REPUBLIC OF KENYA

Ministry of Environment andv Natural Resources

NATIONALLY DETERMINED CONTRIBUTION SECTOR ANALYSIS REPORT 2017

EVIDENCE BASE FOR UPDATING THE KENYA NATIONAL CLIMATE CHANGE ACTION PLAN

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ABBREVIATIONS

AgGDP	Agricultural gross domestic product
ASAL	Arid and Semi-Arid Land
AWF	African Wildlife Foundation
ASDSP	Agricultural Sector Development Support Programme
B10	10 percent of biodiesel
BAU	Business as usual
BRT	Bus rapid transit
CAADP	Comprehensive Africa Agriculture Development Programme
CCAFS	Climate Change, Agriculture and Food Security
CDM	Clean Development Mechanism
CFL	Compact fluorescent light
CGIAR	Consultative Group for International Agricultural Research
CIDP	County Integrated Development Plan
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COMESA	Common Market for Eastern & Southern Africa
CSA	Climate Smart Agriculture
DFID	Department for International Development (UK)
ERC	Energy Regulatory Commission
FAO	Food and Agriculture Organization of the United Nations
GBM	Green Belt Movement
gCO_2e	Grams of carbon dioxide equivalent (measures vehicle greenhouse gas emissions)
GDC	Geothermal Development CorporationGDP Gross domestic product
GEF	Global Environment Facility
GESIP	Green Economy Strategy & Implementation Plan
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German development agency)
GoK	Government of Kenya
GWh	Gigawatt hours
ha	Hectare
HFC	hydrofluorocarbon
ICPS	Improved Charcoal Production Systems
IFAD	International Fund for Agricultural Development
IGAD	Intergovernmental Authority on Development
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
ITDP	Institute for Transport and Development Policy
JICA	Japanese International Cooperation Agency
KAM	Kenya Association of Manufacturers
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
KenGen	Kenya Electricity Generating Company
KENVO	Kijabe Environment Volunteers
KEPSA	Kenya Private Sector Alliance
KES	Kenya Shilling
KFS	Kenya Forest Service
KIWA	Kenya Industrial Water Alliance
KNBS	Kenya National Bureau of Statistics
KRC	Kenya Railways Corporation

KRDP	Kenya Rural Development Programme
Kton	Kilotonne
KWS	Kenya Wildlife Service
LED	Light emitting diode
LPG	Liquefied petroleum gas
LRT	Light rail transit
LULUCF	Land Use, Land-use Change and Forestry
MALF	Ministry of Agriculture, Livestock and Fisheries
MENR	Ministry of Environment and Natural Resources
MOEP	Ministry of Energy and Petroleum
MOTIHUD	Ministry of Transport, Infrastructure, Housing and Urban Development
MPCO	Mikoko Pamoja Community Organisation
MRTS	Mass rapid transit system
MRV	Measurement, reporting and verification
MSW	Municipal solid waste
Mt	Million tonnes
$MtCO_2e$	Million tons of carbon dioxide equivalent
MTP	Medium Term Plan (of the Vision 2030)
MW	Megawatt
MWp	Megawatt peak
NAFP	National Forest Programme
NAMA	Nationally Appropriate Mitigation Action
NaMATA	Nairobi Metropolitan Area Transport Authority
NAP	National Adaptation Plan, 2015-2030
NCCAP	National Climate Change Action Plan 2013-2017
NCCRS	National Climate Change Response Strategy
NDC	Nationally Determined Contribution
NEMA	National Environment Management Authority
NMT	Non-motorized transport
NRT	Northern Rangelands Trust
PHPDT	Peak Hour Peak Direction Traffic
PV	Photovoltaic
REDD+	Reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SDG	Sustainable Development Goal
SLEEK	System for Land-Based Emissions Estimation in Kenya
SLM	Sustainable Land Management
SNA	System of National Accounts
SNC	Second National Communication
StARCK+	Strengthening Adaptation & Resilience to Climate Change in Kenya Plus programme (funded by DFID)
TOE	Tonnes of oil equivalent
TroFCCA	Tropical Forests and Climate Change Adaptation
ULCPDP	Updated Least Cost Power Development Plan
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific & Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USC	Ultra-super critical

1: INTRODUCTION & METHODOLOGY

1.1 INTRODUCTION

Kenya submitted its Nationally Determined Contribution (NDC) on 28 December 2016, when it deposited its instrument of ratification for the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC).[1] The NDC sets out an adaptation contribution of mainstreaming adaptation into Medium Term Plans and implementing adaptation actions. The mitigation contribution intends to abate greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario of 143 million tonnes of carbon dioxide equivalent ($MtCO_2e$). Achievement of the NDC contributions is subject to international support in the form of finance, investment, technology development and transfer, and capacity building.

Climate change action in Kenya is guided by the Climate Change Act, 2016, which provides a framework for mainstreaming climate change across sectors. The Act obligates the Cabinet Secretary responsible for climate change affairs to formulate a National Climate Change Action Plan (NCCAP) that will be approved by the National Climate Change Council chaired by His Excellency, the President of the Republic of Kenya. This five-year plan addresses all sectors of the economy and provides mechanisms for mainstreaming climate change into all sectors and in County Integrated Development Plans (CIDPs). The NCCAP represents the national mechanism through which Kenya's NDC will be implemented, in accordance with the Act.

The current NCCAP expires in 2017 and is being updated for 2018 to 2022. The process of updating the NCCAP will include the development of an implementation plan with clearly defined targets and indicators. The updated NCCAP will guide Kenya on priority climate change actions out to 2030, and the five-year implementation plan will guide Kenya toward the achievement of NCCAP and NDC goals. The NCCAP, 2018-2022 will also be the implementation plan for Kenya's NDC.

The goal of this NDC Sector Analysis is to clarify how Kenya will achieve its NDC, including adaptation goals and the GHG emission reduction contribution of 30% below the 2030 business as usual scenario. The information and analysis in this report comprises the evidence base for:

- Updating of the National Climate Change Action Plan for the period 2018-2022;
- Kenya's NCCAP and NDC implementation plan; and
- Various international research initiatives that are contributing to the development of Kenya's NDC.[2]

The NDC sector analysis first "unpacks" and clarifies the numbers underlying the NDC contribution. The following chapters, 3 to 8, provide the sector analysis, examining mitigation and adaptation considerations for the six mitigation sectors. Chapters of this NDC sector analysis are listed below:

- Chapter 1 – Introduction and Methodology
- Chapter 2 – Kenya's NDC: Contributions by Sector
- Chapter 3 – Agriculture
- Chapter 4 – Energy
- Chapter 5 – Forestry
- Chapter 6 – Industry
- Chapter 7 – Transportation
- Chapter 8 – Waste

1.2 NDC SECTOR ANALYSIS METHODOLOGY

This NDC sector analysis examined options to deliver on Kenya's contributions in the six mitigation sectors set out in Article 4.3 of the UNFCCC: energy, transport, industry, waste, forestry and agriculture. Both adaptation and mitigation actions are analysed, recognizing that adaptation is the priority in Kenya and is a critical part of its NDC.[3,4] This is appropriate given that the country accounted for 0.04% of worldwide and ranked 94 of 162 nations for CO_2 emissions (the primary greenhouse gas) in 2013.[5]

The NDC sector analysis first examined the expected GHG emission reduction contributions by sector. Described in Chapter 2, the mitigation analysis detailed the expected emission reductions required in each sector to achieve the NDC targets. This analysis drew on the figures in the mitigation section of Kenya's Second National Communication (SNC), which largely replicated the low carbon analysis of the 2013-2017 NCCAP, with some updated information.[6] The adaptation discussion elaborated on actions identified in Kenya's National Adaptation Plan, 2015-2030 (NAP)[7] and in the NCCAP.

Preliminary NDC sector reports were developed in April 2016. The work included updating the NCCAP and SNC mitigation analyses with available data and information, and assessing what is doable and achievable in regard to the NDC targets. The mitigation analysis first identified a range of possible emission reductions for each sector, setting out a low and high range of potential emission reductions. The next step was to re-examine the results of applying the bottom-up methodology to assess mitigation options developed by the International Institute for Sustainable Development (IISD) and the Energy research Centre of the Netherlands for Kenya's NCCAP low-carbon analysis. The adaptation analysis included review of the adaptation priorities identified in Kenya's NAP, which are also the priorities in Kenya's NDC.

The sector reports informed a series of initial sector consultations that began in May 2016 and ran to November 2016. The following ministries or departments facilitated the sector consultations, working with the Ministry of Environment and Natural Resources (MENR):

- Agriculture – Ministry of Agriculture, Livestock & Fisheries (MALF)
- Energy – Ministry of Energy and Petroleum (MOEP)
- Forestry – Kenya Forest Service (KFS)
- Transportation – Ministry of Transport, Infrastructure, Housing and Urban Development (MOTIHUD)
- Waste – National Environment Management Authority (NEMA)

Information on the industry sector was gathered through research and in consultation with MENR officials. The sector meetings enabled sector experts to examine the preliminary NDC sector analysis, identify gaps, and provide updated information.[8]

The NDC sector analysis was revised and expanded to incorporate comments and input received at the sector meetings, and include updated research and information provided by sectors. Expanded analysis for each sector included:

MITIGATION

- Understanding of the sector's projected future demand/supply by 2050 in a low carbon and climate resilient development pathway
- Sector implications of the NDC (apportioning the contribution of each sector and disaggregating data on the contribution of each of the actions) to the 30% emission reduction and by 2050.
- Updated analysis of mitigation options including current mitigation status and baseline projections to 2050 (including updated information on assumptions).
- Identification of technology needs and priority actions to achieve Kenya's NDC.
- Updated Development Impact Assessment tables (originally developed during the NCCAP process) that are aligned with the Sustainable Development Goals (SDGs).

ADAPTATION

- Identification of key climate change impacts and vulnerabilities in the sector.
- Critical adaptation needs based on impacts and vulnerabilities.
- Elaboration of priority adaptation actions building on information in the NCCAP, NAP, expert meetings and through research.
- This information also informed the updating of the reference case (projected baseline) of GHG emissions out to 2050, which is presented in a separate report, Update of Kenya's Emission Baseline Projections and Impact on NDC Target.[9]

MENR, working with the sector ministries and departments, held validation meetings with each sector from February to April 2017. Sector experts reviewed and validated the updated NDC sector analysis. In addition, sector experts provided information on climate-relevant projects and programmes in the sector as a basis for developing a climate change registry of mitigation and adaptation actions. Following the validation meetings, final revisions to the NDC analysis were undertaken and the final report developed.

1.3 NEXT STEPS

Kenya's updated NCCAP, 2018-2022 and NDC implementation plan will be developed in a coordinated manner using this NDC sector analysis as the evidence base for identification of priority actions for the next five years. This NDC analysis identifies priority mitigation options and key mitigation technologies for the six sectors; a next step is to formulate implementation plans to achieve adaptation results and mitigation potential.

In regard to mitigation, the NCCAP's five-year plan should detail priority actions, including baseline emissions, expected emission reductions, implementation indicators to track progress, and indicators to track co-benefits. For example, in the transport sector there are numerous options to promote vehicle fuel efficiency to reduce GHG emissions, including promoting hybrid or electric vehicles, setting fuel efficiency standards, establishing a regulatory framework to reduce the number of old inefficient vehicles, or enhancing the vehicle emissions testing programme. The NCCAP will identify the actions and an implementation plan for 2018-2022. Sector experts will need to be engaged to identify actions most likely to achieve mitigation results in a cost-effective manner that are aligned with sectoral plans and Kenya's Third Medium Term Plan (MTP III).

In regard to adaptation, a process is required to identify priority sectors and priority actions within those sectors, building on the broad actions identified in the NAP. For example, short-term priority actions in the agriculture sector in the NAP include "increase awareness of climate change impacts" and "coordinate and mainstream climate change adaptation into agricultural extension services." The NCCAP should provide detail on these actions for the five-year period from 2018-2022, including baseline information, expected adaptation results and indicators to track progress. Like mitigation, the adaptation plans will require the input of sector experts and should be aligned with sectoral plans and the MTP III.

REFERENCES

[1] Kenya submitted its Intended NDC, which previously had been submitted to the UNFCCC on 25 July 2015, as its NDC when it ratified the Paris Agreement. See: Government of Kenya (2015). *Kenya's Intended Nationally Determined Contribution, 23 July 2015*. Nairobi: Ministry of Environment and Natural Resources. Accessed at: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Kenya/1/Kenya_INDC_20150723.pdf

[2] Various entities are providing technical assistance to the Government of Kenya for NDC development. These include the:

- Low Emission Climate Resilience Development project funded by the United States Agency for International Development and managed by the United Nations Development Programme (UNDP)– measurement, reporting and verification (MRV) of NDC implementation;
- UNDP NDC programme – Strengthening MRV systems and financial assessments for NDC implementation;
- Energy research Centre of the Netherlands – benefits approach to NDCs;
- Initiative for Climate Action Transparency – domestic MRV in the energy sector;
- Climate and Development Knowledge Network - Mitigation Action Plans and Scenarios process and NDC quick start guide;
- Capacity Building Initiative for Transparency – transparency in the agriculture, forestry and land-use sector;
- Global NDC Implementation Partners – NDC enabling environment focused on the water sector;
- Agence Française de Développement – support to MOEP for GHG emission measurement and monitoring in the energy sector; and
- Government of Germany – support to the transport sector for GHG emissions monitoring and measuring.

[3] Government of Kenya (2013). *National Climate Change Action Plan: 2013-2017*. Nairobi: Ministry of Environment and Natural Resources. Accessed at: http://www.kccap.info

[4] Government of Kenya (2015). *Kenya's Intended Nationally Determined Contribution (INDC), 23 July 2015.*

[5] World Bank (2016). CO2 emissions (kt), *World Development Indicators*. Accessed at: http://data.worldbank.org/indicator/EN.ATM.CO2E.KT?view=chart

[6] Government of Kenya (2015). *Kenya: Second National Communication to the United Nations Framework Convention on Climate Change*. Nairobi: National Environment Management Authority. Accessed at: http://unfccc.int/resource/docs/natc/kennc2.pdf

[7] Government of Kenya (2016). *National Adaptation Plan, 2015-2030*. Nairobi: Ministry of Environment and Natural Resources.

[8] The NDC sector meeting reports are available online at: http://www.starckplus.com/index.php/starck-components/technical-assistance

[9] Ministry of Environment and Natural Resources (2017). *Update of Kenya's Emission Baseline Projections and Impact on NDC Target.* Developed with the support of the Climate Change Technical Assistance to the Government of Kenya component of the StARCK+ programme. Nairobi: MENR. Accessed at: http://www.starckplus.com/index.php/starck-components/technical-assistance/kenya-ndc-sector-analysis

2.1 THE PARIS AGREEMENT

On 12 December 2015, countries under the UNFCCC adopted the Paris Agreement. The agreement entered into force on 4 November 2016, and by May 2017 had been ratified by 148 of the 197 Parties to the Convention. Kenya ratified the Paris Agreement on 28 December 2016. When depositing its instruments of ratification, Kenya re-submitted its Intended Nationally Determined Contribution (first submission to the UNFCCC was in July 2015) as its first NDC.[1] The Paris Agreement entered into force for Kenya on 27 January 2017. The agreement is now part of Kenya's legal system in line with the country's supreme law. The Constitution of Kenya, 2010 Article 2 (6) states that: "Any treaty or convention ratified by Kenya shall form part of the law of Kenya under this Constitution."[2]

The Paris Agreement aims to keep the increase in global average temperature to well below 2° Celsius above pre-industrial levels, and to reach global peaking of GHG emissions as soon as possible. Countries are expected to determine at the national level what actions they are willing and able to take to achieve this goal, and communicate this through their NDCs. Essentially, NDCs are national climate change action plans that detail plans to achieve GHG emission reduction targets and adaptation goals. Countries are expected to submit a new NDC every five years, and each NDC will represent an increase in ambition.

2.2 KENYA'S MITIGATION NDC

Kenya's mitigation NDC is based on its 2013-2017 NCCAP, which sets out a low carbon development pathway that supports efforts towards the attainment of Vision 2030. Kenya's NDC "seeks to abate its GHG emissions by 30% by 2030 relative to the BAU scenario of 143 $MtCO_2eq$"; and in line with its sustainable development agenda.[3] Achievement of the NDC is subject to international support in the form of finance, investment, technology development and transfer, and capacity building."

Table 2.1. Emission reduction potential by sector: Technical potential and NDC 30% GHG emission reduction targets

SECTOR	GHG EMISSION REDUCTION POTENTIAL (MtCO2e)				NDC TARGET (MtCO2e)
	2015	2020	2025	2030	2030
Forestry	2.71	16.24	29.76	40.2	20.10
Electricity Generation	0.28	2.24	8.61	18.63	9.32
Energy Demand	2.74	5.16	7.92	12.17	6.09
Transportation	1.54	3.52	5.13	6.92	3.46
Agriculture	0.63	2.57	4.41	5.53	2.77
Industrial Processes	0.26	0.69	1.03	1.56	0.78
Waste	0.05	0.33	0.5	0.78	0.39
Total Emission Reduction Potential	–	–	–	85.79	42.90
Total Emissions in 2030	–	–	–	143.00	143.00
% of Total Emissions in 2030	–	–	–	60%	30%

Source: Derived from Government of Kenya (2015), Second National Communication, page 172

The 30% emissions reduction target means that Kenya's GHG emissions in 2030 are expected to be 30% lower than the projected emissions or business as usual (BAU) scenario (depicted in Figure 2.1 as the "Emissions Baseline"). Policies, programs and technologies are expected to be introduced to encourage lower emissions and move Kenya on to a low carbon development pathway. Priority actions to reduce GHG emissions were identified in the NCCAP, and further elaborated in the Second National Communication (SNC) that was submitted to the UNFCCC in December 2015.[4]

The mitigation analysis of the SNC determined that Kenya has the potential to reduce projected emissions by 85.79 $MtCO_2eq$, or 60% lower than the projected BAU scenario (detailed in Table 2.1). The mitigation potential determined through the low carbon analysis undertaken for the NCCAP and SNC is ambitious and based on the technical potential – or what is expected to be achieved if Kenya takes up technology advances, introduces appropriate and enabling policies and regulations, and moves forward on all potential mitigation actions. In short, it is aspirational and based on a best-case scenario – with the intent of providing information and guidance on what is possible to guide decision makers.

Kenya opted for a conservative approach in determining the mitigation potential for its NDC, considering what was feasible and doable in 2015 using known technologies and within established policy and regulatory frameworks. Kenya's NDC is half of the total mitigation potential identified in the SNC, equal to 42.9 $MtCO_2eq$ or 30% lower than the projected 2030 BAU scenario. The decision to take a less ambitious approach is based on the recognition that the NCCAP and SNC used a low-carbon approach that is aspirational; while the NDC should be grounded in reality and reflect what the government is willing and able to commit to.

The NDC target assumes that all sectors will work toward mitigation goals. The detailed NCCAP mitigation chapters provide information on priority technologies to achieve expected emission reductions that is based on research undertaken in 2011 and 2012.[5] This NDC sector assessment uses updated data and information to provide the evidence base to inform detailed assessments by sector experts and the development of an NDC implementation plan, and to project future emissions out to 2050.

2.3 KENYA'S ADAPTATION NDC

The Paris Agreement established a global goal on adaptation to ensure an adequate adaptation response in the context of the 2°C temperature goal. All countries should submit adaptation communications, detailing adaptation priorities, support needs, plans and actions, which should be updated periodically. Collective adaptation efforts will also be subject to review under the global stocktaking process.

Kenya's INDC sets out priority adaptation actions, stating that: "Kenya will ensure enhanced resilience to climate change towards the attainment of Vision 2030 by mainstreaming climate change adaptation into the Medium Term Plans (MTPs) and implementing adaptation actions. Any reasonable achievement of the adaptation goal will require financial, technology and capacity building support."

The adaptation goals in the NDC are based on priority adaptation actions that are identified and elaborated in Kenya's National Adaptation Plan, 2015-2030.[6] These actions, listed in Table 1.2, are based on risk and vulnerability assessments across the MTP sectors, and many of the adaptation actions have strong synergies with mitigation actions. The NAP adopts a mainstreaming approach across all sectors in the national planning, budgeting and implementation processes. Priority macro-level actions and sub-actions are identified in 20 Medium Term Plan planning sectors for the short, medium and long term. For each sector, the NAP identifies gaps, estimates costs of the macro-level actions projected to 2030, and identifies key institutions required for their implementation. These actions form the basis of Kenya's international contribution on adaptation, and implementing these actions will enable enhanced resilience to climate change, which will assist the country in attaining Vision 2030 goals. The identified adaptation actions are expected to be mainstreamed into Kenya's Third MTP (2018-2022) and implemented by sector ministries and county governments. The Government of Kenya will report to the UNFCCC on progress in implementing the priority actions.

Table 2.2. NDC priority adaptation actions

MTP SECTOR	PRIORITY ADAPTATION ACTIONS
Energy	Increase resilience of current/future energy systems
Science, Technology & Innovation	Support innovation and development of appropriate technologies that promote climate resilient development.
Public Sector	Integrate climate change adaptation into reforms.
Human Resource Development, Labour & Employment	Enhance adaptive capacity and resilience of the informal private sector.
Infrastructure	Climate proofing of infrastructure (energy, transport, buildings, ICT).
Land Reform	Mainstream climate change adaptation
Education & Training	Enhance education, training, awareness, participation, access to information on climate change adaptation across public/private sectors.
Health	Strengthen integration of climate change adaptation into the health sector.
Environment	Enhance climate information services, and resilience of ecosystems to climate variability and change.
Water & Irrigation	Mainstream climate change adaptation by implementing National Water Master Plan (2014).
Population, Urbanisation & Housing	Enhance the adaptive capacity of the population, urbanisation and housing sector.
Gender, Vulnerable Groups & Youth	Strengthen the adaptive capacity of the most vulnerable groups and communities through social safety nets and insurance schemes.
Tourism	Enhance the resilience of the tourism value chain.
Agriculture, Livestock & Fisheries	Enhance the resilience of agriculture, livestock and fisheries value chains by promoting climate smart agriculture and livestock development.
Oil & Mineral Resources	Integrate climate change adaptation into the extractives sector.
Private Sector	(and Trade; Manufacturing; Business Process Outsourcing; Financial Services) Create an enabling environment for resilience of private sector investment; demonstrate operational business case.
Devolution	Mainstream climate change adaptation into CIDPs, implement Ending Drought Emergencies Strategy.

Source: Government of Kenya (2015), Kenya's Intended Nationally Determined Contribution, pages 4-5.

REFERENCES

[1] Government of Kenya (2015). *Kenya's Intended Nationally Determined Contribution, 23 July 2015*. Nairobi: Ministry of Environment and Natural Resources. Accessed at: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Kenya/1/Kenya_INDC_20150723.pdf

[2] Government of Kenya (2010). *Constitution of Kenya*. Accessed at: http://www.kenyalaw.org/lex/actview.xql?actid=Const2010.

[3] $MtCO_2eq$ or $MtCO_2e$ is an abbreviation for million tonnes of carbon dioxide equivalent, or the amount of GHG emissions expressed as an equivalent amount or concentration of carbon dioxide. The main greenhouse gases that are measured in a GHG inventory are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

[4] Government of Kenya (2013). *National Climate Change Action Plan: 2013-2017*. Nairobi: Ministry of Environment and Natural Resources. Accessed at: http://www.kccap.info. Government of Kenya (2015). *Kenya: Second National Communication to the United Nations Framework Convention on Climate Change*. Nairobi: National Environment Management Authority. Accessed at: http://unfccc.int/resource/docs/natc/kennc2.pdf

[5] The Ministry of Environment and Natural Resources worked with the International Institute for Sustainable Development (IISD), Energy research Centre of the Netherlands, and local consultants to develop the NCCAP methodology and analysis. ClimateCare, working with IISD experts, used the NCCAP analysis as the basis for the development of the SNC.

[6] Government of Kenya (2016). *Kenya: National Adaptation Plan: 2015-2030*. Nairobi: Ministry of Environment and Natural Resources.

3: AGRICULTURE

3.1 AGRICULTURE SECTOR IN KENYA

Agriculture is a priority of the Government and people of Kenya because of the sector's importance to food security, rural livelihoods and poverty alleviation. Agriculture is a key economic sector and is considered the backbone of Kenya's economy for its direct contribution to the GDP and linkages with other sectors such as manufacturing and trade. The agricultural sector contributes about 25% of Kenya's GDP and about 27% indirectly through linkages to agro-based industries and the service sector.[1]

The agriculture sector– including crop cultivation, livestock and fisheries – is the means of livelihood for the majority of the rural population in Kenya and provides over 70 percent of employment in rural areas.[2] The Agricultural Sector Development Strategy 2010-2020 notes that growth in the national economy has historically been highly correlated with growth in the agricultural sector.[3] The decline in the growth of the Kenyan economy in the last quarter of 2016 was linked to the poor performance of the agriculture sector, a result of much lower than average rainfall.[4]

The crops sub-sector, comprising food, industrial and horticultural crops, contributes 77.6% to the Agricultural Gross Domestic Product (AgGDP). Horticulture contributes 33% to the AgDGP (the largest in the sector) and 38% of export earnings. The main food crops include cereals, pulses, roots and tubers, fruits and vegetables, all of which contribute about 32% of the AgGDP and 0.5% of exports earnings. Industrial crops in Kenya include tea, coffee, sugarcane, cotton, sunflower, pyrethrum, barley, tobacco, sisal, coconut and bixa, all of which contribute about 55% of agricultural exports.[5] Farming in Kenya is primarily small-scale, with 75 percent of total agricultural output produced on rain-fed agricultural lands on farms averaging 0.3 to 3 hectares in size. Approximately 16 percent of Kenya's total land area is of high to medium agricultural potential, and this land supports 80 percent of the country's population who depend primarily on subsistence agriculture for their livelihoods.

