Kenya's Climate Change Action Plan:

Mitigation

Chapter 5: Electricity Generation

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Abbreviations

BAU	business as usual
CO_2e	carbon dioxide equivalent
ERC	Energy Regulatory Commission
GDC	Geothermal Development Company
GDP	gross domestic product
GHG	greenhouse gas
GIZ	German Agency for International
GW	gigawatt
GWh	gigawatt hour
IGCC	integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producers
KEEP	Kenya Electricity Expansion Programme
KenGen	Kenya Electricity Generating Company
KETRACO	Kenya Electricity Transmission Company
Kg	kilogram
KPLC	Kenya Power and Lighting Company
kWh	kilowatt hour
LCOE	levelised cost of electricity
MoE	Ministry of Energy
MPND	Ministry of State for Planning, National Development and Vision 2030
MSD	medium-speed diesel
MSW	municipal solid waste
Mt	million tonnes
MW	megawatt
MWe	megawatt electrical
MWp	megawatt-peak
NAMA	nationally appropriate mitigation action
PPA	power purchase agreement
PV	photovoltaic
TJ	terajoule
TWh	terawatt hour
REA	Rural Electrification Authority
REDD+	reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SREP	Scaling-Up Renewable Energy Program
ULCPDP	Updated Least Cost Power Development Plan
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical

5.1 Introduction

This report is part of an analysis of low-carbon development options in Kenya, which covers the six mitigation sectors set out in Article 4.1 of the United Nations Framework Convention on Climate Change (UNFCCC): energy, transport, industry, waste, forestry and agriculture. The holistic, sectoral analysis aims to inform the Kenya Climate Change Action Plan and provides the evidence base for prioritizing low-carbon development options and developing proposals for Nationally Appropriate Mitigation Actions (NAMAs) and REDD+ actions.

The overall analysis includes a preliminary greenhouse gas (GHG) emissions inventory and reference case projecting GHG emissions to 2030 for the entire Kenyan economy and by sector. The analysis then demonstrates how low-carbon development options can bend down emissions from the proposed reference case in each sector. Recognizing Kenya's development priorities and plans, the analysis also considers how the various options can contribute to sustainable development. The overall work concludes with the identification of priority actions to enable low-carbon development.

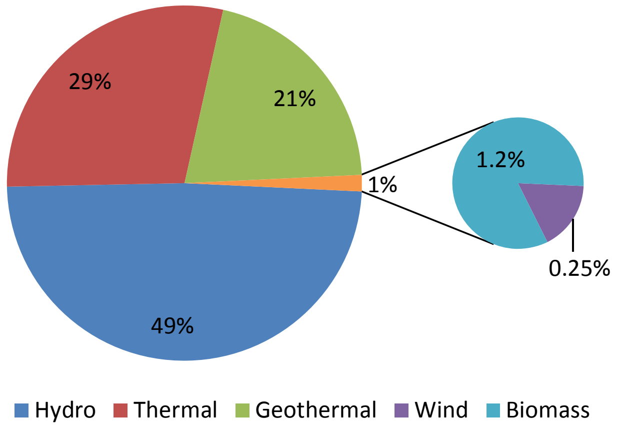
This chapter analyses low-carbon development options in electricity generation in Kenya and is one of seven sectoral chapters developed as part of the overall low-carbon analysis.

5.2 Electricity Generation Sector: Background

5.2.1 Sector context

Electricity generation in Kenya is dominated by hydroelectricity, geothermal and medium-speed diesel (MSD) generation; together making up 99 percent of electricity sent to the national grid (Figure 5.1). In recent years a growing share of electricity has come from MSD, which has made up the largest portion of new capacity added in the last decade due to its ability to be rapidly deployed to meet emergency demand. However, the available renewable energy resources are generally excellent in Kenya, particularly for geothermal power, and the recent discovery of coal resources is expected to play a large part in Kenya's long-term electricity sector planning.

Figure 5.1: Electricity generation by energy source in 2010/2011



Source: Ministry of Energy, 2011. Updated Least Cost Power Development Plan. *Nairobi: Ministry of Energy.*

The effective[1] installed capacity in 2011 was 1,411 megawatts (MW) under normal hydrology.[2] Based on expected system peak demand in that year, the estimated reserve margin is in the order of 100 MW (approximately 7 percent). However, during low hydrology, the reserve margin diminishes which necessitates load shedding and procurement of expensive emergency power.[3]

The sector structure has been dominated by a large public utility (Kenya Electricity Generating Company - KenGen) that has developed the vast majority of generation plants to date, complemented by a small, but growing, number of independent power producers (IPPs) that have started to play a larger role in electricity generation and particularly in proposing new renewable energy projects for development. The current generation plants are listed in Table 5.1, where IPP-owned plants are indicated in parentheses.

Table 5.1: Generation by energy source and plant for 2010/2010

Source	Name	Generation (GWh)	Totals (GWh)
Hydro	Tana	50	3,427
	Kamburu	408	
	Gitaru	802	
	Kindaruma	191	
	Masinga	201	
	Kiambere	899	
	Turkwel	455	
	Sondu Miriu	364	
	Small Hydro	57	
	Imenti Tea Factory (IPP)	0.4	
Thermal (mostly diesel)	Kipevu I Diesel	223	2,020
	Kipevu III Diesel	268	
	Fiat - Nairobi South	0	
	Embakasi Gas Turbines[i]	1	
	Garissa & Lamu - off grid	23	
	Other rural off-grid	21	
	Iberafrica Power (IPP)	722	
	Tsavo Power (IPP)	368	
	Rabai Power (IPP)	394	
Geothermal	Olkaria I	235	1,453
	Olkaria II	846	
	OrPower 4 (IPP)	372	
Wind	Ngong	17.7	17.7
Biomass[ii]	Mumias cogeneration (IPP)	87	87

Notes: [I] Has a capacity of 60 MW but was not operational in 2010-2011.

[ii] Represents only the electricity component of cogeneration from sugar cane bagasse that is exported to the grid. A number of other sugar producers have significant installed capacities that are not shown here, in accordance with Kenyan convention, as they are for local use.

Source: Kenya Power and Lighting Company Ltd. (KPLC). 2011. 2010/2011 Annual Report. *Nairobi: KPLC.*

Broadly speaking the majority of electricity is used by the industrial and commercial sectors (in the order of 60 percent) with the remainder predominantly meeting residential demand. This might be expected to change as more individual customers gain access to the grid-connect electricity in the future. In Kenya electricity is supplied to about 29 percent of the total population, who are predominantly the middle and upper income groups.[4] There is a firm plan (Kenya Electricity Expansion Programme - KEEP) by the Government of Kenya and the Kenyan utility to connect more customers to enhance sales growth.[5] Sector specific demand for electricity is dealt with more thoroughly in the report on Energy Demand.

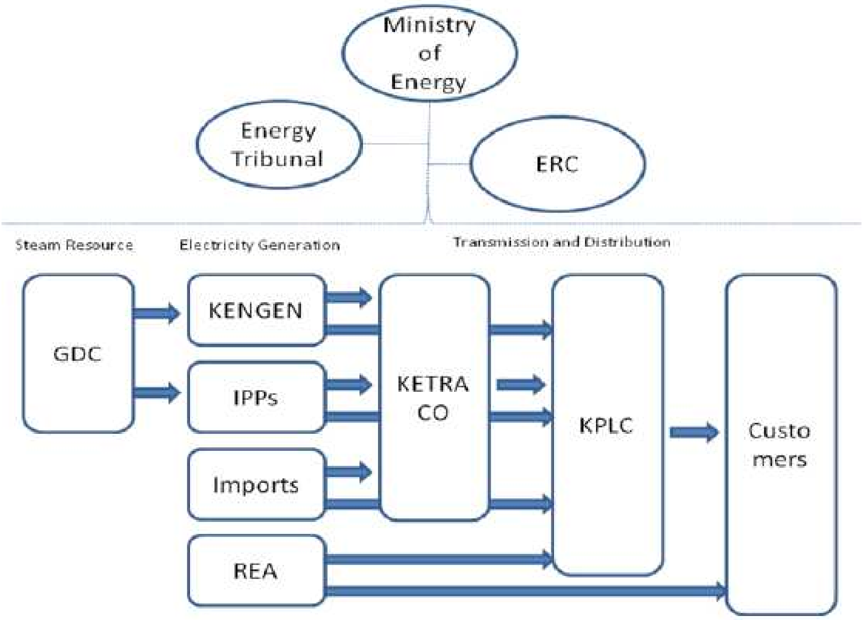
The electricity demand outlook through 2031 anticipates that significant amount of investments would be required to expand electricity generation, transmission and distribution to meet the projected demand. The *Updated Least Cost Power Development Plan* (ULCPDP) 2011 – 2031, which is the official long-term electricity planning document of the Ministry of Energy, envisions that Kenya's electricity peak demand will increase from 1.3 GW at present to 15 GW by 2030 in its reference scenario. The ULCPDP identifies various generation sources to meet this demand with a 25 percent surplus, forecasting 19,220 MW of capacity in 2030; 5,110 MW from geothermal, 1,039 MW from hydro, 2,036 MW from wind, 1,635 MW from MSD, 1,980 MW from gas, 2,000 MW from imports, 2,420 MW from coal and 3,000 MW from nuclear.[6]

5.2.2 Structure

The institutional and market structure of the Kenyan electricity sector is similar to other developing countries. Major reforms in 1997 resulted in the unbundling of the vertically integrated monopoly that previously existed and establishment of a regulatory body. In the current sector the key players of relevance to this analysis are illustrated in **Figure 5.2** and listed below:

- **Ministry of Energy** – mandate to facilitate provision of clean, sustainable, affordable, reliable and secure energy for national development while protecting the environment.[7]

Figure 5.2: Market structure and institutional framework of the electricity sub-sector



Source: World Bank. 2011. Scaling-Up Renewable Energy Program (SREP) Investment Plan for Kenya. *Nairobi: Climate Investment Funds, World Bank.*

- **Energy Regulatory Commission (ERC)** – established following market reforms and is the sole regulatory body for the electricity sector in Kenya. Its technical capacity means that its role in Kenya is expanded to include oversight of the ULCPDP process.
- **KenGen** – publically owned utility that was previously the monopoly provider of electricity
- **Kenya Electricity Transmission Company (KETRACO)** and **KPLC** – are respectively the (new transmission lines) transmission and distribution system operators in Kenya. Old transmission lines owned by KPLC remain its property even after KETRACO was established.
- **Geothermal Development Company (GDC)** – the GDC was set up in 2009 to try and provide a central authority dealing with geothermal power development. Importantly, it has the responsibility for exploratory drilling to realise steam fields that are eventually offered for development.
- **IPPs** – as noted earlier, IPPs are starting to play a larger role in the electricity sector in Kenya following unbundling.

Partly as a result of this, the Kenya government has been very active in pursuing policies and actions to encourage the growth of renewable electricity generation. Key among these are the creation of the GDC to reduce geothermal developer risks, the introduction of IPPs and the establishment of a feed-in tariff in 2008 (and revised in 2010 to include additional technologies) that has created a lot of interest from renewable energy developers. A more detailed discussion of the current policy context in Kenya can be found in both the ULCPDP and the recently published National Energy Policy.[8]

5.2.3 Summary

Kenya has one of the largest, most diverse and rapidly modernising electricity sectors in the region; with a diversity of supply technologies, new policy tools to encourage renewables and medium- and long-term planning horizons that aim to meet the demands of Kenya's vision for its future.

However the sector faces a number of challenges: rapidly growing demand for electricity, enormous capital needs for the associated infrastructure of the coming decades, high dependence on hydroelectric power which has become less reliable, high costs of supply, low access rates, compounded by the additional risk of climate change.[9] As explored in this analysis, low-carbon generation options could help to overcome many of these challenges.

5.3 Development Priorities of the Government of Kenya

Energy is considered to be one of the infrastructural enablers of the three pillars of Vision 2030; the level and intensity of commercial and industrial energy use is a key indicator of the degree of economic growth and development. The primary message of this Vision is that Kenya must generate more energy and increase efficiency of energy consumption.[10]

At present, unreliable power supply, high energy costs and weak electricity network infrastructure could slow Kenya's development and threatens its vision to be a middle-income country by 2030. In the coming years, committed investments in additional generation capacity and in strengthening the electricity network will only just keep up with the rapid increase in electricity demand.[11]

Vision 2030 includes a number of ambitions that are relevant to Kenya's need to significantly expand its electricity sector infrastructure:

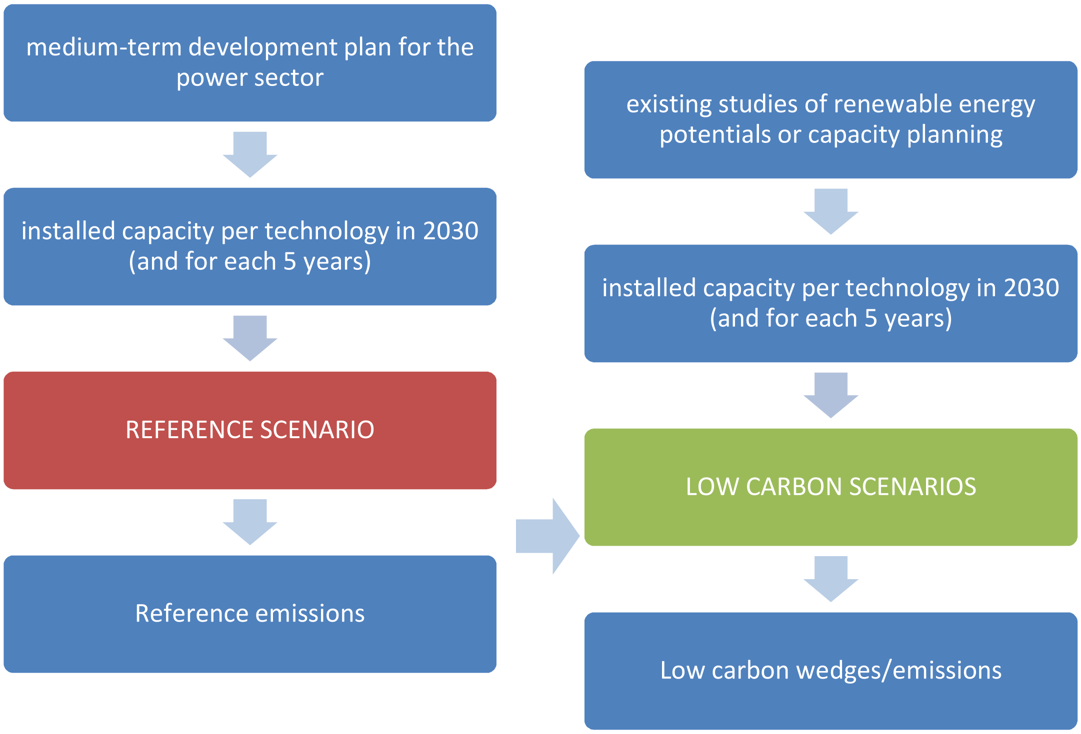
- Increasing access to electricity in rural areas, both grid-connected and off-grid solutions;
- Development of domestic coal resources and construction of a coal-fired power station in 2018 as a flagship project;
- Expansion of geothermal power;
- Expansion of wind power generation; and
- Construction of transmission facilities to allow Kenya to import electricity.[12]

Stakeholders and government representatives consistently stated that developing Kenya's vast geothermal resource is the top priority for the electricity sector.

