewable energy scenario

Consumption'	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Road	39	42	73	119	175	213	258	312	376	453	543
Rail	1	0	0	0	3	4	5	6	7	8	10
Industry	28	36	49	59	61	68	77	88	101	117	142
Agriculture	3	1	1	1	1	1	1	1	1	1	1
Service sectors	30	34	41	47	58	62	60	59	60	61	62
Households	242	272	313	362	402	355	353	317	282	250	219
Sum	342	386	477	589	699	703	754	783	827	889	976

Table A7, final energy demand divided in sectors, BAU scenario

End-use, PJ	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	12	17	22	29	37	44	79	130	194	240	278
Hydrogen	0	0	0	0	0	0	0	12	28	54	49
Charcoal	23	26	30	34	39	31	28	22	17	13	13
Wood, bio	202	242	272	329	376	339	300	256	220	190	166
Biogas	0	0	0	0	0.9	8	16	16	16	16	16
Oil	103	99	148	184	232	240	257	211	124	40	0
Coal	2	2	4	13	13	15	14	15	8	0	0

Table A8: Development of end-use energy demand in the renewable energy scenario, divided in energy carriers

Annex 2

A2.1 Development forecasts for Kenya

Before describing the specific context surrounding energy access in Kenya, it is first useful to contextualize the central electricity sector. Kenya has had a healthy economic development over the last decades and is now in the group of lower middle-income countries. Population estimates is based on the Kenyan population census 2019[23] and the assumptions that population growth will gradually reduce until 2050 from recent 2.2% p.a. (2009-2019) to 1.5%.

The economic growth was an average of 5.7% p.a. of GDP over the latest 8 year, including forecasts for 2019 and 2020, see table 1

Kenya Economic growth	2013	2014	2015	2016	2017	2018	2019, forecast	2020, forecast	Average 2013-2020
percent of GDP	5,88	5,36	5,72	5,88	4,86	6,32	5,7	5,9	5,70

Table A9: Economic growth of Kenya since 2013. Data from World Bank[24]

Based on this relatively stable economic development of Kenya, we assume 5.7% p.a. as average economic growth rate of Kenyan GDP 2020 – 2050. There will of course be crisis years with less economic development, but it can be expected that there will also be years with stronger than average economic development.

With these assumptions, the population and GDP of Kenya will develop as in table 2. Statistical data from 2000 until today is included for reference.

Kenya development	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050

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[23] See https://www.knbs.or.ke/?p=5621

[21] Data 2013-2018 from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=KE . data 2019-2020 from https://www.worldbank.org/en/news/press-release/2019/04/08/kenyas-economic-outlook-remains-stable-amid-threats-of-drought-in-2019

assumptions											
Annual population growth, percentage p.a.	2,9	2,9	2,9	2,2	2,2	2,1	2,0	1,9	1,9	1,7	1,5
Population (millions)	29,5	33,6	38,8	43,6	48,6	53,9	59,4	65,1	71,6	77,9	83,9
GDP (billion USD)	12,7	18,7	40	64,0	97,6	128	169	224	295	390	514

Table A10. Kenya development assumptions for scenarios, Population data 2000-2020 based on Kenyan population census 1999, 2009, and 2019 (see source above). GDP 2000 – 2020 is based on World Bank data for GDP in current USD[25]

With this development, Kenya will increase its GDP/capita from below 2000 USD/capita today to over 6000 USD/ capita, and Kenya will then be in the group of higher middle income countries.

To realize such a development, strong development of productive sectors is needed together with human development; but it is also important that increasing supply of affordable and reliable energy is available.

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[25] World Bank source is https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KE, date for 2020 is calculated based on GDP for 2018 and GDP growth rates 2018-2020

Annex 3
A3.1 Technology and energy cost forecasts

Technology costs

In the technology costs included are; costs of energy production and energy conversion in the form of electricity plants and hydrogen electrolysis plants.

End-use technologies are not included, such as improved cook stoves and vehicles.

For network costs, only the interconnectors are included.

In table A11 is given the main technology cost parameters used in the scenarios. As costs change over time, and that investments have to be made in advance, the investment costs are average of investment costs in technology catalogues for 2015/2020 and 2030 for cost calculations in scenarios for 2030 and average of 2030 and 2050 for cost calculations in scenarios for 2050.

Technology	Invest 2030	Invest 2050	Fixed O&M 2030	Fixed O&M 2050	Var O&M 2030	Var O&M 2050	Sources
	mill USD/MWe	mill USD/MWe	% of invest	% of invest	USD/MWh	USD/MWh	EPT line
Large power plants, biomass	1,90	1,82	1,63	1,64	3,0	3,2	109-111
Windpower	1,06	1,02	3,24	3,34	0	0	132-134
PV-power, large	0,76	0,63	1,30	1,30	0	0	144-146
Hydro-power	2,53	2,55	1,25	1,25	3,3	3,3	170-172
Geothermal power	4,72	4,04	1,70	2,00	1,8	2,2	182-184
H2-electrolysis	0,58	0,53	5,00	5,00	0	0	239-241
	mill. USD/GWh	mill. USD/GWh	% of invest	% of invest			
Hydro-storage	7,50	7,50	1,50	1,50	0	0	174-176
H2-storage	n.a.	7,00	n.a.	2,32	0	0	250-251
	mill.	mill.	% of	% of			

	USD/TWh gas/year	USD/TWh gas/year	invest	invest			
Biogas plant	185,92	167,61	11,00	11,50	0	0	202-204
	mill. USD/MW-bio	mill. USD/MW-bio	% of invest	% of invest			
Biodiesel	3,24	2,89	3,77	5,27	0	0	218-220
	USD/MWh	USD/MWh	% of invest	% of invest			
Interconnectors, 1000 km	1,19	1,07	1,50	1,50	0	0	EU JRC

Table A11 Main technology costs for power system 2030 and 2040. Sources are Energy Plan Technology Catalogue 4.0 (EPT, the numbers in right table column indicate the lines with the technology in the excel version), and EU Joint Research Center's (JRC) technology catalogue[26]

For comparison is current costs of large-scale power supply options today, including non-renewable options in Table A12

	Investment,	Fixed O&M	Var.O&M	Lifetime	Sources	Capac. factor	Efficiency
	mill. $/MWe	%	$/MWh	Years		%	%
Geothermal power	4,97	1,6	1,56	30	[27]	0,95	n.a.
Windpower	1,1	3,2	0	30	[28]	0,40	n.a.
Solar power	0,92	1,31	0	35	As above	0,21	n.a.
Coal	2,11	1,63	2,61	25	As	0,95	0,46

[26] See https://www.energyplan.eu/useful_resources/costdatabase/ and for EU JRC
https://publications.jrc.ec.europa.eu/repository/handle/JRC92496
[24] See study at https://ens.dk/sites/ens.dk/files/Globalcooperation/fuel_price_projections.pdf. The cost of 0,35 USD/kg equals 36 Kenay Shillings
[27] EU Joint Research Center, JRC, Energy Technology Reference Indicator Projections for 2010-2050, currency exchange rate: 1 USD = 0.9 EUR
[28] Danish Energy Agency, Technology catalogue 2017, updated 2019, currency exchange rate 1 USD = 0.9 EUR

power					above [29]		
Nuclear realised	7,33	0	12,2	40		0,91	n.a.
Nuclear low	5	2,1	2,8	60	As geo	0,81	n.a.
Oil power	1,06	0,0	6,0	25	[30]	0,95	0,45