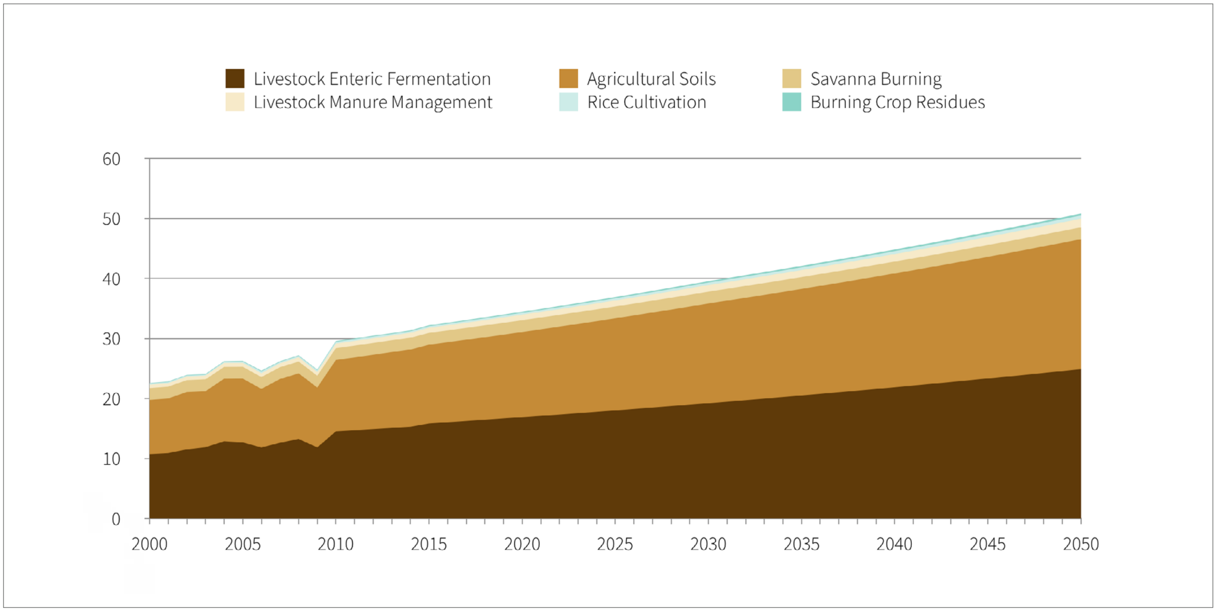
The livestock sub-sector is dominated by pastoralism, which is the most important economic and livelihood activity in the Arid and Semi-Arid Lands (ASALs) that comprise over 80% of the country's land area. The 2009 census data reports the number of livestock as 17.5 million cattle, 27.7 million goats, 17 million sheep, 3 million camels, 31.8 million domestic birds, and 1.8 million donkeys.[6] Beekeeping is described in the Climate Smart Agriculture Strategy 2017-26 as "emerging livestock." The livestock sub-sector contributes about 19.6% of the AgGDP and about 4.9% of overall GDP.[7] Cross-border livestock trade within the Horn of Africa and East Africa is estimated to exceed USD 60 million per year.[8] The livestock sub-sector supports 20% of the Kenyan population (over 10 million people), most of whom who live in the ASALs.[4] These lands are farmed to some extent, but are largely utilised for pastoralism. The dairy industry is a growing sub-sector, following its liberalisation in early 2000s. Data from the Kenya Bureau of Statistics and the Kenya Dairy Board shows an increase in the country's milk production from 495.2 million litres in 2012 to 650.3 million litres in 2016, an increase of about 30%.[9]

The fisheries sub-sector, comprising both capture fisheries and aquaculture, supports about 150,000 people directly and about 800,000 indirectly. On average, 150,000 million tonnes of fish valued at approximately KES 10 billion is landed in the country each year. Exports of fish and fish products earn the country approximately KES 5 billion in foreign exchange annually.[10] At least 300,000 people are directly employed as fishers and fish farmers. The fisheries usb-sector also provides livelihoods for over 4 million Kenyans involved mainly in fish processing, fish trade and input support. Kenya's fishing communities rely on fish as a rich source of protein. The sub-sector contributes about 2% of AgGDP and 0.5% of national GDP.[11]

3.2 CLIMATE CHANGE IN THE AGRICULTURE SECTOR

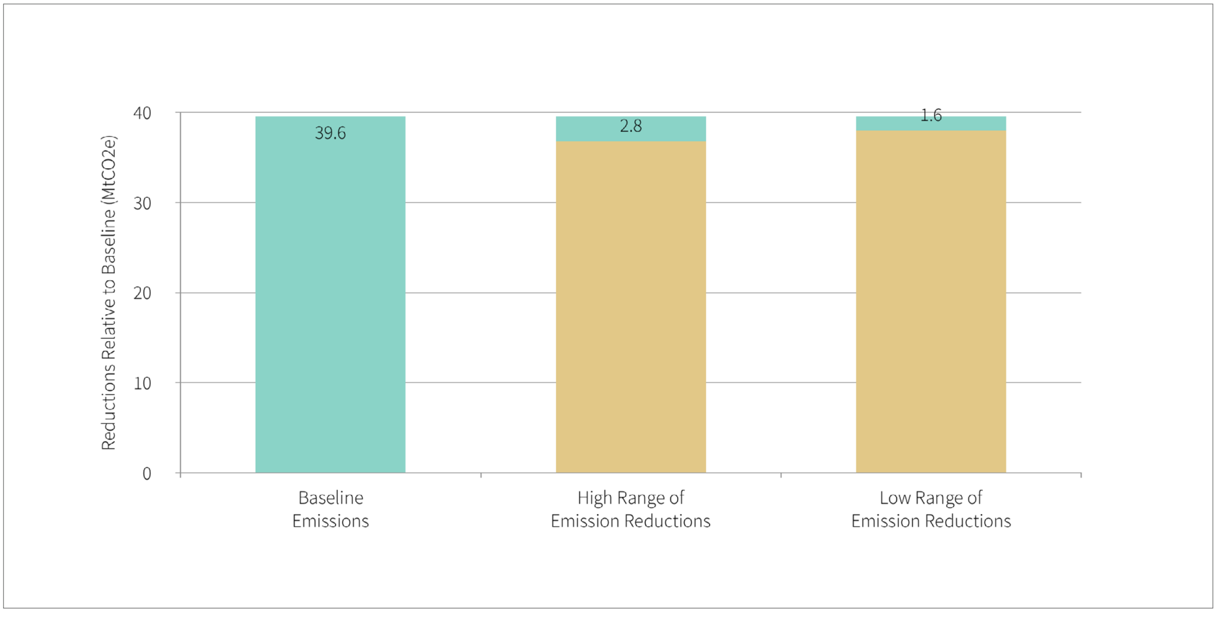
The agricultural sector in Kenya is highly exposed to climate change, as farming activities directly depend on climatic

Figure 3.1. Baseline Agriculture Greenhouse Gas Emissions Projections ($MtCO_2e$)



Source: Derived from Government of Kenya (2015), Second National Communication, p. 166.

Figure 3.2. Comparison of 2030 Baseline Emissions and NDC Target Emission Reductions ($MtCO_2e$)



conditions. Ninety-eight percent of crop production is rain-fed, while livestock feed on grass and other forage whose availability depend on prevailing atmospheric conditions.[12] The high variability of floods and droughts experienced in Kenya in recent decades (including the 2016-2017 drought) is likely to increase with climate change. Globally, climate change is likely to lead to a decline in grain productivity by 1.5% per decade in the absence of effective adaptation.[13] This climate change-induced decline in agricultural productivity is expected to affect Africa the most because of the continent's low adaptive capacity. Soil erosion and nutrient depletion are major issues, and food security, a stated goal of the Government, is under threat, partly due to climate change. The combination of deforestation to open up croplands, the extension of agriculture onto land with low potential, and the use of more basic farming techniques and technologies due to cost and capacity barriers make the current agricultural system unsustainable in the long term.

At the same time, agriculture contributes the most (40 percent of overall total emissions in 2015) to Kenya's greenhouse gas (GHG) emissions. The livestock sector contributes over half of the agriculture emissions, mainly methane emissions through enteric fermentation. The crops sub-sector contributes carbon dioxide, methane and nitrous oxide emissions through such activities as conventional tilling, burning of savannah and crop residues, and rice cultivation.

Climate smart agriculture (CSA) aims to address the three concerns: 1) increasing agriculture production to meet the meets of a growing population; 2) increasing the resilience of agricultural systems climate change; and 3) minimising GHG emissions from the sector. CSA is defined as agriculture that "sustainably increases productivity, enhances resilience, reduces/ removes greenhouse gas emissions, and enhances the achievement of national food security and development goals".[14]

Kenya is at the forefront of adopting CSA, including releasing its Kenya Climate Smart Agriculture Strategy 2017-26. The Strategy's core objective is to "adapt to climate change, build resilience of agricultural systems while minimizing emissions for enhanced food and nutritional security and improved livelihoods."[15] The Strategy is a tool to assist in the development and implementation of Kenya's updated National Climate Change Action Plan for 2018-2022, which will include an NDC implementation plan.

Kenya has attracted climate finance for initiatives in the agriculture sector, including a USD 250 million CSA programme funded by the World Bank, USD 10 million from the Adaptation Fund for a programme that includes actions to enhance food security, USD 6 million to promote adaptation in the ASALs, among others.

Adaptation to climate change is the priority of the Government of Kenya for the agricultural sector, with mitigation pursued as an additional benefit when possible. The NCCAP, 2013-2017 states that the approach to addressing climate change is "to implement adaptation projects or activities in as a low carbon pathway as practically and economically feasible" and that food security takes precedence over mitigation of GHG emissions.[16]

3.3 MITIGATION IN THE AGRICULTURE SECTOR

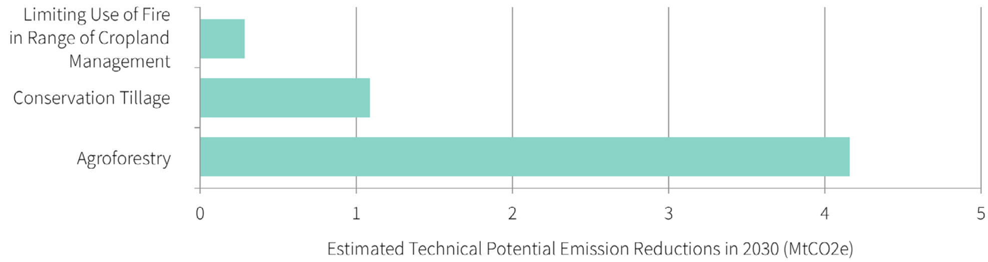
Many agricultural management practices that reduce climate vulnerability and improve agricultural production potential, also reduce emissions. The Government's position, as stated in the NCCAP, is that Kenya will not adopt measures to reduce greenhouse gas emissions if they threaten the country's ability to feed its growing population or reduce export earnings.

BASELINE EMISSIONS PROJECTION FOR THE AGRICULTURE SECTOR

Kenya's Second National Communication (SNC) reported that agriculture emissions accounted for approximately 40% of total national emissions in 2010, with livestock emissions accounting for approximately 30% of total emissions. However, their contribution is expected to decrease to 31% by 2030 as energy-related emissions grow at a considerably faster rate than agricultural emissions. This can be at least partly explained by the lower expected economic growth rates in agriculture compared to other sectors of the economy.

The baseline emissions projection for agriculture is summarized in Figure 3.1. Emissions are sub-divided into six major emission sources. Agricultural greenhouse gas emissions are projected to rise from 32.2 $MtCO_2e$ in 2015 to 39.5 MtCO2e in 2030, an increase of 22%.

Figure 3.3. Technical Potential Emission Reductions in 2030 of Agriculture Mitigation Options



Box 3.1. Assumptions Underlying the Mitigation Options in the Agricultural Sector

AGROFORESTRY

The cost data for plantations on farms was derived from two studies. Lager and Nyburg placed the cost per hectare per year at USD 6.85, while Tennigkeit determined the cost per hectare per year at USD 19.60. An average was used, providing an abatement cost for plantations on farms of USD 13.25 per hectare per year.

SUSTAINABLE LAND MANAGEMENT

Combining and averaging divergent cost data that was found for sustainable agricultural practices and for conservation tillage, which both require similar extension service efforts and in the case of sustainable agriculture includes tillage practices, provided a cost of USD 31.15 per tonne of CO_2e abated per year. Per hectare costs were divergent and were averaged to arrive at a figure of USD 14.36 per hectare per year.

LIMITING USE OF FIRE IN RANGE AND CROPLAND MANAGEMENT

Little cost data was available for this type of intervention. It was assumed that providing extension services to a pastoralist household would be similar in cost to providing extension services to smallholder farmers, which were found in the literature to be approximately USD 10.35 per year. Costs are assumed to be one half this figure for farm-owning households because a network of extension services is already in place. This would lead to an average cost for reductions to crop and rangeland burning of USD 21.00 per tonne of CO_2e abated per year.

Additional information is available in the fact sheets in the NCCAP low-carbon analysis in the agriculture sector, accessible at: http://www.kccap.info. The fact sheets for the six mitigation sectors have been compiled into one document that is available at: http://www.starckplus.com/index.php/starck-components/technical-assistance.

NDC TARGET FOR THE AGRICULTURE SECTOR

Kenya's NDC "seeks to abate its overall GHG emissions by 30% by 2030 relative to the BAU scenario." However, this does not necessarily translate into a 30% emission reduction target for the agriculture sector equivalent to 11.8 $MtCO_2e$ reductions from baseline emissions in 2030 of 39.5 $MtCO_2e$.

Significant work conducted for the Kenya NCCAP, 2013-2017 examined the technical potential of emission reductions related to all sectors (energy, waste, LULUCF, agriculture and industrial processes). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential. With this view in mind, the agriculture sector emission reduction target should be less than the technical potential of individual mitigation options identified while also contributing to the overall 30% emission reduction target.

Figure 3.2 identifies a reasonable low and high 2030 target for emission reductions in the agriculture sector. The low target is aligned with the proportional contribution that the sector would need to make in order for there to be a high level of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The overall target and how the individual six sector targets were calculated is discussed in Chapter 2 that updates the emission baseline projections and impact on the NDC target.

Figure 3.2 illustrates a low (minimum) target emission reduction of 1.6 $MtCO_2e$ for the agriculture sector. This is equivalent to a 4% reduction in 2030 baseline agriculture emissions. This is the lowest proportional contribution of any sector and primarily due to a lack of proven mitigation options and considerable barriers to changing practices in the agricultural sector. Additionally, despite the size and prevalence of the sector, data required to calculate GHG emissions is lacking and considerable uncertainty remains in the calculation of these emissions (compared to energy, transport and industrial sectors) and the impact of mitigation options.

The agriculture sector should strive to meet the low range of emission reductions, requiring that other sectors implement actions to achieve the high range of emission reductions. In the short term – the five-year period of the 2018-2022 NCCAP and NDC implementation plan – the sector should focus climate change efforts on adaptation, while on building expertise and improving data for mitigation action.

MITIGATION OPTIONS IDENTIFIED IN KENYA'S SECOND NATIONAL COMMUNICATION

A total of three mitigation options were developed and presented for the agriculture sector in the NCCAP and SNC. The conservation tillage option was revised to sustainable land management, recognizing that a broad set of land management actions are required to reduce GHG emissions. The three options were assessed to determine their technical potential to contribute to emission reductions in the baseline in 2030. In order to achieve the minimum 1.6 $MtCO_2e$ recommended NDC target for emission reductions in 2030 (see Figure 3.3), there is flexibility and it is not necessary to fully implement all mitigation options. The technical mitigation potential in 2030 of the three agriculture mitigation options is presented in Figure 3.3.

Livestock is not included in Figure 3.3, but mitigation action in this sub-sector is considered a priority because of the large amount of GHG emissions from this sector. Significant work has been undertaken to measure GHG emissions in the dairy sector. While the emission reduction potential is not significant at a national scale, initiatives in this sector are priority mitigation actions.

The four priority mitigation options are described below, and the assumptions used to estimate GHG emissions reduction potential are described in Box 3.1.

Agroforestry is the mitigation option with the greatest emission reduction potential. Agroforestry is the interface between agriculture and forestry, and encompasses mixed land-use practices. The term typically refers to land-use practices in which trees and other woody perennials are spatially or temporally integrated with crops and livestock on a given unit of land. It is distinct from forestry options, discussed in Chapter 5, because it targets lands that are currently in use for agriculture. The mitigation option encourages compliance with the Agricultural Farm Forestry Rules that require every land holder to maintain

Box 3.2. Potential mitigation options in the agricultural sector not included as priority actions

The following mitigation options were not identified as priority actions in the agriculture sector because:
i) emission reductions would not be significant at a national scale,
ii) the likelihood of successful implementation is extremely low, or
iii) there is a lack of data to assess the mitigation potential.

LIVESTOCK SUBSTITUTION

Agricultural experts suggested that some livestock substitution is taking place in Kenya and could be a mitigation option. The substitution of camels for cattle does not result in reduced emissions (assuming one camel replaces one head of cattle) because the Intergovernmental Panel on Climate Change (IPCC) emission factors determine that camels have greater methane emissions through enteric fermentation than cattle. Experts suggested that camels have greater value than cattle in Kenya and that a farmer could keep a few camels and be better off than a farmer with a large herd of cattle, but data was unavailable to substantiate this assertion and not all experts agreed. Information was not available on the ratio of substitution of goats for cattle (for example, one for one, or three for one).

REDUCTION IN THE SIZE OF CATTLE HERDS

A reduction in herd size leading to smaller and healthier herds was suggested as a strategy, and agricultural experts suggested this was taking place in some regions, such as Mandera County. The experts agreed that such an action would not work in the short term because of socio-cultural reasons linked to the importance of cattle in rural Kenya.

MANURE MANAGEMENT

Agricultural experts determined that there was limited opportunity for improved manure management, treatment or storage because the manure of most animals, particularly cattle, is deposited on open grazing land. Some opportunity may exist in larger dairy operations; but the reductions would not be substantial enough at the national level to form a wedge in the mitigation analysis.

ORGANIC AGRICULTURE

Robust data regarding the mitigation potential of organic farming systems is scarce, and no data could be found for Kenya. Organic farming is not a priority for Kenya and is not promoted by the government.

Increased fertilizer application to reduce land clearing because of increased productivityThe Government of Kenya has programs to increase fertilizer usage, recognizing that low rates of fertilizer application because of access, affordability or lack of information contribute to low yields for many farmers. Increasing and optimizing fertilizer application would increase cropland productivity, but there is no available data to determine if this would result in a reduction of land clearing (i.e., converting grasslands or forested land to cropland). Additionally, there is no data around the GHG emissions associated with that land clearing or the increased use of nitrogen fertilizer. More research is needed on the relationships between crop production, fertilizer and GHG emissions to determine if this could be a mitigation option.

REDUCED EMISSIONS FROM RICE PRODUCTION

Emissions from the flooding of rice are relatively low in Kenya, and the potential reductions from mitigation actions would not be substantial enough at the national level to form a wedge in the low-carbon analysis. However, emissions from rice production systems can be reduced through the promotion of rain-fed rice, and the development and promotion of programmes and technologies for efficient rice production.

a compulsory farm tree cover of at least 10% on any agricultural land holdings.[17]

The agroforestry mitigation option targets existing arable cropland and grazing lands that have high or medium agricultural potential. The total area of arable cropland and grazing land is estimated in the Agricultural Sector Development Strategy 2010-2020 to be approximately 5,620,000 hectares. The current extent of tree cover on this agricultural land is not known; however, at least 10 percent tree cover on farms is targeted by the Agricultural (Farm Forestry) Rules 2009. Without additional information, it is assumed that achieving five percent of additional tree cover on these lands using agroforestry practices is possible and a reasonable mitigation scenario. Therefore, the low carbon scenario assumes that an additional 281,000 hectares is converted to agroforestry between the years 2015 and 2030. Implementation of the agroforestry option should include data collection to determine the extent of existing tree cover on arable cropland and grazing land.

Sustainable land management practices contribute to improving soil fertility and structure, adding biomass and nutrients to the soil, causing minimal soil disturbance as well as conserving soil and water. Three main elements typically contribute to sustainable land management: tillage, legumes and crop residues.

The reduction in tillage increases organic matter in the soil, thereby increasing the amount of carbon stored in the soil. The most pronounced type of conservation tillage is no-till, where lands are not ploughed at all and 100 percent of crop residues remain on the land. Given the competing uses for agricultural residues as animal fodder and fuel in Kenya's predominantly mixed farming systems, no-till practices may not be appropriate or feasible. [18]

Kenya agricultural experts have advised that the most viable form of sustainable land management in Kenya is minimum or reduced tillage.[19] Planting takes place on spatially prepared soil surfaces, aiming to leave at least 30 percent of crop residues on the soil surface, which can greatly enhance soil moisture conservation, reduce erosion and increase carbon sinks.

Intercropping crops with legumes can enhance the fertility of the soil by increasing nitrogen levels that in turn can significantly increase crop yields. This type of integrated nutrient management allows farmers to efficiently use nitrogen fertilizer and reduce input costs.

Kenya has 9,500,000 hectares of rain-fed agricultural cropland.[20] Research undertaken for the NCCAP analysis determined that reliable data on the prevalence of different land management practices was not available; and it was therefore assumed that at least 25 percent of these lands employ full tillage. The literature reports that a 20% adoption rate is a reasonable scenario for the promotion of sustainable agricultural practices. Assuming that this figure is also a reasonable scenario for sustainable land management, converting 20% of rain-fed agricultural croplands from full tillage to conservation tillage would mean converting 475,000 hectares over ten years.

Limiting the use of fire in range and cropland management involves reducing the frequency and extent of fires and/or reducing the fuel load through vegetation management and burning at times of year when fewer GHGs are emitted from burning. Fire is used on grass and rangelands in Kenya to clear vegetation, stimulate growth and control pests. On cropland, fire is used to attempt to regenerate soils or facilitate harvesting.[21] It serves a valid purpose as an important land management tool for pastoralists and farmers for its regenerative effects, and for grappling with invasive plants and species and conducting pest control. But burning range and croplands is also a major source of GHG emissions in Kenya due to the permanent loss of protective vegetation and crop residue cover that causes reductions in soil carbon levels. It can also negatively impact the long-term viability of the land.

The practice of using fire to manage rangelands is quite common in Kenya, with over 430,000 hectares burned each year. This results in emissions of approximately 0.26 Mt of CO_2e per year. In addition, burning agricultural residues of maize, wheat, sugarcane and rice crops is a common practice. Approximately 2,300,000 hectares of these crop residues are burned annually, leading to emissions of 0.93 MtCO_2e per year. This mitigation option would prevent 60% of the rangeland and cropland burning that occurs each year. The scale of this intervention allows targeting of burning that negatively impacts the long-

Table 3.2. Key Technologies in the Agriculture Sector

MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Agroforestry	Nurseries, improved market access for small farms, extension service support, capacity building, research and pilot projects
Sustainable Land Management	Agriculture extension services, low cost tillage systems and equipment
Limiting the use of fire in range and cropland management	Extension services to educate pastoralists and farmers on the risks associated with using burning to manage range and croplands, and on the benefits of alternative practices
Livestock – reducing enteric methane	Formulation of improved feeds and feed additives to reduce enteric fermentation, development of breeding schemes, and improved herd health
Enabling actions	MRV capacity building, including data collection and inventory development

Table 3.3. Linkages between priority mitigation actions in the Agriculture Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
Agroforestry Conservation tillage Limiting use of fire in range and cropland management Livestock – reducing enteric methane	Goal 2 – End hunger, achieve food security and improved nutrition, and promote sustainable agriculture	2.3 – by 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous people, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment. 2.4 - By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	Volume of production per labour unit by classes of farming/ pastoral/ forestry enterprise size Average income of small-scale food producers by sex and indigenous status Proportion of agricultural area under productive and sustainable agriculture
Agroforestry Conservation tillage Limiting use of fire in range and cropland management	Goal 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.2 - By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally 15.3 - By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	Progress towards sustainable forest management Proportion of land that is degraded over total land area

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

term viability of the land, recognizing that a certain amount of burning (assumed to be 25%) is needed for regenerative effects, pest control and managing invasive plants. It is assumed that successfully preventing 60% of rangeland burning would require reaching a significant portion of the approximately 854,000 pastoralist households in Kenya. In addition, stopping 60% of cropland burning would involve providing extension services to a significant proportion of farm-owning households in Kenya, or approximately 3.58 million households.

Reducing enteric methane in the livestock sector is the fourth priority mitigation action, consistent with the Kenya Climate Smart Agriculture Strategy, 2016-2025, that prioritizes the reduction of emissions from livestock.[22] A short-term action is to reduce emissions in the dairy sector. An FAO study identified improving animal and herd productivity as one of the key pathways to reduce enteric methane emissions per unit of production. A combination of intervention packages aimed improving feed availability and quality, improving herd health and improved genetics can potentially result in reduction potential of 21-36% in emission intensity relative to the baseline emission intensity.[23]

Other mitigation options that were considered, but not included as priority mitigation options, are described in Box 3.2. Agriculture experts notes that there are strong barriers to actions to reduce emissions from livestock in the pastoral areas including the cultural and economic importance of cattle and resistance to change in rural communities. Awareness raising and education actions in this sector are important to lay the groundwork for future mitigation and adaptation actions. This is particularly important because of the potential positive benefits for pastoralists in the ASALs and the large emissions generated by the sector.

KEY MITIGATION TECHNOLOGIES

A summary of the key technologies associated with the four mitigation options is provided in Table 3.2.

DEVELOPMENT IMPACTS OF MITIGATION ACTION

Mitigation actions to reduce GHG emissions in any sector can have positive adaptation impacts, as well as development impacts that are linked to the Sustainable Development Goals (SDGs). In 2015, the UN General Assembly session adopted the 2030 Agenda for Sustainable Development (the 2030 Agenda) that included 17 SDGs that meet urgent environmental, political and economic challenges. SDG 13 deals with climate change, whereby countries have agreed to “take urgent action to combat climate change and its impacts,” recognizing that the UNFCCC is the primary forum for negotiating the international response to climate change.[24] Action in the agriculture sector directly contributes to achievement of SDG 2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. Table 3.3 illustrates the link between the four priority mitigation actions in the agriculture sector and the SDGs.

Table 3.4 provides an overview of development impacts of the mitigation options in the agriculture sector based on analysis for the NCCAP 2013-17 and updated to include the SDGs.

DEVELOPMENT IMPACTS

Agroforestry, a priority action in the Kenya Climate Smart Agriculture Framework Programme 2015-2030, can significantly enhance the livelihoods of smallholders and contribute to the achievement of SDGs 2 and 15. The products of agroforestry, such as fruit and nuts can enhance food security and diversify farmers’ income.[25] Agroforestry systems can also complement shade tolerant cash crops such as coffee.[26] Trees on farms can act as a source of sustainable fuelwood, on-farm timber and livestock fodder – alleviating pressures on neighbouring forests and contributing to improved livelihoods. Agroforestry has also been shown to lead to higher soil nutrients and water retention as nitrogen-fixing trees and shrubs can increase soil fertility and crop yields.

Sustainable land management practices, including conservation tillage techniques, are important for reducing the risk of soil erosion and improving soil fertility.[27] The improvements in soil fertility can improve plant health and increase the capacity to deal with pests and disease. These techniques enhance the long-term viability of agricultural lands and protect the incomes of those who rely on them. Moreover, these techniques can improve land productivity and decrease yield variance between years.[28] They can also decrease labour requirements, raising labour productivity in the sector.[29] Harnessing farm waste as source of organic fertilizer and the use of and the use of bio of bio-fertilizer that does not contribute to harmful emissions,

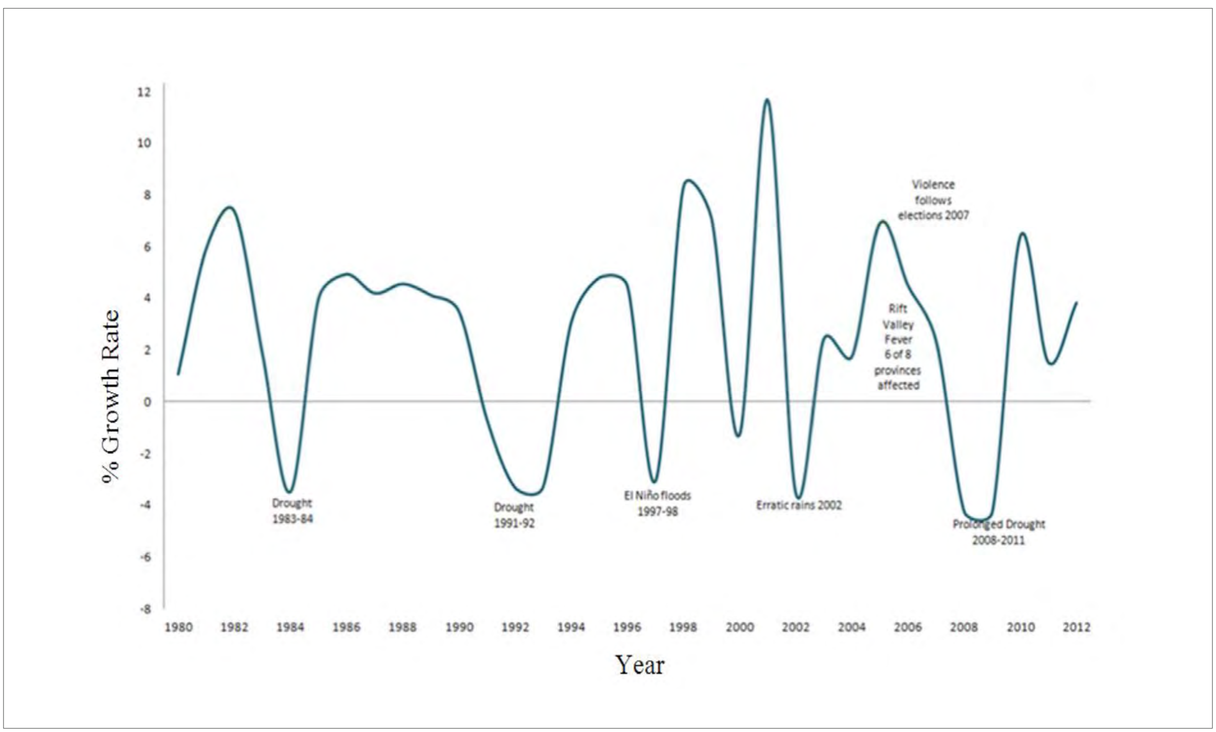
Table 3.4. Overview of Development Benefits of Mitigation Options

● High Potential
◓ High Potential
— High Potential
◡ High Potential
◒ High Potential

	CLIMATE		DEVELOPMENT				
	Abatement Potential ($MtCO_2$)	Adaptation Impact	SDG 2: Food Security	SDG 1: GDP Growth	SDG 1: Rural Livelihoods	SDG 15: Improved Land Management	SDG 15: Environmental Benefits
Agroforestry	4.16	●	◓	◓	◓	●	●
Conservation tillage	1.10	●	◓	◓	◓	●	●
Limiting use of fire in range/ cropland management	1.00	◓	—	—	—	●	◓
Livestock: reducing enteric methane	n/a	—	●	◓	◓	—	—

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis, and updated to include the SDGs.