5.4 Reference Case

This section briefly discusses the methodology, data and assumptions that were used to generate the GHG emissions baseline for the electricity generation sector between the years 2000 and 2030. This is followed by a discussion of data availability and quality. Finally, emissions are projected out to 2030 to create the reference case against which to measure abatement potential. Figure 9.2 illustrates the methodology used to develop the reference case and low-carbon scenario (the latter is discussed in Section 9.5).

Figure 5.3: Approach for determining mitigation potentials of low-carbon development options



5.4.1 Methodology

Developing a reference case for Kenya's electricity sector is challenging because there is considerable uncertainty regarding how the sector may grow to meet a large suppressed demand for electricity. Specific plans are in place but they assume very high growth rates. The *Updated Least Cost Power Development Plan* presumes a 14 percent annual growth rate in electricity supply between 2010 and 2030 in the reference case.[13] This compares to historical growth in electricity supply of about 7 percent between 2000 and 2010. The cost to achieve this dramatic growth is estimated at US$ 41.4 billion (excluding committed projects) while generation technologies that are expected to make up the vast majority of new supply still face considerable barriers to implementation.[14] Technologies such as nuclear, coal and wind have either not been proven in Kenya or have limited current penetration. Geothermal, which is expected to comprise the largest portion of generation, has high initial costs and risk of resource exploration that must be overcome.

An emissions baseline for the electricity sector is developed by estimating the total fossil fuel consumption of different generation technologies and then multiplying the total consumption by appropriate emission factors. This method is the same as the Tier 1 approach used in the 2006 Guidelines of the Intergovernmental Panel on Climate Change (IPCC)[15] for stationary combustion sources and employs the following equation:

Equation 1: GHG emissions from the electricity sector

$$Emissions_{GHG,fuel} = \sum_{tech} Fuel\ Consumption_{fuel} \times Emission\ Factor_{GHG,fuel,tech}$$

$Emissions_{GHG\ ,fuel}$ = emissions of a given GHG by type of fuel (kg GHG)

$Fuel\ Consumption_{fuel}$ = amount of fuel combusted (TJ). Fuel consumption for the electricity sector is estimated by multiplying the total generation (GWh) by the average conversion efficiency of the technology (%) by the conversion factor 3.6 GWh / TJ.

$Emission\ Factor_{GHG,fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ)

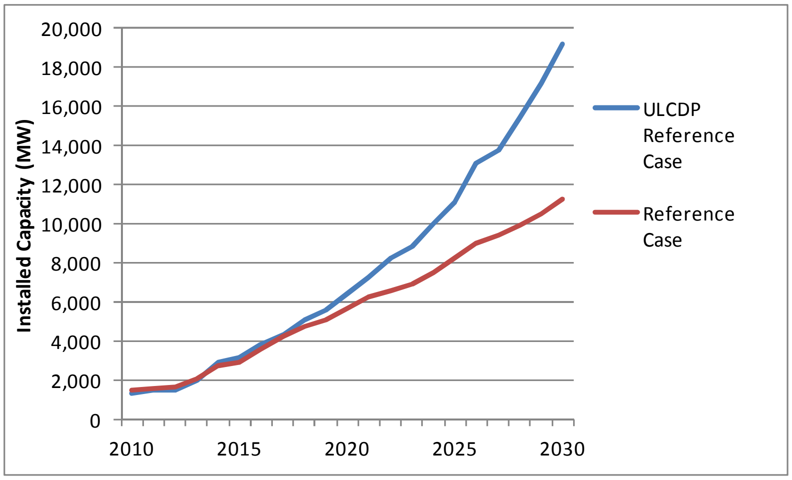
Total generation by technology type is estimated by multiplying the installed capacity (MW) of each technology by an average capacity factor (hours per year).

The data, assumptions and source references used to estimate both historical and forecast emissions are outlined in the following section. The information was mainly taken from *Updated Least Cost Power Development Plan*, personal communications with the Ministry of Energy that update projections of the Medium Term Plan and the 2006 IPCC Guidelines.[16] Expert opinion provided during stakeholder consultations and meetings was also used.

5.4.2 Data and assumptions

The baseline outlined in this section is not identical to the reference case in the *Updated Least Cost Power Development Plan*.[17] The objective of the baseline emissions forecast for the low-carbon scenario assessment is to consider a scenario based on existing policies and regulations and assuming no growth in international aid and related international investments. Specifically, any additional international support and investment for electricity generation projects that may be tied to low-carbon development are not included in the emissions reference case, unless the international support and related investments have already been committed. Including such international support would mean that the Vision 2030 aspiration of substantial investment in geothermal, wind and small hydro could not be part of a NAMA. Including this potential investment in the baseline would mean that investment opportunity through NAMAs could not be considered in the mitigation scenario. Figure 5.4 compares the total installed capacity between 2010 and 2030 of the reference case adopted in this analysis to the reference case that is presented in the ULCPDP.

Figure 5.4: Comparison of installed capacity between 2010 and 2030



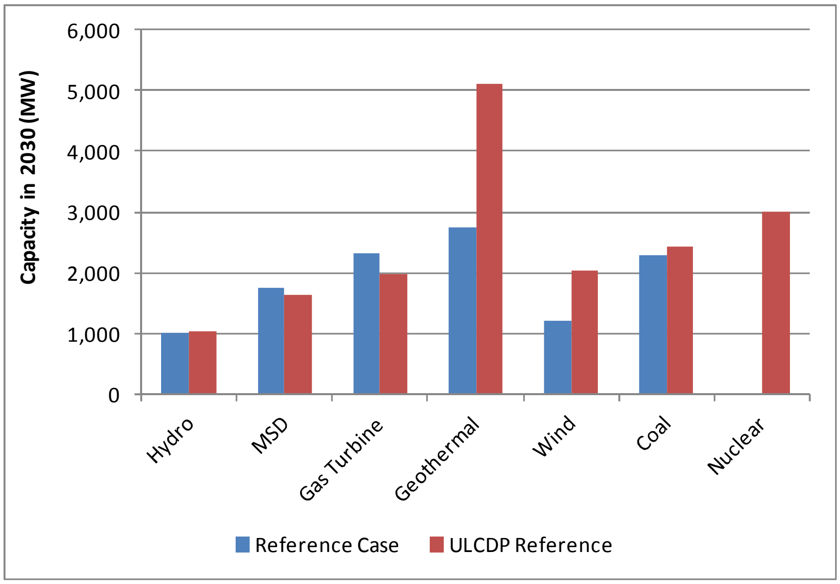
Revised projections of short-term generating capacity installations shown in Table 5.2 were provided by the Ministry of Energy.[18] Table 2 outlines the new generation capacity that is included in the baseline for the years between 2012 and 2017.

Table 5.2: Information provided from the Ministry of Energy on new additions to capacity

New Additions to Capacity Between 2012 and 2017		
New power plants and generating capacity that will come online in the next five years	2012:	HYDRO 21MW – Sang Geothermal 2.3 MW – Eburru Geothermal 75 MW – Olkaria
	2013;	Wind 60MW – Aeolus MSD 81MW – Triumph MSD 84MW – Gulf MSD 87MW – Melec MSD 80MW – Muhoroni Wind 6.8 MW – Ngong
	2014	Geothermal 140 MW – Olk4 Wind 300 MW – Turkana Geothermal 36 MW – Olk3 Wind 50 MW – Osiwo Hydro 32 MW– Kindaruma Geothermal 140 MW – Olk 1 – 4&5
	2015	Geothermal 280MW Hydro 6 MW – small hydro
	2016	IMPORT 400MW Coal 600MW – Mombasa
	2017	Geothermal 140MW Geothermal 45MW

For the years beyond 2017, the reference case deviates from the Updated Least Cost Power Development Plan 2011 reference case in order to reflect a baseline that is based on existing policies and regulations and assuming no growth in international aid and related international investments, specifically assuming no additional international support that would be tied to NAMAs. Since there is no gas generation in the medium term, we have adopted the trend that is identified in the ULCPDP. Imports also follow the same trend as the ULCPDP. All other technologies including coal, MSD, wind, hydro and geothermal are based on the same rate of growth generation capacity that is installed in the medium-term plan (2012 to 2017). In the reference case it is assumed that no nuclear energy will be added before 2030. Figure 5.5 compares the installed capacity of different technologies in 2030 between the reference case adopted in this analysis to the reference case that is presented in the ULCPDP.[19]

Figure 5.5: Comparison of installed capacity in 2030 (MW)



Therefore total generation capacity under the GHG emissions reference case is 11,287 MW in 2030 versus 17,220 MW under the ULCPDP. This represents an annual average growth rate in capacity of 11 percent versus 14 percent in the ULCPDP. The growth rate assumed in the reference case is still considerably larger than historic growth in the economy and the sector. Table 5.3 identifies the total installed capacities of various generation technologies.

Table 5.3: Baseline generation capacity by technology type (MW)

Generation Type	2010	2015	2020	2025	2030
Hydro	758	837	885	944	1,003
MSD	425	877	1,085	1,415	1,745
Gas Turbine	74	14	694	1,414	2,314
Cogeneration	26	26	0	0	0
Geothermal	198	791	1,312	1,872	2,734
Wind	5	415	631	921	1,211
Coal	0	0	1,080	1,680	2,280
Nuclear	0	0	0	0	0
TOTAL	**1,486**	**2,960**	**5,687**	**8,246**	**11,287**

Future electricity generation by technology type was estimated by multiplying the installed capacity (MW) of each technology by an average capacity factor for that technology (hours per year). These utilization rates (in Table 5.4) are based on those presented in the ULCPDP and where applicable, are an average of peaking and baseline load.

Table 5.4: Utilization rate for different plant generation types

Generation Type	Utilization (average % of time operating annually)
Geothermal	90%
Cogeneration	40%
MSD	28%
Hydro	60%
Wind	30%
Gas Turbine	46%
Coal	64%

Table 5.5 presents the total baseline generation forecasted by technology type that is determined by multiplying the installed capacities in Table 5.3 by the utilization rates in Table 5.4.

Table 5.5: BAU generation by plant type (TWh)

	2010	2015	2020	2025	2030
Geothermal	1.34	6.24	10.34	14.76	21.55
Cogeneration	0.09	0.09	0.00	0.00	0.00
MSD	2.87	2.15	2.66	3.47	4.28
Hydro	2.17	4.40	4.65	4.96	5.27
Wind	0.01	1.09	1.66	2.42	3.18
Gas Turbine	0.15	0.02	2.81	5.73	9.38
Coal	0.00	0.00	6.05	9.42	12.78

In addition to this generation supply there is also an expectation that Kenya will import some power to meet needs. Expected imports are based on the ULCPDP projections and are summarized in Table 5.6.

Table 5.6: BAU electricity imports (GWh)

	2010	2015	2020	2025	2030
Imports	38	200	1,000	1,200	2,000

Total consumption is equal to total domestic generation plus imports minus losses from transmission as well as distribution and commercial losses. These losses are based on the ULCPDP and reported in Table 5.7. Note that the analysis does not look at or assume reserves. Basically the capacity factor used accounts for any reserves that are required. For example, MSD has a capacity factor of only 28 percent, which indicates that it is primarily used for peak loading.

Table 5.7: Total consumption (GWh)

	2010	2015	2020	2025	2030
Supply	6,664	14,195	29,182	41,962	58,454
Transmission losses	236	490	986	1,427	1,976
Distribution losses	841.27	1,539.477	3,099.98	4,483.864	6,209.96
Losses (%)	16.25%	14.50%	14.50%	14.50%	14.50%
Total Consumption	**5,587**	**12,166**	**25,095**	**36,052**	**50,268**

The data used to convert total future generation of fossil fuel technologies into GHG emissions is provided in the Table 5.8. Emission factors are from IPCC 2006 guidelines.[20] Average conversion efficiencies reflect those that are reported in the LCDP.[21]

Table 5.8: Emission factors by technology type

Technology	Average Conversion Efficiency (%)	kgCO$_2$e / TJ	KgCO$_2$e / GWh (kgCO$_2$e / TJ) x (3.6 GWh/TJ) x (Average Conversion Efficiency)
MSD	35%	74,100	762,171
Gas Turbine	45%	56,100	448,800
Coal	40%	94,600	851,400

5.4.3 Greenhouse gas emissions reference case

The emissions baseline generated from the electricity supply is summarized in Figures 5.6 and 5.7. Figure 5.6 presents the total generation of each of the generation types and the black line in the figure presents the average emission intensity of generation over time. Total electricity consumption is expected to grow from 5,600 GWh in 2010 to 50,300 GWh in 2030 representing an annual growth rate of 11.5 percent. Renewable electricity generation is projected to increase from its current share of approximately 53 percent to 60 percent in 2020 before declining again to the same level as in 2010 (53 percent).