Table A12 Current costs and main parameters of six technologies for large-scale power supply

Fuel and electricity costs

Fuel costs are important cost parameters. Therefore, we have included fuel forecasts for 2030 and 2050 in the cost calculations of the scenarios. The fuel forecasts are shown in table A13

	2030	2050		Source
Coal	3,4	3,4	USD/GJ	IEA New Policy Scenario 2018
Fuel oil	9,6	10	USD/GJ	IEA Current policy Scenario 2018
Diesel oil	17	17,7	USD/GJ	IEA Current policy Scenario 2018
Petrol	22,5	25,2	USD/GJ	IEA Current policy Scenario 2018
Gas	22	22	USD/GJ	LPG gas, own estimate
Dry biomass	0,35	0,42	USD/kg	Wood, rice husk, study for
	2,5	3	USD/GJ	Vietnam [31]
Wet biomass	0	0	USD/GJ	Manure and other wet materials are expected to be available for free

Table A13 Fuel cost forecasts

In addition to the fuel cost, also the handling costs are important, moving the fuel from source to user. Therefore, we have included the handling costs shown in table A14

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[29] Data from the Olkuluto Nuclear Power Plant, including investment cost of 8.5 billion € for 1600 MW plant from https://uk.reuters.com/article/uk-finland-nuclear-olkiluoto/arevas-finland-reactor-to-start-in-2019-after-another-delay-idUKKBN1CE1NR

[30] Danish Energy Agency, Technology catalogue 2017, updated 2019, currency exchange rate 1 USD = 0.9 EUR, data for Internal Combustion Engine 10 MW for fuel oil.

Handling costs	2030-2050	
Oil to power plant	0,262	USD/GJ
Coal to industry	1,9	USD/GJ
Biomass to industry	1,2	USD/GJ
Diesel to transport	2,1	USD/GJ
Petrol to transport	2,1	USD/GJ
Gas to households, LPG	3,15	USD/GJ
Dry bio to convers.	0,54	USD/GJ
Wet bio. to biogas	1,49	USD/GJ
Dry bio to power plant	0,54	USD/GJ
Dry bio to households	3	USD/GJ

Table A14 Handling costs of fuel, own estimates based on Danish Energy Agency, socioeconomic assumptions, price forecasts of fuels

For comparison, the current fuel costs are for large-scale power production:

- coal 3.45 USD/GJ including handling costs of 0.05 USD/GJ

- Fuel oil 8.96 USD/GJ including handling costs of 0.26 USD/GJ

- Nuclear 1.5 (low) – 2.5 (realized)) USD/GJ

The cost of nuclear fuel includes handling and management of the spent fuel (nuclear waste). Given the worldwide problems with nuclear waste, this cost is particular uncertain and can be much higher than estimated.

With above costs of technologies and fuel, the current costs of power from large scale power production is given in table A15 for financing with 5% interest and A16 for financing with 10% interest.

USD/MWh	Investment	O&M	Fuel	Total
Geothermal power	39	11	0	50
Windpower	20	10	0	31
Solar power	31	7	0	38
Coal power	18	7	27	52
Nuclear realised	54	12	8	74
Nuclear low	37	18	5	60
Oil power ICE	9	6	72	87

Table A15 power cost of large-scale power production, 5% interest, investment in 2020

USD/MWh	Investment	O&M	Fuel	Total
Geothermal power	63	11	0	74
Windpower	33	10	0	43
Solar power	53	7	0	60
Coal power	28	7	27	62
Nuclear realised	94	12	8	114
Nuclear low	71	18	5	94
Oil power ICE	14	6	72	92

Table A16 power cost of large-scale power production, 5% interest, investment in 2020

Electricity costs for import/export use of interconnectors

The interconnectors are expected to connect to a market with electricity costs of 113 USD/MWh, and with a market response of 5 US-cent/MWh for each MW. This mean that if Kenya will sell 1000 MW, the price is lowered from 113 USD/MWh to 113-1000*0.05 = 63 USD/MWh while if Kenya want to buy 1000 MW, the price is increased to 113 +1000*0,05 = 163 USD/MWh.

Annex 4: Kenya Policy Frameworks

- o Ministry of energy gender policy, 2019

- o Sessional Paper No. 4 of 2004 and governed by a number of statutes

- o The Energy Act, 2019

- o Geothermal Resources Act No. 12, of revised 2012

- o Feed-in tariff s for Renewable Energy 2012

- o Standardized PPA for Large Scale Generators More than 10MW

- o Guidelines for Grid Connection of Small Scale Renewables

- o Petroleum (Exploration and Production) Act, Cap 308.

- o Energy Solar Photovoltaic Systems Regulations 2012

- o Electricity Licensing Regulations 2010

Government driven strategies and plans:

- o Kenya Vision 2030

- o Kenya's National Climate Change Action Plan (208-2022)

- o Kenya's 5,000+ MW Power Plan (2013-2016)

- o Kenya's Last Mile Connectivity Project (2015-2017)

- o Least Cost Power Development Plan (2013-2033)

- o Scaling-up Renewable Energy Programme (SREP) – Investment Plan for Kenya

- o Rural Electrification Master Plan

- o Kenya National Climate Change Response Strategy

- o National Electrification Program Prospectus (herein referred to as REA Prospectus) developed by REA with support from NORAD (July 2014)

- o Private Sector Strategies: Kenya National Domestic Biogas Programme (KEDBIP)

- o Kenya Country Action Plan – Cook stoves

Renewable Energy Regulations

- o Renewable scenario is cheaper Regulatory Impact Statement - Draft The Energy (Appliances' Energy Performance And Labeling) (Amendment) Regulations, 2018
- o Designation of Energy Users Gazettement
- o The Draft Energy (Improved Biomass Cook stoves) Regulations
- o The Energy (Solar Photovoltaic Systems) Regulations, 2012
- o The Energy (Energy Management) Regulations, 2012
- o The Energy (Solar Water Heating) Regulations, 2012.

Electricity regulations

- o The Electric Power (Electrical Installation
- o Work) Rules, 2006,
- o The Energy (Complaints and Dispute Resolution) Regulations, 2012,
- o The Energy (Electricity Licensing)
- o Regulations, 2012
- o The National Energy and Petroleum Policy
- o The Petroleum (Exploration, Development and Production) Bill, 2015
- o Petroleum Exploration, Development and Production (Local Content) Regulations 2014

Annex 5 Official plans for Kenya

A5.1 Power development plans

The expansion of the power sector is guided by power sector expansion plans and investment prospects. The planned power sector capacity in 2024 is given in the table below (capacity of 85 plants)

Generation Type	Production
Geothermal	1,984 MW
Hydro	921 MW
Wind	786 MW
Fuel oil	751 MW
Solar	430 MW
Biomass	108 MW
Gas turbine	60 MW
Total:	**5,040 MW**

Source: 10 Year Power Sector Expansion Plan, 2014- 2024; Investment Prospectus 2013- 2016; interviews with developers; benchmarking of time typically takes to complete projects in Kenya and internationally KenGen.