Figure 3.4. Agricultural Sector Growth Index and Major Extreme Events between 1980 and 2012



Source: Kenya Climate Smart Agriculture Framework Programme 2015-2030, page 4.

both of which are forms of conservation tillage, are also priority activities in the Second Medium Term Plan of the Vision 2030.[30]

Reducing cropland burning increases the long-term viability of the land, thus enhancing food security and agricultural incomes. For pastoralists, tree and shrub cover that accumulates as a result of eliminated or reduced burning can provide food, fodder, fuelwood and charcoal, resulting in an additional revenue stream when sustainably harvested. In addition, the negative effects of burning are decreased: burning causes photochemical smog and hydrocarbons, reduces soil water retention, causes nutrient depletion, and leads to soil erosion when bare scorched earth is exposed to wind and rain.

Actions to reduce enteric fermentation in dairy herds can increase milk production by 21-36% compared to the baseline.[31] This has positive impacts on food security and the incomes of dairy farmers.

ADAPTATION & CLIMATE RESILIENCE IMPACTS

The agriculture mitigation options are vulnerable to the impacts of climate change. Agroforestry, just like conventional agricultural activities, could be susceptible to extreme climatic conditions such as drought or high temperatures. Appropriate adaptation measures (discussed below) are required to ensure the success of the mitigation programmes. These could include the adoption of tree species that are adapted to varied weather conditions and tolerant to emerging pests and diseases (e.g. drought tolerant trees for dry regions that also frequently experience suppressed rains), irrigation and other appropriate technologies.

Similarly, efforts to limit the use of fire in rangeland and cropland management could be hampered by high temperatures, with many wildfires reportedly started by unknown factors during hot and dry conditions. Building the capacity of entities and institutions with the mandate of managing wildfires could support the goal of this mitigation option.

3.4 ADAPTATION IN THE AGRICULTURE SECTOR

Kenya's NDC places emphasis on adaptation and resilience because of the country's high vulnerability to climate change and climate variability. The approach is to mainstream adaptation actions into the planning, budgeting and implementation process at both the national and county levels of government. The country's vulnerability to climate change is well documented in its 2010 NCCRS, the Strategy's 2013-2017 NCCAP and the 2015-2030 NAP.[1]

The Paris Agreement recognizes the fundamental priority of safeguarding food security and ending hunger, and the vulnerabilities of food production systems to the adverse impacts of climate change. The Agreement aims to strengthen the global response to the threat of climate change by, inter alia, increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production.[2] Food security is a priority of the Government of Kenya, and actions to address climate change should not threaten the country's ability to feed its population.

The NDC's adaptation goal is enhanced resilience to climate change towards the attainment of Vision 2030. This is to be achieved by mainstreaming climate change adaptation into Kenya's MTPs and implementing adaptation actions. The NDC's adaptation goal for the agricultural sector is to enhance the resilience of the agriculture, livestock and fisheries value chains by promoting climate smart agriculture, livestock and fisheries development.

RISKS & IMPACTS

Growth in the agriculture sector is susceptible to the vagaries of weather, including droughts, floods and extreme weather events, as illustrated in Figure 3.4. Agricultural systems in Kenya are highly vulnerable to climate change due to limited economic resources for investment in more resilient production systems, low levels of technological development or adoption of developed technology, heavy reliance on rain-fed agriculture (98%), frequent droughts and floods, and endemic crop and livestock diseases. Other factors that contribute to the high vulnerability are frequent incidences of pest infestation, relatively high levels of postharvest losses and the general poverty of many smallholder producers.[32]

Several specific climate impacts and risks were identified in the NCCRS, NCCAP 2013-17 and Climate Smart Agriculture Strategy 2017-26. Some crops are expected to experience more favourable growing conditions because of climate change,

Table 3.5. Priority Adaptation Actions in the Agriculture Sector

STRATEGIC ISSUE	ADAPTATION ACTIONS	
Strategic Issue 1: Vulnerabilities due to changes in temperature regimes and precipitation patterns	• Provision of accurate, timely and reliable climate and weather information to inform decisions of actors on crops, livestock and fisheries value chains • Promote crop varieties, livestock and fish breeds and tree species that are adapted to varied weather conditions and tolerant to associated emerging pests and diseases	• Technology development, dissemination and adoption along crops, livestock, fisheries, forestry value chains • Diversification of enterprises and alternative livelihoods • Enhance productivity and profitability of agricultural enterprises
Strategic Issue 2: Vulnerabilities due to extreme weather events	• Develop and implement strategies for early warning and response, and ensure preparedness for extreme weather event	• Develop and use index-based agricultural insurance
Strategic Issue 3: Vulnerabilities due to unsustainable natural resource management	• Establish baselines and undertake inventory of the existing natural resources • Promote sustainable management and utilization of natural resources • Promote water harvesting and storage, irrigation infrastructure development and efficient water use	• Promote and support conservation and propagation of germplasm of species with adaptive capacity • Strengthen research, technology and dissemination for sustainable natural resource management • Establish and implement mechanisms for resolving natural resource use conflicts

Source: Government of Kenya (2017). Climate Smart Agriculture Strategy 2017-26. Nairobi: Ministry of Agriculture, Livestock and Fisheries.

Annex 1: Priority Adaptation Actions in the Agriculture Sector in the NAP, 2015-2030

SHORT TERM SUB-ACTIONS	MEDIUM TERM SUB-ACTIONS	LONG TERM SUB-ACTIONS
Agriculture • Promote indigenous knowledge on crops • Coordinate and mainstream climate change adaptation into agricultural extension services • Promote new food habits *Livestock* • Conduct capacity building on indigenous knowledge on crops, livestock insurance schemes, early warning systems, early action, livestock management and breeding • Strengthen land management systems including rangeland management, fodder banks and strategic reserves *Fisheries* • Upscale sustainable aquaculture initiatives • Promote sustainable fish farming as a means of economic diversification, to reduce over-fishing in inland lakes and rivers, and adapting to climate change	*Agriculture* • Establish, maintain and promote the uptake of climate change related information on agriculture • Develop and up-scale specific adaptation actions: promotion and bulking of drought tolerant traditional high value crops; water harvesting; index-based weather insurance; conservation agriculture; agroforestry; and integrated soil fertility management • Develop and apply Performance Benefit Measurement methodologies for adaptation and development • Support adaptation of private sector agricultural value chain actors through capacity building efforts *Livestock* • Develop new feeds. • Promote livestock diversification and market access (camels, indigenous poultry, beekeeping, rabbits, emerging livestock – quails, guineas fowl, ostrich, etc.) • Establish price stabilization schemes and strategic-based food reserves • Restore degraded grazing lands *Fisheries* • Develop and implement a pilot project on climate resilience fish species and the related value chain	*Agriculture* • Promote and implement climate smart agriculture practices *Livestock* • Enhance selection, breeding and management of animals to adapt to climate change • Promote climate smart agriculture *Fisheries* • Strengthen monitoring capacity and capability to prevent overfishing and unauthorized exploitation in inland waters and Exclusive Economic Zone. • Promote upscaling of climate resilient strategy technologies in fisheries and climate resilient fish varieties • Expand the fishing zones in both inland and coastal waters

Source: Government of Kenya (2016). National Adaptation Plan, 2015-2030. Nairobi: Ministry of Environment and Natural Resources.

whereas others will find future climatic conditions intolerable. Equally, some regions (namely the mixed rain-fed temperate and tropical highlands) are projected to experience an increase in crop yields, whereas others (mainly the ASALs) are projected to witness a significant decline in crop yields and livestock numbers as water resources become increasingly scarce. These patterns are largely driven by regional variability in future precipitation and geographic exposure to extreme events, particularly drought. The CSA Strategy 2017-26 reports that a temperature rise of 2°C would lead to large areas of Kenya currently suited to growing tea becoming unsuitable, with significant impact on the industry and the 8% of the population (at present) that it employs.

The potential climate impacts on livestock include change in production and quality of feed crops and forage, water availability, animal growth, milk production, disease, and reproduction. The impacts are primarily due to an increase in temperatures and precipitation variation.[33] The CSA strategy notes that livestock numbers are projected to decline in the ASALs as water resources become increasingly scarce.[34]

Temperature rises also affect fish stocks. As oceans warm, the ideal water temperature for species shifts and fish stock could diminish to move to different areas, negatively impacting fishing communities. Fishers may be challenged to switch gear to catch a different species, especially those fishers who are dependent on reef fisheries.[35] Water is essential for fish farming and scarcity of water due to rainfall fluctuations caused by climate change could have negative impacts.

PRIORITY ADAPTATION ACTIONS

The NDC's adaptation goal is enhanced resilience to climate change towards the attainment of Vision 2030. This is to be achieved by mainstreaming climate change adaptation into the Medium Term Plans (MTPs) and implementing adaptation actions. The NDC's adaptation goal for the agricultural sector is to enhance the resilience of the agriculture, livestock and fisheries value chains by promoting climate smart agriculture, livestock and fisheries development.

The sector is already responding to the effects of climate change, and effort has gone into integrating climate change impacts into agricultural programmes and projects. Adaptation actions for the sector have been identified and set out in the CSA Strategy around three strategic issues for the ten-year period from 2017 to 2026, set out in Table 3.5. Additionally, the NAP identifies priorities for the period 2015-2030, which are included in Annex 1. These adaptation actions are to be supported by enabling actions that enhance the policy and regulatory framework, finance, capacity building, research and technology development and dissemination.

Food security is a priority of the Government of Kenya, and actions to address climate change should not threaten the country's ability to feed its population. Thus, adaptation is the priority and actions to help farmers, pastoralists and fishermen adapt to climate change should be undertaken in as low-carbon a manner as possible.

REFERENCES

[1] Government of Kenya (2017). *Climate Smart Agriculture Strategy 2017-26*. Nairobi: Ministry of Agriculture, Livestock and Fisheries.

[2] Government of Kenya (2013). *Vision 2030 Second Medium Term 2013-2017 (Transforming Kenya: Pathway to Devolution, Socio-economic Development, Equity and National Unity)*. Nairobi: Ministry of Devolution and Planning.

[3] Government of Kenya (2010). *Agricultural Sector Development Strategy 2010-2020*. Nairobi: Government of Kenya.

[4] Kenya National Bureau of Statistics (KNBS) (2017). *Economic Survey 2017.* Nairobi: KNBS. Page 18.

[5] Government of Kenya (2017).

[6] Government of Kenya. (2010). *The 2009 Population and Housing Census*. Nairobi: Central Bureau of Statistics, Ministry of Finance and Planning; in Government of Kenya (2017).

[7] Government of Kenya (2017).

[8] COMESA (2009). *Hidden Value on the Hoof: Cross-Border Livestock Trade in East Africa*, CAADP, Policy Brief No. 2 (as cited in Government of Kenya (2012): *Development Strategy for Northern Kenya and other Arid Lands*: Office of the Prime Minister).

[9] Kenya National Bureau of Statistics (2017).

[10] Government of Kenya (2015). *Ministry of Agriculture, Livestock and Fisheries Strategic Plan 2013-17 (Revised 2015)*, Nairobi: Ministry of Agriculture, Livestock and Fisheries

[11] Government of Kenya (2017).

[12] Government of Kenya (2017).

[13] Lobell, D. M. and Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology* 160(4): pages 1686-1697.

[14] FAO (2013). *Climate Smart Agriculture Sourcebook*. Rome: Food and Agriculture Organisation of the United Nations.

[15] Government of Kenya (2017).

[16] National Environmental Management Authority and Ministry of Environment and Natural Resources (2005). *Kenya's Climate Change Technology Needs Assessment Report under the United Nations Framework Convention on Climate Change*. Nairobi: Government of Kenya

[17] Ministry of Agriculture (2009) *Agriculture Act (Cap. 318) on farm forestry rules*. Nairobi: Government of Kenya.

[18] Kassie, M., Shiferaw, B., and Muricho, G. (2011). Agricultural technology, crop income and poverty alleviation in Uganda. *World Development,* 39(10), pages 1784– 1795.

[19] A report of the NDC Agricultural Sector Experts Group Meeting held on 23rd May 2016 in Nairobi to prioritise NDC Activities. Accessed at: http://www.starckplus.com/index.php/about-starck

[20] Brown, S., Grais, A., Ambagis, S., Pearson, T. (2012). *Agricultural GHGs in East and West Africa: Baseline emissions and mitigation potential*. CCAFS Working Paper No. 13. Copenhagen: CGIAR Program on Climate Change, Agriculture and Food Security.

[21] Yevich, R. and Logan, J. (2003). "An assessment of biofuel use and burning of agricultural waste in the developing world." *Global Biogeochemical Cycles*, 17(4).

[22] Government of Kenya (2017).

[23] FAO and New Zealand Agricultural Greenhouse Gas Research Centre (2017). *Options for low emission development in the Kenya dairy sector - reducing enteric methane for food security and livelihoods.* Rome: FAO. Page VIII.

[24] United Nations (2017). *Revised list of global Sustainable Development Goal indicators.* Accessed at: https://unstats.un.org/sdgs/indicators/Official%20Revised%20List%20of%20global%20SDG%20indicators.pdf

[25] Neufeldt, H., Wilkes, A., Zomer, R., Xu, J., Nang'ole, E., Munster, C. and Place, F. (2009). *Trees on farms: Tackling the triple challenge of mitigation, adaptation and food security*. Nairobi: World Agroforestry Centre.

[26] Place, F., Njuki, J., Murithi, F., and Mugo, F. (2006). Agricultural enterprises and land management in the highlands of Kenya. In Pender, J, Place, F. and Ehui, S. (eds). *Strategies for sustainable land management in the East African highlands.* Washington DC: International Food Policy and Research Institute.

[27] Kassie, M., Shiferaw, B., and Muricho, G. (2011).

[28] Food and Agriculture Organization. (2010). *The state of food and agriculture 2010-2011*. Rome: Food and Agriculture Organization.

[29] Kassie, M., Shiferaw, B., and Muricho, G. (2011).

[30] Government of Kenya (2013). *Vision 2030 Second Medium Term 2013-2017.*

[31] Food and Agriculture Organization & New Zealand Agricultural Greenhouse Gas Research Centre. 2017. *Options for low emission development in the Kenya dairy sector - reducing enteric methane for food security and livelihoods.* Rome: FAO. Page VIII.

[32] Odera M.M., Thomas T.S., Waithaka M., and Kyotalimye M. (2013). Kenya, in Waithaka M., Nelson G.C., Thomas T.S. and Kyotalimye M. (eds). *East African Agriculture and Climate Change: A Comprehensive Analysis.* Washington, DC: International Food Policy Research Institute.

[33] Rojas-Downing, M.M., Nejadhashemi, A.P>, Harrigan, T. and Woznicki, S.A. (2017). Climate change and livestock: Impacts, adaptation and mitigation. *Climate Risk Management* (vol. 16), pages 145-163.

[34] Government of Kenya (2017).

[35] Cinner, J.E., Huchery, C., Darling E.S., Humphries, A.T., Graham, N.A.J., Hicks, C.C., Marshall, N. and McClanahan, T.R (2013). Evaluating Social and Ecological Vulnerability of Coral Reef Fisheries to Climate Change. *PLOS/one*. Accessed at: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0074321

4.1 THE ENERGY SECTOR IN KENYA

Clean and sustainable energy is essential for Kenya's sustainable development and is considered one of the infrastructure enablers of the socio-economic pillar of Vision 2030.[1] Energy use in Kenya in 2013 was 0.49 tonne of oil equivalent (TOE) per capita while electricity consumption was 167.7 kilowatt hours per capita (3% of the total national TOE, with the remaining supply is used for transport, household cooking and industrial processes).[2] The energy sector in Kenya is largely dominated by biomass, electricity and imported petroleum, with biomass (wood fuel, charcoal, and agricultural waste) providing the basic cooking and heating energy needs of the rural communities, urban poor and the informal sector. An analysis of the national energy shows heavy dependency on biomass that accounts for 70% of total primary energy. The balance is supplied by petroleum (21%) and electricity (9%).

The draft 2015 Energy and Petroleum Policy indicates that rapid growth in Kenya's economy over the past decade is partly attributed to increased investment in the energy sector, particularly in the electricity sub-sector. The draft policy aims "to ensure an affordable, competitive, sustainable and reliable supply of energy to meet national and county needs at least cost, while protecting and conserving the environment."[3] The Energy Bill, 2015, that aims to consolidate the laws relating to energy and provide for National and County Government functions in relation to energy, was passed by the National Assembly in November 2016 and forwarded to the Senate for consideration.[4] The Bill sets out institutions in the energy sector; promotes renewable energy; provides a framework for the exploration, recovery and commercial utilization of geothermal energy; regulates petroleum and coal activities; and regulates electricity supply and use.[5]

Climate change analysis in the energy sector considers both energy supply, or electricity generation; and energy demand at the household, industrial and commercial levels. Both are discussed below.

ENERGY SUPPLY

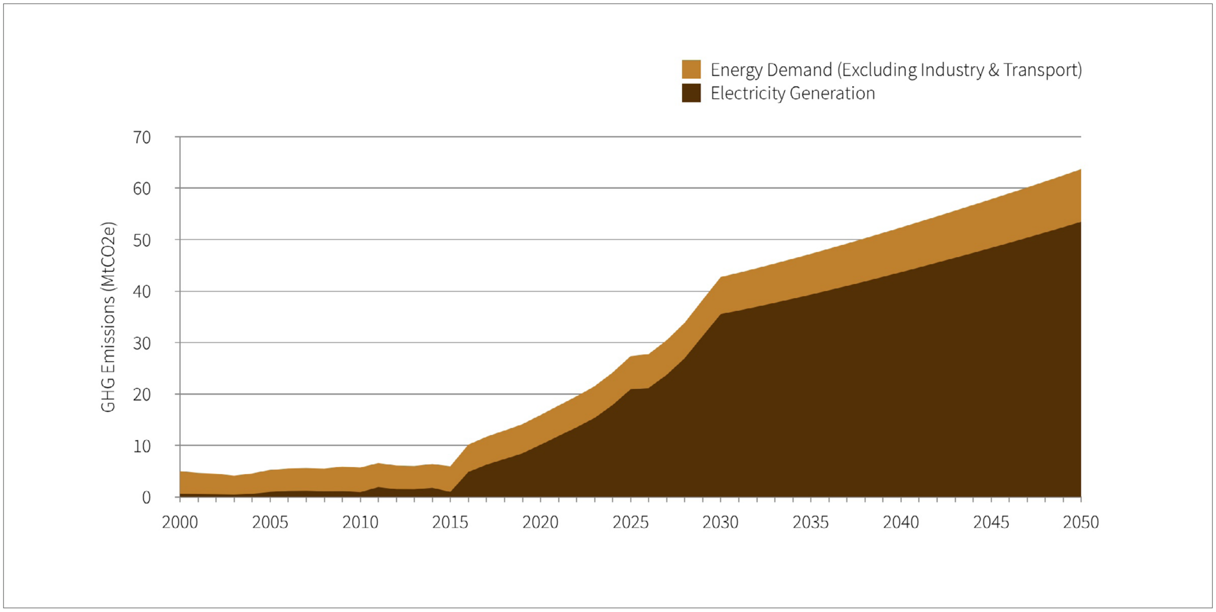
The three main electricity generation sources in Kenya are hydro, geothermal and thermal, together making up 99% of electricity sent to the national grid under normal hydrological conditions. Total installed electricity capacity stood at 2,334 megawatts (MW) in 2015.[6] About 65% of electricity was generated locally using renewable energy sources (hydropower 35.9%, geothermal 25.9%, cogeneration from bagasse 1.7%, wind 1.1% and solar 0.08%) while approximately 35% was generated using fossil fuels in the form of diesel plants.[7]

Recently discovered coal resources are expected to play an important part in Kenya's long-term electricity sector planning as set out in the Power Generation and Transmission Master Plan 2015-2035. The plan ranks coal as the fourth largest contributor to the generation capacity after geothermal, hydro, and imports in that order, from 2020 onwards. Coal-fired power plants in Lamu and Kitui are included in the baseline projection. Nuclear is also expected to play a role in electricity generation in 2030.[8]

Along with an increase in generation capacity, the Government of Kenya has prioritized action to increase grid connectivity. Reduced connection fees to the national grid, from KES 35,000 to KES 15,000 in May 2015 contributed to Kenya Power adding at least one million new connections. The national connectivity access rate increased from 47% in March 2013 to 55% in June 2016.[9] The Government's Last Mile Connectivity project aims to attain a 70% electricity access rate by 2017 and universal access by 2020.[10]

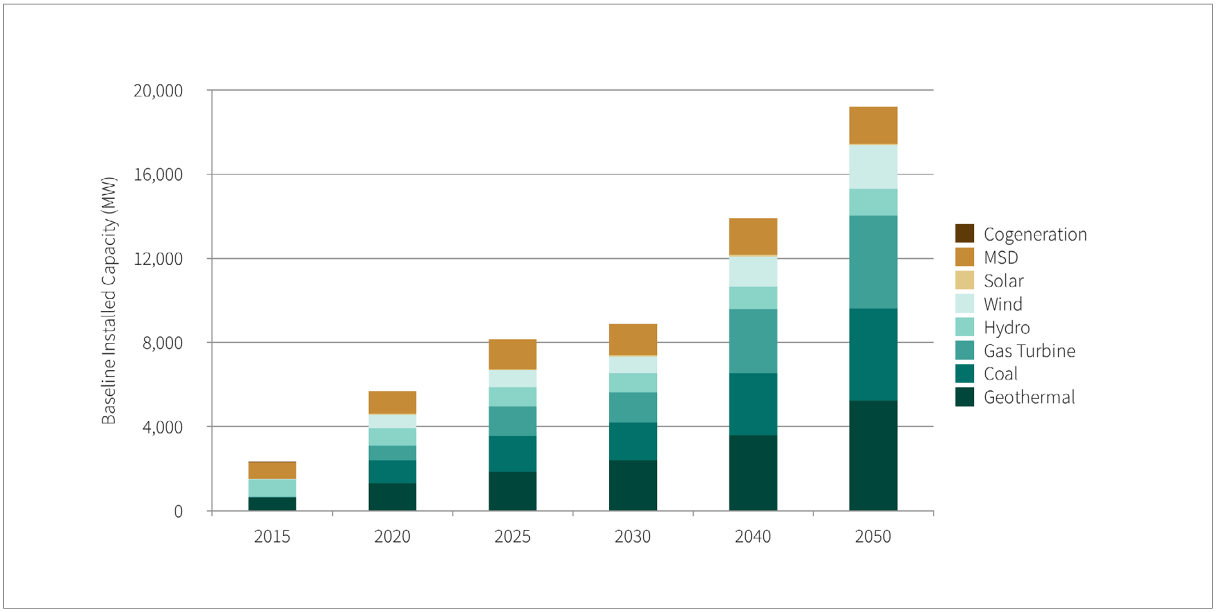
An estimated 6.7 million households comprised the off-grid and decentralized electricity market in 2013. Supply consisted of micro and pico systems, mini-grids, and stand-alone systems – with solar, wind and hydro being the main resources in use. Stand-alone solar photvoltaic (PV) systems are the most widely used technology in Kenya, with well over 200,000 systems installed and sales estimated at 20,000 systems per year.[11] Solar-based initiatives – including private sector businesses such as

Figure 4.1. Baseline Energy Supply and Energy Demand GHG Emissions Projections (MtCO2e)



Note: Emissions from fossil fuel production are in relative terms so small they do not appear in the figure.

Figure 4.2. Baseline Electricity Generation Capacity (MW)



M-Kopa, Sunlar and Go Solar Systems – have been instrumental in increasing access for solar home systems that provide off-grid energy solutions for lighting and powering electronic devices. Households with access to solar energy increased from 3% in 2013 to 15% in 2016.[12]

Kenya is expected develop its domestic oil and gas reserves over the next few decades. The baseline includes only a small amount of crude oil production (about 2,000 barrels/day) starting in 2017 and rising modestly to 6,000 barrels/day by 2030.

ENERGY DEMAND

Energy demand is divided among three main types of energy carriers: fossil fuels, biomass and electricity. Fossil fuels and biomass are used to produce heat for productive purposes in the commercial and industrial sectors, and for cooking and heating purposes in the household sector. Kenyans rely on the traditional use of biomass as the primary energy source for heating and cooking. About 87% of the rural population uses firewood for cooking and 82% of the urban population uses charcoal for cooking.[13] Considered holistically, the annual contribution of charcoal to the economy is estimated to be about KES 135 billion.[14] The charcoal industry faces several challenges, including unsustainable fuelwood resources and the informal nature of the sector's operations.

Energy efficiency measures help to reduce energy consumption in households and reduce the energy costs in commercial and industrial services and products. The government, in partnership with stakeholders, has taken several energy efficiency and conservation initiatives. The Ministry of Energy and Petroleum (MOEP) has worked with the Kenya Association of Manufacturers (KAM) to establish a Centre for Energy Efficiency and Conservation (CEEC) that promotes energy efficiency in private sector companies and public institutions such as government buildings. Kenya Power has implemented a programme to distribute compact fluorescent lights (CFLs). MOEP has implemented improved cookstoves programmes, and developed regulations that influence the update of climate-related technologies, such as for solar water heating, solar PV systems and cookstoves.