Figure 5.6: Baseline reference case generation of electricity (TWh) and average emissions intensity (tCO2e/MWh)

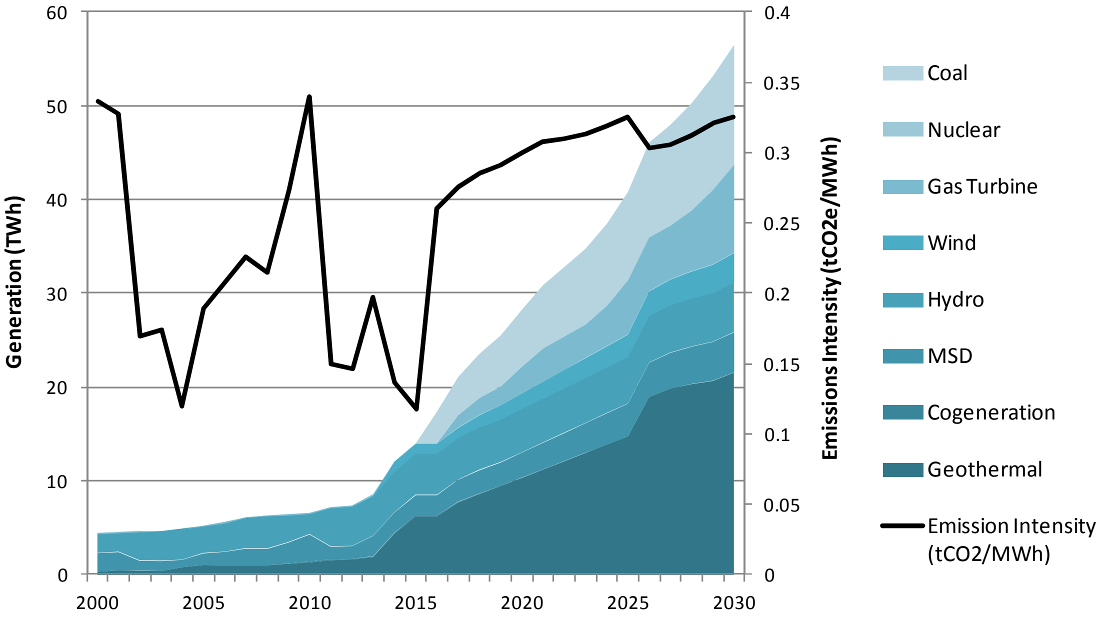
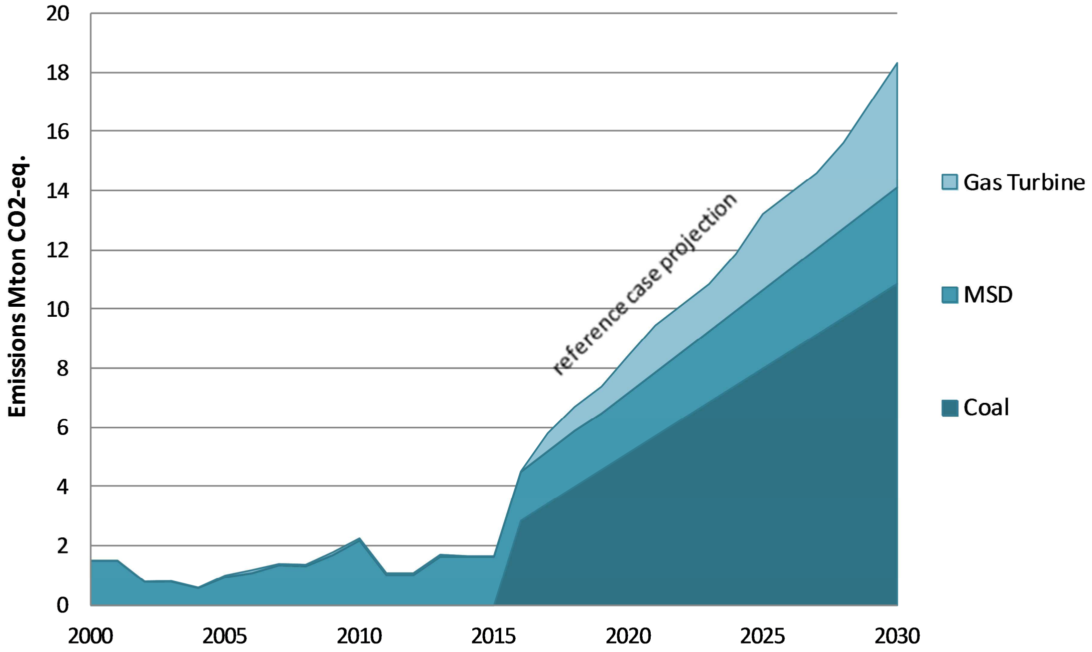


Figure 5.7 presents the overall electricity sector emissions by technology type. Electricity sector emissions are projected to grow from 2.2 $MtCO_2e$ to 18.4 $MtCO_2e$ representing an annual growth rate of 11 percent.

Figure 5.7: Baseline greenhouse gas emissions by technology type (MtCO2e)



5.5 Low-carbon Scenario Analysis

5.5.1 Choice of abatement options

The choice of low-carbon options for further analysis followed a participatory multi-step, approach as described in Chapter 1. For the electricity sector, this yielded six low-carbon development options:

1. Geothermal generation expansion;
2. Wind generation expansion;
3. Hydroelectricity expansion;
4. Solar photovoltaic (PV) – distributed grid-connected;
5. Landfill gas generation; and
6. Clean coal (ultra-supercritical - USC).

Stakeholders at local validation meeting identified additional low-carbon options. The bioenergy-based generation from agricultural residues (biogas and bagasse cogeneration) option was added, and is shown in the corresponding report on energy demand because a significant portion of the produced electricity will be used onsite by the food processing industry where the residues are produced or readily available. This split is broadly in line with the philosophy used in the ULCPDP, where electricity produced and consumed on site by sugar producers from bagasse is not included in national generation totals. Box 5.9 discusses other options that were suggested by Kenyan experts and the rationale for not including in the low-carbon scenario.

This chapter of the technical analysis report only deals with supply-side mitigation options related to the generation of electricity. Options for moving towards a low-carbon pathway through energy savings and efficiency measures are dealt with in Chapter 6 on Energy Demand. Some discussion of various supply-side mitigation options that were excluded from the analysis is provided in Box 5.1.

5.5.2 Calculation of abatement potentials

As discussed in Section 5 on the electricity sector reference base, the government has a long-term sectoral plan, the ULCPDP, which contains the projected year on year electricity generation mix in Kenya. This plan forecasts large growth in the total installed capacity in Kenya to almost 20 GW in 2030. However, this plan is not capital constrained (it assumes that all modelled plants can be financed) and is broad in scale; so it does not take into account many current developments in renewable energy (for example, the growth being stimulated by the Government of Kenya's feed-in tariff).

The assumed large development of geothermal, wind and nuclear power in the ULCPDP presents something of a dilemma for a typical "wedge" analysis of low-carbon development options. The ULCPDP, in its current form, already assumes a mix of technologies with a relatively low-carbon intensity, notwithstanding the fact that it does not consider where the necessary investments will come from. As noted when developing the baseline, it is arguably more relevant to consider a slightly constrained vision of growth based on current rates of expansion in the medium-term plan and then look for opportunities where low-carbon technologies could be introduced or expanded (ideally supported by international financing, for example through NAMAs) to fill the gap between supply and forecasted demand.

This suppressed supply in the baseline is the basis for determining mitigation potentials. It is assumed that the additional required growth could be achieved through either expansion or introduction of low-carbon technologies, or from expanded use of thermal generation in line with the National Energy Policy.

Box 5.1: Low-carbon options in the electricity sector not considered in the analysis

Supply side technologies proposed at local validation meetings but excluded after further analysis are described below.

Nuclear power was not considered to meet the criteria of eligibility for climate finance that underpins the analysis. Nuclear power has low life-cycle GHG emissions, but it has not featured in any prominent way in international discussions on support for mitigation actions. While nuclear energy would certainly be a low-carbon development option for electricity generation significant barriers to developing nuclear power would have to be overcome, making its development less certain.

Woody biomass or commercially grown biomass as a source of bioenergy for electricity was excluded for three main reasons:

1) Deforestation through burning of woody biomass is already a concern for the Government of Kenya (wood and charcoal provide roughly 70 to 75 percent of total energy consumption in Kenya), which has an aggressive reforestation target to achieve 10% forest cover. This will prove a significant challenge, even without finding additional land for biomass feedstock.
2) A good biomass resource is available in the form of agricultural residues, which is largely untapped (except for a small amount of bagasse from sugar manufacturers).
3) Woody biomass or commercial biomass, if produced in large quantities for electricity, could compete for land with food.

Sustainable woody biomass production still has an important role to play (for example the use of woodlots to provide fuel wood to tea plantations) but is not considered for electricity generation. The use of endemic dry land plants such as *Euphorbia Tirucalli* to produce biogas and generate electricity was proposed. A lack of data suggests that dedicated dryland crops require further analysis

Waste incineration is better suited to areas that have a scarcity of space for landfill (due to lower costs for using landfill) and that generate waste with a lower moisture and higher energy content (less likely in Kenya because of high organic waste content).[22] Although incineration can still prove beneficial under these conditions, there is significant overlap with the option of electricity generation from landfill gas.

Reducing losses in transmission and distribution could be a feasible option for lowering GHG emissions. Current levels of transmission and distribution losses are 16.3 percent.[23] Reducing the level to 10 percent would reduce energy supply requirements by 6.8 percent, effectively reducing electricity sector emissions by a similar amount. However, this was not considered in the analysis because:

1) Transmission and distribution operators already have a strong incentive to reduce losses to improve their economic performance and plans are in place to reduce losses in the coming years.
2) In a supply constrained electricity sector, any extra supply will be consumed, offering little net difference in emissions.

It is interesting to note that although the reference case of the ULCPDP forecasts almost 2.5 GW of coal-fired generation in 2030, the recent National Energy Policy action agenda lists a capacity of almost 4.5 GW of coal generation in 2030. **It is against this backdrop that any additional renewables (in the low-carbon development options), beyond those forecast in the reference case, are assumed to displace thermal generation (mainly coal, with some MSD and gas).**

The conceptual approach to developing the low-carbon mitigation potentials in the electricity sector is illustrated in Figure 5.3.5. For each low-carbon generation option an assessment was made of the generation capacity that could be developed by 2030, looking at periods of five years. These form the basis for low-carbon development scenarios that contrast with the baseline scenario. The low-carbon scenario capacities were estimated using different approaches depending on the technology in question. In general, the available data on resource potentials and/or existing studies of generation capacity provided a starting point for estimating potential future capacity, supplemented with input from local experts. However, each technology also required some specific assumptions on rates of expansion and limits to growth. These scenarios are described in more detail in Section 5.7.

As noted earlier, the baseline scenario assumes that medium-term development plans represent a feasible growth path for Kenya that continues until 2030. The low carbon technologies are considered as offering ways for this growth to be accelerated with additional support. Based on this idea, mitigation potentials were calculated using a suppressed demand approach. It is assumed that coal and MSD would be the BAU technologies of choice to fill the forecast gap between supply and demand, should additional domestic support be available for them beyond the reference case. This is supported by the ambitions for thermal generation announced in the National Energy Policy, which go beyond the capacities forecast in the ULCPDP.

On this basis the mitigation potential for each low-carbon option is calculated versus an emissions intensity of avoided coal, MSD and gas; where the mix is set equal the ratio of coal, MSD and gas in the reference scenario in 2030.[24] This gave an emission intensity of suppressed new fossil fuel generation of approximately 640 tCO_2/GWh which was used to calculate the potential impact of each of the low-carbon scenarios.

The case of net-metered solar PV is somewhat distinct from the other technologies, as much of the electricity produced would be used at the point of generation. As such this distributed PV generation does not suffer from losses incurred in the transmission and distribution system. This means that one MWh of local generation and consumption offsets more than one MWh of central generation. To provide a full MWh of end-use electricity from the grid, more energy has to be generated to account for the losses. For net-metered solar PV the guidelines from the International Energy Agency are used, which suggest that "…distributed generation (and not the other electricity projects) should be credited with avoided T&D losses, using average grid area losses (excluding "non-technical losses")."[25]

Landfill gas generation is also treated differently as the mitigation potential can be considered as two separate contributions. Firstly, landfill gas generation can be considered as displacing additional conventional generation (as per the other renewable energy technologies), which reduces CO_2 emissions from electricity generation. Secondly, the methane that is captured and used as a source of energy is itself a GHG with a significant global warming potential.[26] This section on electricity generation only shows the emission reductions from the former, the avoided methane is recorded under the section on waste.[27] In making this split it is assumed that the organic component of municipal solid waste (which generates the methane) is domestically produced and is renewable as it is biogenic. This is in accordance with protocols for determining emissions reductions from renewable generation facilities.[28]

5.5.3 Calculation of abatement costs

Costs in the electricity sector are determined as marginal abatement costs in US dollars per tonne of CO_2e avoided. The starting point for determining these marginal costs is the levelised costs of electricity (LCOE) reported in the ULCPDP. These have been developed for the local context and were indicated as the preferred basis for calculating costs. The only significant change to these figures is a modification of the geothermal LCOE to account for exploration and appraisal costs; something that is currently subsidised by the GDC, but should be considered when looking at overall abatement costs from a social perspective. The financing plan for the 280 MW Olkaria I and IV generation plants shows that total drilling costs are in the order of 25 percent of the total investment cost for this project (approximately US$ 330 million). For pre-production drilling, a green field will require about US$ 100 million to explore and appraise.[29]

Following the same logic as the calculation of mitigation potentials, the mix of coal, MSD and gas seen in the reference case in 2030 is used to determine the marginal abatement costs. The LCOE for suppressed conventional supply is thus calculated to be US$ 115 per MWh in the near term based on the ULCPDP.

Some technologies – net-metered solar PV, landfill gas generation and clean coal – are not included in the ULCPDP and for these technologies surrogate figures from external reports were used.

- Net-metered solar PV costs in Kenya were taken from Hille *et al.* (2011), which indicates a LCOE of roughly 35 Kenyan shillings (KSh) per kWh for distributed PV in Nairobi. To determine marginal abatement costs this is compared to Kenyan consumer electricity tariffs provided in the same report, but using lower assumptions for future tariff increases that do not deviate so far from the ULCPDP.[30]
- Landfill gas generation LCOE are taken from Fischer *et al.* (2010) using an average of the two largest sized plants that are calculated in that study.[31]
- Clean-coal costs are affected by two assumptions: the efficiency of the plant and the cost of coal. The cost comparison between supercritical and USC coal generation provided by an Electric Power Research Institute study was used, normalised to local Kenyan coal generation costs using the information in the ULCPDP.[32]

Finally, it is important to note that the costs of generation with a certain technology today may be significantly different to costs in the future. This could make certain technologies more appealing in the short to medium term, while others become more viable in the longer term. To account for anticipated cost decreases in the future, a fractional cost improvement over the coming 20 years is assumed for each low-carbon technology, as well as for conventional generation technologies against which they are compared. These fractional cost reductions are estimated from generation cost data that has been collated by the authors across a number of European and American studies of expected future generation costs.

5.5.4 Data availability and uncertainties

Data problems are lower in the electricity sector than other sectors considered by this analysis because there are relatively few well studied, commercially operated sources of electricity and emissions. However, data relating to renewable energy resources is still often lacking, of low quality or not readily available.

Wind resources were broadly mapped in 2008 with indicative data, but this has not been used to develop any detailed estimates of feasible potential. The Ministry of Energy is in the process of collecting site-specific data from a number of government installed met-masts.

With regards to landfill gas generation, limited data is available on rates of waste generation and landfilling in Nairobi, but not much is known about waste practices across most of Kenya. It can be assumed that Nairobi is representative of the major urban areas that have landfill gas generation potential.