Proposed Renewables Additions (2018- 2022) with CAPEX Estimates

Technology	Capacity (MW)	Year of Installation	Estimated Budget (Million USD)
Geothermal		Based on 3,557 USD/kW	
Olkaria V	158	2019	562
Olkaria I Additional unit 6	70	2019	249
Olkaria I & IV Upgrade and Top-Up	47	2020	167
Olkaria I refurbishment	6	2021	21
Olkaria VI-PPP	140	2022	498
Olkaria Agil	140	2022	498
Wellheads Modular Plants	47	2019	167
GDC Menengai Phase 1 (Sosian, Quantum and Orpower 22)	105	2022	373

GDC Menengai Phase II	60	2021	213
Orpower 4	60	2021	213
Orpower 4	10	2021	36
Marine Power Akiira	70	2022	249
Total	**913**		**3,247**

Technology	Capacity (MW)	Year of Installation	Estimated Budget (USD)
Biomass		Based on 3,045 USD/kW	
Kwale Sugar	10	2020	30
Cummins	10	2020	30
Roadtech (Kisaju)	10	2019	30
Biogas Holdings	0.25	2022	1
Rea Vipingo DWA	1.44	2020	4
Thika way Investment	10	2020	30
Crystal Energy	40	2021	122
Sukari	35	2021	107
Sustainable Energy Management	40	2022	122
Sub Total	**157**		**477**

Technology	Capacity (MW)	Year of Installation	Estimated Budget (USD)
Wind		Based on 2,030 USD/kW	
Ngong Wind Farm III	10	2020	20
Meru (Isiolo) Wind Farm I	80	2021	162
Turkana Wind	300	2018	609
Oldanyat	10	2021	20
Kipeto Wind	100	2020	203
Prunus	50	2021	102
Electrawinds Kenya (Bahari) Phase I	90	2022	183
Chagem/Chania Green	50	2020	102
Kinangop/Aeolus	60	2022	122
Aperture Green	50	2022	102
Total	**800**		**1,624**

Proposed Priority Mitigation Actions in the Energy Supply Sub-Sector for the Period 2018-2022

Strategic Objective 3.2.1: Ensure an electricity supply mix based mainly on renewable energy that is resilient to climate change, and promote energy efficiency				
Issue/Problem: Renewable (and affordable) electricity supply with low GHG emissions needs to increase to meet the demands of a growing population and industrializing nation.				
Opportunity	**Actions**	**Sector**	**Mitigation**	**SDG Target**
Availability of renewable energy resources	Develop 2,405 MW of new renewables (Geothermal: 913 MW, Solar: 442 MW, Hydro: 93 MW, Wind: 800 MW, Biomass/Biogas: 157 MW and Distributed solar and mini-grids: 30 MW) and retire 300 MW of thermal plants (Kipevu: 120 MW, IberAfrica: 108.5 MM and Tsavo: 74 MW) by 2022	MoE, ERC, KenGen, KP, County Governments, Local NGOs, Private sector, GDC	Adaptation and Mitigation	1,7,8,9, 11, 2, 13
Captive renewable generation potential	Increase captive renewable energy generation capacity by 250 MW by 2022 (at least 50 MW of solar, wind, hydro and 200 MW of cogeneration)	Industry, KAM, KIRDI, MoE, ERC	Adaptation and mitigation	7,9,12, 13
Significant proportion of the population are either not connected to the grid or have unreliable electricity supply	Expand, refurbish, and modernize electricity infrastructure with Unspecified Kilometers of new lines and new or upgraded transformers by 2022.	MoE, KP, Ketraco, ERC	Mitigation and adaptation	1,2, 3,7,13, 15

Available renewable energy resources	Increase the use of green energy along agricultural value chains by 5 MW by 2022	MoE, Ministry of Agriculture and Irrigation, Ministry of Industrialization and Enterprise Development, KIRDI, GDC, ERC	Mitigation and adaptation	1,2,7,9, 13
Opportunity	**Actions**	**Sector**	**Mitigation**	**SDG Target**
Available renewable energy resources	Promote the increased use of renewable energy resources (small hydros, solar, biogas, biomass, wind and hybrid systems) Carry out research on possible application and extent of use of renewable energy resources	MoE, County Governments, ERC	Enabling	1,2,7,9, 13
Inefficiencies in electricity generation, supply and use	Improvement of operational efficiency in generation and reduction of transmission and distribution losses Reduce the distribution and transmission losses from current 18% to 14% by 2020 Improve electricity system utilization and efficiency through demand management Optimize the operations of the Seven Forks Dams Promote efficient lighting technologies such as LED and CFL bulbs (Distribution to households)	MoE, ERC, KenGen, KP, KAM, KEPSA, Ministry of Transport, Infrastructure, Housing and Urban Development (MTIHUD), KIRDI	Mitigation and adaptation	

	Building efficiencies through codes and standards			
	Energy efficiency programmes for users (industries, national and county governments, households) Awareness, training, skills, incentives for energy efficiency programmes (Enabling activities)			
	Establish Standards and labeling for at least 5 additional products			
Opportunity	**Actions**	**Sector**	**Mitigation**	**SDG Target**
Biennial updates of the power development plans	Mainstreaming climate change in electricity planning process Develop and apply of tools to integrate climate change considerations and broader development impacts into electricity sector master planning processes - Develop draft prototype of assessment tools, including methodology development workshops with relevant stakeholders, by fourth quarter 2018 Development of concept and workshop series on how to integrate the	MoE, ERC, KP	Enabling activity	

	tools into the LCPDP process, by fourth quarter 2018 Regular reporting of climate change mitigation and adaptation implications in the electricity sector master planning documents.			
Primary Fossil Fuel Production (currently all plans are unconfirmed)	Mainstream climate change considerations in the planning of the primary fossil fuel (crude oil, gas and coal) production activities Incorporate the climate change impacts, especially GHG emissions, of the production processes in the national GHG inventory estimation Access the impact of proposed production activities on the realization of the NDC	Ministry of Petroleum and Mining, Ministry of Environment and Forestry, ERC	Enabling	

Source: National Climate Change Action Plan 2018-2022

A5.2 Actions in energy demand

The prevalent energy use practices are not necessarily energy efficient. In addition to available technology, some important determinants for energy use practices appears to the socioeconomic class (i.e. linked to wealth/poverty) and education levels of the household decision-makers. These attributes also seem to influence the choice of energy and information sources. Other important factors include the cost of energy and quality of appliances, user attitudes, and access to adequate information on energy conservation and efficiency.

We find that there have been and are several Energy Efficiency policies/regulations and initiatives in the country. However, their implementation and effectiveness face (or faced) a myriad of challenges including lack of support from the regulators, the regulated and the political leadership. Most Kenyans also are oblivious of these regulations or policies and the specific Energy Efficiency initiatives in their localities.