4.2 CLIMATE CHANGE IN THE ENERGY SECTOR

Globally, energy contributes the most to climate change due to fossil fuel-related emissions. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) noted that total annual anthropogenic GHG emissions increased by about 10 gigatonnes of CO_2 equivalent between 2000 and 2010. This increase directly came from the energy (47%), industry (30%), transport (11%) and building (3%) sectors (medium confidence).[15] The entire African energy system is responsible for only 1 to 4% of total global emissions.[16]

In Kenya, the energy sector's contribution to GHG emissions is expected to increase sharply from 2015 to 2030. This NDC analysis indicates that the energy sector (excluding transport and industry) accounted for 7.1% of total emissions in 2015, and this is projected to rise to 29.7% of total emissions in 2030.

In regard to adaptation, temperature rise and an increasing number and severity of extreme weather events – such as heavy rains resulting in floods – have the potential to damage energy infrastructure. Climate change impacts can have consequences for the design, construction, location and operations of power infrastructure. The impact of drought on hydro-generated electricity is well understood in Kenya. Low water levels in the country's hydroelectric dams because of a drought in early 2017 led to the increased use of diesel-powered generators and an increase in the price of electricity.[17] Kenya's NAP recommends climate-proofing of energy infrastructure.

Energy plays a role in enhancing adaptive capacity and resilience to climate change. Communities with access to energy (electricity, in particular, through connection to the grid or through mini-grids) can tap it for income generating activities to boost their income and livelihoods. This can enhance their capacity to adapt to climate challenges such as drought-induced crop failures.

4.3 MITIGATION IN THE ENERGY SECTOR

The baseline GHG emissions projection for energy supply, and residential and commercial energy demand is summarised in Figure 4.1 below. Energy supply emissions are emissions that are generated from the production of electricity and from domestic sources of primary fossil fuel energy. In 2016, Kenya's production of coal, natural gas and crude oil was insignificant and

Figure 4.3. Comparison of 2030 Baseline Emissions and INDC Target Emission Reductions (MtCO2e)

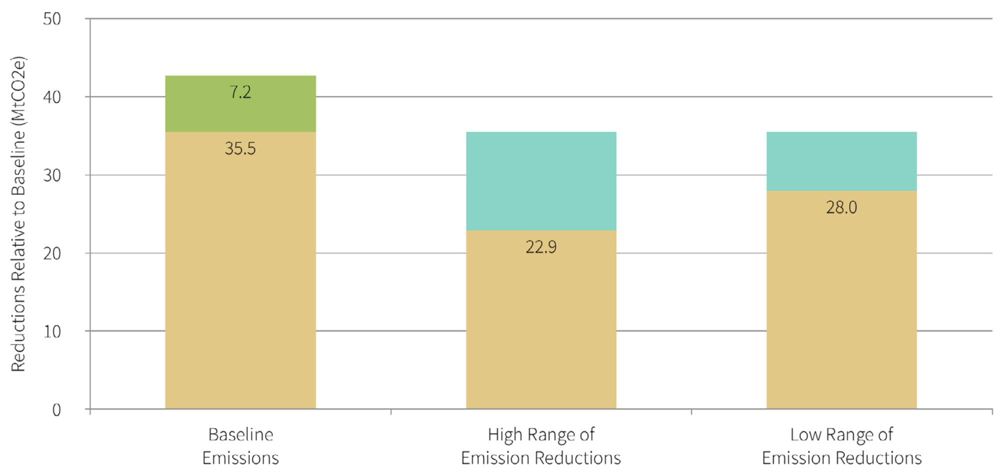
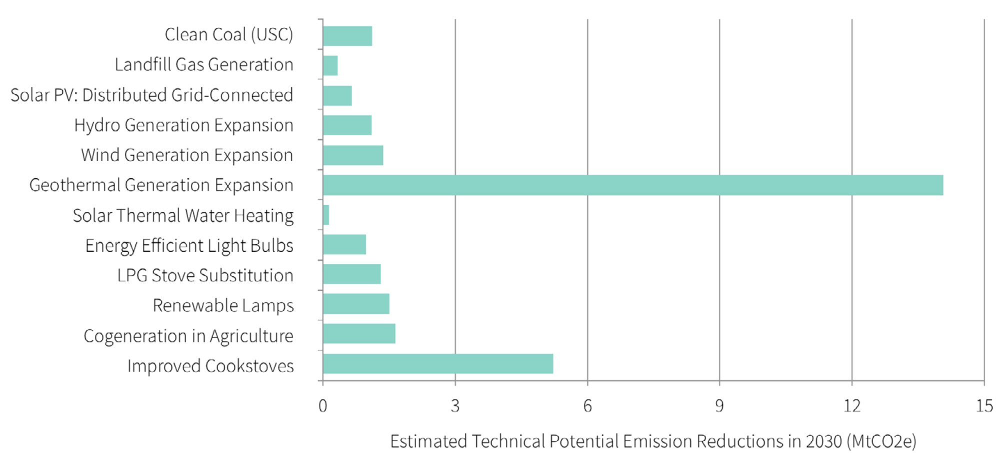


Figure 4.4. Technical Potential Emission Reductions in 2030 of Mitigation Options



generated no GHG emissions. However, the projected baseline includes a small amount of emissions that will result from the production of up to 6,000 barrel of crude oil per day by 2030. Energy demand emissions are those related to the combustion of fossil fuels by residential and commercial energy end-users. The emissions related to energy use in the transport and industry sectors are considered in the transport (Chapter 5) and industry (Chapter 7) sector analyses of this NDC assessment.

Baseline electricity generation emissions currently account for less than 2% of total national emissions and are smaller than emissions from residential and commercial energy demand. However, projections are that electricity generation emissions will account for approximately 25% of total national emissions in 2030 as there is expected to be a considerable addition of coal and natural gas generation capacity in the next 15-year period.

Greenhouse gas emissions are projected to rise from 6.0 million metric tons of carbon dioxide equivalent ($MtCO_2e$) in 2015 to 42.7 $MtCO_2e$ in 2030, a seven-fold increase. The vast majority of the emissions increase (93%) is related to new fossil fuel electricity generation projects. Figure 4.2 illustrates the type of baseline generating capacity that was installed in 2015 and expected out to 2050 in the baseline. Historic emissions are based on actual dispatched electricity generation by generation type and not based on installed capacity.

NDC TARGET FOR THE ENERGY SECTOR

Kenya's NDC "seeks to abate its overall greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario." However, this does not necessarily translate into a 30% emission reduction target for the energy sector equivalent to 12.8 $MtCO_2e$ reductions from baseline emissions in 2030 of 42.7 $MtCO_2e$.

Significant work conducted for Kenya's NCCAP examined the technical potential of emission reductions related to all sectors (agriculture, energy, industrial processes, LULUCF, transport and waste). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential as well as costs. With this in mind, the energy supply and residential and commercial energy demand sector emission reduction target must be less than the technical potential of individual mitigation options identified while also contributing to the overall 30% emission reduction target.

Figure 4.3 identifies a reasonable low and high range for a 2030 target for emission reductions in the energy sector. The low target is aligned with the proportional contribution that the sector would need to make in order for there to be a high level of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The overall target and how the individual six sector targets were calculated is discussed in Chapter 2.

Relative to the baseline, there has already been a significant shift in policy and planning that impacts baseline emissions (for a detailed analysis, see the companion report, *Update of Kenya's Emission Baseline Projections and Impact on NDC Target*[18]). While the MOEP's new Master Long Term Plan forecast to 2035 is consistent with the 2011 Updated Least Cost Development Plan that was used to project emissions for the NCCAP and SNC[19], there has been a general evolution in planning from 2011 to 2017. The newer Master Long Term Plan forecast to 2035 in the electricity sector is dramatically lower than the forecast in the 2011 Updated Least Cost Development Plan (and used to calculate the GHG emission baseline in the NCCAP and SNC).[20] Total supply drops by almost 40% by 2030; and because most of his was to be supplied with coal-fired electricity generation, a dramatic drop in overall emissions of approximately 7.2 $MtCO_2e$ is projected (green bar in baseline emissions in Figure 4.3). This decrease in emissions is considered separately from the target and the implementation of mitigation options because it represents the current condition.

Figure 4.3 illustrates a low (minimum) target of emission reductions of 7.5 $MtCO_2e$ for the Energy Supply and Residential and Commercial Energy Demand Sector, equivalent to a 21% reduction in 2030 baseline energy emissions.

Table 4.1. Key Mitigation Technologies in the Energy Supply and Residential and Commercial Energy Demand Sector

SUB-SECTOR	MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Electricity Generation	*Geothermal*	Feasibility studies and resource assessments, test drilling, directional and deeper drilling and construction of production wells, steam condensing turbines, injection optimization, scaling/corrosion, inhibition, reservoir simulation modelling.
	Wind	Wind turbine siting, electric system integration, advanced rotors and blades, advanced turbine control and condition monitoring, advanced drive trains, generators and power electronics.
	Solar	PV module manufacturing, cell efficiency, stability and lifetime, inverters, charge controllers, system structures, off-grid solar home systems.
	Hydro	Hydropower turbines technologies are mature. Some of the promising technologies under development are variable-speed and matrix technologies, fish-friendly turbines, hydrokinetic turbines, abrasive-resistant turbines, and new tunneling and dam technologies.
	Clean Coal (Ultra-Super Critical)	High pressure and temperature steam generator, turbine, piping systems.
Residential & Commercial Energy Demand	*Improved Cookstoves*	Improved heat retention, formulation of standards for cookstoves, regulating fuel wood harvesting to reflect true value of resource. National Forestry Inventory and monitoring to determine sustainable forest harvesting levels.
	Energy Efficient Lighting	CFLs, LEDs, national energy efficiency policy, use of energy audits, standards development, public awareness of energy efficiency technologies through labeling of end-user consumer technologies.
	Co-generation in Agriculture	Gasification technology, high-efficiency boiler and combustion technology, demonstration and awareness raising.

MITIGATION OPTIONS IDENTIFIED IN KENYA'S SECOND NATIONAL COMMUNICATION

Twelve mitigation options were developed and presented for the energy supply and residential and commercial energy demand sector in Kenya's NCCAP and SNC. Each of these options was assessed to determine its technical potential to contribute to emission reductions in the baseline in 2030. In order to achieve the 7.5 $MtCO_2e$ recommended NDC target for emission reductions in 2030 (see Figure 4.3), there is flexibility and it is not necessary to fully implement all 12 mitigation options. The technical mitigation potential in 2030 of the 12 energy mitigation options organized by sub-sector is presented in Figure 4.4.

Based on Figure 4.4, many different scenarios can be envisioned to achieve the 7.5 $MtCO_2e$ low emission reduction target for the energy supply and residential and commercial demand sector. For example, if only the geothermal generation expansion mitigation option was fully implemented (technical potential) this could achieve 14.0 $MtCO_2e$ of emission reductions in 2030, exceeding the target.

However, if the geothermal generation expansion mitigation option that envisions 2,775 Megawatts (MW) of additional geothermal capacity (total of 5,510 MW in 2030) could not be implemented, it would require that the top three mitigation options with the next highest technical mitigation potential be fully implemented. Ultimately choosing appropriate mitigation options to implement in the sector to achieve the target will require a careful balancing of priorities and may involve greater breadth in lieu of maximizing technical potential.

Cookstoves will need to be addressed in a substantive way to achieve the recommended emission reduction target in the energy demand sector. Inefficient biomass cookstoves and over fire cooking contribute directly to GHG emissions in the energy sector through emissions of methane and nitrous oxide, as well as emissions of carbon dioxide originating from biomass that is unsustainably harvested. At a minimum, biomass cooking needs to improve 10% from the 2010 baseline average efficiency (baseline efficiency is estimated to be approximately 18-20% accounting for the existing penetration of improved cookstoves) by 2030 to deliver emission reductions in line with the overall technical potential of energy demand mitigation options. Improvements greater than 10% from the baseline average efficiency substantially reduce the need to implement a wide range of other mitigation options such energy efficiency improvements in lighting or industry.

Other important mitigation options have also been identified by the ergy Sector Expert Group for Kenya's NDC. These include electricity generation from the country's natural gas resources and replacement of standalone generation sets. Estimates of emission reductions from these options have not been made due primarily to lack of data. Two other options that the group identified – waste to energy and pipeline transportation of oil – are considered under the NDC assessment in the waste (chapter 8) and transportation (chapter 7) sectors.

KEY MITIGATION TECHNOLOGIES IN THE ELECTRICITY GENERATION SUB-SECTOR

Meeting future demand for electricity in Kenya and keeping the average emission intensity of the grid low enough to meet the NDC target will require substantial deployment of renewable energy technologies. Restrictions will be needed to ensure the amount of new fossil fuel generation capacity (such as coal, natural gas and diesel plants) remains below 7,000 MW. The main sources of technical potential for renewables identified in the NCCAP and SNC were geothermal, wind, hydro and grid-connected solar photovoltaic (either distributed or from central plants). Geothermal was identified as best suited to provide the bulk of additional renewable potential between 2015 and 2030. The low-carbon scenario that was considered included 5,500 MW of geothermal capacity to be installed by 2030 up from 627 MW installed by end of year 2015. Achievement of this level of geothermal would proportionally exceed the emission reduction target for the energy sector.

However, it may be prudent to consider a mixed renewable portfolio approach that balances regional resources, transmission and distribution requirements, investment costs, technical barriers and specific grid demands. Another approach to achieving emission reductions in the electricity generation sector would be to ensure that any new coal generation capacity installed was ultra-super critical technology (USC – that, is clean coal) as opposed to the baseline supercritical technology. This would result in an improvement in emissions intensity performance of approximately 10-12%. While this is not an extraordinary improvement, if 5,000 MW of additional clean

Table 4.3. Linkages between priority mitigation actions in the Energy Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
• Expanding geothermal power • Expanding wind power • Expanding hydro power • Distributed solar PV • Landfill gas generation • Clean coal • Improved cook stoves • Solar lanterns • Energy efficient light bulbs and appliances • Solar water heaters	Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix 7.3 By 2030, double the global rate of improvement in energy efficiency 7.4 By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in accordance with their respective programmes of support	• Proportion of population with access to electricity • Renewable energy share in the total final energy consumption • Energy intensity measured in terms of primary energy and GDP • Investments in energy efficiency as a proposition of GDP and the amount of foreign direct investment in financial transfers for infrastructure and technology to sustainable development services
	Goal 12 Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	• Material footprint, material footprint per capita, material footprint per GDP • Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
• Improved and LPG cook stoves • Solar lanterns • Landfill gas generation	Goal 3 Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	• Mortality rate attributed to household and ambient air pollution
• Landfill gas generation • Improved cook stoves • Energy efficient light bulbs and appliances • Solar water heaters	Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	• Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities • Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)
	Goal 12 Ensure sustainable consumption and production patterns	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	• National recycling rate, tons of material recycled

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

coal was installed in lieu of 5,000 MW of baseline coal, then approximately 2.4 $MtCO_2e$ could be reduced. For example, the plan for the coal-fired power plant in Lamu includes supercritical technology, which could be upgraded to USC technology for the GHG emission reduction benefits.

KEY MITIGATION TECHNOLOGIES IN THE RESIDENTIAL AND COMMERCIAL ENERGY DEMAND SUB-SECTOR

Charcoal and wood cookstoves were estimated to consume more than 13 million tonnes of wood in 2015 either directly as fuel or indirectly through charcoal production. Both wood and charcoal consumption in cookstoves is typically very inefficient and while many competing technologies offer efficiency improvements, adoption has been slow. Technologies that can double the efficiency and half wood consumption for the same level of cooking service are available but face a number of constraints including higher initial capital costs, and social and behavioral barriers. Improved cookstoves include reduce charcoal and firewood consumption per meal and include locally produced and imported stoves. Actions to increase the uptake of liquefied petroleum gas (LPG) stoves would be focused on urban areas, and uptake is assumed to replace charcoal stoves.

Achieving a 10% improvement over the baseline would require a minimum of 20% penetration of improved cookstoves that are 50% more efficient by 2030. (Baseline efficiency is estimated to be approximately 18-20% accounting for the existing penetration of improved cookstoves.) However, a greater penetration is likely required since the analysis does not assume rebound effects where cooking demand increases as fuel costs are lowered.

Efficient lighting initiatives can be undertaken in both residential and commercial sectors. The aim of initiatives is to replace inefficient incandescent lighting or T8 fluorescent lighting with more efficient CFL or light-emitting diode (LED) alternatives.

The co-generation in agriculture option considers the production of biogas from agricultural residues (such as sugar cane and flower farm waste) for use in industrial-scale applications. The farming of crops as a feedstock for biogas digesters is not considered because of the potential impacts on food security; and biogas production from solid waste is considered in the NDC waste analysis in chapter 8. A summary of the key technologies is provided in Table 4.1.

DEVELOPMENT IMPACTS OF MITIGATION ACTIONS

Development impacts are an imperative consideration in pursuing mitigation in Kenya. Mitigation actions in the energy sector can have adaptation benefits as well as positive development impacts that are linked to Sustainable Development Goals (SDGs). In 2015, the UN General Assembly session adopted the 2030 Agenda for Sustainable Development (the 2030 Agenda) that included 17 SDGs that meet urgent environmental, social and economic challenges. SDG 13 deals with climate change, whereby countries have agreed to “take urgent action to combat climate change and its impacts,” recognizing that the UNFCCC is the primary forum for negotiating the international response to climate change.[21]

SDG 7 recognizes the specific role of energy: “ensure access to affordable, reliable, sustainable and modern energy for all”. SDG 7 further recognizes the important role that energy plays in “achieving almost all of the Sustainable Development Goals, from its role in the eradication of poverty (SDG 1) through advancements in health (SDG 3), education (4), water supply (SDG 6) and industrialization (SDG 9), to combating climate change (SDG 13).” Linkages between priority mitigation actions in the energy sector and the SDGs are described in Table 4.3.

An analysis of the development benefits of mitigation options was undertaken for the NCCAP and updated for SDGs. Tables 4.3 and 4.4 below provide an overview of development benefits of the mitigation options in the energy sector.

DEVELOPMENT IMPACTS

Mitigation options that reduce electricity consumption or the need to import fossil fuels improve energy security in Kenya. It is for this reason that geothermal power, besides being a low-cost generation source, is prioritised over other sources. Its gradual adoption as a base-load source in place of climate sensitive hydropower has improved power stability. That said, geothermal exploitation can have environmental impacts that need to be managed. These may include subsidence, local air emissions (methane, sulphur dioxide and nitrous oxide) and surface water pollution.

Table 4.3. Overview of Development Benefits of Mitigation Options in Electricity Generation Sub-Sector

	CLIMATE		DEVELOPMENT				
	Abatement Potential 2030 ($MtCO_2$)	Adaptation Impact	SDG 7: Energy Security	SDG1: GDP Growth	SDG 8: Employment	SDG 12: Improved Waste Management	SDG 3: Environmental Impact
Expanding geothermal power	14.1	●	●	●	—	—	—
Expanding wind power	1.4	⯊	⯊	⯊	—	—	—
Expanding hydro power	1.1	◡	⯊	⯊	—	—	◓
Distributed solar PV	1.0	⯊	⯊	⯊	⯊	—	—
Landfill gas generation	0.5	⯊	⯊	⯊	—	●	⯊
Clean coal (USC)	1.1	⯊	—	⯊	—	—	◡

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis, and updated to include the SDGs.

Table 4.4. Overview of Development Benefits of Mitigation Options in Residential & Commercial Energy Demand Sub-Sector

	CLIMATE		DEVELOPMENT				
	Abatement Potential 2030 ($MtCO_2$)	Adaptation Impact	SDG 1: Cost Savings	SDG 1: Effect on Standard of Living	SDG 3: Health	SDG 7: Energy Security	SDG 15: Lower Deforestation
Improved cookstoves	5.6	●	◓	●	●	●	●
Use of LPG for cooking	1.7	●	◓	●	●	◠	●
Distributed solar lanterns	1.8	—	●	●	●	⯊	—
Solar thermal water heating	0.1	—	⯊	—	—	●	—
Energy efficient lightbulbs	1.2	—	●	—	—	●	—
Energy efficient appliances	0.1	—	◓	—	—	⯊	—
Co-generation in agriculture	1.6	—	●	—	—	⯊	—

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis, and updated to include the SDGs.

Renewable energy technologies such as solar PV (distributed and grid-connected), hydro-generation, wind generation, geothermal generation, solar thermal water heating and cogeneration in agriculture that have been prioritised in this NDC analysis increase the share of renewable energy in the energy mix and contribute to the achievement of SDG 7.2. The large investments in geothermal, wind and solar are consistent with SDG 7.b to expand infrastructure and upgrade technology for supplying modern and sustainable energy services.

Investments in renewable energy projects, besides delivering targets 7.2 and 7.b as illustrated above, have the potential to create new jobs; solar installation and maintenance is an example. They thus can contribute to SDG 8 (promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all). These investments also enhance energy security by reducing or eliminating the need for imported fossil fuels to run thermal plants.

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 technology, 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. It therefore has a negative impact on SDG 3, Target 3.9 (by 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination). On the other hand, improved cookstoves, the use of LPG and distributed solar lanterns have significant positive impact on SDG 3 because indoor air pollution from cooking fires and kerosene burning is lowered in the case of improved cookstoves, or completely avoided in the case of renewable lanterns and LPG. More than 14,000 Kenyans die every year from health conditions that can be traced back to indoor air pollution.[22]

Renewable lanterns can also raise general standards of living as their light is usually much brighter and better suited for productive uses or for children's homework (and contribute positively to SDG 4 on Quality Education) than the light given by kerosene lamps. Improved cookstoves reduce the time needed to collect fuel wood, and that time can be put to better productive or recreational use, potentially increasing the standard of living.

ADAPTATION AND CLIMATE RESILIENCE IMPACTS

In regard to adaptation and climate resilience, improved cookstoves and substituting wood fuels with LPG stoves have the potential to significantly reduce rates of deforestation. An improved stove with an improved efficiency of 50 percent requires half the fuel of a traditional stove; and LPG stoves totally mitigate the need for biomass resources. This reduces pressure on the country's wood biomass resources or enables the wood to be used for other purposes.

Hydro generation is the mitigation 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 largely 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 from 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.[23]

4.4 ADAPTATION IN THE ENERGY SECTOR

Kenya's NDC emphasizes adaptation and identifies priority adaptation actions drawing on the National Adaptation Plan, 2015-2030 (NAP).[8] Adaptation in the energy sector is generally framed within the broader framework of climate-proofing infrastructure. Kenya's NCCAP defines climate-proofed infrastructure as that which is "designed, constructed and operated in a way that accounts for anticipated risks and opportunities that result from climate change, ensuring that infrastructure investments are not compromised in the future."[24] Care International explains that climate proofing aims to protect development investments and outcomes from the impacts of climate change, and "increases the sustainability of projects by analysing the risks that climate change poses to project

Table 4.5. Examples of Direct and Indirect Impacts of Climate on Energy Systems

CHANGE IN METEOROLOGICAL VARIABLE	IMPACT ON ELECTRICITY GENERATION AND TRANSMISSION	IMPACT ON ELECTRICITY USE
Increase in temperature	Some	Increase in higher cooling needs Decrease if sea-level rise displaces population and industrial production
Decreases in cloud cover	None	Decrease in lighting needs
Increase in cloud cover	None	Increase in lighting needs
Increase in frequency and/or strength of storms	Failure/damage of transmission lines Disrupted generation Disrupted distribution of fuel	Decrease in demand due to the destruction of houses and factories
Floods	Failure of transmission equipment Disrupted generation from flooded power plants Disrupted distribution of fuel	Sharp decrease in demand due to interruption of production in flooded factories/cessation of electricity consumption in flooded houses
Drought	Risk of destruction of transmission lines due to forest fires Lower water levels reducing hydropower generation	Slight decrease in demand due to interruption of production in factories whose supply of raw materials have been depleted/cessation of electricity consumption in houses of people abandoning the drought area

Adapted from: Williamson, L., Connor, H. and Moezzi, M. (2009), Climate-proofing energy systems. Paris: Helio International. Page 6.

Table 4.6. Priority Adaptation Actions in the Energy Sector

ACTION	• Enhance the implementation of an energy generation mix plan that increases the resilience of the current and future energy systems to the impacts of future climate variability and change (NAP).
SHORT TERM SUB-ACTIONS	• Conduct risk and vulnerability assessments of major energy infrastructure (NAP). • Increase the solar, wind and other renewable energy systems network to provide power to off-grid areas (NAP). • Promote modern cooking fuels and technologies. • Use reinforced concrete posts and under-ground cabling.
MEDIUM TERM SUB-ACTIONS	• Increase small hydropower and geothermal power generation plants to provide electricity to communities and businesses in the rural areas enabling job creation (NAP). • Promote energy efficiency programmes (NAP). • Consider use of fiberglass poles. • Provide strategic and sufficient fuel storage capacity across the country (International Energy Agency recommendation: 90 days storage capacity). • Construct new infrastructure in a manner that accounts for climate risks (accessing climate finance for additional costs).
LONG TERM SUB-ACTIONS	• Continue the rehabilitation of water catchment areas in order to provide sustainable ecosystem services, including energy production (NAP).

Adapted from: Government of Kenya, Kenya National Adaptation Plan, 2015-2030, page 23, and supplemented with inputs from the Energy Sector expert group.

activities, stakeholders and results; then modifying project designs or implementation plans to reduce those risks."[25]

RISKS AND IMPACTS

The impacts of climate change – flooding, seasonal droughts, storm surges, landslides, extreme winds, higher temperatures and heat waves – affect energy transmission and use regardless of how the energy is produced. Table 4.5 provides examples of the impacts of climate change on electricity systems.

A 2009 assessment of the vulnerability of Kenya's energy system to climate change identified the following impacts:

- A reduction in hydroelectric generation capacity due to reduced rainfall;
- Potential damage to above-ground electricity transmission and distribution lines by storms and floods;
- Reduced biomass energy availability due to drought and changing rainfall patterns; and
- Disruption in transportation of energy such as fossil fuel and charcoal caused by damaged transportation infrastructure.[26]

PRIORITY ADAPTATION ACTIONS IN THE ENERGY SECTOR

The main action in the electricity sub-sector identified in Kenya's NAP is the development of "an energy generation mix plan that increases the resilience of the current and future energy systems to the impacts of future climate variability and change."[27] (See Table 4.6 for priority action identified in the NAP and through expert input.) Kenya has progressively implemented this action over the past decade with tangible climate change adaptation and resilience benefits. The improved reliability of Kenya's power supply, as noted in the 2016 Economic Survey, is attributed to an increasing contribution of the climate-insensitive geothermal to the energy generation mix and its use as a base load power source.[28]

Given the slow rate of capital stock turnover in the energy sector and the long lifetime of equipment, a sustainable energy system should climate proof infrastructure. Hydropower and wind power systems likely have taken account of some climate risks because investment decisions are linked to uncertainty related to climate conditions; yet specific adaptation measures across the energy system can reduce vulnerability to climate change. Inadequate attention to climate impacts can increase the long-term costs of energy sector investments and reduce the likelihood that these investments will deliver intended benefits.

Climate resilience actions include reinforcing technical equipment, diversifying energy supply sources, siting power equipment more appropriately, expanding linkages with other regions, disaster preparedness planning, managing demand, and investing in technological change —renewables, efficiency, management — to further expand the portfolio of options.

Various methodologies and guidelines have been developed to climate proof investment in the energy sector. For example, the Asian Development Bank has developed guidelines for climate proofing investment in energy systems; and the World Bank's Climate Impacts on Energy Systems provides an overview of how energy systems might be impacted by climate change and options to address these impacts.[29] The Public Infrastructure Engineering Vulnerability Committee Protocol developed by Engineers Canada has been used since 2008 to assess climate risks across a range of infrastructure systems, including electricity distribution systems. The protocol estimates the severity of climate impacts and informs engineering decisions on design and operations.[30]

Hydroelectricity currently constitutes about 35% of the installed generation capacity. This large share in the energy generation mix in the short to medium term requires a robust assessment of the potential impact of climate change on existing facilities as well as improved use of weather and climate information in developing and siting new ones.