5.6 Low-carbon Development Options

The excellent domestic renewable energy resources available to Kenya present a wide range of possible low-carbon development options in relation to electricity generation. This chapter only deals with supply-side mitigation options related to the generation of electricity. Options for moving towards a low-carbon pathway through energy savings and efficiency measures are dealt with in Chapter 6, Energy Demand.

This section provides some background context for each of low-carbon development options, explaining their current status and potential. The results of the analysis are then described in six sections:

- Scenarios;
- Mitigation potentials;
- Costs;
- Development benefits;
- Climate resilience; and
- Feasibility of implementation

5.6.1 Context

Geothermal generation expansion

Kenya had 198 MW of installed geothermal capacity[33] that produced 1,453 GWh (20 percent) of electricity in 2010/2011.[34] All of the geothermal based electricity generation constructed in Kenya to date has been in the Olkaria geothermal field near Naivasha. Approximately another 400 MW of capacity is planned in this field over the next three years.[35] Further to this, the recent SREP financing package seeks to promote generation of 200 MW of geothermal in the Menengai field[36] and an IPP AGIL is seeking to develop a 140 MW plant in the Longonot geothermal system in 2015.[37]

The high temperature geothermal prospects in Kenya are located within the Kenya Rift, a continental scale volcano-tectonic feature that stretches from northern to southern Africa.[38] Surface studies suggest that 5,000 MWe to 10,000 MWe could be generated, clustered into three regions namely the Central Rift (1,800 MW), South Rift (2,450 MW) and North Rift (3,450 MW).[39]

The high initial cost and risk of resource exploration have slowed-down the development of geothermal power despite its cost-competitiveness on a life-cycle basis.[40]

It should be noted that there are also direct-use, or using the heat directly rather than generating electricity, options for geothermal. This is already done in at least one tourist facility in Kenya and for greenhouse heating in the flower industry. However, the option is not taken into further consideration in this report because of a lack of readily available quantification of the potential for the direct use of geothermal energy. Another limitation is that industry must be situated near suitable geothermal resources.

Wind generation expansion

Large-scale wind generation is a technology that is well understood and is already deployed successfully in many countries across the world. It provides substantial shares of the electricity generation in many European countries and is growing at a rapid rate. Large-scale wind energy in Kenya is currently limited to KenGen's six turbine 5.1 MW farm in Ngong installed in 2009. However, the Government of Kenya's feed-in-tariff scheme has created significant interest from the private sector and, as of the end of 2011, there were 23 expressions of interest to develop projects with total capacity of 1327 MW (the largest being the 300 MW Turkana wind farm).[41]

On average, the country has an area of close to 90,000 square kilometres with wind speeds of 6 metres per second and above.[42] From available literature, most of this has not been translated into technical or economically viable potentials. The ULCPDP forecasts just over two GW of wind generation in 2030, but theoretically the potential is significantly larger than this.

Notwithstanding the relatively recent introduction of the feed-in tariff policy in Kenya that made wind power economically viable with carbon credits considered, its growth is considered to be constrained by a number of key factors. These include: the challenge of managing variable supply within the future electricity grid, difficulties in planning and financing the necessary transmission lines to areas of interest and the provision of finance for IPPs to develop sites.

Hydroelectricity expansion

According to the ULCPDP, based on an earlier study from 1991, Kenya has considerable hydropower potential, estimated in the range of 3,000 to 6,000 MW. Of this, just over 750 MW is currently exploited, mainly in large installations owned by the national power generation utility, KenGen.[43] The same document states that at least half of this overall potential is from small-hydro plants and that 1,249 MW of projects of roughly 30MW or larger remain. However, limited information is publically available on the hydropower resources available in the country.

In spite of this large stated potential in the ULCPDP, local experts consistently stated that most of the viable large hydropower potential in Kenya has been exhausted and very few options remain for larger scale generation. This is supported by unreferenced figures from the International Energy Agency's Small Hydro Annex that states that total technically feasible potential is in the order of 1100 MW.[44]

Small-scale generation was low on the agenda during experts with Kenyan experts. This is possibly partly due to a lack of reliable data on yearly flows, both in terms of measured data and data access. (Experts stated in validation meetings that there were problems with data sharing between the Ministry of Energy and the Ministry of Regional Development). In contrast to this, as of the end of 2011, there were 20 expressions of interest to develop projects with total capacity of 84 MW under the Feed-in Tariff policy.[45] The recent Kenyan National Energy Policy calls for the development of 50 MW of small-scale hydro in the short term, 100 MW in the medium term and 300 MW in the long term.[46] These plans are taken into account when developing the mitigation potential for hydropower.

Hydropower has also posed challenges to Kenya in the past. Over recent decades a number of droughts have intermittently reduced generation capacity across the country, leading to power rationing and emergency supplies. Stakeholders often expressed the potential impact of climate change on hydropower as a reason to reduce its role in the electricity mix. For this reason this study takes a conservative position on the potential expansion of the hydropower resources in the country beyond the reference case.

Solar PV – distributed grid-connected

Even though solar PV prices have dropped dramatically in recent years, they are still not at the level where they would be considered directly competitive with Kenya's hydro and geothermal resources for large-scale generation.[47] Discussions with stakeholders in Kenya supported this as did previous consultations with the World Bank on the SREP plan.[48] Solar power (in general) is less attractive for large-scale power generation in Kenya.

However, a number of studies have concluded that solar PV grid parity has been achieved in several countries, particularly when considering the "socket parity" or competition with residential electricity prices.[49] Residential and commercial electricity end tariffs in Kenya are relatively high (in the order of US$ 0.24 per kWh); and solar resources, while not excellent, are still good across large parts of the country (roughly 1.5 times better than Germany, one of the largest solar PV markets in the world).[50] Given this, there is the potential for solar PV to be a viable option for end-use customers to offset their purchased electricity and sell back to the grid in times of excess production. The current regulatory framework and physical metering system does not easily allow for this.

A study produced by the German Agency for International (GIZ) suggests that 200 MWp could be feasibly installed in the near term. This is based on their relatively conservative assumptions as to what percentage of different customer groups could be persuaded to install local grid-connected PV panels.[51]

Landfill gas generation

The municipal solid waste (MSW) created by a population is a significant management problem for any country. From a GHG perspective, methane is produced as the organic content in MSW degrades anaerobically (that is, without exposure to oxygen). Although methane is a GHG with a relatively high global warming potential contributing to climate change, it is also a potential source of energy if it can be captured. Operations in many countries capture and use methane from MSW to generate electricity, but it would be a new technology for Kenya. Dandora, the largest dumpsite in Kenya, has previously been the subject of an unsuccessful bid to develop a landfill gas generation project.

A recent GIZ study considered data on theoretical potentials from 13 selected groups of biomass available from the agro-industrial business in Kenya as well as for MSW in Nairobi.[52] MSW was found to have the largest potential for electricity generation (and equally for cogeneration, should this technology be chosen) ranging from 11 to 64 MW, depending on permissible cost assumptions, with a mean value of 37.5 MW. This potential was calculated based only on the amount of MSW generated in Nairobi, about 996,450 tons per year. Nairobi was chosen the literature on MSW in Kenya focuses on Nairobi.[53] This means that a higher potential could be expected if: more cities were considered; as urban populations continue to grow (and, accordingly, MSW volumes); and as MSW practices increase the percentage of MSW that reaches landfills (currently roughly 60 percent).[54]

Clean coal – ultra-supercritical

Coal power is not currently a part of the generation mix in Kenya, but there are plans to generate 620 MW of electrical power by 2018 from coal, and anywhere from 2,400 MW to 4,490 MW in 2030 depending on figures in the ULCPDP or the National Energy Policy respectively. Much of the coal technology that is forecast in the ULCPDP is modelled with efficiencies broadly comparable to best in-class supercritical pulverised coal generation (roughly 45 percent thermal efficiency). At present the country has no domestic coal production; however, there are adequate coal deposits for commercial exploitation in the Mui Basin in Kitui County and the Government is fast tracking exploration and development of the resource for power generation and industrial use.[55]

Clean coal was raised as a low-carbon technology by government. In this sense clean coal is mainly meant to mean “lower carbon”, but of course alternate technologies such as integrated gasification combined cycle (IGCC) also have other emissions benefits in regards to reduction of sulphur dioxide and other pollutants.

The focus of this analysis is on ultra-supercritical (USC) coal plants as a lower carbon coal technology, as opposed to IGCC technology. USC plants are very similar to supercritical plants but operate at higher temperatures that allow them to achieve higher efficiencies (for this study an improvement of five percent is assumed in line with existing literature). This choice is influenced by: the current capital cost premium for IGCC versus USC plants (estimated at anywhere between 30 and 90 percent); differences in net design efficiency; and the lack of carbon capture and storage opportunities in Kenya (meaning that the fact that IGCC is considered to be more adaptable for carbon capture and storage is less relevant).[56]

Clean coal is presented in the results section, but does not significantly feature in the sections covering implementation feasibility and policies for two main reasons. Few clean coal projects are discussed in the context of climate finance negotiations, and development co-benefits are small compared to supercritical coal electricity generation.

5.6.2 Scenarios

Geothermal and wind power expansion – Total incremental capacity in each year until 2030 is calculated as the difference between the reference scenario and the capacity development profile in the ULCPDP. This assumes that a NAMA or other form of climate financing would be used to move beyond a reference case to fulfil the ambitious growth forecast of the ULCPDP. This approach is based on the argument that the ULCPDP forecast would be very challenging to achieve without additional external financing. The maximum potentials assumed in 2030 for the low carbon scenarios do not aim higher than the ULCPDP capacity targets, but rather make the case for low carbon growth to reach these targets. While this can be considered a sound approach for geothermal power – for which a large share (more than 5.5 GW) of the estimated resource is developed – the total potential for wind power in Kenya could be significantly larger than the capacity forecast in the ULCPDP. However, in the absence of more detailed analysis of the technically and economically viable wind resource the ULCPDP figures are used.

Hydropower expansion – Stakeholders often cited the climate sensitivity of hydropower and perceived lack of untapped large-scale resource as major barriers. For this reason capacity assumptions in the low-carbon scenario for hydropower are relatively conservative. A similar approach to geothermal and wind (as described above) was taken, but with the addition of the small-hydro ambitions of the National Energy Policy out to 2030, which are not currently included in the ULCPDP.

Solar PV – A GIZ study estimates that 200 MWp is realistically feasible within a relatively short timeframe, assuming that only a small fraction of relevant large consumers, between one and three percent, invest in solar PV under net-metering.[57] On the basis of these assumptions on the percentage of consumers who take up the technology, the total potential for distributed grid-connected solar PV could be very large. A greater penetration of installations could be reached over time because urban populations are growing, average rates of electricity use per consumer are growing and the ULCPDP estimates that electricity tariffs could be expected to increase by 27 percent in its reference case by 2031. However, the limiting factor for solar PV uptake will be system costs and payback periods; these issues are discussed in more detail in the section below on costs. Based on an assumed uptake of 200 MWp in 2020, then a total capacity of 1,000 MWp is taken as a nominal figure in 2030, based on a rough estimate of rates of adoption. This could vary significantly depending on the cost competitiveness of net-metered solar PV in the future. The 1,000 MWp figure should be seen as illustrative and needs to be interpreted in combination with the costs listed further on this report.

Landfill gas – From a starting point of no installed capacity today, conservative assumptions based on the work of Fischer *et al.* (2010) are used to define capacities in 2015, 2020 and 2025. Their study found that 11 to 64 MW (depending on costs) of MSW biogas electricity could be installed in Nairobi, based on 2012 waste levels. MSW biogas generation has finite limits on the amount of electricity that can be generated, which is directly proportional to the amount of methane that is captured, which in turn depends on the volume of waste in suitable landfills. The upper limit from this study is assumed to be feasible in 2025; however, by 2030 it is assumed that the current maximum MSW potential, that was observed for Nairobi only, will have doubled covering the whole of Kenya.[58]

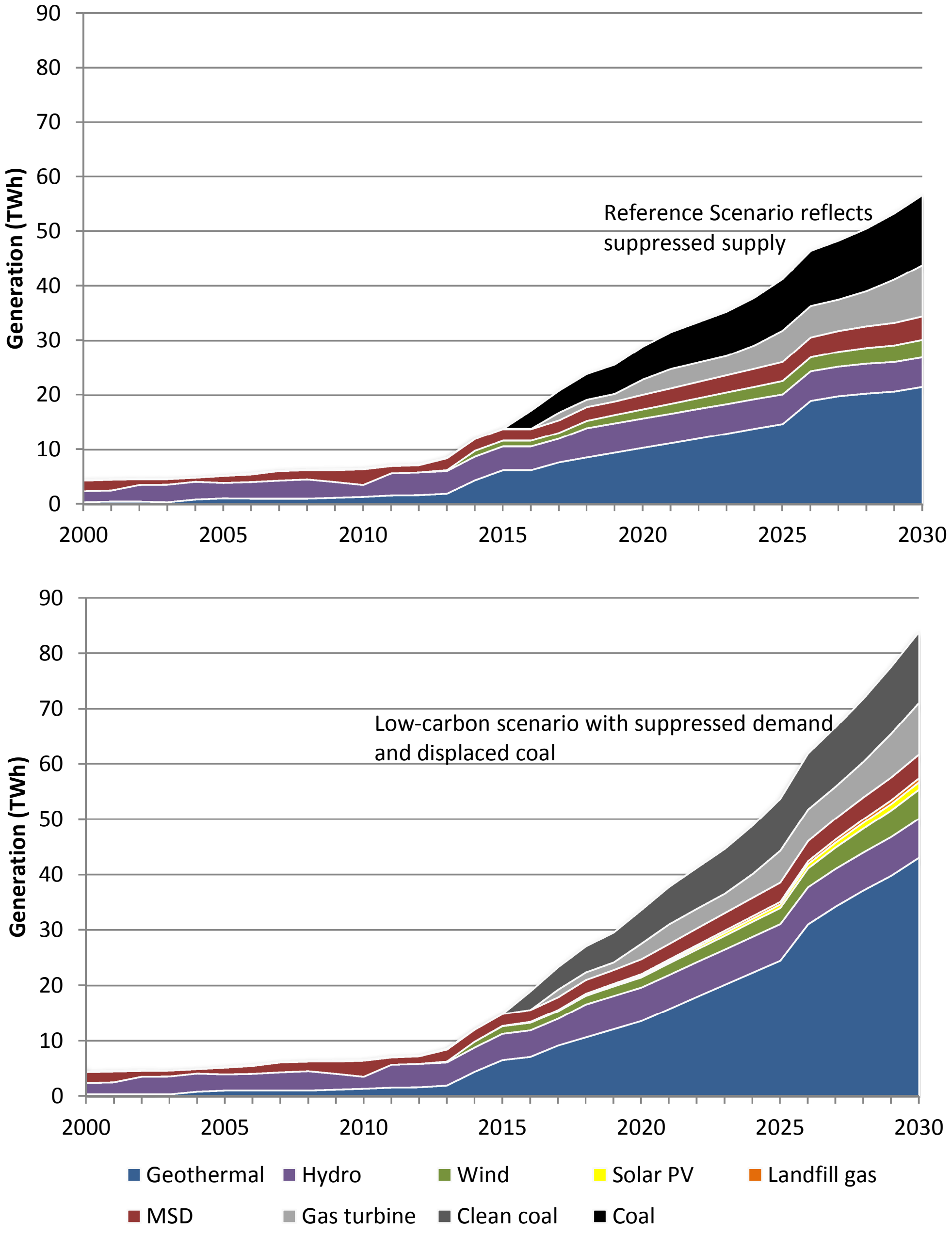
Clean coal – The way in which capacities are determined for introducing clean coal technology is relatively simple. The low-carbon scenario assumes that all coal installed in Kenya uses USC technology rather than supercritical technology.