Proposed Priority Mitigation Actions in the Energy Demand Sub-Sector for the Period 2018-2022

Enhancing energy security and reducing dependence on unsustainable energy resources				
Issue/Problem: 80% of Kenyans depend on biomass for primary energy most of which is non-renewable. This leads to indoor air pollution and deforestation				
Kenyans depend on biomass for primary energy.	Develop and distribute 4 million improved biomass stoves by 2022 -Charcoal (2 million) -Biomass (2million)	MoE, KFS, ERC, County Governments, Local NGOs, Private sector	Mitigation and adaptation	1,2,3, 7,13,15
Existing technology, resources, and potential market for LPG, ethanol, and biogas	Develop and distribute 1 million clean energy stoves by 2022 Develop LPG, biogas, and ethanol stoves and related supply chains	Ministry of Petroleum and Mining (MPM), MoE, KFS, ERC, County Governments, Local NGOs, Private sector	Mitigation and adaptation	1,2,3, 7, 13,15
	Strengthen the institutional frameworks that oversee household energy services and provide an adequate policy framework for the promotion of sustainable wood fuel	MPM, MoE, MEF, KFS, ERC, County Governments, Local NGOs, Private sector	enabler	

production and plantations (See Agriculture sector) Strengthen supervision and law enforcement with regard to sustainable wood fuel supply strategies							

Emission Reductions through Development and Distribution of 4 million Improved Biomass Stoves by 2022

	tCO2e per stove per year	2018	2019	2020	2021	2022	2030
Number of Charcoal Stoves		200,000	600,000	1,200,000	1,600,000	2,000,000	2,000,000
Number of Biomass Stoves		200,000	600,000	1,200,000	1,600,000	2,000,000	2,000,000
Emission Reductions from Charcoal Stoves	2.00	400,000	1,200,000	2,400,000	3,200,000	4,000,000	4,000,000
Emission Reductions from wood fuel Stoves	2.50	500,000	1,500,000	3,000,000	4,000,000	5,000,000	5,000,000
Total Annual ER from Improved Stoves (MtCO2e)		0.90	2.70	5.40	7.20	9.00	9.00
Total Annual ER from Improved Stoves -Adjusted for 70% Implementation Rate (MtCO2e		0.63	1.89	3.78	5.04	6.30	6.30

Emission Reductions through Development and Distribution 1.5 Million Clean Energy Stoves by 2022

	tCO2 per stove per year	2018	2019	2020	2021	2022	2030
Number of LPG Stoves		100,000	200,000	300,000	400,000	500,000	500,000
Number of Biogas Stoves		50,000	100,000	150,000	200,000	250,000	500,000
Number of Ethanol Stoves		50,000	100,000	150,000	200,000	250,000	500,000
Emission Reductions from LPG Stoves/HH per year	1.19	119,000	238,000	357,000	476,000	595,000	595,000
Emission Reductions from Biogas Stoves/HH/year	1.19	59,500	119,000	178,500	238,000	297,500	297,500
Emission Reductions from Ethanol Stoves/HH/year	1.19	59,500	119,000	178,500	238,000	297,500	297,500
Total Annual ER from Clean Fuel Stoves (MtCO2e)		0.238	0.476	0.714	0.952	1.190	1.190
Total Annual ER from Clean Fuel Stoves - Adjusted for 70% Implementation rate (MtCO2e)		**0.167**	**0.333**	**0.500**	**0.666**	**0.833**	**0.833**

Source: Adapted from Government of Kenya (2017), NDC Sector Analysis

Emission Reductions through Energy Demand Actions by 2022

Emission Reduction (tCO2e)						
Stove Types	2018	2019	2020	2021	2022	2030
Charcoal Stoves	280,000	840,000	1,680,000	2,240,000	2,800,000	2,800,000
Biomass/firewood Stoves	350,000	1,050,000	2,100,000	2,800,000	3,500,000	3,500,000
LPG Stoves	83,300	66,600	249,900	333,200	416,500	416,500
Biogas Stoves	41,650	83,300	124,950	166,600	208,250	208,250
Ethanol Stoves	41,650	83,300	124,950	166,600	208,250	208,250
Total Annual ER (tCO2e)	796,600	2,223,200	4,279,800	5,706,400	7,133,000	7,133,000
Total Annual ER (MtCO2e)	0.8	2.2	4.3	5.7	7.1	7.1

Source: Adapted from Government of Kenya (2017), NDC Sector Analysis

Proposed Mitigation Actions in the Agriculture Sector for the Period 2018-2022

Reducing GHG emissions from agricultural systems without compromising productivity				
Issue/Problem: Climate change is negatively impacting agricultural productivity and resilience of value chain actors, including households (farmers, pastoralists and fisher folks)				
Opportunity	Actions	Sector	Mitigation/ Adaptation/	SDG Target
Agroforestry	Increase the total area, under agroforestry at farm level by 200,000 acres (81,000 Ha) by 2022.	Ministry of Agriculture and Irrigation (MoAI), KFS, County Governments	Adaptation and mitigation	1, 2, 13, 15

Sustainable Land Management	Increase farm area under sustainable land management by 250,000 acres (101,000 Ha) by 2022.	Ministry of Agriculture and Irrigation, County Governments	Adaptation and Mitigation	1, 2, 13, 15
Efficient livestock management systems that enhance productivity.	Implement the Dairy Nationally Appropriate Mitigation Action (NAMA) 267,000 households involved in the programme leading to Greenhouse Gas emissions reductions.	Ministry of Agriculture and Irrigation (MoAI), County Governments	Adaptation and mitigation	2, 1,15
Manure management	Increase adoption of biogas technology use by 80,000 households leading to abatement of 1.2 million tCO2e by 2022 (Linked to biogas cooking in the energy sector) Increase adoption of biogas technology use by at least 200 abattoirs leading to abatement of 0.8 million tCO2e by 2022	Ministry of Agriculture and Irrigation (MoAI), County Governments	Adaptation and mitigation	2, 1,15
Overcapacity of artisanal fishing vessels	Increase deep/offshore fishing fleet from 9 to 68 by 2022	Ministry of Agriculture and Irrigation	Adaptation/ mitigation	1,2,14 and 15
Aquaculture production	Increase the number of farmers using low-carbon (Recirculating) aquaculture systems from 20 to 180 by 2022	Ministry of Agriculture and Irrigation	Mitigation and Adaptation	1,2, 14 and 15
Increased rice production	Put 50% of 30,000 hectares under rice production into efficient production technologies by 2022. Increase area under rain fed rice production from 400 hectares to 600 hectares by 2022	Ministry of Agriculture and Irrigation, County Governments	Adaptation and mitigation	1,2, 3,12, 13, 15

Source: Adapted from Government of Kenya (2017), NDC Sector Analysis
Under the Bonn Challenge, Kenya has established a restoration target of 4,210,000

hectares by 2030, described in Table 3.3.1. The Bonn Challenge is a global effort to restore 150 million hectares of the world's degraded and deforested lands by 2020 and 350 million hectares by 2030.