Large electricity generation projects such as the proposed 1000 MW Lamu Coal Power Project and the proposed nuclear power project should be climate-proofed for two main reasons. Their significant contribution to the total energy generation for the country implies that any damage to, or reduced generation capacity of, such projects – be it climate change-related or otherwise – can have significant economy-wide impacts. Secondly, destruction of such projects by extreme weather events, such as storms and wind, can result in environmental and health challenges of unprecedented magnitude. In line with the NAP, large energy projects should therefore be "designed, constructed and operated in a way that accounts for anticipated risks and opportunities that result from climate change, thus ensuring that they are not compromised in the future."[31] Their final design and materials of construction should be able to withstand anticipated climate risks such as sea level rise and extreme weather events.

Enhanced climate resilience of the electricity transmission and distribution system has included a recent policy and technology shift towards the use of reinforced concrete posts and under-ground cabling. In 2015, Kenya Power announced that concrete poles would be used for all new transmission lines, limiting wooden poles, which have a shorter lifespan and are more prone to destruction by extreme weather events, such as strong winds and heavy rain, for domestic connections only. Fiberglass poles are being considered for the same purpose.[32]

Adaptation in the energy sector should also consider potential disruption in the transportation networks since they play an important role in delivering fuels (oil and gas) to electricity generators as well as consumers. In this respect, recent investments in rail and pipeline infrastructure are expected to ameliorate some of the climate change challenges associated with road transportation of fuels. These actions should be complemented with additional strategic fuel storage facilities particularly in those regions not served by the pipeline and rail networks.

Lastly, while improved cookstoves deliver several sustainable development benefits, greater attention could focus on the technology's sustainability and resilience in the face of a changing climate. Kenya's high dependence on wood biomass energy (over 70% of primary energy needs) is a main driver of deforestation and forest degradation, along with population growth and agricultural expansion.[33] Increased uptake of improved cookstoves will reduce the dependency on forest products by minimizing the number of trees cut down. Maintenance of forest cover is critical to maintain watersheds and water towers, which help to ensure water flow in rivers during drought, reduce flooding at times of heavy rain, and maintain water dam levels.

ANNEX 4.1 ASSUMPTIONS UNDERLYING THE MITIGATION OPTIONS IN THE ENERGY SECTOR

The assumptions underlying the mitigation options in the NDC analysis are described below, drawing on the information included in the detailed energy demand and electricity supply chapters developed for the NCCAP mitigation analysis.[34]

Improved cook stoves – The mitigation scenario assumes that the overall efficiency of using fuelwood and charcoal for cooking can be improved by 10% by 2030 through the increased penetration of improved cookstoves. It is estimated that improved cookstoves can increase the efficiency of cooking (reduce use of fuelwood and charcoal) by as much as 50% over inefficient cooking equipment and methods used today. Increased penetration of improved cookstoves to replace inefficient cookstoves or traditional over fire cooking (three stone or mud stove) will reduce average household use of both fuelwood and charcoal, of which it is estimated that 30% is unsustainably produced in Kenya. Considering assumptions that baseline efficiency will not improve over time until 2030 and that existing penetration rates of improved cookstoves remain stable, the overall result of the mitigation scenario is that emissions from the use of biomass for cooking would be 30% lower in 2030. Baseline emissions are estimated at 17.5 $MtCO_2e$ in 2030.

There are different pathways to achieving this mitigation outcome. The overall efficiency of new improved cookstoves is variable as are the number of households using traditional open fire cooking, inefficient cookstoves or improved cookstoves. The target is deliberately vague as the scenario was not developed using a detailed baseline of household fuelwood and charcoal consumption for cooking that is linked to specific technologies, each with their own operating efficiency. In addition, the impact of the measure on the renewable fraction of wood harvested is not taken into account. A significant decrease in fuelwood demand as estimated for this improved cookstove action would likely increase the renewable fraction of wood harvested, and as a result decrease baseline emissions and emissions from the LULUCF sector further still.

In any case, millions of improved cookstoves will need to be manufactured, distributed and efficiently utilized by the majority of households in Kenya if the full 5.3 MtCO2e emission reduction potential of the mitigation scenario is to be achieved by 2030.

LPG stove substitution – The assumption is that in 2020 almost all urban households, representing 30 percent of the total population, use LPG as a cooking fuel. Overall country-wide penetration rate of LPG will increase by 10% every 5 years from 2020 to 50% in 2050. The emission reductions used for LPG are 30% , which is the average reduction when compared to charcoal and fuelwood stoves and therefore does not account for users of fuelwood in 'open' fires due to a lack of data.

Solar Lanterns replacing kerosene lamps – One hundred percent adoption of solar lighting technologies is assumed (for off-grid applications) by 2030, completely replacing kerosene lamps. This is a result of decreasing prices for solar lighting technologies, which have dropped significantly over the past few years. Given the short payback times for a solar lantern, a rapid increase in penetration to reach 65% of the population by 2020 is assumed, further increasing to 100 percent by 2030. This leads to the elimination of the use of kerosene for lighting.

Solar thermal water heating – Relatively modest adoption rates are assumed for solar thermal water heating because of the high upfront investment cost and smaller reach, with end-users being limited to the urban population. The penetration of solar thermal water heating systems is assumed to increase by five percent a year, reaching 20 percent in 2030.

Energy efficient light bulbs – In 2030 it is assumed that an adoption rate of 100 percent will be achieved through an intervention to phase out incandescent bulbs, leading to 80 percent lower electricity consumption for lighting versus the reference case by 2030.

Co-generation in agriculture – The low-carbon scenario for biogas-based cogeneration assumes that the mean potential from a GTZ study is utilized in 2020 (42 MW) and that this doubles by 2030. This is a relatively ambitious assumption being 50 percent higher than the current estimated maximum potential; however, it is assumed that agricultural output will have grown to cover this by 2030. It is also assumed that 25 percent of installed capacity is small scale and 75 percent large (as per the "industrial" scenario of the GTZ study).[35]

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 climate finance would be used to move beyond a reference case to fulfil the ambitious growth forecast of the ULCPDP.

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 mitigation 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 – The GIZ study estimates that 200 Megawatt peak (MWp) is realistically feasible within a relatively short timeframe, assuming only a small fraction of relevant large consumers, between 1 and 3% invest in solar PV under net metering. Based on these assumptions, 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 electricity tariffs are expected to increase significantly by 2030. 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.

Landfill gas – From a starting point of no installed capacity in 2015, 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.[36]

Clean coal – The low-carbon scenario assumes that all coal installed in Kenya uses USC technology rather than supercritical technology.

ANNEX 4.2 MITIGATION OPTIONS IN THE ENERGY SECTOR NOT CONSIDERED IN THE ANALYSIS

Biogas – Biogas was not included mainly because of specific requirements for operation. To use a biogas digester, a household needs at least two head of cattle herded in a way that allows manure collection. Most cattle in Kenya are free ranging, which reduces the potential for a national biogas program. Biogas can be a feasible option in certain regions. Dairy farming is a large industry in Kieni in Nyeri County, where many farmers have adopted biogas generation, with significant benefits reported including substitution for firewood. Plans are underway to collect excess gas from farmers for purification, packaging and sale within the region.

Replacing cement consumption with alternative building materials – Replacing cement consumption with alternative building materials could be a viable alternative in some situations, such as buildings where the construction requirements allow for replacement of cement with brick. No public data was available on the potential for cement replacements, and the option could not be analysed further.

Biofuels for cooking practices – Biofuels for cooking practices were not included because the costs of production of refined fuels on a community scale are too high for cooking and lighting. Other (relatively) low-cost options, such as solar lanterns and LPG, are considered to be more suitable for this market. Stakeholders at county consultations reported mixed experiences with biofuels production based on jatropha. Large-scale production of biofuels to replace fossil fuels is better suited to the transport sector where alternatives are scarce (see Chapter 7).

Implications of the oil discovery – The implication of expected oil production was added to the baseline scenario. The assumption is that domestic oil production will rise to 6,000 barrels per day by 2020. Mitigation measures to reduce fugitive emissions were not considered.

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

- 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.
- 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).
- 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 – 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). Although incineration can still prove beneficial under these conditions, there is significant overlap with the option of electricity generation from landfill gas (see Chapter 8).

Reducing losses in transmission and distribution – 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. 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:

- 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.
- In a supply constrained electricity sector, any extra supply will be consumed, offering little net difference in emissions.

REFERENCES

[1] Government of Kenya (2007). *Kenya Vision 2030*. Nairobi: Government of the Republic of Kenya.

[2] World Bank (2016). *World Development: Indicators*. Accessed at: http://data.worldbank.org/country/kenya#cp_wdi

[3] Government of Kenya (2015). *Draft National Energy and Petroleum Policy*. Nairobi: Ministry of Energy and Petroleum, page 11. Accessed at: http://www.erc.go.ke/index.php?option=com_content&view=article&id=207

[4] Parliament of Kenya (2017). *Bill Tracker 2 February 2017*. Accessed at: http://www.parliament.go.ke/the-national-assembly/house-business/bills-tracker

[5] Government of Kenya (2015). *The Energy Bill, 2015*. Accessed at: http://www.erc.go.ke/index.php?option=com_content&view=article&id=207

[6] Kenya National Bureau of Statistics (2016). *Economic Survey 2016*. Nairobi: Kenya National Bureau of Statistics.

[7] Ministry of Energy and Petroleum (2016). *Sustainable Energy for All: Kenya Action Agenda*. Nairobi: Ministry of Energy and Petroleum. page 10.

[8] Government of Kenya (2016). *Electricity Generation and Transmission Master Plan 2015-2035*. Nairobi: Ministry of Energy and Petroleum.

[9] Wasike, N. (2016). *A Decade of Energy Access Transformation (2006-2016): Is energy inclusion in Kenya on the Rise?* FSD Kenya (20th July). Accessed at: http://fsdkenya.org/blog/a-decade-of-energy-access-transformation-2006-2016-is-energy-inclusion-in-kenya-on-the-rise/

[10] Kenya Power (2016). *Milestones in Kenya's Electricity Sector*. Accessed at: http://www.kplc.co.ke/content/item/1038

[11] Stock Taking and Gap Analysis Report (2013), cited in Ministry of Energy and Petroleum (2016). *Sustainable Energy for All: Kenya Action Agenda*. page 5.

[12] Wasike, N. (2016).

[13] Ministry of Environment, Water and Natural Resources (2013). *Analysis of Demand and Supply of Wood Products in Kenya*. Accessed at: http://www.kenyaforestservice.org/documents/redd/Analysis%20of%20Demand%20and%20Supply%20of%20Wood%20Products%20in%20Kenya.pdf

[14] Ministry of Environment, Water and Natural Resources (2013). *Analysis of Demand and Supply of Wood Products in Kenya.*

[15] IPCC (2014), *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the IPCC. (Core writing team: R.K. Pachuri and L. A. Meyer (eds.) Geneva: IPCC. page 46. Accessed at: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_All_Topics.pdf

[16] Climate and Development Knowledge Network (2014). *Integrating Climate Change in the Post-2015 Development Agenda.* London: Climate and Development Knowledge Network.

[17] Otuki, N. (2017). Power bills forex levy hits 15-month high. *Daily Nation* (9th February), page 34.

[18] StARCK+ Technical Assistance to the Government of Kenya component (2017). *Update of Emission Baseline Projections and Impact on Kenya's NDC Target.* Developed for the Ministry of Environment and Natural Resources NDC analysis.

[19] Government of Kenya (2016). *Electricity Generation and Transmission Master Plan 2015-2035*. Nairobi: Ministry of Energy and Petroleum. Government of Kenya (2011). *Updated Least Cost Power Development Plan Study Period: 2011-2031.* Nairobi: Energy Regulatory Commission.

[20] Government of Kenya (2016). *Electricity Generation and Transmission Master Plan 2015-2035*. Nairobi: Ministry of Energy and Petroleum. Government of Kenya (2011). *Updated Least Cost Power Development Plan Study Period: 2011-2031.* Nairobi: Energy Regulatory Commission.

[21] United Nations (2017). *Revised list of global Sustainable Development Goal indicators.* Accessed at: https://unstats.un.org/sdgs/indicators/Official%20Revised%20List%20of%20global%20SDG%20indicators.pdf.

[22] United Nations Environment Programme (2016). *Actions on Air Quality*. Nairobi: United Nations Environment Programme.

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

[24] Government of Kenya (2013). *National Climate Change Action Plan: 2013-2017*. Page 35.

[25] Care International (2010). *Tool Kit for Integrating Climate Change Adaptation into Development Projects: Version 1.0*. Accessed at: http://www.careclimatechange.org/tk/integration/en/about_the_toolkit/what_do_we_mean_by.html

[26] Kirai, P. (2009). *Energy Systems: Vulnerability-Adaptation-Resilience (VAR) Project*. Paris: Helio International.

[27] Government of Kenya (2013). *National Climate Change Action Plan 2013-17*. page 35.

[28] Kenya National Bureau of Statistics (2016). *Economic Survey 2016*. Nairobi: Kenya National Bureau of Statistics.

[29] Asian Development Bank (2013). G*uidelines for Climate Proofing Investment in the Energy Sector*. Manilla: Asian Development Bank. World Bank (2011). *Climate Impacts on Energy Systems: Key issues for energy sector adaptation*. Washington, D.C.: Energy Sector Management Assistance Program. Williamson, L., Connor, H., Moezi, M. (2009). *Climate Proofing Energy Systems*. Paris: Helio International.

[30] Engineers Canada (2014). Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol. Accessed at: https://pievc.ca/protocol

[31] Government of Kenya (2016). *National Adaptation Plan, 2015-2030*. Nairobi: Ministry of Environment and Natural Resources.

[32] Odhiambo, A. (2014). Shift to concrete electricity poles hurts wood suppliers. *Business Daily.* Accessed at: http://www.businessdailyafrica.com/Shift-to-concrete-electricity-poles-hurts-wood-suppliers/539552-2476334-xdoopm/index.html

[33] Ministry of Forestry and Wildlife (2013). *Analysis of drivers and underlying causes of forest cover change in the various forest types of Kenya.* Developed by Ruri Consultants, Nairobi. Accessed at: http://www.kenyaforestservice.org/documents/redd/Analysis%20%20of%20Drivers%20of%20Deforestation%20&forest%20Degradation%20in%20Kenya.pdf

[34] Government of Kenya (2013). Chapter 5: Electricity Supply and Chapter 6: Energy Demand. *Mitigation*. Developed by the International Institute for Sustainable Development (IISD) and the Energy research Centre of the Netherlands (ECN) as background reports for *Kenya's National Climate Change Action Plan, 2013-2017.* Accessed at: http://www.kccap.info/index.php?option=com_phocadownload&view=category&id=36&Itemid=41

[35] 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: German International Cooperation (GIZ).

[36] Fischer, E., et al. (2010).

5: FORESTRY SECTOR

5.1 THE FORESTRY SECTOR IN KENYA

Sustainable and productive management of land and land resources are enshrined in Chapter 5 of the Kenyan Constitution, which among other things, stipulates that the state will work to achieve and maintain a tree cover of at least 10% of total land area. The Constitution further states that "land in Kenya shall be held, used and managed in a manner that is equitable, efficient, productive and sustainable," and entrenches "sound conservation and protection of ecologically sensitive areas."[1]

The Forest Policy, 2014, notes that forests play "critical ecological, social, cultural and economic functions", and contribute to 3.6% of Kenya's GDP, excluding charcoal and direct subsidence uses. Forests also support most productive and service sectors in the country, particularly agriculture, fisheries, livestock, energy, wildlife, water, tourism, trade and industry that contribute between 33% to 39% of the country's GDP. Biomass comprises about 80% of all energy used in the country, and forests provide a variety of goods that support the subsistence livelihoods of many communities.[2]

The Forest Conservation and Management Act, 2016 provides for the development and sustainable management of all forest resources. The Act classifies forests in Kenya as public, community or private forests. Public forests are vested in the Kenya Forest Service (KFS), community forests are vested in the community, and each County Government is responsible for the protection and management of forests and woodlands under its jurisdiction. [3]

Forests serve several purposes such as the provision of forest products, and ecological and environmental services such as water purification, erosion control and carbon sequestration. They slow water dispersion and enhance infiltration and percolation of rainwater, which recharge soil and underground water storage. This is crucial in supplying clean water for drinking, agriculture and other uses. Forests protect soils from wind and water erosion, avalanches and landslides. Forests also provide habitats that support biodiversity and ecological processes and have cultural, religious and recreational values that are important to many forest users.[4] The exclusion of these services in accounting for the forestry sector's contribution to the economy using the conventional United Nation's System of National Accounts implies that the economic value of forests and forest resources in Kenya is grossly under-estimated.[5]

A 2010 inventory undertaken by KFS, and cited in the National Forest Programme 2016-2030, determined forests in Kenya occupied 6.99% of total land area (or 40,726.9 km^2 of the country) in 2010. These forests are categorised as Montane, Western rainforest, Bamboo, Afro-montane undifferentiated forest, Coastal and Dryland forests. The montane forest and the coastal forest regions are the most forested with 18% and 10% forest cover, respectively.[6]

Kenya is classified as a low forest cover country. Kenyan data submitted to the FAO Global Forest Resources Assessment indicated that forested land (including natural forests, public and private plantations) declined from 4,724,000 hectares (ha) in 1990 to 3,437,000 ha in 2000; but then increased to 4,037,000 ha in 2010.[7] While there is considerable uncertainty in regard to the exact forest extent in Kenya and the rates of deforestation, it is clear that over the last twenty to thirty years considerable deforestation has occurred in Kenya. The major reasons for deforestation are conversion of forest land to agriculture, unsustainable utilization of forest products (including charcoal), forest fires and shifting cultivation.[8]

5.2 CLIMATE CHANGE AND THE FORESTRY SECTOR

The Forest Policy, 2014 highlights that climate change has a direct impact on forest resources and ecosystems and on people and their livelihoods - through flooding, landslides and drought. The policy notes that forestry can play an important role in both mitigation and adaptation to climate change.[9]

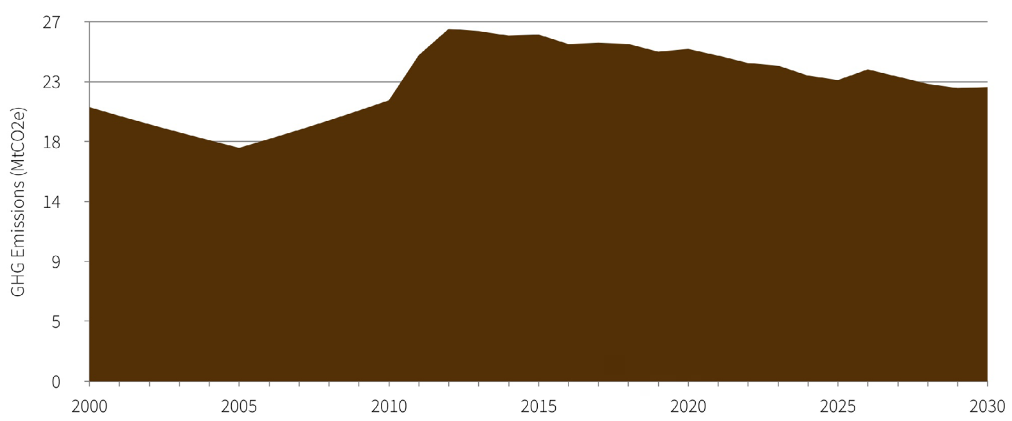
Actions to increase forest cover and prevent deforestation have important climate resilience and low carbon benefits. Forests play a role in mitigating the harmful effects of greenhouse gas

Table 5.1. Kenya: Existing Forest Restoration Targets

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

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

Figure 5.1. Baseline LULUCF Sector GHG Emissions Projections (MtCO$_2$e) NDC Target for the Forestry Sector



emissions by acting as a "sink" by sequestering carbon and storing it for long periods of time. The Forest Conservation and Management Act, 2016 (Section 42) indicates that indigenous forests and woodlands are to be managed on a sustainable basis for, *inter alia*, carbon sequestration. Section 8 indicates that KFS is to manage water catchment areas in relation to soil and water conservation, carbon sequestration and other environmental services; and Section 21 notes that County Governments are to promote afforestation activities.

Land Use, Land-Use Change and Forestry (LULUCF) is a mitigation sector under the United Nations Framework Convention on Climate Change (UNFCCC) that is concerned with the exchange and balance of carbon dioxide between the atmosphere and the terrestrial biosphere system (sink).[10] Forests sequester a significant amount of carbon through growth of trees and accumulation in soil carbon. The Global Forest Resources Assessment 2010 estimated that the world's forests and other wooded lands store more than 485 gigatonnes of carbon.[11]

The LULUCF sector is the second largest contributor to Kenya's greenhouse gas emissions after agriculture, accounting for 32% of emissions in 2015; largely a result of deforestation.

Forests also play a vital role in adaptation to climate change. Forests provide ecosystem services that contribute to reducing the vulnerability of sectors and people. Mangroves can protect coastal areas against storms and waves, which are projected to become even more intense with climate change and climate-induced sea-level rise. Forest products can provide safety nets to local communities when climate variability causes crop failures. Forests also provide hydrological ecosystem services such as regulation of storm waters. In addition, upper watersheds can increase infiltration of rainwater, reduce surface run-off and control soil loss, thus decreasing the destructive impacts of floodwaters. By storing run-off, forests can also act as natural water recharge areas by replenishing stream-flows.[12]

The forestry sector is also vulnerable to climate change, which is expected to have important effects on the composition, growth rates and regenerative capacity. The NCCAP reports that climatic changes are expected to increase desertification and forest degradation, with impacts on economic benefits and livelihoods derived from the forestry sector.[13]

The government is taking action to address climate change in the forestry sector, including through tree planting initiatives and preparatory activities to enable participate in REDD+ (reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks) as a climate change mitigation process. Under the Bonn Challenge, Kenya has established a restoration target of 4,210,000 hectares by 2030, described in Table 5.1. The Bonn Challenge is a global effort to restore 150 million hectares of the world's degraded and deforested lands by 2020 and 350 million hectares by 2030.[14]

5.3 MITIGATION IN THE FORESTRY SECTOR

The LULUCF sector emissions include estimates of emissions and removals of greenhouse gases associated with increases or decreases of carbon in living biomass as land-use changes occur over time. Such land-use changes include the conversion of a forest area to cropland, or when establishing new forest lands through rehabilitation of degraded forests or afforestation.

LULUCF emissions accounted for approximately 32% of total national emissions in 2015. Their contribution is expected to decrease to 17% by 2030 as the rate of current deforestation in the baseline is projected to slow down due to existing government actions. However, the estimates of the carbon stocks of forest (that is Forest Land Remaining Forest Land in the LULUCF sector) has the highest uncertainty of emission estimates because of uncertainty in activity data and emissions factors. In fact, there is still some uncertainty in regard to the actual extent of total forest cover.

A review of the recent biomass literature available as part of the System for Land-Based Emissions Estimation in Kenya (SLEEK) project indicates that it is likely that total biomass stocks of forests have been underestimated in the modelling work conducted for Kenya's Second National Communication (SNC), which is one of the primary data sources for estimating net baseline emissions. However, more modelling and forest inventory data would be required to determine if net baseline emissions are more or less than the baseline LULUCF emissions projected in the SNC and summarized in Figure 5.1.

Greenhouse gas emissions are projected to decline from 26 $MtCO_2e$ in 2015 to 22 $MtCO_2e$ in 2030, a decrease of 16%.

Figure 5.2. Comparison of 2030 Baseline Emissions and INDC Target Emission Reductions ($MtCO_2e$)

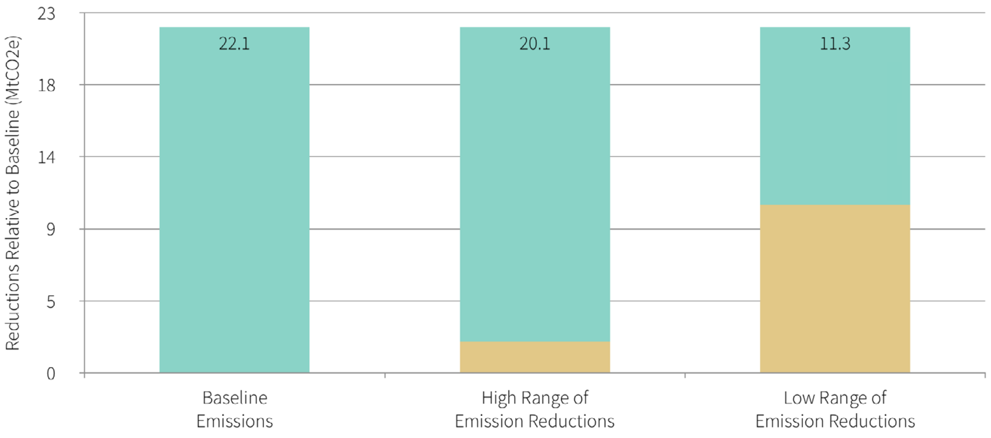
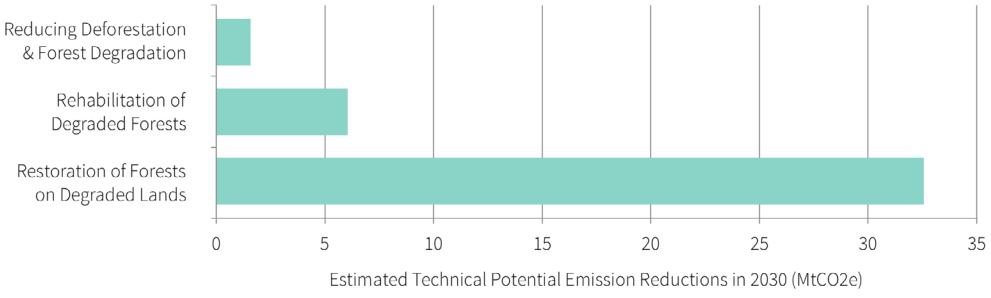


Figure 5.3. Technical Potential Emission Reductions in 2030 of Mitigation Options



Kenya's NDC "seeks to abate its overall greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario." However, this does not necessarily translate into a 30% emission reduction target for the LULUCF sector equivalent to 6.6 $MtCO_2e$ reductions from baseline emissions in 2030 of 22 $MtCO_2e$.

Significant work conducted for the NCCAP examined the technical potential of emission reductions related to all sectors (energy, waste, LULUCF, agriculture and industrial processes). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential as well as costs. With this view in mind, the forestry sector emission reduction target must be less than the technical potential of individual mitigation options identified while also contributing to the overall 30% emission reduction target.

Figure 5.2 identifies a reasonable low and high range for a 2030 target for emission reductions in the LULUCF sector. The low target is aligned with the proportional contribution that the sector would need to make in order for there to be a high level of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The overall target and how the individual six sector targets were calculated is discussed in Chapter 2 of this NDC Assessment Report, and Chapter 9 updates the emission baseline projections and assesses the impact on Kenya's NDC.