The resulting capacity profiles for the low-carbon options, out until 2030, are provided in the fact sheets in Annex 1.

The resulting generation profiles are shown in Figure 5.8, where the large growth of geothermal electricity is the most prominent change between the two scenarios. By basing the reference scenario on planned rates of capacity growth in the medium-term, the 'rampup' in growth observed in the ULCPDP is not seen. As a result the total generation in 2030 in this study's reference scenario (56.6 TWh) is significantly lower than that indicated in the ULCPDP's reference scenario (93.8 TWh).

Figure 5.8: Electricity generation by technology until 2030 in the reference scenario (top) and low-carbon scenario (bottom).

Note: The low-carbon scenario has suppressed demand that is not represented in the Reference Scenario. Supply explanation could occur with additional climate financing and would likely be met with thermal coal. As a result, the Low-carbon Scenario has avoided emissions above the Reference Scenario, which are displaced with low-carbon alternatives. See Section 5.5.2 for more detail.



Reference Scenario reflects suppressed supply

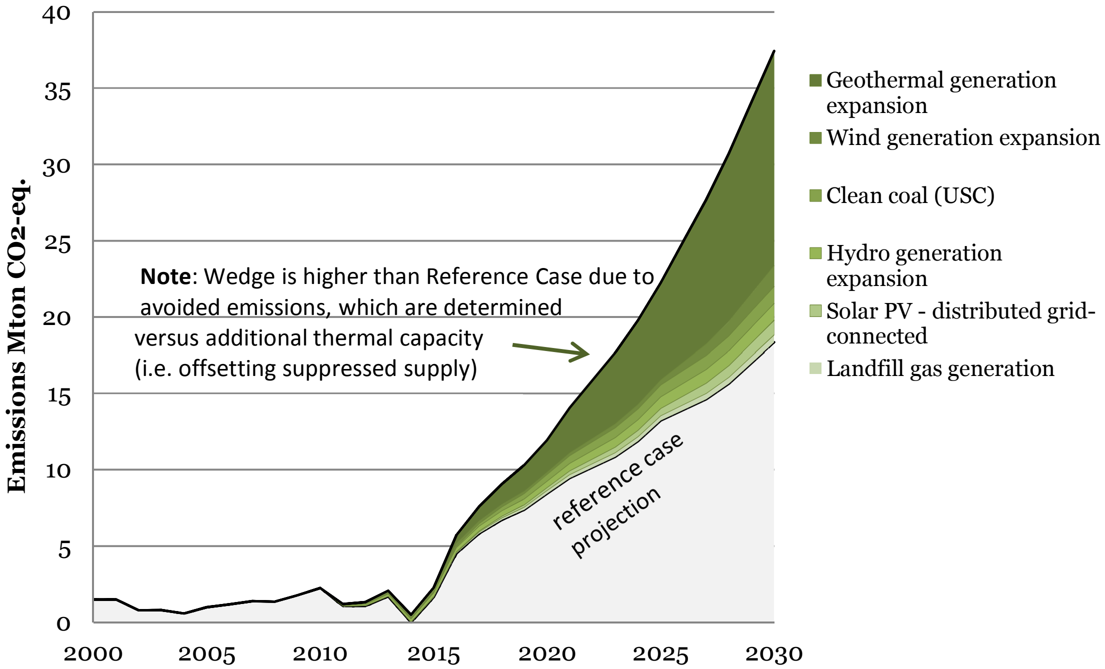
Low-carbon scenario with suppressed demand and displaced coal

As discussed, the expansion of low-carbon generation options offers a way of increasing supply beyond the reference case. Total generation in 2030 in the low-carbon scenario grows to 84 TWh through increases in generation from geothermal, wind and hydro power, along with additional incremental generation from solar PV and landfill gas (clean-coal does not offer additional supply, but rather a slight decarbonising of planned coal plants). Although this is still lower than the ULCPDP's reference scenario, the generation in the low-carbon scenario is higher than the ULCPDP's low-load scenario (80 TWh).

5.6.3 Mitigation potentials

Figure 5.9 shows the low carbon mitigation wedges in the electricity sector. Figure 5.9 shows a simple addition of the wedges for each low-carbon development option (see fact sheets in Annex 1 for the wedges for each option). The wedge analysis does not account for interactions between the wedges. In the electricity sector, such interactions are expected to be minimal, as the renewable energy technologies can be added to the electricity generation mix independent from each other.

5.9: Low-carbon development option mitigation wedges in the electricity sector (Mt CO2e)



As discussed in Section 5.4.2 on the methodology for the low-carbon assessment (and demonstrated in Figure 5.9) the results assume that renewable energy generation capacity is additional to the baseline capacity and replaces a hypothetical mix of coal and MSD-based electricity generation. Geothermal power generation has by far the largest abatement potential in 2030, with 14.1 Mt CO_2e per year. The abatement potentials for the other technologies vary between 0.5 and 1.4 Mt CO_2e.

5.6.4 Costs

Marginal abatement costs in both 2020 and 2030 are presented in Figure 5.10 and Figure 5.11.

Figure 5.10: Marginal abatement cost curve for different low-carbon development options in the electricity sector in 2020 (costs are relative to reference supply cost in 2030)

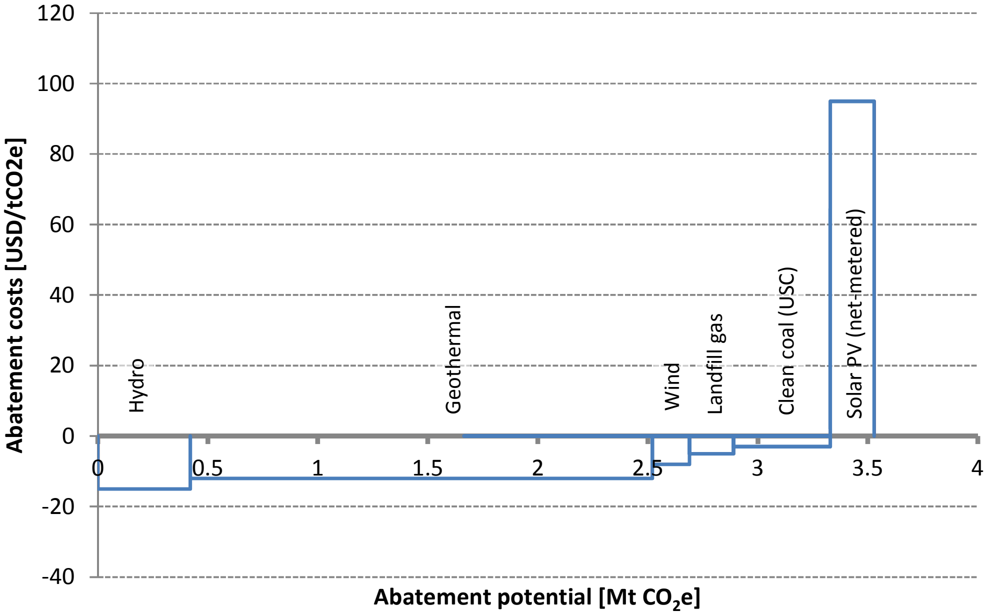
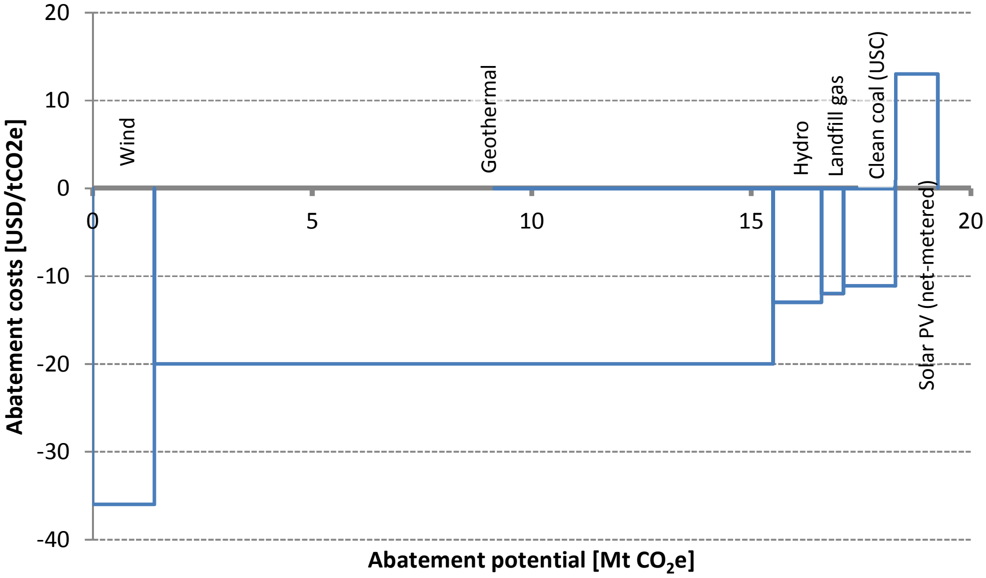


Figure 5.11: Marginal abatement cost curve for different low-carbon development options in the electricity sector in 2030 (costs are relative to reference supply cost in 2030)



The impact of the assumed learning rates of different technologies can be observed in the changing marginal abatement costs over time. However, the same set of technologies shows a negative marginal abatement cost in both time horizons. As described earlier, the underlying local Kenyan electricity generation costs have not been calculated within the frame of this analysis, but build on the work of the ULCPDP and other technology-specific studies performed in Kenya (see Section 5.4 on Methodology).

Moreover, while marginal abatement costs give an indication of the cost-effectiveness of different low-carbon options, their results should be interpreted with a high-level of caution: results are highly dependent on the assumptions underlying the levelised cost of electricity (LCOE) and don't give an indication on the capital intensity of the options. The latter is especially relevant for many renewable energy sources, which require high upfront costs but no fuel costs. As a consequence, access to capital is an important barrier for many renewable energy options. Marginal abatement costs also do not reflect other barriers to the deployment of technologies and generally don't include transaction costs required for project development. Finally, marginal abatement cost curves say nothing about the development benefits of various options, and thus can only provide one input into a more comprehensive process of selecting mitigation options to pursue.

5.6.5 Development benefits

Development benefits have been qualitatively described within the study and tested with stakeholders at workshops, expert panels and individual interviews. Table 5.9 shows an overview of development benefits of the low-carbon options in the electricity sector (see also fact sheets in Annex 1).

Table 5.9: Overview of development benefits of low-carbon development options in the electricity sector

● High Positive ◓ Positive ▬ Neutral / Minor impact ◡ Negative ⊖ Uncertain	Climate			Development				
	Abatement potential 2030 ($MtCO_2$)	Abatement cost 2030 (USD/tCO_2)	Adaptation impact	Energy security	GDP growth	Employment	Improved waste management	Environmental impact
Expanding geothermal power	14.1	-19.9	●	●	●	▬	▬	▬
Expanding wind power	1.4	-36.7	◓	◓	◓	▬	▬	▬
Expanding hydro power	1.1	-13.2	◡	◓	◓	▬	▬	⊖
Distributed solar PV	1.0	13.3	◓	◓	◓	◓	▬	▬
Landfill gas generation	0.5	-12.4	◓	◓	◓	▬	●	◓
Clean coal (USC)	1.1	-11.1	◓	▬	◓	▬	▬	◡

All renewable energy based options contribute to improving energy security in Kenya because the deployed resources are renewable and do not require import of fossil fuels and don't compete with other uses for domestically available fossil fuels. Moreover all of the low-carbon options in the electricity sector contribute to GDP growth, because electricity use is constrained by supply, thus any additional electricity generation capacity in Kenya attributable to low carbon finance may contribute to economic activity. Given that geothermal electricity generation has by far the largest generation potential, its potential contribution to energy security and GDP growth was assessed as being highly positive.[59] In terms of employment, it was assumed that none of the options but distributed solar PV would directly lead to the creation of additional employment opportunities.

Distributed solar PV was assumed to have the potential to contribute to job creation, as the installation and maintenance of PV systems requires specialist installers. To a lesser degree all the renewable technologies have the potential to create new skilled jobs, and these will require new skills, knowledge and experience (such as geothermal drilling, wind firm operation and maintenance). Electricity generation from landfill gas has the additional benefit that it requires an improved waste management system and consequently also lowers the environmental impact of the waste disposal site by reducing leakage of pollution into surface- and ground-water and generally improving the hygienic conditions of the site.

The impact of new hydropower plants on the environment is uncertain. Hydropower dams may disturb the natural flow regime of a river and can negatively impact biodiversity. However, depending on the ecosystem where the river is located, on the hydrological regime and the type of dam, the negative environmental impact of hydropower may be minimal. Ultra-supercritical coal, while having lower GHG emissions than less-efficient coal-fired power generation, still generates local air pollution through emissions of sulphur dioxide and nitrous oxide thus having a negative environmental impact.

5.6.6 Climate resilience impacts of low-carbon development options

Hydro generation is the low-carbon development option most vulnerable to climate change. Reductions in rainfall, and thus water reserves, directly reduce the availability of hydroelectricity. The other mitigation options discussed in this chapter are, by and large, resilient to climate change, or would experience very small impacts in comparison to hydropower. Very small risks in the timeframe of 2030 are associated with changing wind regimes and increased extreme weather events for wind generation; increased temperatures and/or cloud cover for solar generation; and reductions in cooling capacity for river cooled clean coal as well as small efficiency losses if temperatures increase.[60]

5.6.7 Feasibility of implementation

Several broad classes of barriers have been identified for low carbon options in the electricity sector in Kenya. These relate to:

- Project risk;
- Upfront financing;
- Rates of return;
- Regulatory framework and planning; and
- Capacity.