Kenya: Existing Forest Restoration Targets

Category	Description	Existing Restoration Target
Forest Land without Trees - Planted Forests and Woodlots	Planting of trees on formerly forested land. Native species or exotics and for various purposes, fuel-wood, timber, building, poles, fruit production, etc.	4,100,000 Ha
Degraded Forest Land - Silviculture	Enhancement of existing forests and woodland of diminished quality and stocking, e.g., by reducing fires and grazing and by liberation thinning, enrichment planting, etc.	10,000 Ha
Agricultural Land - Agroforestry	Establishment and management of trees on active agricultural land (under shifting agriculture), either through planting or regeneration, to improve crop productivity, provide dry season fodder, increase soil fertility, enhance water retention, etc.	100,000

Source: Bonn Challenge (2016). Kenya. Accessed at: http://www.bonnchallenge.org/flr-desk/kenya

2014 Draft National Strategy, renewable energy expansion plans until 2030

Energy Type	Expansion Plans
Solar	+500 MW +300,000 solar home systems +700,000 solar water heating units
Biogas/biomass	+10,000 bio digesters +1,200 MW of biomass co-generation
Geothermal Energy	+5,500 MW
Small hydro generation	+300 MW
Wind Energy	+3,000 MW

ENERGY ACCESS IN KENYA
A6.1 Status summary

Kenya has seen one of the fastest increases in electrification rates within sub-Saharan Africa since 2013, 75% of the population had access *(Kenya Energy Outlook (IEA's), 2019)*. Kenya aims to reach full access by 2022; the grid would be the principal least-cost solution for the majority of the population (mainly in the south) still lacking access

Currently in Kenya, 99% of the existing off-grid electrification is provided by small-scale stand-alone PV systems. Future plans include mini-grids powered by solar and diesel. However, the available funds can only mobilize projects at a limited number of areas, making even more important to prioritize least-cost solutions that are sustainable at long-term (Moner-Girona, Szabó, & Bhattacharyya, 2016). Each candidate solution has its own advantages and needs to be assessed in a comprehensive framework dealing with the several aspects of the issue, including resource availability, economic feasibility and technological reliability and robustness. Accordingly, it employs a least-cost electricity analysis that spatially compares the costs of several decentralized options and grid extension across the country. Identifying locations with advantageous off-grid options can support a better planning of capacity needs, divert grid extension towards areas with higher yields, and avoid fragmentation of energy investments.

Access to energy is as a Continuum of service levels; Multi-Tier Framework *(Measuring Energy Access, Introduction to the Multi-Tier Framework by the World Bank Group)* measures not only whether users receive energy services, but also whether these services are of **adequate quality, reliable, affordable, safe and available** when needed. MTF provides a path towards universal access that can be customized for each country circumstance; acknowledging progress as households move from lower to higher tiers.

Among the decentralized power options, decentralized renewable energy options such as mini-hydro, PV stand-alone and mini-grid systems with the option of complementing with wind turbines, and clean technologies will enhance the access. The model output is placed side by side with Kenya's national Rural Electrification Master (REM) Plan.

In 2018, the energy mix remained relatively stable with the contribution of geothermal sources increasing to 47% up from 43.6% in 2017. Hydro and conventional thermal plants

contributed 30.1% and 20.6% of the total energy produced in 2018, respectively (The Kenya Power and Lighting Company Limited-KPLC, 2018). In 2017, wind power in Kenya contributed only a small amount of the country's electrical power. However, its share increased dramatically in 2018 with the addition of the 310 MW Turkana wind farm, increasing the share of wind to 13% in the total capacity. Hydroelectric generation fluctuates due to the year-to-year hydrologic conditions (±20% compared with average values) making the electricity generation portfolio susceptible to changing weather and climate patterns. Solar energy accounted for <1% of the power generation capacity in 2018; yet the recently installed 55 MW PV facility in Garissa will slightly increase the share of solar.
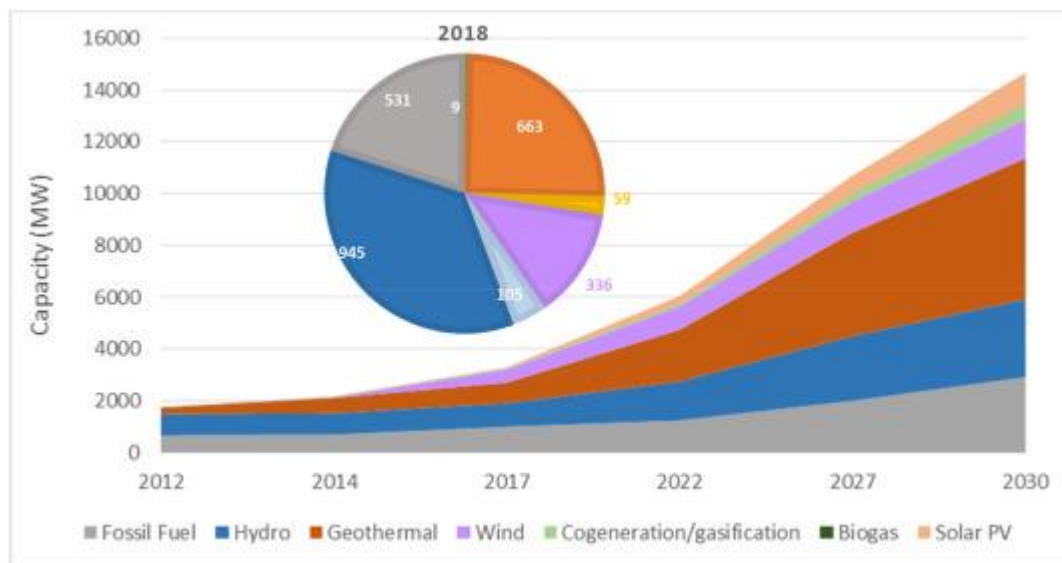
Source: The Kenya Power and Lighting Company Limited-KPLC, 2018)

As of 30th June 2014, the distribution system comprised of 1,212 km of 66 kV lines, 20,778 km of 33kV lines, 30,860 km of 11 kV lines and low voltage lines, primary distribution substations with transformation capacity of 3,311 MVA and distribution transformers with total capacity of 6,317MVA. It is projected that by 2020, capacities of primary and distribution substations will be 11,888 MVA, 190,204 MVA, while the lengths of HV lines and MV lines will be 7,925 km and 118,875 km respectively. In the year 2030 capacities of primary distribution substations and distribution transformers will be 37,565 MVA and 60,104 MVA, while lengths of HV and MV lines will be 25,043km and 187,825 km, respectively.

The government also plans to develop new transmission lines comprising of about 5,438 km in the short term and 18,173 km by 203382. Through the LCPDP process and feasibility

studies, KETRACO has identified priority projects for implementation totaling about 6,270 km of transmission lines comprising 2,081 km of 132 kV, 1,278 km of 220 kV and 2,299 km of 400 kV AC lines as well as 612km of 500 kV High Voltage Direct Current (HVDC) line between 2011 and 2017. It is projected that by 2033 KETRACO will have constructed over 18,000 km of transmission lines.

A6.2 Gender and Energy

Access to sustainable energy by all is a key global development target under the Sustainable Development Goals (SDGs). Goal 7 on access to affordable, reliable, sustainable and modern energy for all; and goal 13 on climate change and its impacts recognize energy as a key driver to achieving Goal 1, which aims to end poverty and hunger. Sustainable energy resources enhance the quality of life and wellbeing of the population by enabling the production of goods, access to and provision of services related to water through water pumping; agriculture through food processing and irrigation; health, education, industrial productions and environmental conservation. Provision of modern energy services is therefore critical for social- economic development and environmental sustainability.