Figure 5.2 illustrates a low (minimum) target emission reduction of 11.3 $MtCO_2e$ for the LULUCF Sector. This is equivalent to a 51% reduction in 2030 baseline LULUCF emissions. The target is so high because of the unique position of the LULUCF sector to create net sinks of carbon when, for example, new forests are planted. It is possible for emission reductions to exceed baseline emissions as identified by the maximum technical potential of 40.2 $MtCO_2e$. Emission reductions in the LULUCF sector are attractive because of the relatively low cost to create these carbon sinks compared to actions in other sectors.[15]

MITIGATION OPTIONS IDENTIFIED IN KENYA'S NCCAP AND SECOND NATIONAL COMMUNICATION

Three mitigation options were developed and presented for the LULUCF sector in Kenya's NCCAP, and re-examined in the SNC. The descriptions of the three options below are taken from the Forestry chapter of the NCCAP mitigation analysis. The development of the technical mitigation potential began with the assumption that Kenya's forest increases from 6% to 10% by 2030, which would involve regenerating forests on 2.4 million hectares of land.[16] More detail on the assumptions is available in the fact sheets developed for the NCCAP mitigation analysis.[17]

Restoration of forests on degraded lands – Degraded lands refers to all types of land uses – including grazing lands, bushland, woodland and forest – where previously established tree cover has been reduced and degraded by excessive harvesting of wood and non-wood products, poor management, repeated fires grazing or other disturbances that damage soil and vegetation to a degree that inhibits or severely delays the re-establishment of forests. Assuming half of the 10% tree cover is achieved by 2030 would mean that 1.2 million hectares of forest are established in fifteen years. Consultations with KFS experts determined that 80 percent of this amount, or approximately 960,000 hectares, could be attained through enhanced natural regeneration of degraded lands through conservation and sustainable management, whereas the other 20% could be attained through tree planting.

Rehabilitation of degraded forests – Rehabilitation involves planting trees on lands that have been severely degraded. This includes lands that do not strictly meet the definition of forest because they have fallen below a threshold of tree cover or biomass density. These degraded forests are characterized by significantly diminished tree cover and inhibited natural regeneration. Assuming that 20% of net increase in forest cover would be achieved through rehabilitation, 240,000 hectares would need to be replanted over a period of fifteen years, or approximately 16,000 hectares per year between 2015 and 2030. Achievement of the Bonn Challenge target of planting of trees on 410,000 ha of formerly forested land would exceed the NDC target.

Table 5.1. Key Mitigation Technologies and Initiatives in the LULUCF Sector

MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Restoration of forests on degraded lands	Community forestry programmes, research into degraded lands and appropriate conservation techniques, forest management and planning, protection and conservation programmes
Rehabilitation of degraded forests	Tree nurseries and production of tree seedlings, tree planting, tree genetics, forest management and planning, silvicultural interventions
Reducing deforestation and forest degradation	Technologies for community monitoring, forest management tools, development of alternatives to reduce demand for fuel wood, financial innovations including payments through carbon markets
Enabling actions	MRV technologies, including remote sensing and global positioning systems, computer tagging and tracking systems)

Table 5.2. Linkages between priority mitigation actions in the Forestry Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
Restoration of Forests on Degraded Lands Rehabilitation of Degraded Forests Reducing Deforestation and Forest Degradation	Goal 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	7.1 - By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements 7.2 - By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally 7.3 - By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral	Forest area as a proportion of total land area Progress towards sustainable forest management Proportion of land that is degraded over total land area
	Goal 6 - Ensure availability and sustainable management of water and sanitation for all	6.6 - By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Change in the extent of water-related ecosystems over time
	Goal 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2.4 - By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	Proportion of agricultural area under productive and sustainable agriculture
	Goal 12 - Ensure sustainable consumption and production patterns	12.2 - By 2030, achieve the sustainable management and efficient use of natural resources	Material footprint, material footprint per capita and material footprint per GDP

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

Reducing deforestation & forest degradations – The reducing deforestation and forest degradation component of REDD+ includes measures to reduce emissions from deforestation and forest degradation, relative to a pre-determined reference case or BAU scenario. Increasing Kenya's forest cover to 10% would also entail halting and eventually reversing deforestation and forest degradation, such that net forestation would increase. There is considerable uncertainty in the historic rate of deforestation. 2010 FAO data indicates that the historic deforestation rate between 1990 and 2010 was approximately 12,000 hectares per year.[18] The most recent FAO Global Forest Resources Assessment in 2015 indicates that the deforestation rate of Natural Forests was approximately 26,000 ha per year over the same 20-year period, but that the total area of Natural Forest has actually increased between 2000 and 2010. The best estimates using available modelling data indicate that decreasing the rate of deforestation for *extant* forest lands by 50 percent would result in 63,000 hectares of reduced deforestation by 2030, or an average of approximately 4,000 hectares per year between 2015 and 2030.

Complementary measures to reduce deforestation and forest degradation, such as improved cookstoves and sustainable charcoal production systems, are discussed in the chapters on energy (Chapter 4) and industry (Chapter 6). Agroforestry is considered in the NDC analysis of the agriculture sector (Chapter 3). They are not included as forestry mitigation options to avoid double-counting.

TECHNICAL POTENTIAL TO CONTRIBUTE TO NDC EMISSION REDUCTIONS

Each of the three options was assessed to determine its technical potential to contribute to emission reductions in the baseline in 2030. Based on this analysis and the 20.1 $MtCO_2e$ NDC target for emission reductions in 2030 (see Figure 5.2), restoration of forests on degraded lands is the priority mitigation option for the LULUCF sector. Technical mitigation potential in 2030 of the forestry mitigation options is presented in Figure 5.3.

Effective implementation of the identified key mitigation options will require the deployment of forestry technologies and enabling actions. A summary of key technologies is included in Table 5.1.

KEY MITIGATION TECHNOLOGIES IN THE FORESTRY SECTOR

Actions to ensure effective restoration of forests on existing degraded lands in Kenya will accelerate natural processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and reducing disturbance, such as grazing, wood harvesting and fire. Actions include protection and conservation actions including limiting or prohibiting access to forests; community management programmes; and preventing disturbances through enforcement and monitoring. Forest restoration and sustainable enhancement of forest carbon stocks through sustainable forest management or conservation could fall within the "plus" scope of REDD+ and be part of the government's REDD+ strategy.

Rehabilitation of degraded forests involves planting seedlings over an area of land where the forest has been harvested or damaged by fire, disease or human activity. Tree planting, if performed properly, can result in the successful regeneration of a deforested area. Plantations established through afforestation or reforestation can effectively sequester carbon. Agroforestry or initiatives to plant trees on farms are considered in the NDC agriculture analysis (Chapter 3). Clean Development Mechanism (CDM) projects under the "Afforestation and Reforestation" category were restricted to include actions to replant trees commercial or indigenous tree species on areas of land that had no forest cover since 1990.

Reducing deforestation and forest degradation includes actions to protect forests. This mitigation option aims to reduce emissions of greenhouse gases by reducing the removal of forests (i.e., the cutting of trees). The REDD+ mechanism under the UNFCCC is a vehicle to financially reward developing countries for their verified efforts to reduce emissions from deforestation through improved forest management. There are a variety of forest management options. Countries are to undertake an assessment of the drivers of deforestation, and then develop policies and measures based on this assessment. Strategies adopted by REDD+ projects include protecting forests, identifying and supporting alternative livelihood opportunities (such as ecotourism and production of high-value export products), establishing incentive schemes which compensate communities for forest conservation, and promoting the

Table 5.3. Overview of Development Benefits of Mitigation Options in the Forestry Sector

	CLIMATE		DEVELOPMENT				
	Abatement Potential ($MtCO_2$)	Adaptation Impact	SDG 1: GDP Growth	SDG 7: Energy Security	SDG 1: Rural Livelihoods	SDG 15: Environmental Impacts	SDG 15: Improved Land Management
Reducing Deforestation & Forest Degradation	1.6	●	—	◓	◓	●	●
Restoration of Degraded Forests	6.1	●	—	◓	◓	●	●
Restoration of Forests on Degraded Lands	32.6	●	—	◓	◓	●	●

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis.

Table 5.4. Priority Adaptation Actions in the Forestry Sector

ACTION	• Mainstream climate change adaptation in the environment sector
SHORT TERM SUB-ACTIONS	• Develop a forestry adaptation strategy that builds on existing initiatives (considered a priority action that would inform projects and projects that are specific to different regions/locations for implementation) • Enhance community forestry programmes • Strengthen tree-planting and conservation initiatives • Development of a business case to achieve the 10% tree cover • Application of the information the Kenya Tree-based Landscape Restoration document to identify priority areas for action
LONG TERM SUB-ACTIONS	• Provide guidance and improve access to climate resilient tree species and cultivars • Integrate ecosystem and community based approaches in sector strategies in support of adaptation to reduce natural resource based conflicts

Adapted from: Government of Kenya (2016), National Adaptation Plan 2015-2030 and updated with input from the Forestry Expert Group.

sustainable use of timber and non-timber forest products. As noted, complementary strategies in regard to improved cookstoves and sustainable charcoal production could be part of a REDD+ programme.

Perhaps just as important as implementing mitigation options in the forestry sector, is improving the ability to measure, report on and verify (MRV) the actions and achievements of forestry projects. This includes improving the knowledge and understanding of carbon biomass stocks in Kenya. Kenya's forests are still experiencing major losses of woodland and dryland forests[19] and an overall deficit in wood products that is exacerbated by slow restocking of Kenya's public forest plantations that may mean that net baseline emissions are increasing rather than decreasing overtime as illustrated in Figure 5.1. The SLEEK programme has developed land cover maps using satellite data, but analysis as to land conversion over time and transitions from one land-use type to another have not been completed. This type of data is essential for understanding emissions and sinks in the sector and for planning appropriate mitigation action. Development Impacts of Mitigation Actions

Mitigation actions to reduce GHG emissions in the forestry sector have adaptation benefits, as well as positive development impacts that are linked to the Sustainable Development Goals (SDGs). SDG 13 deals with climate change, whereby countries have agreed to "take urgent action to combat climate change and its impacts," recognizing that the UNFCCC is the primary forum for negotiating the international response to climate change. [20] Forests play a crucial role in addressing SDG 13.

The three priority mitigation actions in the forestry sector contribute to the attainment of SDG 15 that seeks to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Forest resources provide important environmental and ecosystem services such as clean air, water and fuel, and contribute to economic development through ecotourism and other resources. In this respect, because of their contribution to healthy forests, the priority mitigation actions also contribute to SDGs 2, 6 and 12, described in Table 5.2.

Table 5.3 provides an overview of development impacts of the mitigation options in the forestry sector based on analysis for the NCCAP 2013-17 and updated to include SDGs.

DEVELOPMENT IMPACTS

Restoration of Forests on Degraded Lands can increase adaptive capacity in vulnerable areas like mountain slopes, and fragile ecosystems like natural forests and wetlands. Regeneration of degraded forestlands also reduces erosion and sediment discharge in rivers, and improves the health of soil. Much restoration could be realized through a dry area landscape conservation approach, which could bring benefits to the ASAL regions because dryland forests and forest products – including timber, gums and resin, and charcoal – bring important economic benefits. These actions can thus support the realisation of SDG target 15.3, and by improving livelihoods can also contribute to SDG Target 2.4, and SDG 1 to end poverty

Rehabilitation of Degraded Forests also provides many natural benefits, including stabilizing and maintaining the soil, biodiversity and climate of the forest - contributing to the achievement of SDG 15. Some of the water absorbed by trees is released through transpiration, which restores moisture to the atmosphere and helps maintain the water cycle. Forests also provide natural habitat for animals, important in Kenya because of the tourism industry. The roots of trees prevent excessive erosion of soil and its nutrients, and slow the loss of rainwater from the ecosystem through run-off. For example, re-vegetated slopes of degraded catchment forest areas like the Mau complex can reduce the likelihood of landslides, as well as reduce migration to search for water during dry spells, and potential conflicts that may arise from such movements. These actions can contribute to SDG target 13.1 to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries). Additionally, the conservation of water-catchment ecosystems (rivers, lakes and wetlands) can safeguard this key source of water for production (agriculture) and domestic use. Plantation forests can help to prevent environmental disasters and represent a useful source of income.

Reducing Deforestation and Forest Degradation: Natural forests can be used in a sustainable manner for a variety of non-timber forest products, including mushrooms, medicines and others. Carbon payments and payments for ecosystem services are possible means for supplementing the incomes of local communities and supporting the attainment of SDG 1 to end poverty in all its forms everywhere. The protection of natural forests also protects biodiversity, natural habitats and their wildlife, continuing to the achievement of SDG 15. Loss of forest cover has led to significant reductions in the amount of water flowing in rivers in the dry seasons and reduced capacity for hydroelectricity generation, meaning that forest protection has important impacts on energy security and economic development.

The benefits of mitigation in the forestry sector are realized over many years. This can affect the permanence of carbon stocks that can be susceptible to issues of land-tenure security.

ADAPTATION AND CLIMATE RESILIENCE IMPACTS

Restoration of forests on degraded lands and rehabilitation of degraded forests essentially involves growing trees. Climate change-related effects such as drought, high temperatures and emerging pests and diseases could lead to extreme die off of newly planted tree seedlings, and therefore impact on the success of programmes to restore forests on degraded lands as well as rehabilitation of degraded forests. Appropriate adaptation measures are therefore required to ensure the programmes succeed. These could include the adoption of tree species that are adapted to varied weather conditions and tolerant to emerging pests and diseases (e.g. drought tolerant trees for dry regions that also frequently experience suppressed rains), irrigation and other appropriate technologies.

Similarly, efforts aimed at Reducing Deforestation and Forest Degradation could be hampered by high temperatures, with many wildfires reportedly started by unknown factors during hot and dry conditions. Building the capacity of entities and institutions with the mandate of managing wildfires could support the goal of this mitigation option.

5.4 ADAPTATION IN THE FORESTRY SECTOR

Kenya's NDC places emphasis on adaptation and resilience because of the country's high vulnerability to climate change and climate variability. The approach is to mainstream adaptation actions into the planning, budgeting and implementation process at both the national and county levels of government. The country's vulnerability to climate change is documented in its NCCRS, NCCAP, and NAP, 2015-2030.[21] Actions to increase forest cover to 10% of land area will have strong adaptation benefits and help to increase climate resilience.

There are strong synergies between adaptation and mitigation in the forestry sector. Forest conservation can facilitate the adaptation of forests to climate change by reducing anthropogenic pressure on forests, enhancing the connectivity between forest areas, and conserving biodiversity hotspots. Strengthening the resilience of forests also increases the permanence of carbon. Adaptation and forestry mitigation projects can be linked by incorporating adaptation standards into forest carbon certification and strengthening the capacities of projects developed to accommodate both components.[22]

CLIMATE RISKS AND IMPACTS

Forests in Kenya face several climate change-related threats and impacts, which are documented in the NCCRS and its 2013-2017 action plan. Climate change is likely to affect the growth, composition and regeneration capacity of forests resulting in reduced biodiversity and capacity to deliver important forest goods and services, such as fuelwood to meet energy needs. This can contribute desertification, deforestation, and forest and land degradation as communities strive to derive their livelihoods on declining forest resources. The NCCRS documents that such changes are already evident in many places including upper parts of north-eastern and eastern Kenya, such as Machakos, Kitui, and Taita Taveta, as well as the ASALs of Kenya.

Some areas of the country will undergo changes in vegetation types and species composition. New assemblages may be established and more invasive species are projected to emerge. The emergence, invasion and spread of species such as ***Prosopis juliflora*** in places such as Tana River, Baringo and Garissa is partly linked to climate change, according to the NCCRS.

Other documented impacts and potential impacts include rising temperatures and long periods of drought leading to more frequent and intense forest fires; rising temperatures extending the ecosystem range of pests and pathogens with consequences on tree growth, survival, yield and quality of wood and non-wood products; a shift of vegetation to higher elevations and extinction of some species as a consequence of increasing temperatures; and submergence of mangrove forests in low-lying coastal areas as a result of climate-induced sea level rise.

Climate change has the potential to increase the impacts of deforestation. Forests in water catchments are critical for sustaining water availability and for the generation of hydropower as well as helping to mitigate the impacts of flooding. Forests help to offset the climate impacts of decreased amounts of water flowing into rivers (particularly during the dry seasons) which reduces water availability for communities and reduces hydroelectric power potential.[23]

Forestry adaptation actions can help to abate flooding and landslides, two climate-related hazards in Kenya. The UNDP's Kenya Natural Disaster Profile reports that "landslides occur mostly during the rainy season and are associated with floods." Western, Nyanza and the north Rift Valley regions are most affected by landslides. The report indicates that "the number of landslides in Kenya is increasing as forested lands are converted to agriculture, resulting in looser soils and fewer trees to slow the flow of water down slopes."[24] Restoring forests on degraded lands has the additional benefits of potentially increasing adaptive capacity in vulnerable areas such as mountain slopes, ASALs, and fragile ecosystems like natural forests and wetlands. Moreover, these actions help reduce erosion and sediment discharge in rivers and improve soil health.

FORESTRY SECTOR PRIORITY ADAPTATION ACTIONS

The NDC's adaptation goal is enhanced resilience to climate change towards the attainment of Vision 2030. This is to be achieved by mainstreaming climate change adaptation into MTPs and implementing adaptation actions. Forestry actions are included in the *Environment Sector* of the NAP 2015-2030, which aims to "mainstream climate change adaptation in the environment sector."

In the forestry sector, adaptation includes management practices designed to reduce the vulnerability of forests to climate change, as well as reduce the vulnerability of people to climate change. Actions in the forestry sector need to promote forest adaptation, or "how practice contributes to or detracts from building forest resilience to climate change"; as well as people's adaptation or "how practice contributes to or detracts from building people's resilience to climate change impacts, particularly forest-dependent people."[25]

UNEP-DTU has identified adaptation strategies for forests, which can include:

- Anticipatory planting of species along latitudes and altitudes;
- Assisted natural regeneration;
- Implementation of mixed-species forestry programmes;
- Planting of species-mix adapted to different temperature tolerance regimes;
- Fire protection and management practices;
- Thinning, sanitation and the intensive removal of invasive species;
- Surplus seed banking;
- Altering harvesting schedules and other silvicultural practices;
- Conservation of genetic diversity;
- Investing in drought and pest resistant tree species for commercial plantations;
- Adaptation of sustainable forest management practices;
- Increasing protected areas and linking them, when possible, to promote the migration of species;
- Forest conservation and reduced forest fragmentation enabling species migration; and
- Provision of energy efficient fuelwood cook stoves to reduce the pressure on forests.[26]

In addition, the National Forest Programme 2016-2030 identifies priority climate change interventions in the forestry sector and emphasises land-use planning, climate smart agriculture, and afforestation and reforestation actions.[27]

These actions are to be complemented by the enabling actions in Table 5.4 that are based on the NAP 2015-30 and views of the forestry sector expert group.

REFERENCES

[1] Government of Kenya 2010. *The Constitution of Kenya.* Nairobi: National Council for Law Reporting with the Authority of the Attorney General.

[2] Ministry of Environment, Water and Natural Resources (2014). *Forest Policy, 2014*. Nairobi: Ministry of Environment, Water and Natural Resources. page 1.

[3] Government of Kenya (2016). The Forest Conservation and Management Act, 2016. In *Kenya Gazette Supplement No. 155 (Acts No. 34)*.

[4] Food and Agriculture Organisation of the United Nations (FAO) (2016). *Global Forest Resources Assessment 2015 - How Are the World's Forests Changing? (Second Edition)*. Rome: FAO.

[5] Ministry of Environment, Water and Natural Resources (2013). *Legal Report on Forest Governance, REDD+, and Sustainable Development in Kenya*. Nairobi: Ministry of Environment, Water and Natural Resources.

[6] Government of Kenya (2016). *National Forest Programme 2016-2030*. Nairobi: Ministry of Environment and Natural Resources.

[7] Food and Agricultural Organization (2015). *Global Forest Resources Assessment 2015. County Report Kenya*. Rome: FAO. Page 7.

[8] Gichu, A. and Chapman, S. (2014). *Overview of REDD+ in Kenya*. REDD+ Law Projects – Briefing Paper. Accessed at: http://www.4cmr.group.cam.ac.uk/filecab/redd-law-project/20140821%20BP%20Overview%20of%20REDD-%20in%20Kenya.pdf

[9] Ministry of Environment, Water and Natural Resources (2014). *Forest Policy, 2014*. page 5.

[10] UNFCCC (2014). *Land Use, Land-use Change and Forestry (LULUCF).* Accessed at: http://unfccc.int/land_use_and_climate_change/lulucf/items/1084.php

[11] UNFCCC (2014).

[12] Tropical Forests and Climate Change Adaptation (2012). *Forests for the adaptation of people.* Accessed at: http://www1.cifor.org/trofcca/forest-and-adaptation/forests-for-the-adaptation-of-people.html

[13] Government of Kenya (2013). Chapter 4: Forestry, Mitigation Analysis. Background paper prepared for the *National Climate Change Action Plan, 2013-2017*. Nairobi: Ministry of Environment and Natural Resources. page 4. Accessed at: http://www.kccap.info/index.php?option=com_phocadownload&view=category&id=36&Itemid=41

[14] Bonn Challenge (2016). ***Kenya.*** Accessed at: http://www.bonnchallenge.org/flr-desk/kenya

[15] Valatin, G. and Price, C. (2013), How Cost-Effective is Forestry for Climate Change Mitigation*? Challenges and opportunities for the World's Forests in the 21st Century.* Volume 81 of the series Forestry Science. Pages 297-339.

[16] Government of Kenya (2013), Chapter 4, Forestry, Mitigation Analysis.

[17] The fact sheets are available in the sector chapters of the NCCAP mitigation analysis, available at: http://www.kccap.info/index.php?option=com_phocadownload&view=category&id=36&Itemid=41

[18] Food and Agricultural Organization (2010). *Global Forest Resource Assessment Country Report: Kenya*. Rome: Food and Agricultural Organization.

[19] Pfeifer, M., Platts, P.J., Burgess, N.D., Swetnam, R.D., Willcock, S., Lewis, S.L., and Marchant, R. (2013). Land use change and carbon fluxes in East Africa quantified using earth observation data and field measurements. *Environmental Conservation*, vol. 40, pages 241-252.

[20] United Nations (2017). *Revised list of global Sustainable Development Goal indicators.* Accessed at: https://unstats.un.org/sdgs/indicators/Official%20Revised%20List%20of%20global%20SDG%20indicators.pdf [21] Government of Kenya (2010), *National Climate Change Response Strategy*, Nairobi: Ministry of Environment and Mineral Resources. Government of Kenya (2015). Kenya *Second National Communication*. Nairobi: National Environment Management Authority. Accessed at: http://unfccc.int/resource/docs/natc/kennc2.pdf.

[22] Bakkegaard, R.K., Moller. L. R. and Bakhtiari, F. (2016). *Joint Adaptation and Mitigation in Agriculture and Forestry*. UNEP DTU working paper series; Climate Resilient Development Programme, Working Paper 2. Copenhagen: UNEP DTU.

[23] Government of Kenya (2013). *National Climate Change Action Plan*. p. 37.

[24] United Nations Development Programme (no date), *Kenya Natural Disaster Profile.* Nairobi: UNDP Enhanced Security Unit.

[25] Bakkegard, et al. (2016), page 23.

[26] Bakkegard, et al. (2016), page 20.

[27] Government of Kenya (2016). *National Forest Programme: 2016-2030*. Nairobi: Kenya Forest Service. page 119.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6.1 THE INDUSTRIAL SECTOR IN KENYA

Kenya's industrial sector is the largest in the Eastern African region, underscoring the importance of the sector to the economy of Kenya and neighbouring countries. The industrial sector is critical to achieving the Vision 2030 goal of transforming Kenya into "a newly-industrializing, middle-income country providing a high quality of life by 2030."[1] The Ministry of Industry, Trade and Cooperatives reports that the sector holds large potential to create employment, bridge disparities in regional development and address inequality, and boost foreign exchange earnings from exports.[2] Kenya's Industrial Transformation Programme aims to revitalise the sector and turn Kenya into an industrial hub. The programme anticipates the doubling of formal jobs in the manufacturing sector to approximately 700,000 and a USD 2-3 billion addition to GDP.[3]

In 2015, the manufacturing component of the industrial sector contributed 10.6% to Kenya's GDP, second after the agricultural sector.[4] The manufacturing sector is mainly agro-processing (such as grain milling, beer production and sugarcane crushing), and also includes paper production, textile and apparels, leather, pharmaceutical and medical equipment, construction materials and services, and chemical and chemical-related industries. The manufacture of cement is identified as a core industrial sector, with a growing demand for cement from within Kenya and from neighboring countries.

The charcoal manufacturing sub-sector employs almost 1 million people on a part and full-time basis, and contributes an estimated KES 135 billion annually to the Kenyan economy. Charcoal production uses mainly traditional inefficient technologies and the sector remains largely informal. Energy and forestry policies and legislation have legalized sustainable charcoal production, and efforts are underway by the government to implement this legislation.[5] Although charcoal manufacturing is an important part of the Kenyan economy, the wood-fuel sector is systematically neglected in formal economic analyses due to its informal nature.

6.2 CLIMATE CHANGE AND THE INDUSTRIAL SECTOR

The industrial sector is part of the climate change equation, both producing GHG emissions while being impacted by changes in temperature and precipitation. Globally, the industrial sector is a large GHG emitter. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that the global industrial sector contributed 30% of total global emissions in 2010, mainly because of the sector's reliance on fossil fuels for its primary energy supply.[6]

Domestically, the industrial sector contributes 7% of total national GHG emissions. This is because of larger contributions by other sectors, notably land use, land-use change and forestry (LULUCF), energy and agriculture; as well as the fact that Kenya produces insignificant amounts of industrial gases such as perfluorocarbons and hydrofluorocarbons that have a high global warming potential (5,000 to 10,000 times the global warming potential of CO_2). While absolute emissions are projected to grow from 5.4 $MtCO_2e$ in 2015 to 9.9 $MtCO_2e$ in 2030, the percentage of national emissions is expected to remain at about 7%.

Climate change is beginning to influence action in the industrial sector in Kenya, but for the most part, accounting for climate change is not common in business activities and decisions. The manufacturing sector is capital intensive, with many long-life fixed assets, long supply chains and significant water requirements, which are negatively impacted by floods, droughts and extreme weather events. Additionally, the industrial sector relies on services and products offered by other sectors such as energy, agriculture and transport. Consequently, climate impacts on these sectors directly affect the industrial sector, including through higher electricity prices and power outages because of reduced electricity generation from hydropower, reduced agricultural production and supply chain disruptions.