Project risk

Three specific types of project risk are discussed here. The first is so-called exploration risk that is particularly relevant for geothermal generation when identifying sites with suitable resources. The costs to drill exploratory holes to test for the presence of sufficient steam is expensive and risky as unsuccessful drilling efforts would be very difficult to fund for all but the largest developers. Kenyan experience shows that multilateral, bilateral, private entities are unwilling to invest in these exploration and appraisal phases.[61] The risk and costs associated with geothermal drilling have largely been addressed by the Government of Kenya through their direct finance of drilling activities, with the successful sites and steam-resource then made available for power producers at, effectively, very little risk.

The second risk related barrier is in securing a power purchase agreement (PPA). Anecdotal evidence from developers suggested that the PPA process was often not transparent and lengthy. This can disadvantage smaller developers who do no have the resources to pursue a PPA over a longer period of time, and could also influence investors who will look for a PPA before committing to finance. This lack of certainty on timing and success for developers significantly increases project risk. This position on the limitations of the current PPA process is supported by observations in the recent National Energy Policy and was raised in a 2012 workshop organized by the World Economic Forum in Nairobi on *Unlocking Financing for Clean Energy in Kenya*.[62]

Thirdly, and more specifically for hydro, is resource risk. Uncertainty in climactic conditions from year to year can greatly influence hydro generation output. This makes sites with more variable hydrological conditions less favourable and increases the perception local developers that small hydro projects can be unreliable.

Upfront financing

Local financing conditions offer a number of hurdles to developers seeking upfront capital for renewable energy projects. A combination of high interest rates from local lending institutions, a lack of familiarity with renewable electricity projects, insufficient reserves for lending on the scale required for larger projects and doubts about the robustness of non-guaranteed PPAs all contribute to making project financing one of the largest barriers for developing low carbon technologies in the electricity sector.

Government officials noted that many developers who had applied for feed-in tariffs and negotiated PPAs were still having trouble raising project financing. The French Development Agency supported a small loan scheme for renewable energy and energy efficiency projects that was quickly oversubscribed, predominantly by renewable generation projects.

The challenges of upfront financing are particularly acute for geothermal power. After exploration is successful and the presence of steam is confirmed, large costs are incurred for production drilling. This requires significant capital investments well before electricity production begins. The Government of Kenya largely finances these upfront costs through its scheme to effectively lease out production-ready steam fields. However, the government would be challenged to fund the upfront costs related to the capacity forecasts in the ULCPDP. Although there are plans for much of the necessary financing to be raised from GDC steam revenues, there is still a significant proportion that will need to be provided by the Government of Kenya.[63]

Rates of return

In many countries without renewable energy incentives the rates of return on renewable generation projects are a fundamental barrier. Of course, the Kenyan feed-in tariff is designed to address this issue directly and is based on an estimate of actual plant development, construction and operation costs along with an assumed margin for project developers. Although calculated in detail, the final tariffs are still open to being too high (offering larger profits) or too low (does not provide sufficient incentive for development). Anecdotal evidence from project developers suggests that some tariffs are too low to attract significant investment. This may be supported by observations that the feed-in tariff has been very successful at attracting applications for certain renewable technologies but not for others. While not conclusive, this suggests that revisiting tariffs to assess their efficacy could be useful.

Country risk (political stability, legal and regulatory framework, and institutional change)

The 25-year economic life (or longer) of a geothermal project will see several changes of government. Investors and financiers seriously worry over whether they will be able to repatriate their investment to their country of origin, convertibility of the local currency to other currency without making serious exchange losses or restriction and whether investment owned by foreigners will not be expropriated by rogue governments.

Kenya targets foreign investment as a source of capital for national development especially in the energy sector. In 2010, the country promulgated a new constitution that was aimed at creating stronger institutions and that devolved power to stem abuse and thereby create a stable political environment in the country. The country has further liberalized the exchange rate and has created institutions to promote foreign investment in Kenya.

All investments will result in various business transactions and contractual relationships. Potentially all these transactions and relationships could give rise to disputes necessitating arbitration and or court adjudication. Therefore investors and financiers will be concerned whether justice can be served and be enforced by the appropriate institutions and national policies. In this regard, Kenya continues to work towards and independent judiciary and enters into varies treaties and membership so as to provide comfort to investors.

On the regulatory front, there have been large changes in the last decade in terms of access for IPPs and guarantees for connection. However, in some areas more support for IPPs and certain technologies could be offered.

Some stakeholders felt that the planning and implementation of grid connections for IPPs is a lengthy process. Access to electricity markets is a fundamental requirement for developers to ensure their business plan will be successful. Increased transparency of connection times as well as reduced times to connection could be beneficial for more remote projects.

A barrier that is specific to distributed grid-connected solar PV is the need for net-metering. Individual consumers wishing to generate their own electricity and sell surplus back to the grid require an appropriate regulatory framework (for example detailing connection requirements) and a clear process for receiving compensation. At present this is very difficult in Kenya and, largely as a result, extremely rare.

Capacity

This is a broad class of barriers that covers aspects such as low public and private sector awareness of low-carbon technologies, but there are also more specific limitations in current systems, for example in terms of:

- Collection of waste - although the generation of MSW has grown rapidly, the capacity to collect and dispose the residues has declined.[64]
- Dispatch of generation plants - local experts noted that hydropower is not currently optimally dispatched, hydro resources could be more effectively conserved and used in times of need with improved technology
- Local expertise - notwithstanding the large demands of localising manufacturing in a new country, the installation and on-going maintenance of renewable generation plants also require a high level of technical training and familiarity with the equipment. For Kenya to use local labour resources for the expansion of renewable electricity, this capacity will need to be built up.

- Inclusion of development benefits into planning - several stakeholders felt that if external benefits from developing renewable energy were considered in the preparation of the ULCPDP, more renewable energy sources could become competitive.[65]

Both investors and financiers will consider the capacity and financial security of institutions in the entire electricity generation and distribution chain. KETRACO is mandated to develop transmission infrastructure and KPLC (now Kenya Power) is mandated to off-take power, distribute and sell to consumers. There is some evidence that KPLC's viability as a long term power off-taker may be perceived as a risk for IPPs, with some demanding Government of Kenya guarantees or letters of comfort.

5.7 Potential Policy Measures and Instruments

Generally speaking, renewable electricity generation likely has better chances of being successfully developed in countries with the following characteristics:

- Suitable levels of renewable resource, with data on resources certified by an appropriate expert institute;
- Financial incentives for renewable electricity in general, or high electricity prices from the current generation portfolio;
- Supportive policies, government initiatives and regulatory framework;
- Strong domestic capacity in a number of areas including technical expertise, financial institutions and political and private sector awareness; and
- Appropriate grid connection regulations and infrastructure for utility-scale renewable energy.

Governments have many options to reduce barriers to renewable electricity and create an appropriate enabling environment, discussed below are the broad categories of market access policies, regulatory frameworks and supporting measures.

5.7.1 Market access policies

Renewable electricity generation will often require support in order to allow it to compete with conventional generation in terms of cost and feasibility to develop. The policies that provide this kind of support can be viewed as providing access for renewables to the market. If renewable energy technologies are not cost-competitive with conventional energy, support can be provided as direct incentive (in the case of Kenya through a feed-in tariff). To overcome the barrier of high-upfront capital costs, soft loans or loan guarantees that improve the financial feasibility and reduce risks of projects respectively, can be deployed.

Feed-in tariffs

A feed-in tariff provides a set premium price for a set period to power producers for renewable electricity generation. With a feed-in tariff in place since April 2008 and high level of interest shown in the policy from the private sector – more than 1,750 MW of capacity had applied for a feed-in tariff as at the end of 2011 (MoE, 2012) – Kenya has an excellent foundation for the promotion of renewable energy. A feed-in tariff can be a very effective tool to promote the development of renewable electricity in a targeted, cost effective and controlled way (when quotas on permissible capacities are introduced). They are well suited to younger liberalized electricity markets with a relatively low level of competition (unlike tenders or quota systems) and can provide investor certainty in such fledgling markets where quotas may not. Furthermore they are relatively simple to combine with other mechanisms -

such as carbon market financing. Finally, feed-in tariffs are generally considered simpler to administer and enforce.

There are two key aspects to ensure the success of a feed-in tariff scheme. First, the correct setting of tariffs is required to attract developers without offering windfall profits. Without performing an extensive analysis of the current feed-in tariffs in Kenya it is difficult to say anything conclusive about the current incentives. However, the somewhat uneven distribution of applications from the private sector across different technologies, as well as anecdotal evidence from workshops, suggests that there could be value in revisiting the current tariffs to ensure that they offer sufficient incentive to developers for 'undersubscribed' technologies. A second concern relates to the structure of the FiT policy, which defines a maximum, or ceiling, tariff for each technology. This introduces an element of revenue uncertainty for investors, which the policy is meant to eliminate. Another important aspect of remunerating IPPs relates to PPAs, both the perceived strength of these agreements and the ease with which they can be negotiated. These issues are discussed further in the sections below on loan guarantees and the regulatory environment.

Loan guarantees and low-interest loans

The scale of many renewable energy projects (that is, the size of investment required), as well as the often limited capital reserves of many project developers in developing countries, means that the loans are the primary method of obtaining debt capital. However, borrowing institutions in developing countries often have little experience with renewable energy projects. As a result they: i) are less likely to offer competitive interest rates; ii) may demand infeasible collateral; or iii) only offer shorter term loans that do not suit the longer term revenue models of most forms of electricity generation.[66] Furthermore, commercial interest rates in many countries may be incidentally high, even for more traditional borrowers.

The resulting high costs of debt can be reduced through financial assistance in the form of soft or low-interest loans (below full commercial interest rates). If such loans can be made available to developers of renewables they can greatly influence the viability of a project, both in terms of access to capital, but also the interest rates on that capital. A similar smaller-scale initiative has already been funded by the French Development Agency in Kenya and is managed, from a technical perspective, by the Centre for Energy Conservation and Efficiency at the Kenyan Association of Manufacturers.[67] If sufficient funds can be made available (typically through a longer-term revolving fund) then such loans can be a key part of overcoming financing barriers for renewables.

Rather than directly providing loans for projects or developers, loan guarantees – guaranteeing lenders that they will be paid should the borrower default – can be used to reduce investment risk and allow more conventional streams of debt to be accessed. These instruments are often provided by governments or international sources of support and have underpinned a number of recent large renewable projects in countries with less developed banking structures. Based on the feedback of interviewees and Kenyan experts, the inability to obtain project financing, often with a PPA in place, is a key barrier to renewable energy deployment. Setting up the appropriate structures to be able to offer loan guarantees or guarantees of PPA payments could provide reassurance to investors. The Consolidated Energy Fund proposed in the recent National Energy Policy could be used to assist developers in securing loans or providing lower interest rates; however, its scope and capitalisation is not clear at this stage.[68]

5.7.2 Regulation

Legal and regulatory environment

Compared to many countries, Kenya is advanced in having a legal framework that supports IPPs – alongside the incumbent KenGen. It is important that independent producers have the right to generate and sell electricity to suppliers. Such sales are negotiated in the form of long-term PPAs, contracts that define the conditions and tariffs for the sale of electricity in the future from a particular developer. For capital-intensive generation projects, trustworthy PPAs are the key aspect of a project that determines the ability to secure financing.[69] Guarantees can provide a large part of the assurance for investors as to the robustness of a PPA, but at the same time, it is important that the PPA process is transparent and fast enough to suit private sector needs. This is recognised in the Kenyan National Energy Policy which recommends, amongst other points, that model PPAs be developed that can make the process clearer for developers.[70]

Specifically for solar PV – which is considered here as grid connected but distributed – there is a need for changes that will allow individual customers to send unneeded electricity back onto the grid and receive compensation for it. At the moment this does not seem to be possible – without special dispensation – with the current Kenyan regulatory framework and practices. Clear simple guidelines and rules for how small consumer generation sources should be connected and compensated are needed because barriers should be very low for these individuals to have an effective system.

However, frameworks that allow IPPs are only part of the required environment for encouraging renewable energy development. Other factors include: i) clearly defined guidelines for the authorization of renewable energy projects in terms of environmental, construction and land permitting; and ii) well defined roles and responsibilities within public consenting bodies. The recent changes to the permitting procedures for geothermal power in Kenya are a good example of how regulatory frameworks can be changed to remove barriers for renewable energy project developers. Previously, companies seeking to invest in geothermal power were required to seek licences and approvals from three different ministries. These processes were simplified through the establishment of a one-stop service through the GDC, an approach that can also benefit the broader range of renewable technologies.[71]

Connection regulations

Timely and cost effective grid access is critical for larger scale renewable energy development. When wind energy developers do not know how long they will have to wait or how much it will cost before projects can be connected, the risk to investors is higher. Kenya has regulations in place that provide guaranteed grid access for IPPs; however it is important to supplement these guarantees with appropriate grid planning and financing (to ensure timeliness of connection). Clear connection standards, connection timelines and transparent access charges are vital in minimising grid access as a barrier. A greater integration of capacity planning and transmission facilities planning between KPLC and KETRACO could be a first step towards this.

Special consideration needs to be given to small distributed renewables technologies, such as solar PV. These technologies require net-metering for consumers that choose to generate electricity, so that they can be duly compensated. Systems need to be in place that specify how connections are to be made, what certification is required, and possibly compensating current electricity distributors to ensure that there is no perverse incentive to refuse new connections.[72]

5.7.3 Supporting measures

While market access policies and appropriate regulatory frameworks could be seen as the primary requirements for enabling renewable electricity, there are also a number of supporting policies and initiatives that can be used to reduce barriers to technology uptake.

Capacity development, awareness raising and training

For all new technologies, in any country, initial awareness and technical and institutional capacity is lower. Several government interventions can help to build this capacity, as well as critical private sector awareness, both in terms of the technology and the policy incentives available. These include training programs for personnel to construct, operate and maintain facilities, as well as awareness programmes to build public support. In addition, public authorities need to develop a good level of understanding of renewable technologies and their benefits.

Demonstrations

Demonstration and pilot projects can be a valuable source of experience, awareness and social acceptance in a country. They can help to prove that certain technologies will work and what the benefits could be; an important aspect for new unfamiliar investors. Demonstrations can also be helpful to identify any bottlenecks or barriers in the development of new projects. While less relevant in Kenya for many of the technologies considered in this report – as there is some experience with them already domestically or they are better understood – demonstrations could be considered in instances where there is limited local experience, or even in specific regions where familiarity is lower.