Mainstreaming gender perspectives in Kenya's national energy policy, budgeting, planning and project management is critical in ensuring the effectiveness of not only the energy programs, but also all development activities that involve energy use. Studies show that energy affects men and women differently. While the degree of gender implications may differ from one energy project to another, projects that deal with people should not be gender-neutral. A gender-neutral project assumes that women and men have the same needs, priorities, opportunities and expectations. Such approaches reinforce existing gender-based discrimination. This effectively makes some marginalized communities to remain underserved by energy policies, appropriate technologies and delivery models. (Poor Peoples Outlook; 2018). Basic services such as electricity for lighting and cleaner cooking technologies are still a luxury for many rural women and men hence the need to improve access to modern energy services.

The Sustainable Development Goal No.5 specifically addresses gender equality in all forms of development. The goal aims at building more environmentally sustainable and climate-resilient societies, whereby both women and men have equal opportunities to access and control available resources within their environment. Access to modern energy is a key enabler for women's empowerment as it plays a key role in meeting practical gender needs of women such as cooking, food processing and water hauling as well as strategic gender needs like street lighting for safety and power for enterprise

development. While access to energy services would not necessarily guarantee gender equality, it helps in relieving women and girls of the drudgery associated with their daily tasks and provides them time for income-generating opportunities and education (UNDP; 2015).

A6.3 Existing Plans/Strategies

GoK has embarked to increase connectivity per year to one million starting in the 2014/2015 financial year to reach 100% connectivity by 2022. To achieve these targets, the following strategies are being employed;

Rural Electrification Master Plan: The GoK is implementing initiatives to make electricity more accessible to the population especially in rural areas. Among the consumers were some 382,630 rural households electrified through the Rural Electrification Programme under REA. In addition, REA connected more than 23,000 public facilities in the last five years constituting 89% of the main public institutions that were to be electrified in REA's first strategic plan (2008/09-81 Updated LCPDP 2011-2031, GoK 82 Updated LCPD 2011-2031, GoK 31 2012/13). The focus on electrification of primary schools started in 2013, as one of the priority projects by the new government, which was elected in March 2013. By June 2013, out of the overall 21,222 primary schools in the country, 10,157 had been electrified. To complete the electrification of all primary schools by June 2015, the Authority put in place a programme aimed at completing electrification of the remaining 11,062 primary schools in two years with 5,000 primary schools planned for electrification in the 2013/14 financial year and 6,065 in the 2014/15 financial year.

The 5,000+MW Project: A roadmap to increase the installed generation capacity from 1664 MW as at October 2013 by at least 5000 MW to 6,762 MW by 2017. Through the plan the generation cost is projected to reduce from US¢ 11.30 to 7.41, while indicative end-user tariffs are projected to reduce from US¢ 14.14 to 9 for commercial/industrial customers and from US¢19.78 to 10.45 for domestic customers

Scaling Up Renewable Energy Programme (SREP). The decentralized segment, mini-grids development has been getting the most attention, especially from the Government, development partners, and programs such as SREP. It is also an area of growing interest from the private sector. Private sector approaches to mini and micro-grid development are being developed, though there is still no formal regulatory framework for this. Donors such as DfID, working with GIZ, have recently introduced innovative mini-grid development financing, with the introduction of Results Based Financing, targeting 20 private-sector-operated mini-grids and working with locally based financial institutions.

Conventional solar, wind, diesel or hybrid plants exist, with 22 mini-grids developed by Kenya Power and Lighting Company (KPLC), with a reach of over 20,000 customers,

mainly installed in remote areas. The private sector and civil society have installed at least a dozen wind/solar/micro hydro/hybrid mini-grids. Isolated solar/diesel mini-grids managed by KPLC contribute almost 1 MW, while wind mini-grids produce 550 kW. Efforts are underway by the Ministry of Energy and Petroleum, working with Kenya Power and REA to scale this up under hybrid mini-grid initiatives. At least 68 new sites are in development under Kenya's Scaling up Renewable Energy Programme (SREP) Investment Plan, 2011.

Last Mile Connectivity Project- The project involves extension of the Low Voltage network (415 and 240 volts) around existing distribution transformers within the transformer protection distance, currently caped at a radius of 600 Metres.

The Project aims to offer connections to up to 1,416,000 connectable households in a period of 3 years (2015-2017).

Provision of Stima loan: Stima Loan is a Kenya Power initiative in partnership with the French Development Agency (AFD) through the Government of Kenya. It aims at connecting low income families that cannot afford the connection fees upfront by providing loans at 5% administration fee (one-off payment) and 20% upfront payment. The balance is payable over a period of 24 months. As at May 2014, more than 49,000 Kenyans have benefitted from the loan scheme.

Least Cost Power Development Plan (LCPDP): A long-term commitment (2013-2033) to electrification plan that provide a framework for institutional, technical, economic and financial design and implementation of specific programs.

National Electrification Strategy that is expected to provide a framework for electrification, encompassing technical, financial, and institutional planning.

Distribution Expansion Plan 2014-2018. The medium term distribution expenditure plan was projected to cost KSHS 35,067 million equivalents to US$433.45million. Besides the distribution master plan, Kenya Power through their Distribution Division has developed strategies geared towards absorbing the additional generation capacity totaling to about KSHS 5 Billion. Funding the electrification of informal settlements. Informal settlements are a reality of Kenya's urban areas. Millions of Kenyans live in informal settlements with unsafe electrical installations and limited access to legal connections, while power theft in the informal settlements results in high commercial and technical losses for the Company. However, electrification of informal settlements is often uneconomic for power utilities as returns are too low to recover the cost of investment, operations and service.

The Company, therefore, has been exploring sustainable ways to provide electricity to the settlements in partnership with the Government and development partners. Towards this, in February 2012, the Company obtained a grant from the International Development Association (IDA), acting as administrator of the Global Partnership on Output-Based Aid (GPOBA), for electrification of informal settlements in the country. The programme entails the Company pre-investing in the electrification of informal settlements, after which GPOBA will reimburse the Company US$75 per meter connected up to a total of US$5million; while the World Bank will reimburse US$150 per meter connected up to a total of US$10 million. About 66,000 customers are expected to benefit from this initiative.

The Kenya Joint Assistance Strategy (KJAS) presents a core strategy of 17 development partners for 2007–12. The KJAS partners aimed to aid the government program in several ways. They will continue to support implementation of substantial changes in the organization and structure of the electricity market (including agreement on a management contract for the Kenya Power and Lighting Corporation), and institutional reforms of the rural electrification program. They will finance investments to expand generation capacity (including through geothermal and hydro); improve efficiency of power production, transmission, and distribution; and increase access to modern energy services in rural areas. They will support cross-border projects, including the Kenya–Ethiopia, and the Kenya–Tanzania–Zambia power interconnection projects.

Kenya Joint Assistance Strategy 2007-2012 capacity of the regulatory bodies and of the Ministry of Energy, improves energy management and governance, and promotes cross-border cooperation in the energy sector.