Figure 6.1. Baseline industrial sector GHG emissions projections ($MtCO_2e$)

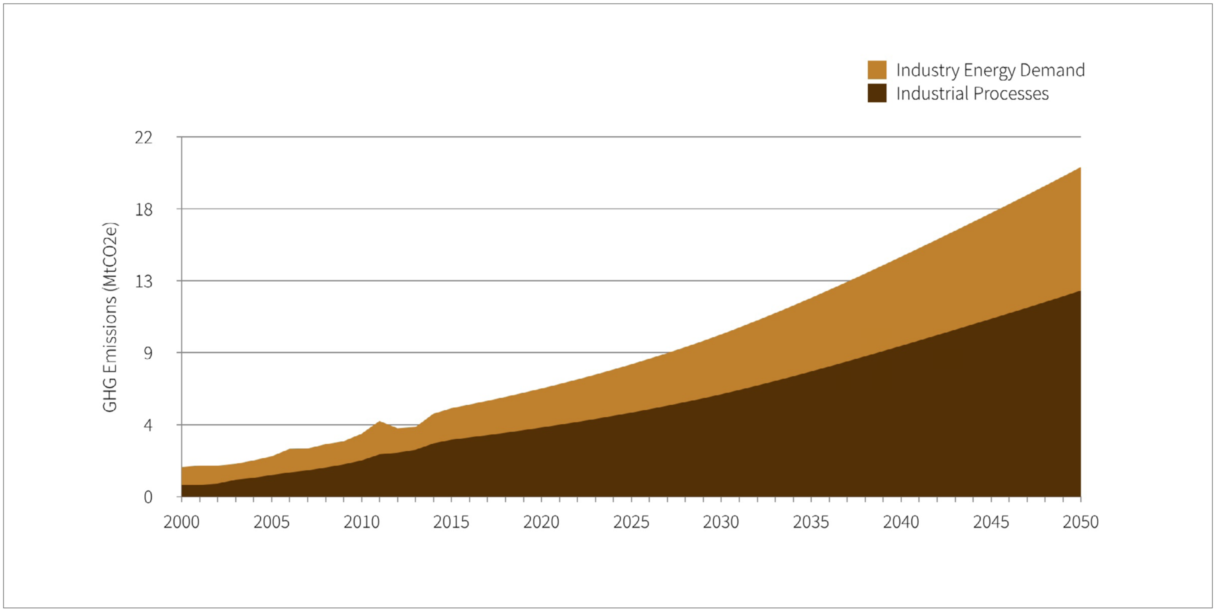
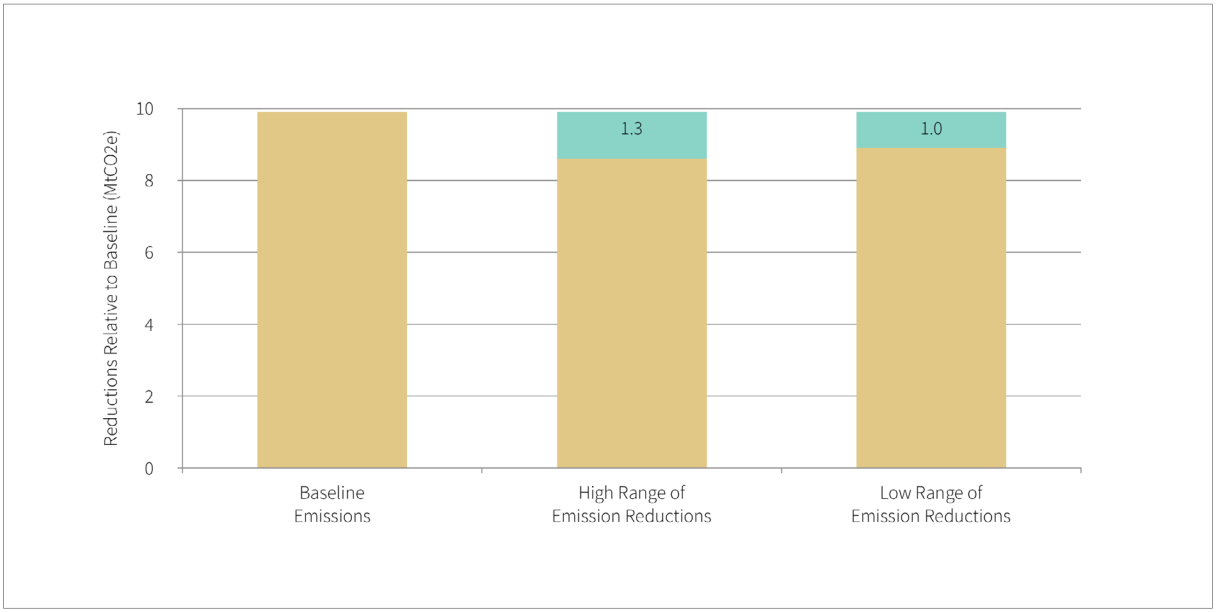


Figure 6.2. Comparison of 2030 baseline emissions and NDC target emission reductions ($MtCO_2e$)



6.3 MITIGATION IN THE INDUSTRIAL SECTOR

Greenhouse gas emissions from the industrial sector accounted for approximately 7% of total national emissions in 2015 and their contribution in 2030 is expected to be similar.[7] GHG emissions are projected to rise from 5.4 $MtCO_2e$ in 2015 to 9.9 $MtCO_2e$ in 2030, an increase of 83%. The baseline emissions projection for the industrial sector is illustrated in Figure 6.1

Industrial emissions, including those from the production of cement, lime and soda ash, include emissions associated with fuel combustion, as well as anthropogenic emissions from industrial production processes. However, industrial emissions do not include indirect emissions associated with energy supply including the generation of electricity, which are included in the energy sector. This categorization is different from Kenya's NCCAP analysis where the industrial process sector only included emissions associated with industrial processes, and industry combustion emissions were captured in the energy sector. These emissions have been re-categorized so that all industry emissions could be considered within one analysis, rahter than across two sectors.

NDC TARGET FOR THE INDUSTRIAL SECTOR

Kenya's NDC "seeks to abate its overall greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario." However, this does not necessarily translate into a 30% emission reduction target for the industrial sector, equivalent to 3.0 $MtCO_2e$ reductions from baseline emissions in 2030 of 9.9 $MtCO_2e$.

Significant work conducted for Kenya's 2013-2017 NCCAP examined the technical potential of emission reductions related to the six mitigation sectors (agriculture, energy, industrial processes, LULUCF, transport and waste). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential as well as costs. With this view in mind, the industrial sector emission reduction target must be less than the technical potential of individual mitigation options identified, while also contributing to the overall 30% emission reduction target.

Figure 6.2 identifies a reasonable low and high range for a 2030 target for emission reductions in the industrial sector. The low target is aligned with the proportional contribution that the sector would need to make for there to be a high level of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The calculation of the overall NDC target and the individual targets for the six sectors is discussed in Chapter 2 of this report.

Figure 6.2 illustrates a low (minimum) target emission reduction of 1.0 $MtCO_2e$ for the industrial sector. This is equivalent to a 10% reduction in 2030 baseline industry emissions, substantially less than half of the overall NDC target of 30%. A lower proportional contribution may make sense because of the high cost of mitigation (i.e., $/tonne reduced) in the industrial sector relative to other sectors.

MITIGATION OPTIONS IDENTIFIED IN KENYA'S SECOND NATIONAL COMMUNICATION

Three mitigation options were identified, developed and presented for the industry sector in Kenya's SNC. Each of these options was assessed to determine their technical potential to contribute to emission reductions in the baseline in 2030. Based on this analysis and the low range 1.0 $MtCO_2e$ NDC target for emission reductions in 2030 (see Figure 6.2), there is considerable flexibility and it is not necessary to fully implement all the industry mitigation options. In fact, an aggressive program to reduce emissions from charcoal production alone could potentially be sufficient to meet the high range NDC target (1.3 $MtCO_2e$). The technical mitigation potential in 2030 of the three industry mitigation options is presented in figure 6.3.

The mitigation options address two types of GHG emissions. The first are industrial process emissions, which are emissions released during a manufacturing process. Industrial process emissions in Kenya are dominated by the cement and charcoal manufacturing industries; the emissions associated with soda ash production are insignificant. The sources of GHG emissions are very different for the cement and charcoal manufacturing sectors. Process emissions from the cement sector are due to calcination, whereby limestone releases CO_2 as it is heated in the kiln and transformed into clinker. Charcoal production results in CO_2 and methane emissions from incomplete combustion of biomass.

Figure 6.3. Technical potential emission reductions in 2030 of mitigation options

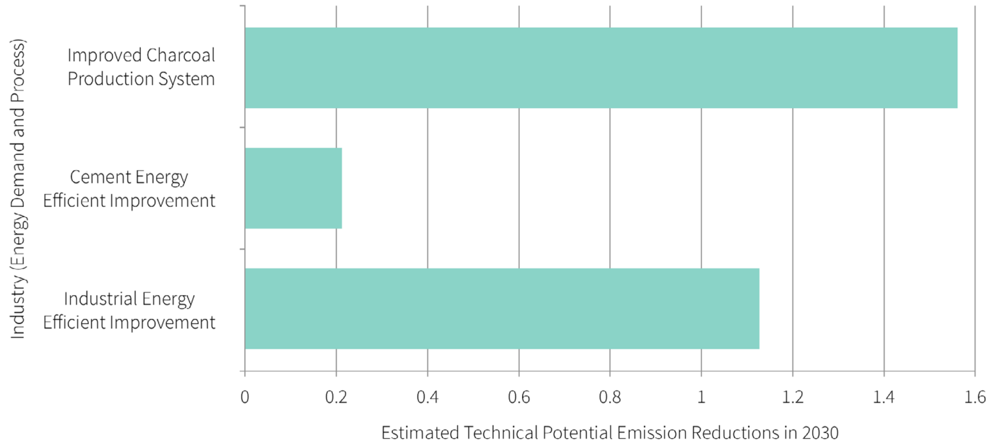


Table 6.1. Key mitigation technologies and initiatives in the industrial sector

MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Industrial Energy Efficiency Improvement	Motors with variable speed drives / high efficiency motors, more efficient boilers, upgraded burners, air preheaters, waste heat recycling/utilization, biomass fuel substitution, combined heat and power systems, energy management and control systems
Cement Energy Efficiency Improvement	Efficient cement kilns, including high efficiency motors and drives, variable speed drives, high efficiency calcifies, and efficient grinding technologies, energy management and process control systems, oxygen-enhanced combustion, waste heat utilization; clinker substitutes (pozzolans); and biomass and waste fuels.
Improved Charcoal Production Systems	Metal kiln or drum kiln charcoal production technologies, regulations to control illegally produced charcoal.

A reduction of process and energy emissions from cement is feasible by replacing a certain amount of clinker with slag or Pozzolana (the latter being volcanic ash that is abundantly available in Kenya), which reduces the generation of CO_2 from the heating of limestone to produce clinker. This is not considered a low-carbon option because existing cement plants are either using the maximum allowable level of Pozzolana in the blended cement or are at advanced stages of implementing such blending projects because they are financially very attractive. New cement plants are designed for maximum Pozzolana blending.

The improved charcoal production mitigation option considers a shift from the use of traditional earth mound kilns, which generally have an efficiency of 10% to 22% (calculated using oven-dry wood with zero percent water content) to an increased use of improved charcoal production systems (ICPS) using retort kilns with an efficiency of approximately 30% to 42%.[8] The mitigation analysis in the 2013-2017 NCCAP assumed that charcoal production emissions can be reduced by 75% through the use of retort kilns, when compared to traditional charcoal production methods using earth mound kilns. The adoption rate of this technology is assumed to be 50% in 2030 because of policy interventions promoting the use of ICPS. This conservative assumption was chosen because of expected higher material costs, increased labour input, lack of knowledge and immobility of charcoal producers.

Energy efficiency improvements refer to mitigation actions that reduce the amount of energy, often fossil fuel generated, required for industrial processes. In the cement industry, which is the highest emitting industry in Kenya, about 50% of emissions are process-related emissions (discussed above), while 40% are direct energy-related emissions from fossil fuel combustion used to heat the kiln and 5 to 10% are indirect energy-related emissions from electricity consumption used to power machinery.[9]

This cement energy efficiency improvement mitigation option looks at a reduction of indirect energy-related emissions by introducing energy-efficient technologies. The mitigation scenario assumes a 10% improvement in total energy efficiency by 2030, assuming that all possible reductions in indirect energy use are fully realized. Moreover, it is assumed that increasing the overall efficiency of the plant can also lead to efficiency improvements of direct energy use, i.e., some reductions in fossil fuel use, for heating the kiln. This is quite an ambitious assumption and would likely require that any new cement manufacturing capacity becoming operational up to 2030 would deploy best-available technologies and operate according to best practices. To mitigate emissions beyond this figure would demand a fuel switch to renewable biomass or waste to heat the kiln, which is not considered in this mitigation option. Recent developments in the Kenyan cement sector show coal as a preferred substitute, which lowers prices but increases emissions, and would impact the mitigation scenario and expected emission reductions from the sector.

The industrial energy efficiency mitigation option assumes a 15% energy efficiency improvement by 2030. The industrial and commercial sector in Kenya is dominated by small and medium enterprises, and includes agriculture and food, pulp and paper, information and communication, and textile industries. These industries use a wide variety of equipment and appliances typical to the product or service, and mitigation options exist for each subsector, but upfront costs are often a barrier to adoption. Results from energy audits undertaken in different commercial and industrial facilities in Kenya indicate potential for measures like the use of more efficient pumps and motors. With payback times of less than two years, savings in electricity consumption of between 8% (for a tourist resort) and 26% (for a tea factory) could be achieved. Fuel efficiency improvements of more than 9% could be achieved for a boiler in a tea factory through an adjustment of the oxygen for combustion, a measure with a payback time of about half a year.[10] If longer payback times of up to five years would be acceptable, the level of energy savings would be significantly higher.

KEY MITIGATION TECHNOLOGIES AND INITIATIVES IN THE INDUSTRIAL SECTOR

The achievement of the mitigation potential is premised on the introduction of various clean technologies and initiatives, some of which are listed in Table 6.1 below. Several options exist to improve energy efficiency in the industry sub-sectors, and therefore, to achieve reductions in overall energy consumption and associated GHG emissions.

Table 6.2. Linkages between priority mitigation actions in the Industrial Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
Industrial Energy Efficiency Improvement Cement Energy Efficiency Improvement Improved Charcoal Production Systems	Goal 7 - Ensure access to affordable, reliable, sustainable and modern energy for all	7.3 - By 2030, double the global rate of improvement in energy efficiency	Energy intensity measured in terms of primary energy and GDP
	Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.4 - By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	CO_2 emission per unit of value added
	Goal 12 - Ensure sustainable consumption and production patterns	12.2 - By 2030, achieve the sustainable management and efficient use of natural resources 12.5 - By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	Domestic material consumption, domestic material consumption per capita and domestic material consumption per GDP National recycling rate, tons of material recycled
Improved Charcoal Production Systems	Goal 15 - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.2 - By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	Progress towards sustainable forest management

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

Table 6.3. Overview of SDG and adaptation benefits of mitigation options in the industrial sector

	CLIMATE		SDG BENEFITS			
	Abatement Potential ($MtCO_2$)	Adaptation Impact	SDG 7: Energy Efficiency	SDG 9: Resilient Infrastructure & Sustainable Industrialization	SDG 12: Sustainable Production & Consumption	SDG 15: Reduce Deforestation
Industrial Energy Efficiency Improvement	1.12	–	●	●	●	◒
Cement Energy Efficiency Improvement	0.21	–	●	●	●	–
Improved Charcoal Production Systems	1.56	●	–	●	●	●

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis, and updated to include the SDGs.

DEVELOPMENT IMPACTS OF MITIGATION ACTIONS

Mitigation actions to reduce GHG emissions in the industrial sector can have positive adaptation impacts, as well as development impacts that are linked to the Sustainable Development Goals (SDGs). In 2015, the UN General Assembly session adopted the 2030 Agenda for Sustainable Development (the 2030 Agenda) that included 17 SDGs that meet urgent environmental, political and economic challenges. SDG 13 deals with climate change, whereby countries have agreed to "take urgent action to combat climate change and its impacts," recognizing that the UNFCCC is the primary forum for negotiating the international response to climate change. [11]

The role of industry is recognized by the 2030 Agenda and particularly by SDG 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation." Additionally, SDG 13 emphasizes the need to transform industry to become low carbon and climate resilient. Other SDGs linked to mitigation actions in the industrial sector are described in Table 6.2 below.

Table 6.3 provides an overview of development impacts of the mitigation options in the industrial sector based on analysis for the NCCAP 2013-17 and updated to include the SDGs.

DEVELOPMENT IMPACTS

Actions to improve charcoal production processes could have a significant positive impact on rates of deforestation, and help to achieve SDG 15 because less wood is required to produce the same amount of charcoal. The charcoal industry may be able to use the invasive tree species *Prosopis juliflora* (locally known as "mathenge") as a substitute for local species to foster sustainable charcoal making. Improved manufacturing processes, that could help to achieve SDG 9, are only likely if the sector is formalized, although the impact on the employment situation in the charcoal production sector is uncertain. Individual producers who do not have access to sufficient capital to deploy improved production processes may be negatively impacted; but the elimination of the middleman structure could have a positive overall effect on income generation in the sector. Another potential benefit of formalizing the sector is increased tax payments to government.

Energy efficiency improvements that decrease electricity use or the need to import fossil fuels improve energy security in Kenya, and achieve SDG 7. These mitigation actions also help to achieve the objective of the Green Economy Strategy and Implementation Plan (GESIP) 2016-2030 to increase national energy efficiency as part of its resource efficiency guiding principle.[12] Many actions to improve energy efficiency also increase resource-use efficiency (SDG 9) and help achieve the sustainable management and efficiency use of natural resources, which contribute to the achievement of SDG 9 and 12, respectively. Actions to improve energy efficiency have the potential to lead to significant cost savings for companies. As noted earlier, results from energy audits indicate that energy efficiency improvements can have payback times of less than two years based on savings in electricity consumption of between 8% and 26%.

ADAPTATION AND CLIMATE RESILIENCE IMPACTS

The energy efficiency mitigation options are not directly vulnerable to the potential impacts of climate change. There may be indirect impacts, which would be related to the performance of the sector, rather than the specific mitigation option. For example, continuous drought could increase the cost of hydroelectricity for cement production, leading to a shift to lower-cost coal as a source of power.

Charcoal production would not be directly susceptible to the possible impacts of climate change. However, improving charcoal production methods could increase Kenya's climate resilience because intact forests have higher water retention and increased biomass cover lessens climate impacts.

6.4 ADAPTATION IN THE INDUSTRIAL SECTOR

Kenya's NDC places emphasis on adaptation and resilience because of the country's high vulnerability to climate change and climate variability. The approach is to mainstream adaptation actions into the planning, budgeting and implementation process at both the national and county levels of government. The country's vulnerability to climate change is documented in its National Climate Change Response Strategy (NCCRS), the Strategy's 2013-17 NCCAP, and the2015-2030 NAP.[13]

CLIMATE CHANGE RISKS AND IMPACTS

Many of the climate change risks and impacts faced by the industrial sector can be classified as indirect impacts because of the sector's linkages with other sectors. For example, the moderately higher growth of the industrial sector in 2015 (3.5%) in comparison to 2014 (3.2%) was partly attributed to robust growth in the agricultural sector in 2015.[14]

The National Climate Change Action Plan 2013-17 indicated that impacts to critical supporting infrastructure such as energy, water, communications and transport, have the potential to reverberate into the private sector, with consequences for business continuity, revenue, workforce and associated supply chains. The following impacts were identified in the 2013-2017 NCCAP and through research:

Energy fluctuations or blackouts because of energy supply interruptions – A large percentage of electricity is generated by hydropower (despite recent increases in baseload geothermal power) and lower annual rainfall has reduced the electricity generating capacity of hydroelectric power plants. The manufacturing sector is one of the biggest casualties of reduced generation capacity of hydropower dams caused by droughts and reduced rainfall. In 2009, Kenya experience a mild form of electricity rationing that had a devastating impact on heavy power consumers, such as manufacturers.[15] The 2016-2017 drought reduced hydro generation capacity and increased the fuel cost charge levy to KES 3.52 per kilowatt hour in January 2017 from KES 2.34 per kilowatt hour in November 2016.[16] Shortages in hydropower generation are replaced by diesel generation, which increases the cost of electricity for industries. Kenya has made significant progress in diversifying its electricity generation mix away from a reliance on hydro to a greater emphasis on geothermal.

Greater resource scarcity (e.g. water and raw materials) – Climate variability has contributed to reduced crop production that directly impacts the manufacturing sector, particularly the agro-processing sector. An example is the serious production losses in the tea sector in 2015 due to a water shortage because of reduced rainfall.[17] The 2016-2017 drought, characterised by below average short (October to December) and long (March to May) rains in most parts of the county has greatly impacted agricultural production. Cereal production was 15% below the average of the previous five years, and maize prices in March 2017 were 66% higher than twelve months earlier.[18] Some industries such as agro-processing are major consumers (and polluters) of water. Water resources are generally scarce and are likely to become more so with climate change.

Greater risk of plant, product and infrastructure damage and supply chain disruptions from extreme weather events (e.g. heat waves, floods, droughts, cyclones and storms) – Rising temperatures are expected to strengthen coastal winds and storms, which will affect ship navigation and other port operations. Motor vehicle assembly, machinery, electronics and other industries that depend on export and import services are likely to be negatively affected. Adverse weather events will also impact local and regional trade. The eight-month 1997-1998 El-Niño rains caused damage of KES 62 billion to transportation infrastructure.[19]

Higher costs – Such as higher insurance premiums due to increased costs associated with more frequent extreme weather events.[20]

PRIORITY ADAPTATION ACTIONS IN THE INDUSTRIAL SECTOR

The Kenyan private sector recognizes the challenges that climate change poses to the sector, and played a pivotal role in the development of Kenya's NCCAP, Climate Change Act 2016 and the National Climate Change Framework Policy. Some Kenyan firms have taken energy and water conservation measures, which address climate change adaptation and mitigation, although the primary incentive for these actions is cost savings. The energy efficiency programme of the Kenya Association of Manufacturers (KAM), which is being broadened to cover resource efficiency in general, is an example of the industry's proactive approach to addressing climate change through concrete actions.[21] In addition, a sector-wide partnership on water resource management has been initiated under the umbrella of the Kenya Industrial Water Alliance,[22] a move that signals the industry's understanding of the complexity of the climate change challenge and the potential role of partnerships in addressing such complex problems.

A climate resilient industrial sector will need to build on these initiatives that promote cleaner and resource-efficient production technologies and practices that de-couple economic growth from unsustainable resource consumption and environmental degradation.[23] Additionally, adaptation actions help to protect industrial infrastructure and supply chains. A 2014 Kenya Private Sector Alliance (KEPSA) publication identified the following actions at the level of the firm:

- Climate risk assessments to improve planning and decision-making – Understanding how climate change will affect business activities and the risks to growth and production. This includes assessing climate change impacts on infrastructure; business and regulatory risks, such as changes in insurance coverage; and markets risks, such as potential changes in the pattern and volume of supply chains and trade flows.
- Protection of industrial assets – Ensuring a firm's buildings and related infrastructure can cope with heavier downpours and extreme weather events, protecting business data and essential operating equipment.
- Management of climate change impacts along supply chains.
- Building long-term resilience through employee and management training.[24]

The United Nations Industrial Development Organization (UNIDO) has put forward the following supportive actions to enhance the industrial sector's preparedness to address climate change:

- Generation of data to improve awareness of impacts and decision making in the sector.
- Support for the growth of insurance markets to help manufacturers have access to a range of insurance products, including those that can cushion them against climate-related risks.
- Technology development, transfer and deployment at scale.
- Fostering innovation and entrepreneurship in green industries and green industrial technologies and processes.
- Bolstering partnerships with state and non-state actors, including cities, business and regional-level networks, to attract investment.[25]

Kenya's NAP identified priority adaptation actions in the industrial sector that are included within the broader frameworks for energy, infrastructure, manufacturing and water (listed in Table 6.4).

Table 6.4. Priority adaptation actions in the industrial sector

SHORT TERM SUB-ACTIONS	**Infrastructure** – Conduct risk and vulnerability assessments of existing infrastructure, including buildings and industrial/manufacturing facilities. **Manufacturing** – Build the capacity of the private sector (formal and informal) to enhance the resilience of their investments, through identification of new products and services that are more resilient to climate change impacts, for example. **Manufacturing** – Demonstrate an operational business case for private sector investment in adaptation. **Water** – Promote awareness on climate change impacts and the water sector including promoting public awareness on water conservation (recycling, waste water management) and efficient water use.
MEDIUM TERM SUB-ACTIONS	**Energy** – Promote energy efficiency programmes. **Infrastructure** – Climate proof buildings and industrial/manufacturing facilities. **Manufacturing** – Develop fiscal incentive measures to encourage businesses to undertake investment in adaptation and resilience building measures. **Water** – Promote technologies that enhance water resource efficiency.
LONG TERM SUB-ACTIONS	**Manufacturing** – Implement long term private sector investment in adaptation and resilience building measures.

Source: Government of Kenya (2016). Kenya's National Adaptation Plan, 2015-2030.

REFERENCES

[1] Government of Kenya (2008). *Kenya Vision 2030*. Nairobi: Government of Kenya.

[2] Ministry of Industrialisation and Enterprise Development (2015). *Investment Opportunities in the Manufacturing Sector in Kenya*. Nairobi: Ministry of Industrialisation and Enterprise Development.

[3] Ministry of Industrialisation and Enterprise Development (2015). *Kenya's Industrial Transformation Programme*. Nairobi: Ministry of Industrialisation and Enterprise Development.

[4] Kenya National Bureau of Statistics (2016). *Economy Survey 2016*. Nairobi: Kenya National Bureau of Statistics.

[5] Ministry of Environment, Water and Natural Resources (2013). *Analysis of the Charcoal Value Chain in Kenya.* Nairobi: Kenya Forest Service.

[6] Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T. and Minx, J.C. (eds.)]. Cambridge and New York: Cambridge University Press.

[7] Based on the updated baseline, and developed building on calculations undertaken for the National Climate Change Action Plan, 2013-17 and updated for the Second National Communication.

[8] Adam, J.C. (2009). Improved and ore environmentally friendly charcoal production system using a low-cost retort kiln (Eco-charcoal), *Renewable Energy* (January).

[9] Shammakh, B., Caruso, H., Elkamel, A., Crsoset, E. and Douglas, P.L. (2008). *Analysis and Optimization of Carbon Dioxide Emission Mitigation Options in the Cement Industry.* Dhahran, Saudi Arabia: Department of Chemical Engineering, King Fahd University of Petroleum and Minerals, Science publications.

[10] Bellanger, M. (2010). *Technical Assistance to the Ministry of Energy*. Nairobi: French Development Agency.

[11] United Nations (2017). *Revised list of global Sustainable Development Goal indicators.* Accessed at: https://unstats.un.org/sdgs/indicators/Official%20Revised%20List%20of%20global%20SDG%20indicators.pdf.

[12] Government of Kenya (2016). *Green Economy Strategy and Implementation Plan (GESIP) 2016-2030*. Nairobi: Ministry of Environment and Natural Resources.

[13] Government of Kenya (2010), *National Climate Change Response Strategy*; Government of Kenya (2013), *National Climate Change Action Plan, 2013-2017*; and Government of Kenya (2016) *National Adaptation Plan, 2015-2030*.

[14] Kenya National Bureau of Statistics (2016). *Economic Survey 2016*. page 17.

[15] Money & Markets (2017). Kenya faces electricity crisis if drought persists (11 January). Accessed at: http://moneyandmarkets.co.ke/kenya-faces-electricity-crisis-drought-persists/

[16] Senelwa, Kennedy (2017). Kenya switches to thermal power as hydroelectric dams dry up. *The East African* (18 January). Accessed at: http://www.theeastafrican.co.ke/news/Kenya-switches-to-thermal-power-as-hydroelectric-dams-dry-up/2558-3521662-6y5qi7z/index.html

[17] United Nations Industrial Development Organization (UNIDO) (2015). *Promoting Climate Resilient Industry*. Vienna: UNIDO. page 15

[18] Food and Agriculture Organization of the United Nations (FAO) (2017). *Global information and Early Warning System: County Briefs- Kenya* (25 April). Accessed at: http://www.fao.org/giews/countrybrief/country.jsp?code=KEN

[19] Government of Kenya (2013), page 40.

[20] Smith, M. (2013), *The Manufacturing Sector – Climate Change Risk and Opportunity Assessment. An Educational Module to Help Identify and Implement Climate Change Adaptation and Mitigation Opportunities.* Canberra: Australian National University.

[21] Kenya Private Sector Alliance (2014). *Climate Change and the Energy and Manufacturing Sector*. Climate Change and Your Business Briefing Note Series.