Resource assessments and data management

Most types of renewable energy technology will require reliable measurements of the available resource in order to determine the expected performance. This could be measurements of average wind speeds, seasonal flow rates in rivers, average insolation levels or assessments of biomass feed-stocks. Collecting the necessary data can be a time consuming and expensive exercise, and an absence of data could be a large initial barrier for developers interested in a technology. Governments can perform initial resource assessments and provide publicly available maps in an effort to show the viability of different technologies. Resource assessments are also a valuable tool for governments when planning capacity and grid expansions, as well as providing an important input for determining incentive policies such as feed-in tariffs.

Assessments are already being done, to a certain degree in Kenya, and even being taken a step further for wind resources where the government is setting up a system of met-masts for direct measurements and certification.[73] However, there is still significant room to improve the resource mapping and data availability of many of the renewable resources in Kenya. This would also provide an additional signal to investors that the government is committed to pursuing renewables.

Hydropower is a somewhat special case as the level of available resource is directly tied to weather patterns in a given year. It is noted that the government is considering a hydro risk mitigation fund, under the proposed Consolidated Energy Fund, to cater for risks such as prolonged droughts.[74]

5.8 Conclusion

The analysis in this report demonstrates how low-carbon development options for electricity generation in Kenya can lower GHG emissions compared to a reference case and, at the same time, provide sustainable development benefits, thus contributing to Kenya's development goals.

Kenya has excellent potential for cost-effective generation of electricity from renewable energy sources. **The largest potential lies in the expansion of geothermal electricity that can provide low-cost, base-load power, thus facilitating economic activity and development while increasing energy security and contributing to climate resilience through lowering the reliance on hydropower.** This priority has been confirmed in stakeholder consultations.

Annex 1: Fact Sheets - Low-carbon Development Options

Geothermal Power Generation

Support for scaling up geothermal power as a low-carbon base load energy source, can increase electricity demand and improve energy security in Kenya.

Current situation: At present, geothermal energy accounts for 13% of electricity generation in Kenya. With an installed capacity of 198 MWe (with an additional 332 MWe scheduled for commissioning in 2013), this is only a small fraction of the technical potential estimated in Rift Valley (7,000 to 10,000 MWe). Geothermal has experienced a slow growth rate in the past, but recently have been significant efforts to scale up growth, including establishment of GDC and SREP.

Low-carbon scenario: In the ULCPDP scenario, full exploitation of geothermal generation is forecasted (5,500 MW in 2030), which is a significant increase compared to the business as usual scenario (2,700 MW in 2030).

Development benefits and priorities

Development benefits:

- May reduce energy bills for consumers,
- Improves energy security through lower fossil fuel imports,
- Provides stable base load electricity as basis for economic growth,
- Low environmental impact when well-managed, and
- Increase economic activity in the Rift Valley.

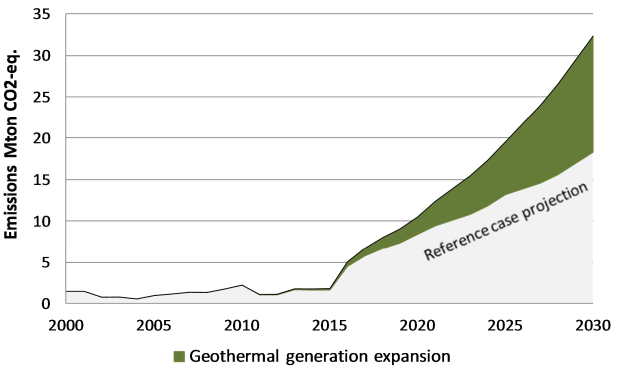
Alignment with Government of Kenya priorities: Geothermal can be the source of power for the future of Kenya. As such, it is a top priority of the Kenyan Government, which is made explicit in several strategic planning documents, such as Vision 2030 and SREP.

Links to adaptation: less vulnerable to a changing climate than hydropower.

Abatement potential and costs

Greenhouse gas abatement: Geothermal capacity can replace the need for additional fossil fuelled generation capacity. Every 100 MWe capacity can mitigate approximately 600 $ktCO_2$/year of GHG emissions. The low carbon scenario indicates a total abatement potential of 14,000 $ktCO_2$/year in 2030.

Costs: The unit costs of mitigation are expected to be favourable, from a marginal abatement cost of US4 -4 per tCO_2 today to US$ -20 per tCO_2 in 2030. However, the upfront investment in developing a geothermal site is substantial. The financing plan for a 200MW geothermal plant, including the grid connection, shows a total project cost of USD 800 mln (or 83 billion KSh).[75]



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	198	791	1,312	1,872	2,734
Capacity - low carbon scenario (MW)	198	826	1,727	3,127	5,509
Abatement potential ($ktCO_2e$)	-	177	2,104	6,364	14,073

Feasibility of implementation

Existing barriers are the lack of technical expertise, high capital investments, availability of drilling rigs and equipment, and infrastructure availability (such as roads and grid). For IPPs, additional barriers include the need for guarantees or insurance.

The lead time for projects currently under development is 13 to 15 years. GDC seeks to reduce the project development period to about five years for the 400MW project in Menengai by undertaking the initial project activities. This includes include detailed surface exploration, infrastructural development, drilling of exploratory and appraisal wells.

Stakeholders are aware of the benefits and potential for scaling up geothermal. Acceptance is large and no behavioural changes are required (it is an upstream technology). Issues may arise when exploration and exploitation lead to displacement of local communities.

Wind Power Generation

Current situation: The existing installed capacity is small, mostly accounted for by the 5 MW park in Ngong. A further 610 MW[76] are planned to be installed by IPPs, the largest being the 300 MW Lake Turkana park.

Low-carbon scenario: Wind generation grows from a business-as-usual projection of 1,200 MW in 2030 and exploits slightly more than the capacity forecast in the ULCPDP, for a total of 2,000 MW in 2030).

Development benefits and priorities

Development benefits:

- Improved energy security through lower oil and coal imports.
- Low environmental impact.

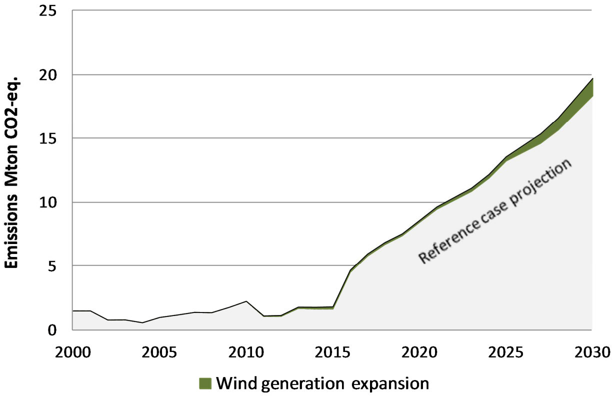
Alignment with GoK priorities: As stated in Vision 2030, Kenya aims to increase reliance on national energy resources and increase electricity generation from renewable sources.

Links to adaptation: Less vulnerable to the changing climate than hydropower.

Abatement potential and costs

Greenhouse gas abatement: Wind capacity can prevent the need to build new fossil fuel generation capacity. On this basis, the mitigation potential is in the order of 1,360 ktCO$_2$e per year in 2030.

Costs: Unit costs of mitigation are expected to improve over time, from a marginal abatement cost of US$ 20 per tCO$_2$e in 2012 to US$ -37 per tCO$_2$e in 2030, due to the fall in component costs globally and domestic process learning.



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	5	415	631	921	1,211
Capacity - low carbon scenario (MW)	5	516	751	1,116	2,016
Abatement potential (ktCO$_2$e)	-	170	143	329	1,360

Feasibility of implementation

Barriers include:

- Large up-front capital investments and support (such as a feed-in tariff) needed in the medium term.
- IPPs need guarantees or insurance due to the strength of PPAs.
- Difficulty of securing grid connection, particularly in remote wind sites.
- Limited in-county experience.

Hydroelectric Power Generation

Current situation: 750 MW currently exploited with reasonable level of resource remaining (including small-hydro), but most are not economical.

Low-carbon scenario: Similar to the business-as-usual scenario of the ULCPDP in that plans for hydro are fulfilled at 950 MW in 2030, plus an Increase of 100 MW in 2030, for a low-carbon scenario of 1,050 MW in 2030.

Development benefits and priorities

Development benefit:

- Improves energy security through lower oil and coal imports.

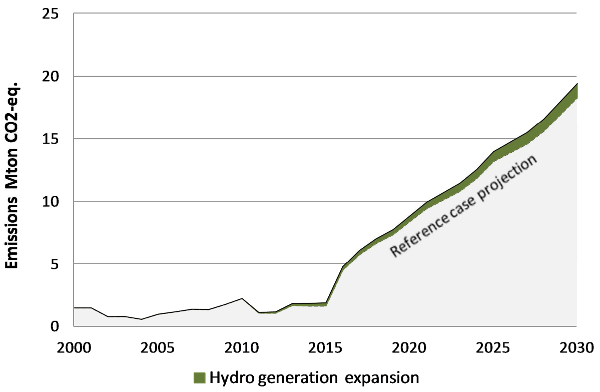
Alignment with GoK priorities: Vision 2030 aims to increase the reliance on national energy resources and achieve an expansion of electricity generation from renewable sources.

Links to adaptation: Hydropower is vulnerable to climatic changes.

Abatement potential and costs

Greenhouse gas abatement: Hydro capacity can prevent the need to build new fossil fuel generation capacity. On this basis the mitigation potential is in the order of 1,100 $ktCO_2$/year in 2030.

Costs: The unit costs of mitigation are expected to remain roughly constant over time, varying from a marginal abatement cost of US$ -17 per tCO_2e in 2012 to US$ -13 per tCO_2 in 2030.



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	758	831	1,031	1,031	1,031
Capacity - low carbon scenario (MW)	758	906	1,156	1,256	1,356
Abatement potential ($ktCO_2e$)	-	253	422	760	1,098

Feasibility of implementation

Barriers for implementation:

- Many of the best hydropower sites have been already been exploited;
- Projects are capital intensive and present a risk for investors;
- Securing low interest rate loans for community projects is difficult;
- Lack of awareness of small-hydro in many areas; and
- Economics of smaller sites.

Solar PV - Distributed

Current situation: Experience gained through the installation of 200,000 with solar home systems; but and very limited experience with larger-scale distributed PV (such as found at the UNEP site)

Low-carbon scenario: Moderate uptake of distributed solar PV in the medium term (200 MW by 2020[77]) and 1,000 MW by 2030.

Development benefits and priorities

Development benefits:

- Improved energy security through lower oil and coal imports.
- Lower environmental impact than other forms of electricity generation.

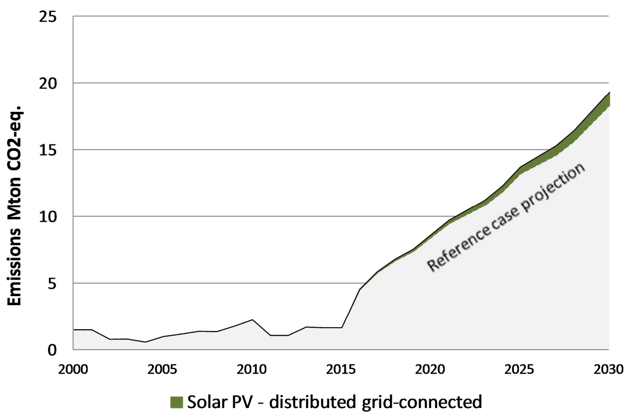
Alignment with GoK priorities: As stated in Vision 2030, Kenya aims to increase the reliance on national energy resources and increase electricity generation from renewable sources.

Links to adaptation: Minimally affected by weather conditions and can replace vulnerable hydropower.

Abatement potential and costs

Greenhouse gas abatement: Solar capacity can prevent the need to build new fossil fuel generation capacity. On this basis the mitigation potential is in the order of 1,000 ktCO_2e per year in 2030.

Costs: The unit costs of mitigation is expected to improve over time, from a marginal abatement cost of US$ 177 per tCO_2e in 2012 to US$ 13 per tCO_2e in 2030.



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	negligible	-	-	-	-
Capacity - low carbon scenario (MW)	negligible	5	200	500	1,000
Abatement potential (ktCO_2e)	-	5	192	480	960

Feasibility of implementation

Kenya has good solar resources, but further price decreases of solar PV systems are required to be directly competitive with consumer electricity tariffs. In addition, a net-metering system or equivalent is required. Acceptable definitions of payback period are critical.

Electricity Generation from Landfill Gas

When municipal solid waste (MSW) is dumped to a landfill, the organic component can degrade in the absence of oxygen, which is called anaerobic digestion. This process releases methane that typically escapes to the atmosphere and contributes to climate change. The methane can be captured and can be used as a source of fuel to generate electricity and heat through combustion.

Current situation: A feasibility study examining the use of landfill gas (from MSW) in Nairobi has been carried out, but there are no concrete plans for implementation. Initial studies suggest up to 64 MW of generation capacity exists in Nairobi.[78]

Low-carbon scenario: Moderate growth such that the existing capacity in Nairobi is exploited in 2020, growing to 100 MW across all of Kenya in 2030.

Development benefits and priorities

Development benefits:

- Improved management of landfills.
- Potential source of baseload for reliable power supply.
- Improved energy security.
- Incentive to collect waste and environmental and health benefits resulting from this collection.

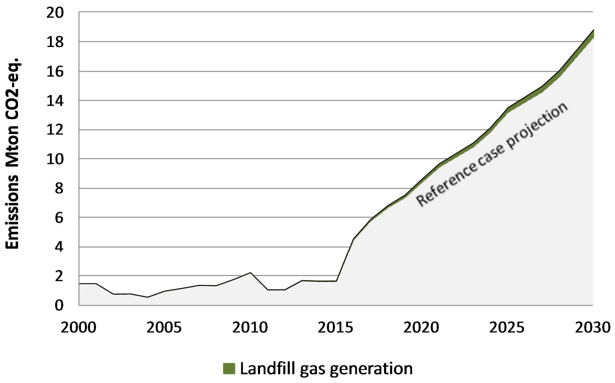
Alignment with GoK priorities: As stated in Vision 2030, Kenya aims to increase the reliance on national energy resources and increase electricity generation from renewable sources.

Links to adaptation: May be very marginally affected by weather conditions (the moisture content of the waste is a key factor in determining methane production) but it can replace hydropower which is more vulnerable.

Abatement potential and costs

Greenhouse gas abatement: Landfill gas capacity can prevent the need to build new fossil fuel generation capacity. On this basis the mitigation potential is in the order of 479 $ktCO_2e$ per year in 2030.

Costs: The unit costs of mitigation are found to be favourable and are expected to improve over time, from a marginal abatement cost of US$ -3 per tCO_2e in 2012 to US$ -12 per tCO_2e in 2030.