They will facilitate access to environmentally friendly technology, including solar and wind power. Finally, they will support Kenya's efforts to regularize, improve efficiencies, and reduce the environmental impact of the charcoal industry, on which 75% of Kenyans depend for domestic energy.

M-KOPA business models for solar- raising US$ 20 million (KSHS 1.72 billion) to fund expansion of their customer base from 50,000 homes to one million homes by 2018. M-KOPA provides affordable solar-powered lighting and mobile charging to rural Kenyans on a pay-as-you-go basis, with payments conveniently sent via M-PESA (Kenya's leading mobile money service). When customers have fully paid for the value of the solar product, they own the product and can continue to use it freely.

According to International Finance Corporation 2012 report, the private sector is vibrant in the solar sector, with 21 distributors/importers, and over 1500 SMEs selling solar lanterns in Kenya. There are currently with 29 quality verified solar lighting products, from 17 manufacturers, currently on sale in the country. The solar lantern market grown

by more than 200% in the last 3 years with about 700,000 solar lanterns sold to off-grid families in rural Kenya by end of 2014.

In light of the overarching objectives, these plans are ambitious enough to meet the challenge, and have targets that aim to achieve the energy access objective sooner than 2030. The activation of these plans, are not fully operationalized, and their funding, will be necessary to make them effective.

A6.4 Clean Cooking

While universal access to modern cooking services by 2030 refers to both use of non-solid fuels and improved (efficient) cook stoves, clean cooking refers to use of non-solids fuels for cooking. Hence, According to 2009 census report over 80% of rural and 10% of urban households regularly use firewood, while about 7% of rural households, and over 30% of urban, use charcoal. The rate of use of biomass has outstripped the rate of supply thus rendering biomass non-renewable sources of energy. In Kenya, use of improved (efficient) cook stoves is being taken as a stopgap measure as efforts are being made to transit to clean cooking fuels and sustainable bioenergy strategies being put in place.

A6.4.1 existing plans/strategies for clean cooking

- o The Government has prioritized clean cooking in its climate change action plan 2018-2022 and recognizes its impacts on climate change; therefore, it is at the forefront in advocating for improved cooking technologies and alternative clean cooking fuels.

- o The Kenya National Action Plan (NAP) for Clean Cook stoves and fuels, which has a target of 5 million households by 2020.

A6.5 Existing Gaps
A6.5.1 Universal Access - Electricity

The main challenges/gaps that Kenya faces to reach SE4ALL universal access to electricity by 2030 are as follows:

Affordability of electricity:

Although connection fees were significantly lowered in May 2015, their cost is still a deterrent for rural households and the poor especially female -headed households. The same is true for off-grid solutions such as solar home systems and mini-grids, although these can be scaled down to an appropriate cost for consumers.

Although universal access makes sense from economic and equity perspectives, its financial viability is often uncertain. The financial viability of electrification for those

without access usually requires subsidies to cover part of its capital and/or operating costs, as many unconnected households cannot pay fully for the cost of electricity service.

The upfront cost of connection is a more serious barrier to extending access than the monthly payments for consumption and only 35–40% of household in electrified areas are usually ready to connect.

Fragmented energy access market:

Most population lacking access to modern energy services are dispersed and not properly mapped which is a challenge for companies providing services to this market resulting in uncoordinated, immature and not widely known services to stakeholders.

Need to develop mini grid policy

Although there are strategies and plans to address access above 1 MW, there is no comprehensive strategy for mini-grids and stand-alone systems for access below 1 MW. Such a strategy will boost the development of micro-decentralized systems that may be a cost effective solution to small settlements in remote areas of Kenya.

- o Lack of regulations to a policy for mini grids
- o Lack of net metering regulations

Infrastructure

Primary substations (and BSPs) are equipped with just a single transformer and even those with two or three transformers are often loaded such that no spare capacity exists to cater for a transformer failure. This is a particular issue for parts of the network with no alternative means of supply.

Much of the distribution network does not have adequate capacity to effectively manage the present demand; the distribution network suffers from poor reliability and quality of supply, which is generally due to underinvestment. Many parts of the distribution network are supplied over extremely long, radial 33 kV and 11 kV feeders, with no alternative source of supply.

In some cases, 33 kV feeders may be hundreds of km long, with many spurs, resulting in a total length (in extreme cases) in excess of 1000 km supplied from a single source. A fault on such a long feeder will have widespread impact, be difficult to locate and therefore will result in a long restoration time.

Due to excessive feeder lengths and use of undersized conductors, voltage levels on feeders, particularly outside of the urban areas are typically poor and significantly under

the required standard. Automatic voltage regulators (AVRs) have been installed on feeders in the past, however many of these have failed and have subsequently been bypassed.

Excessively long, undersized feeders also result in high losses.

Electricity generation shortage: An obstacle to rural electrification in many countries with low access rates is insufficient generation capacity of the main electricity system. It is unrealistic to expect these countries to make more than modest gains in increasing electricity access by means of grid extension until the capacity constraint is eased.

Costs and financial considerations:

Lack of appropriate incentives. The high costs of electricity supply in rural areas and the limited capacity of households to pay for the service make it difficult to attract investment in rural electrification. To do so, it requires a system of tariffs and subsidies that ensures sustainable cost recovery while minimizing price distortions. However, such a revenue generation scheme is absent.

High costs of supplying rural and peri-urban households. Low population density and a very high percentage of poor households characterize most rural communities, as well as many peri-urban areas. Demand for electricity is usually limited to residential and some agricultural consumers, and many households consume less than 30 kilowatt-hours (kWh) per month. The combination of these factors results in high costs of supply for each unit of electricity consumed.

Financial and Operational Sustainability. Making service sustainable is one of the main challenges in extending access, both in rural electrification and in low-income urban areas.

While a large portion of capital costs is usually subsidized through specially designated funds (frequently supported by donors), more financial assistance is often needed because many households cannot pay the full cost of operation.

Rural Electrification Strategy:

Adequate design and effective implementation of a rural electrification program requires technical and managerial skills that are not always available. This process may entail new or amended legislation, institutional strengthening, planning, and establishing technical standards and regulatory procedures tailored to the nature of rural electrification.

Under these circumstances, extending access in rural areas requires a system of subsidies that recognizes the lower income levels of rural households and higher costs of supply.

A6.5.2 Universal Access – Clean Cooking

For Kenya to achieve universal access to clean cooking by 2030 the following gaps, need to be addressed:

Regulatory issues:

Policy, strategy and regulations related with biomass use are still insufficient to ensure the sustainable use of biomass in the cooking sector despite being the major energy consumer in the country.

Charcoal production sector is largely unregulated and, therefore, informal with low efficiency in transforming biomass into charcoal.

Limited availability of performance or other standards for energy products and where they exist, lack of implementation and enforcement. Consumers are therefore unprotected against substandard equipment and services.

Awareness and knowledge issues:

Lack of awareness of indoor pollution and its impact on health within the general population limits the rate of adoption of efficient cooking stoves, especially by the rural population.

People tend to prefer traditional cooking solutions because of cultural heritage. In order to increase the use of modern cooking solutions it would be necessary to raise awareness about its benefits so people will start to shift to cleaner or improved cooking.

Need to mainstream gender, cultural practices and the nexus of energy, especially with the sectors of health, cooking and water.

Information and sector analysis:

There are no gender-disaggregated data on the status of the clean cooking appliances and fuels adoption. Statistics used are estimates. This needs a comprehensive study to inform the sector.

No impact study of the ongoing clean cooking appliances and fuels adoption.

Cook stove quality and performance:

The number of improved cook stove models and fuel production solutions customized for local environments is still low, there is evidence that many basic ICS perform poorly in the field at least in part due to the difficulty of accessing high quality materials, and systemic support for innovation

R&D on breakthrough solutions that can offer higher performance (e.g., fan gasifiers) and, even more important, more attractive and functional end-user focused designs, is still limited.

For clean cooking and improved solutions that do reach the market, access to standardized testing is limited or unaffordable for many, and does not increase end user understanding of their likely performance so they are able to make informed purchasing decisions.

Last-mile distribution and producer finance:

Distribution of clean cooking products is costly, with no easy answers to the challenge of reaching rural consumers; progress will require both experimentation with new institutional and retail approaches and significant investment into channel development.

In the immediate term, commercially oriented ventures likely need to focus on more profitable urban and charcoal user consumer segments, reaching the rural consumer requires cross-subsidization from more profitable urban market segments or less commercially driven business models.

Building successful last mile clean cooking businesses in Africa is a costly endeavor, due to product importation hurdles, logistic and transport challenges, the need for intensive consumer marketing, and the importance of extending credit to both last mile retailers and end-users (i.e., via pay as you go schemes). Global Village Energy Partnership, *Kenya Market Assessment*, 2012.

A6.6 High Impact Initiatives for Energy Access
A6.6.1 Increasing Access to Modern Clean Cooking

MoE to lead on the creation of a cross-sectoral initiative to bring together different on-going efforts, like Global Alliance Clean Cookstove (GACC), and improve coordination across agencies, private sector, CSOs and NGOs. This initiative aims to; Foster an enabling environment by engaging national and local stakeholders, building the evidence base for the benefits of stoves, promoting standards and rigorous testing protocols and enhancing monitoring and evaluation.

- o Promote industry standards for efficiency, safety, and emission reduction, based on testing and certification for clean cooking appliances, such as ICS. Support development and implementation of large national programme on scaling up ICS.

- o Contribute to improving the policy framework, train entrepreneurs and develop sustainable value chains and robust infrastructure for clean and efficient cooking stoves and fuels.

- Support continuous research on consumer use and demand for efficient stoves and on the design of products that meet user needs.

- Universal Adoption of Clean Cooking Solutions, objective that can be pursued under the umbrella of the GACC;

- Human and Institutional capacity development - cook stoves;

- Support the use of improved cooking appliances by engaging youth organizations and women SMEs in the production, dissemination and distribution of these technologies.

- Conduct awareness campaigns on the benefits of clean cooking appliances and fuels for remote/isolated populations. These awareness campaigns should additionally inform consumers on how to purchase quality ICS.

- Raise general awareness to the public about the available clean cooking technologies.

- Innovative Finance, to support financial closure and financing access to energy services and clean cook stoves.

- Develop financing schemes to provide credit to households that cannot afford the upfront costs of access to modern energy services.

- Provide regulatory support for scalable and sustainable business and financial models.

A6.6.2 Increasing Access to Modern Electricity

Rural Electrification and Renewable Energy Corporation (REREC) formerly REA (Rural Electrification Authority: is tasked with the development and implementation of a clean energy mini-grid programme as a means to accelerate clean off-grid access, including: To Provide distributed electricity solutions that support productive use and economic development , Create more favorable business environments with appropriately refreshed (or new) policies, regulations, and energy plans to incentivize commercial investments (small, medium and large scale) and develop markets (power hive concept). Facilitating financing for mini-grid and stand-alone energy access projects.

Formulation of mini- grid regulation: - effectiveness of enforcement of the liberalized regulatory environment by Energy and Petroleum Regulatory Authority: the ease of obtaining generation and distribution licenses by independent power producers, as well as Power Purchase Agreements in the event of the grid coming to the locality of the mini grid project.

Distributed electricity solutions:-Distributed electricity solutions i.e. mini-grids or individual systems are deployed to the underserved community too distant from the existing grid and/or that their demand is too small to justify the high fixed cost of extending the grid.

The regulatory environment for Pico solar and solar home systems for lighting and productive use is already being developed; REREC has published regulations for installation of solar systems, and Lighting Africa (IFC/World Bank) has made major strides in helping the market to improve product standards. Kenya Renewable Energy Associations (KEREA) is currently implementing a voluntary quality accreditation programme for solar vendors and integrators.

Strategy is to increase competition and flexibility in mini-grid provision through measures to simplify licensing: development of an off-grid strategy, a conducive, legal, and regulatory environment must be developed to support the private sector and avoid direct subsidization as much as possible.

Create a clear timetable for grid rollout to avoid unexpected duplication of infrastructure. It should be very clear to installers of off-grid equipment what time they have before the grid arrives at the locality, as this will affect the payback periods that they need to work with when considering their investments.

Improve smart grid technology solutions, grid-scale storage and interaction between renewables and fossil fuels.

A6.7 Relevant High-Impact Opportunities

o Clean Energy Mini-Grids, to accelerate clean off-grid access.

o Develop and implement small-scale renewable energy solutions.

o Provide distributed electricity solutions that support productive use and economic development.

o Study on decentralized system. Mapping out of regions/populations for decentralized energy systems.

o Invest in disaggregated data to reveal gender disparities in relation to energy poverty to achieve effective gender mainstreaming in decentralized energy solutions. This is crucial in informing relevant policy interventions.

o Mini-Grid /micro-grid Development strategy. Development of mini grid and micro grids policy. Develop framework for implementation of mini-grids.

- o Scaling Up of Renewable Energy Programme (SREP).

- o Setting up of commercial renewable energy micro grid in rural areas without access to national grid.

This is based on the list of HIOs identified by the Global Action Agenda

- o DfiD in partnership with AfD solar PV mini-grids: € 30 million available for funding mini-grid projects (Solar PV mini-grids).

- o Kfw Solar PV mini-grids High-Impact Initiatives Targeting 3 pilot projects. Result based financing.

- o DfiD Hydroelectric initiative, Kfw Solar PV minigrids: Financing electricity access

- o Joint Import up to 50 kW, Joint credit Mechanisms (JCM)-Japanese government.

- o Local manufacture of small wind turbines supporting electricity access.

- o Universal Adoption of Clean Cooking Solutions, objective that can be pursued under the umbrella of the GACC

- o Improve smart grid technology solutions, grid-scale storage and interaction between renewables and fossil fuels.

- o Innovative Finance, to support financial closure and financing access to energy services and clean cookstoves:

- o Develop financing schemes to provide credit to households that cannot afford the upfront costs of access to modern energy services;

- o Provide regulatory support for scalable and sustainable business and financial models.

- o M-Kopa Solar Initiative. Offering solar Pico and solar Home Systems at a credit with a repayment of over 12 months.