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	-	-	-	-	-
Capacity - low carbon scenario (MW)	-	6	42	64	100
Abatement potential ($ktCO_2e$)	-	28	201	306	479

Feasibility of implementation

Electricity generation from landfill gas faces some barriers:

- An effective waste collection and management system needs to be in place.
- Moderate up-front investment required for the infrastructure,
- New landfill sites take many years to start producing significant quantities of methane
- Upfront planning of new sites is needed to incorporate the possibility of landfill gas generation.
- The amount of MSW that currently reaches the deeper landfill (defined by the IPCC defines as >5m or where there is a high water table). At the moment only about 18% of total urban MSW reaches this type of landfill; and Dandora landfill in Nairobi is this type. The amount going to the deeper landfill needs to increase to approximately 50% by 2030 to improve electricity generation potential out to 2030 (and support the capacities are shown here). This should be possible, and is a valid assumption, because of alignment with the development goals of the government.

Clean Coal

Current situation: First 300 MW coal-fired power plant to become operational in 2018 with further expansion expected. There is promising coal exploration project in the Mui basin.

Low-carbon scenario: Instead of the state of the art pulverised coal generation (with approximately 40% thermal efficiency) an ultra-supercritical generation (USC) with approximately 45% thermal efficiency is installed.

Development benefits and priorities

Development benefits:

- Limited benefits, slightly improved energy security through higher efficiency and reduced imports.

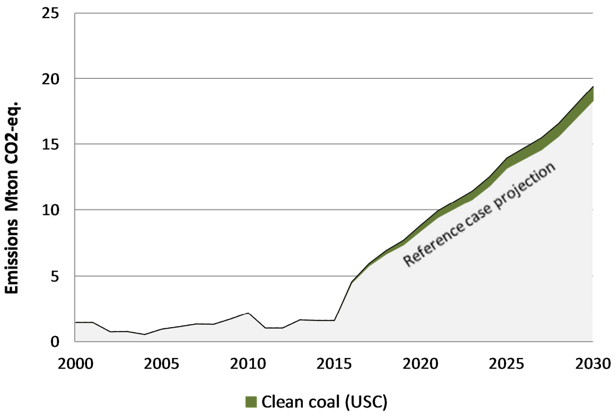
Alignment with GoK priorities: Coal generation is one of the Vision 2030 flagship projects.

Links to adaptation: Plants using ocean water for cooling are minimally affected by weather conditions and inland plants using river water could also be vulnerable to changing flow conditions.

Abatement potential and costs

Greenhouse gas abatement: The abatement potential of clean coal is limited as the relatively modest efficiency improvement of USC coal plants only leads to a small decrease in the emissions intensity. On this basis the mitigation potential is in the order of 1,110 ktCO$_2$e per year in 2030.

Costs: The unit costs of mitigation are expected to improve over time, from a marginal abatement cost of US$ 5 per tCO$_{2e}$ in 2012 to US$ -11 per tCO$_2$e in 2030.



Scenario	2010	2015	2020	2025	2030
Capacity - baseline (MW)	-	-	-	-	-
Capacity - low carbon scenario (MW)	-	-	320	920	2,120
Abatement potential (ktCO$_2$e)		-	437	774	1,110

Feasibility of implementation

Larger upfront capital investments and more technically demanding facilities are required for more efficient technologies.

References

Angell, C., Ben-Artzi, G., Notides, E. and Taplin, N. 2010. *The role of IGCC in China: past, present and future*. Boston: John Hopkins University School of Advanced International Studies.

Bazilian, M., Onyeji, I., Liebreich, M., MacGill, I., Chase, J., Shah, J., Gielen, D., Arent, D., Landfear, D., and Zhengrong, S. 2012. R*e-considering the Economics of Photovoltaic Power*, forthcoming.

Chicago Climate Exchange, Inc. 2009. *Landfill Methane Collection and Combustion Offset Project Protocol*. Chicago: Chicago Climate Exchange, Inc.

Chicago Climate Exchange, Inc. 2009. *Renewable Energy Systems Offset Project Protocol*, Chicago: Chicago Climate Exchange, Inc.

Fischer, E., Schmidt, T., Hora, S., Geirsdorf, J., Stinner, W., and Scholwin, F. 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.

Government of Kenya. 2007. *Kenya: Vision 2030*. Nairobi: Ministry of Planning and National Development and the National and Economic Council, Office of the Prime Minister.

Hille G. et al. 2011 *Grid Connection of Solar PV: Technical and Economical Assessment of*

Net-Metering in Kenya, Berlin: GIZ.

Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama: Institute for Global Environmental Strategies on behalf of the IPCC.

International Energy Agency. 1999. *International small hydro atlas: Kenya*. Paris: International Energy Agency. Accessed at: http://smallhydro.wesa.ca/index.cfm?Fuseaction=countries.country&Country_ID=49.

International Energy Agency and Organisation for Economic Co-operation and Development. 2002. *Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector*. Paris: Organisation for Economic Co-operation and Development and International Energy Agency.

Kenya Power and Lighting Company (KPLC). 2010. *Kenya electricity expansion project – KPLC distribution component*. Nairobi: Kenya Power and Lighting Company.

KPLC. 2011. *2010/2011 Annual Report*. Nairobi: KPLC.

KPLC. 2011. *Kenya Electricity Expansion Project (KEEP): Transmission Component*. Nairobi: KPLC.

Ministry of Energy (MoE). 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.

MoE. 2012. *Ministry of Energy website*. Accessed 4June 2012 at: http://www.energy.go.ke/?page_id=2 .

MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

MoE. 2012. Personal Communication from the Ministry. provided 14th February 2012.

Ngugi, P. 2012. Financing the Kenya geothermal vision, Short Course on Geothermal Development and Geothermal Wells, El Salvador: United Nations University-Geothermal Training Programme and LaGeo.

Omenda, P. 2007. *Status of Geothermal Exploration in Kenya and Future Plans for its Development*. Nairobi: United Nations University and KenGen.

Phillips, J.N. and Wheeldon, J.M. 2010. *Economic Analysis of Advanced Ultra-Supercritical Pulverized Coal Power Plants: A Cost-Effective CO2 Emission Reduction Option?* Palo Alto: Electric Power Research Institute.

United Nations Environment Programme. 1996. *International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management*. IECT Technical Publication Series 6. Nairobi: Division of Technology, Industry and Economics, UNEP.

UNEP. 2005. *Selection, Design and Implementation of Economic Instruments in the Solid Waste Management Sector in Kenya: The Case of Plastic Bags*. Geneva: Economics and Trade Branch, UNEP.

UNEP (2006) *City of Nairobi Environmental Outlook*. Accessed at: http://www.unep.org/DEWA/Africa/docs/en/NCEO_Report_FF_New_Text.pdf.

Urban, F. and Mitchell, T. 2011. *Climate change, disasters and electricity generation*. Brighton: Institute of Development Studies.

World Economic Forum. 2012. *Unlocking Financing for Clean Energy in Kenya*. Workshop in Nairobi, Kenya, 15 May.

World Bank 2008. *REToolkit: A Resource for Renewable Energy Development*, Washington, D.C.: World Bank. Accessed at: http://go.worldbank.org/SFJ8KQ6PS0.

World Bank. 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission,* 7-11th February.

World Bank. 2011. *Scaling-Up Renewable Energy Program (SREP) Investment Plan for Kenya*, Climate Investment Funds.

Endnotes

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[1] Contracted output from the station under normal operating conditions.
[2] Kenya Power and Lighting Company Limited (KPLC). 2011. *2010/2011 Annual Report*. Nairobi: KPLC.
[3] World Bank, 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission*. Nairobi, February 7-11.
[4] KPLC. 2011. *2010/2011 Annual Report*. Nairobi: KPLC.
[5] KPLC. 2010. *Kenya electricity expansion project – KPLC distribution component*, Nairobi: KPLC. KPLC. 2011. *Kenya Electricity Expansion Project (KEEP): Transmission Component*. Nairobi: KPLC.
[6] Ministry of Energy (MoE). 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[7] MoE. 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[8] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE. MoE. 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[9] World Bank, 2011b. *Scaling-Up Renewable Energy Program (SREP) Investment Plan for Kenya*. Climate Investment Funds.
[10] Government of Kenya. 2007. *Kenya: Vision 2030*. Nairobi: Ministry of Planning and National Development and the National and Economic Council, Office of the Prime Minister.
[11] World Bank, 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission*. Nairobi, February 7-11.
[12] Government of Kenya. 2007. *Kenya: Vision 2030*. Nairobi: Ministry of Planning and National Development and the National and Economic Council, Office of the Prime Minister.
[13] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[14] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[15] Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama: Institute for Global Environmental Strategies on behalf of the IPCC
[16] MoE (2011) *Updated Least Cost Power Development Plan*, Republic of Kenya – Ministry of Energy, Nairobi, March 2011; MoE. 2012. *National Energy Policy – third draft*. Nairobi: MoE; IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama: Institute for Global Environmental Strategies on behalf of the IPCC
[17] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[18] MoE (2012b) *Ministry of Energy website*. Accessed 4th June 2012 at*:* http://www.energy.go.ke/?page_id=2.
[19] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[20] IPCC, 2006
[21] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[22] United Nations Environment Programme. 1996. *City of Nairobi Environmental Outlook*. Accessed at: http://www.unep.org/DEWA/Africa/docs/en/NCEO_Report_FF_New_Text.pdf
[23] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[24] As noted earlier, the methodology adopted here is not a typical wedge analysis, as the calculation of avoided emissions is not based on the mix in a given year in the reference scenario. The reference scenario is rather considered as a capital, or growth, constrained future. Considering the mix in any given year and using this to calculate an avoided emissions intensity would be somewhat artificial. In the absence of an unconstrained, carbon intensive baseline, the 2030 mix is used a representative fossil fuel mix for calculating avoided emissions.
[25] International Energy Agency and Organisation for Economic Co-operation and Development. 2002. *Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector*. Paris: Organisation for Economic Co-operation and Development and International Energy Agency.
[26] Assumed here as a conservative 20 tCO_2e per tCH_4 for a 100 year time horizon.
[27] However marginal abatement costs calculated later in this section are based on the full mitigation potential of both electricity decarbonisation and avoided methane.
[28] CCX, 2009a and 2009b
[29] Ngugi, P. 2012. *Financing the Kenya geothermal vision*. Short Course on Geothermal Development and Geothermal Wells. El Salvador: United Nations University-Geothermal Training Programme and LaGeo.
[30] Hille G. *et al*. 2011. *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*. Berlin: GIZ.

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[31] Fischer, E. *et al.* 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.
[32] Phillips, J.N. and Wheeldon, J.M. 2010. *Economic Analysis of Advanced Ultra-Supercritical Pulverized Coal Power Plants: A Cost-Effective CO2 Emission Reduction Option?* Palo Alto: Electric Power Research Institute.
[33] Geothermal installed capacity had increased to 208 MW as of July 2012
[34] KPLC. 2011. *2010/2011 Annual Report*. Nairobi: KPLC
[35] KPLC. 2011. *2010/2011 Annual Report*. Nairobi: KPLC
[36] World Bank, 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission*. Nairobi, February 7-11.
[37] KPLC. 2011. *2010/2011 Annual Report*. Nairobi: KPLC.
[38] Omenda, P. 2007. *Status of Geothermal Exploration in Kenya and Future Plans for its Development*. Nairobi: United Nations University and KenGen.
[39] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[40] World Bank. 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission,* 7-11th February.
[41] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[42] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[43] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE.
[44] International Energy Agency. 1999. *International small hydro atlas: Kenya*. Paris: International Energy Agency.
[45] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[46] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[47] Bazilian et al., 2012. 2012. R*e-considering the Economics of Photovoltaic Power*, forthcoming.
[48] World Bank. 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission,* 7-11th February.
[49] Bazilian *et al*., 2012, 2012. R*e-considering the Economics of Photovoltaic Power*, forthcoming.
[50] Hille G. *et al.* 2011. *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*. Berlin: GIZ.
[51] Hille G. *et al.* 2011. *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*. Berlin: GIZ.
[52] Fischer *et al.* 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.
[53] UNEP. 2005. *Selection, Design and Implementation of Economic Instruments in the Solid Waste Management Sector in Kenya: The Case of Plastic Bags*. Geneva: Economics and Trade Branch, UNEP.
[54] UNEP (2006) *City of Nairobi Environmental Outlook*. Accessed at: http://www.unep.org/DEWA/Africa/docs/en/NCEO_Report_FF_New_Text.pdf.
[55] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[56] Angell *et al*., 2010. *The role of IGCC in China: past, present and future*. Boston: John Hopkins University School of Advanced International Studies.
[57] Hille G. *et al.* 2011. *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*. Berlin: GIZ.
[58] Fischer *et al.* 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.
[59] That said, geothermal exploitation can have environmental impacts that need to be managed such as: subsidence, local air emissions (methane, sulphur dioxide and nitrous oxide) and surface water pollution.
[60] Urban, F. and Mitchell, T. 2011. *Climate change, disasters and electricity generation*. Brighton: Institute of Development Studies.
[61] Ngugi, P. 2012. *Financing the Kenya geothermal vision*. Short Course on Geothermal Development and Geothermal Wells. El Salvador: United Nations University-Geothermal Training Programme and LaGeo.
[62] World Economic Forum. 2012. *Unlocking Financing for Clean Energy in Kenya*. Workshop in Nairobi, Kenya, 15 May; and MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[63] Ngugi, P. 2012. *Financing the Kenya geothermal vision*. Short Course on Geothermal Development and Geothermal Wells. El Salvador: United Nations University-Geothermal Training Programme and LaGeo.
[64] Fischer *et a*l. 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.

---

[65] World Bank. 2011. *KENYA Scaling-Up Renewable Energy Program (SREP) Joint Development Partner Scoping Mission,* 7-11th February.

[66] World Bank. 2008. *RETToolkit: A Resource for Renewable Energy Development*. Washington, D.C.: World Bank.

[67] See: http://www.kam.co.ke/index.php/kam-services/energy-services/regional-techical-assistance-programme.

[68] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

[69] World Bank 2008. *RETToolkit: A Resource for Renewable Energy Development*, Washington, D.C.: World Bank.

[70] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

[71] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

[72] Hille G. et al. 2011 *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*, Berlin: GIZ.

[73] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

[74] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.

[75] World Bank, 2011. *Scaling-Up Renewable Energy Program (SREP) Investment Plan for Kenya, Climate Investment Funds, September 2011.*

[76] MoE. 2011. *Updated Least Cost Power Development Plan*. Nairobi: MoE. March 2011.

[77] Hille G. *et al*. 2011. *Grid Connection of Solar PV: Technical and Economical Assessment of Net-Metering in Kenya*. Berlin: GIZ

[78] Fischer *et al*. 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: GTZ.