[22] Wakiaga, P. (2016). *Towards a Water-Smart Future.* Accessed at: http://www.kam.co.ke/towards-water-smart-industrial-future/

[23] UNIDO (2015).

[24] Kenya Private Sector Alliance (2014).

[25] UNIDO (2015).

7.1 THE TRANSPORT SECTOR IN KENYA

The Integrated National Transport Policy of 2009 identifies road transport, rail transport, maritime and inland water transport, pipeline transport, air transport and non-motorised and immediate means of transport as the main modes of transport in Kenya.[1]

Kenya has experienced high rates of urbanisation and development, but transport systems and infrastructure have not kept pace. Transport services are poorly integrated, overburdened and inaccessible to many Kenyans. About half of all trips in Nairobi are accounted for by walkers and bicycle riders (non-motorized transport [NMT]), and the private car accounts for about 15% of all trips.[2] Traffic conditions in Nairobi and other major cities are characterised by congested and unsafe roadways that contribute to local air pollution and significant economic losses as much time and fuel is spent in traffic congestion. The National Transport and Safety Authority (NTSA) estimated the fleet size at the end of 2015 as 2,776,374 vehicles and an average 10% annual increase in number of vehicles. Kenya is projected to have 4,141,189 vehicles in 2020. About 46% of these will be privately owned cars, a trend that is consistent with the growing economy and rising income levels.[3] Of note is the rise of registrations for motorcycles, from 6,350 in 2006 to 166,870 in 2015.[4] These challenges have informed infrastructural and regulatory developments in the sector.

The Integrated National Transport Policy of 2009 puts emphasis on an efficient transport system, noting that it is an important prerequisite for facilitating national and regional integration, promoting trade and economic development, contributing to poverty reduction and wealth creation, and achieving the objectives of Vision 2030. Kenya has implemented many transport sector infrastructural development programmes over the last one and half decades that aim to meet the growing demand for transportation services arising from economic growth and rapid urbanisation.

Major transport infrastructure development projects were implemented during the first and second MTPs, including construction of 2,200 km of new roads and rehabilitation/ reconstruction of 1,860 km of roads. Among these are the Nairobi-Thika super-highway and the Northern Corridor Transport Improvement Project that stretches from Mombasa to Western Kenya. In water transport, Mombasa Port was dredged and widened, and a new berth developed.[5] Recent developments in railway transport include upgrading of Nairobi commuter rail systems, completion of Phase 1 (Mombasa to Nairobi) of the Standard Gauge Railway (SGR) Project and initiation of the second phase (Nairobi to Naivasha). In air transport, Kenya is currently served by 6 international airports, and around 300 mostly unpaved airfields.[6]

The Nairobi commuter rail system will be upgraded to provide efficient movement of passengers from the SGR terminal in Syokimau to the city centre. This upgrading is part of the Nairobi Metropolitan Mass Transport Master Plan that aims to create a mass rapid transport (MRT) system comprised of bus rapid transit and commuter rail, complemented by NMT.

The Nairobi County NMT Policy aims for the development and full integration of NMT within the whole of the Nairobi transport system, is a “county where NMT is the mode of choice for short and medium trips” (pedestrian trips up to 5km; and cycling trips up to 15 km).[7]

Other major transport projects that are in the pipeline or various stages of development include the Lamu Port-Southern Sudan-Ethiopia Transport Corridor and its various components/ infrastructures and the East African Road Network Project.[8]

7.2 CLIMATE CHANGE IN THE TRANSPORT SECTOR

The ongoing and continued improvements in transport infrastructure in Kenya provide mitigation and adaptation opportunities. Climate change is likely to damage transport infrastructure in Kenya through higher temperatures, heavy rainfall and more severe storms. Coastal roads, railways, airports

Figure 7.1. Baseline Transport Greenhouse Gas Emissions Projections ($MtCO_2e$)

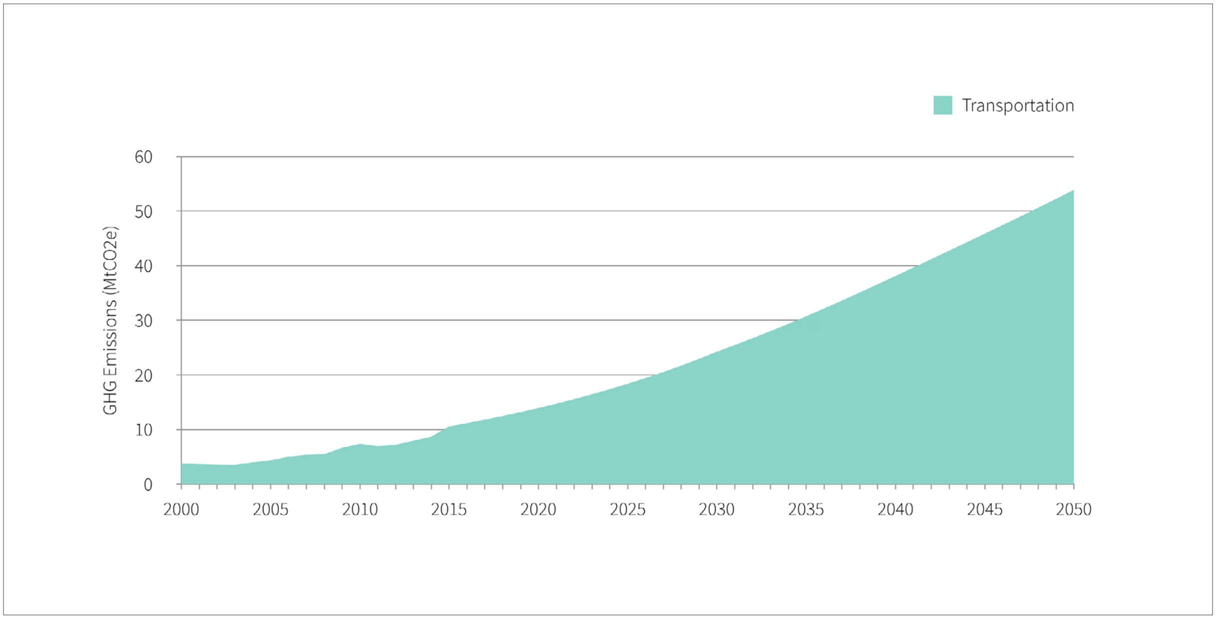
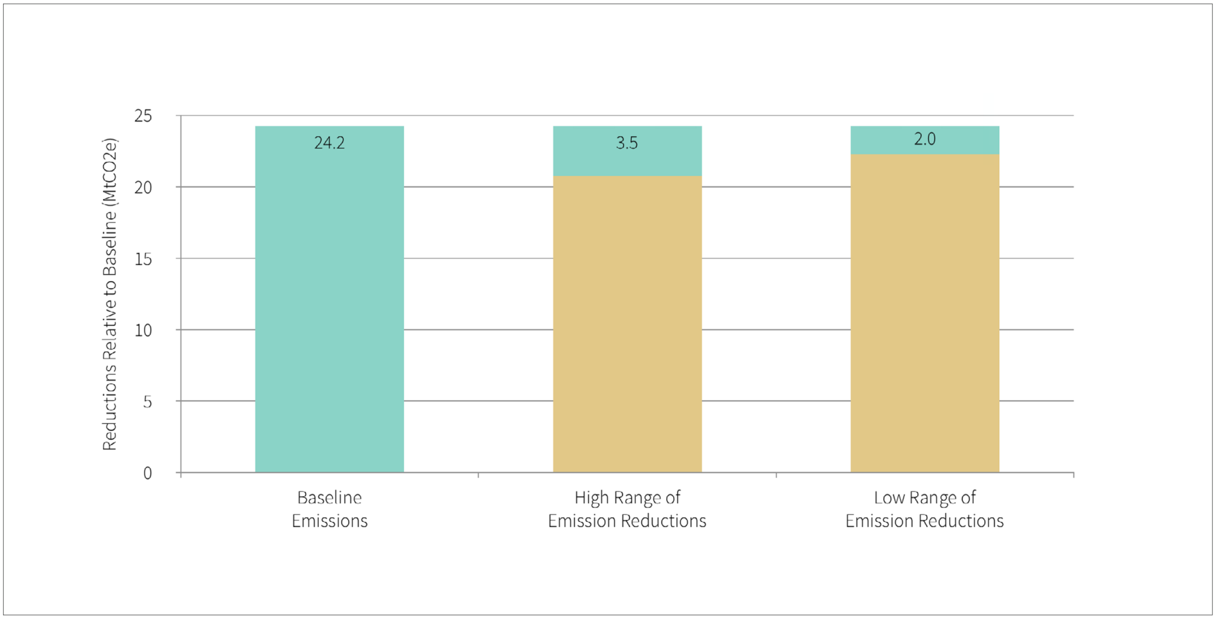


Figure 7.2. Comparison of 2030 Baseline Emissions and NDC Target Emission Reductions ($MtCO_2e$)



and ports are vulnerable to sea level rise. These changes could increase the risk of delays, disruptions, damage and failure across land-based, air and marine transportation systems. Studies demonstrate that climate proofing, or proactive adaptation, can be cost-effective for transport infrastructure with a long life span. Railways, ports and airports are the most critical and should be made climate-resilient first, followed by tracks and bridges. Given their longevity, with most transportation infrastructure expected to last for 50 years or longer, this climate proofed infrastructure should be able to withstand climate conditions of 2050 and out to 2100.[9] Further, climate-proofing is a key recommendation of Kenya's NAP as a means of addressing infrastructure-related climate change impacts.[10]

In regard to mitigation, the transport sector is a significant source of greenhouse gas (GHG) emissions both globally and nationally. This NDC analysis indicates that the transportation sector directly accounted for about 13% of total GHG emissions in 2015. Transport emissions are increasing at a faster rate than other sectors – and are projected to rise to 17% of total national emissions in 2030. Numerous studies have demonstrated mitigation actions in the transport sector, and the road transport sub-sector in particular, offer opportunities for savings on imported fuels through improved efficiency, alternate modes of transport and fuel substitution.[11]

Many transport projects in Kenya that address Vision 2030 and national development priorities also address climate change. Broadly speaking, for developing countries like Kenya that are yet to adequately develop their energy, transport and telecommunication infrastructure, addressing climate change in these sectors should not present significant additional costs to conventional development costs, and should not be viewed as negating a country's development agenda. Development goals and climate goals are in many instances, interlinked. Examples include improvements in the efficiency of the vehicle fleet that, in addition to reducing GHG emissions, also lessen urban air pollution and generate associated health benefits. The standard gauge railway is expected to shorten travel time between Nairobi and Mombasa and improve road safety, while the shift of freight from road to rail will reduce GHG emissions. The planned MRT for Nairobi, a priority mitigation action in the NCCAP, will reduce congestion on roads and improve air quality. Mitigation actions such as improvement in the efficiency of vehicle fleet link with and build on the government's programme on motor vehicle inspection and standardisation.

Climate finance offers an opportunity to access funds for development and climate change goals. Kenya has attracted climate finance for Nairobi's bus rapid transit system, including approval of a EUR 20 million grant through the NAMA (Nationally Appropriate Mitigation Action) Facility that is funded by the Governments of Germany and the United Kingdom.

7.3 MITIGATION IN THE TRANSPORT SECTOR

Transport emissions accounted for approximately 13% of total national emissions in 2015. However, their contribution is expected to increase to 17% by 2030 because of an increase in the number of passenger and freight vehicles on the road, as well as an increase in rail transport that is expected to rise at a rate that is faster than overall economic growth. The baseline emissions projection for transport are summarised in Figure 7.1.

Greenhouse gas emissions are projected to rise from 10.5 $MtCO_2e$ in 2015 to 24.2 $MtCO_2e$ in 2030, an increase of 130%.

NDC TARGET FOR THE TRANSPORT SECTOR

Kenya's INDC "seeks to abate its overall greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario." However, this does not necessarily translate into a 30% emission reduction target for the transport sector equivalent to 7.3 $MtCO_2e$ reductions from baseline emissions in 2030 of 24.2 $MtCO_2e$.

Significant work conducted for Kenya's 2013-2017 NCCAP examined the technical potential of emission reductions related to all sectors (energy, waste, LULUCF, agriculture and industrial processes). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential as well as costs. With this view in mind, the transport sector emission reduction target must be less than the technical potential of individual mitigation options identified while also contributing to the overall 30% emission reduction target.

Figure 7.2 identifies a reasonable low and high range for a 2030 target for emission reductions in the transport sector. The low target is aligned with the proportional contribution that the sector would need to make in order for there to be a high level

Box 7.1. Assumptions Underlying the Mitigation Options in the Transport Sector

IMPROVING PASSENGER VEHICLE STOCK EFFICIENCY

This option results in total fuel efficiency improvements of 7% versus the reference case by 2030 for petrol and diesel cars. This can be achieved through different avenues including restrictions on the import of second hand vehicles, removing older (15+ year), low-efficiency vehicles and providing incentives to increase the market share of hybrid and electric vehicles. Incentives could include purchase price subsidies or rebates, import tax exemptions, support for electric vehicle charging infrastructure network and license fee reductions.

IMPROVING HDV STOCK EFFICIENCY

The option assumes fuel efficiency improvements of up to 10% in 2030 through improved rolling resistance of tyres, tyre pressure monitoring and on-road testing of emissions regulations for all heavy-duty vehicles. Other options for achieving efficiency improvements include eco-driving training, regular maintenance, tracking and route planning with global positioning systems, and real-time engine and driver telemetry.

BRT SYSTEM IMPLEMENTATION IN NAIROBI

A significant shift of private transport in Nairobi to BRT assumes that the mass transit system is implemented, with BRT as the dominant mode of public transport complimented by some minimal use of LRT services. The low-carbon scenario assumes a moderate level of level of BRT infrastructure in place by 2018. It should be noted that the shift to BRT from private vehicles and taxis would probably be a smaller fraction (in the order of 10 t0 20 percent) of its ridership; the rest would come from matatus and buses (which still give an efficiency gain) and NMT (which does not realise any emissions reduction).

LRT SYSTEM IMPLEMENTATION IN NAIROBI

The mitigation scenario assumes a moderate shift of private transport (as well as other modes such as matatus) in Nairobi to LRT (noting that each of the two mitigation options assumes a mix of LRT and BRT are being implemented). The scenario assumes that the mass transit system from the above mentioned feasibility study is implemented, but with BRT as the dominant mode of public transport complimented by some minimal use of LRT. The scenario assumes a moderate level of LRT infrastructure in place by 2018 (although even this assumption may be optimistic given the timeframes necessary to construct the required infrastructure).

BIOETHANOL

The government is piloting an E10 blend in Kisumu and Nakuru, an initiative that will require significant increases in bioethanol supply (initial estimates put the shortfall at approximately 60% of demand). Given the financial and efficiency issues that have dogged the predominantly government-owned sugar industry,[9] it is assumed in the reference case that bioethanol use does not reach widespread adoption across Kenya. Under the low-carbon development scenario, 10% of regular petrol is replaced by bioethanol by 2020, which is equal to the introduction of an E10 blending requirement. This requires a substantial increase in bioethanol production capacity and feedstock availability.

SHIFT OF FREIGHT FROM ROAD TO RAIL

A large majority of freight movements currently are undertaken by road transport. This scenario assumes that approximately 30 percent of transit freight is moved on the Standard Gauge Railway by 2030.[12]

Additional information is available in the fact sheets in the NCCAP low-carbon analysis in the transport sector, accessible at: http://www.kccap.info. Fact sheets for the six mitigation sectors have been compiled into one document that is available at: http://www.starckplus.com/index.php/starck-components/technical-assistance.

of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The overall target and how the individual six sector targets were calculated is discussed in Chapter 2 that updates the emission baseline projections and impact on the NDC target.

Figure 7.2 illustrates a low (minimum) target emission reduction of 2.0 $MtCO_2e$ for the Transport Sector. This is equivalent to an 8% reduction in 2030 baseline transport emissions, considerably lower than the overall NDC target of 30%. A proportionately lower target in the transportation sector may make sense because of the high cost of mitigation (i.e. $/tonne reduced) in the transport sector relative to other sectors.

MITIGATION OPTIONS IDENTIFIED IN KENYA'S SECOND NATIONAL COMMUNICATION

Seven mitigation options were presented for the transport sector in Kenya's SNC, building on the analysis undertaken for the NCCAP. Biodiesel has been removed from consideration as it is no longer considered a viable option, given that previous efforts to produce biodiesel were unsuccessful. Bioethanol remains as a feasible option, with sugar companies increasing production.[12]

Each of the remaining six mitigation options was assessed to determine their technical potential to contribute to emission reductions in the baseline in 2030. In order to achieve the minimum 2.0 $MtCO_2e$ recommended NDC target for emission reductions in 2030 (Figure 7.2) there is flexibility and it is not necessary to fully implement all transport mitigation options.

The technical mitigation potential in 2030 of the 6 transport mitigation options is presented in Figure 7.3. Assumptions underlying the mitigation options are elaborated in Box 7.1. Numerous combinations of the 6 mitigation options in Figure 7.3 could achieve the low (2.0 $MtCO_2e$) or high (3.5 $MtCO_2e$) range emission reduction target for the transport sector. For example, full implementation of the Bus Rapid Transit and Light Rail Transit Systems in Nairobi, as well as the freight from road to rail mitigation option, would achieve the high range target.

Other important mitigation options were identified by the Transport Sector Expert Group for Kenya's NDC. While detailed estimates of emission reductions have not been made, some preliminary work was completed to determine their potential as indicated in Table 7.1.

Several other mitigation options can reduce emissions, but are not included in the list of priority mitigation options because the reductions are not significant at a national scale. An example is NMT, which can help to reverse the trend toward more private vehicles by making walking and cycling safe and attractive, and assist in improving accessibly to the Nairobi's MRTS. Improving conditions for pedestrians and bicyclists are an important component of Vision 2030, Integrated National Transport Policy and Nairobi's NMT Policy. Annex 7.1 discusses other transport options that were suggested by Kenyan experts and the rationale for not including in the mitigation scenario.

Players in the aviation industry, particularly international aviation, must anticipate potential business risks because of mitigation obligations on the industry. The recent agreement on a global market-based measure to control CO_2 emissions from international aviation serves as an example. Kenya has signaled it is likely to join the Carbon Offsetting and Reduction Scheme for International Aviation in 2021.[13]

KEY MITIGATION TECHNOLOGIES

The option with the largest mitigation potential in the transport sector is the development of an extensive mass transit system for greater Nairobi in the form of bus rapid transit (BRT) corridors complemented by light rail transit (LRT) in high thoroughfare corridors. A mass transit system that achieves an estimated peak hourly ridership of 148,000 passengers in 2030 could reduce emissions by approximately 2.3 $MtCO_2e$ annually.

Improvement in passenger vehicle efficiency can be achieved through many different policies including new vehicle fuel efficiency standards, removing low efficiency vehicles from the market, and providing subsidies or incentives for higher efficiency vehicles. Higher efficiency vehicles include hybrid and electric vehicles that can significantly reduce emissions per kilometre provided the national electricity generation mix remains predominantly based on renewable generation. The technical potential of the improvement in passenger vehicle

Table 7.1. Summary of Additional Mitigation Options for the Transport Sector

ADDITIONAL MITIGATION OPTIONS	PRELIMINARY ESTIMATES OF EMISSION REDUCTION POTENTIAL
Road Passenger to Rail	A shift from passenger private vehicle to rail would likely reduce emissions in the order of 80% or roughly a reduction of 288 gCO_2e/passenger•km shifted. This assumes a low road passenger vehicle occupancy (2 persons).
Air Passenger to Rail	A shift from passenger air travel to rail on domestic short haul would likely reduce emissions in the order of 60% or roughly a reduction of 104 gCO_2e/passenger•km shifted.
Electric Motorcycles	A shift from petrol motorcycles (100cc) to electric motorcycles of a similar power would likely reduce emissions in the order of 60% or roughly a reduction of 56 gCO_2e/passenger•km shifted based on the emission intensity of the grid in 2015. However, if significant fossil fuel electricity generation is developed (~5000 additional megawatt by 2030), the reduction falls to approximately 18% or roughly a reduction of 14 gCO_2e/passenger•km shifted.
Transport of Oil by Pipeline	A shift of the transport of oil by truck to pipeline would likely reduce emissions in the order of 90% or roughly a reduction of 10 gCO_2e/barrel•km shifted based on the adoption of electric pumping stations.

Figure 7.3. Technical Potential Emission Reductions in 2030 of Mitigation Options

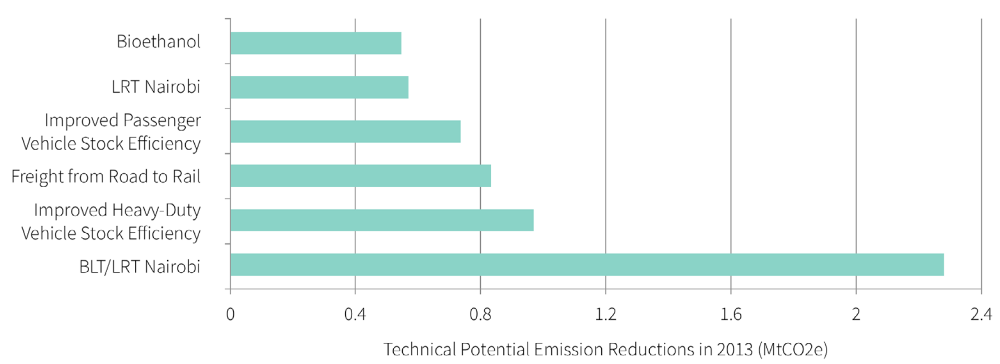


Table 7.2. Key Technologies in the Transport Sector

MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Public Transit (BRT and/or LRT)	Financial incentives and modification of road infrastructure to create enabling conditions, consideration of electric rail and hybrid electric buses (provided Kenya's energy mix remains largely based on renewables)
Passenger Vehicle Fuel Efficiency	Hybrid/electric vehicles, electric vehicle charging network, fuel efficiency standards for new/imported used vehicles, regulatory and economic framework that will lead to reduction of old inefficient vehicles, vehicle testing equipment
Freight Vehicle Fuel Efficiency	Hybrid or electric vehicles, fuel efficiency standards for new or imported used vehicles, regulatory and economic framework that will lead to reduction of old inefficient vehicles.
Freight from Road to Rail	Efficient engines and streamlined locomotives, logistical planning to maximize loads and reduce engine idling, consideration of electrification (provided Kenya's energy mix remains largely based on renewables)

efficiency mitigation option considered an improvement of approximately 5% in overall passenger vehicle efficiency in 2030 resulting in 0.74 $MtCO_2e$ emission reductions. A 1% improvement in overall passenger vehicle efficiency in 2030 would reduce emissions on the order of 0.15 $MtCO_2e$. Aggressive adoption of electric vehicles could significantly exceed the technical potentials outlined here.

The same mechanisms and policies can be applied to improve freight vehicle efficiency. Technical potential of the improvement in freight vehicle efficiency mitigation option considered an improvement of approximately 15% in overall freight vehicle efficiency in 2030 resulting in 0.97 $MtCO_2e$ emission reductions. A 1% improvement in overall freight vehicle efficiency in 2030 would reduce emissions on the order of 0.064 $MtCO_2e$.

The adoption of technologies to improve vehicle fuel efficiency can be complemented with support programmes that monitor and enforce vehicle emission standards. Testing and inspection of vehicles, either as a mandatory program or as part of highway enforcement, even if it affects only a small percentage of vehicles, can still significantly improve overall vehicle emission efficiency as they target the highest emitters.

The shift of freight from road to rail mitigation options is expected to shift approximately 30 percent of transit freight to rail transport by 2030, consistent with the Government's efforts to develop the standard gauge rail line. If Kenya's energy mix were to remain green, and the train system was electrified, the GHG emissions abatement could be increased. A summary of the key technologies is provided in Table 7.2.

DEVELOPMENT IMPACTS OF MITIGATION ACTION

Actions to reduce GHG emissions in the transport sector can have positive development impacts that are linked to the Sustainable Development Goals (SDGs). The specific role of transportation is recognised within SDG 11: "sustainable cities and communities", whereby by 2030, the goal is to "provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons." Other SDGs linked to mitigation actions in the transport sector are described in Table 7.3 below. Table 7.4 includes the development and adaptation benefits assessment undertaken for Kenya's NCCAP mitigation analysis, which has been updated and aligned with the SDGs.

DEVELOPMENT IMPACTS

Effective mass transit systems, which act to remove vehicles from the road, could have positive impacts on congestion, road safety, air quality and road quality – resulting in high development benefits and contributing to SDG 3 by reducing the number of deaths and injuries from road traffic accidents. In addition, affordable high-quality mass rapid transit has the potential to help improve social equality and reduce poverty, contributing to SDG 1.

Shifting freight from road to rail also realises strong benefits in regard to congestion, road safety, air quality and road quality, and contributes to achievement of SDG 3. However, the smaller number of heavy-duty vehicles and smaller level of displacement through rail (only certain types of freight lend themselves to rail transport) would result in lower overall benefits than major public transport initiatives.

Options related to older vehicle retirement would have positive safety and air quality impacts and contribute to SDG 3. Old vehicles are inefficient in their consumption of fuel and management of exhaust gases, and emit more airborne pollutants per litre of fuel than newer models. Improving vehicle efficiency is one of the most cost-effective interventions to reduce transport-related emissions.[14]

Finally, by reducing imported oil use (roughly in direct proportion to the emissions reduction achieved), each option has the potential to improve the security of energy supply.

ADAPTATION AND CLIMATE RESILIENCE IMPACTS

Most of the mitigation options are not expected to be impacted by climate change. Road and rail infrastructure can be vulnerable to climate change impacts; for example, roads can be severely impacted by flash floods. In this sense, the mitigation options are comparable to the reference case in terms of resilience. Bioethanol could be vulnerable to climate change as weather conditions and rainfall could directly impact crop yields and availability of water for irrigation.

Table 7.3. Linkages between priority mitigation actions in the Transport Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
Improved passenger vehicle stock Improved HDV stock BRT system for Nairobi LRT system for Nairobi Shift of freight from road to rail	Goal 3 - Ensure healthy lives and promote well-being for all at all ages	3.6 - By 2020, halve the number of global deaths and injuries from road traffic accidents 3.9 - By 2030, substantially reduce the number of deaths and illness from hazardous chemicals and air, water and soil pollution and contamination	Death rate due to road traffic injuries Mortality rate attributed to household and ambient air pollution
	Goal 7 - Ensure access to affordable, reliable, sustainable and modern energy for all	7.3 - By 2030, double the global rate of improvement in energy efficiency	Energy intensity measured in terms of primary energy and GDP
	Goal 11 - Sustainable cities and communities	11.2 - By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and the elderly 11.6 - By 2030, reduce adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Proportion of population that has convenient access to public transport, by sex, age, persons with disabilities Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)
Bio-ethanol for transportation	Goal 7 - Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 - By 2030, increase substantially the share of renewable energy in the global energy mix	Renewable energy share in the total final energy consumption

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

Table 7.4. Overview of Development Benefits of Mitigation Options

	CLIMATE		LINKS TO SDG			
	Abatement Potential ($MtCO_2$)	Adaptation Impact	SDG 11.2 Congestion & Road Quality	SDG 11.2 Road Safety	SDG 11.6 Air Quality	SDG 7 Energy security
Improved passenger vehicle stock	0.6	–	–	◓	◓	◓
Improved HDV stock	0.8	–	–	◓	◓	◓
Bioethanol	0.55	◡	–	–	◓	◓
BRT system for Nairobi	2.3	–	●	●	●	●
LRT system for Nairobi	0.6	–	◓	◓	◓	◓
Shift of freight from road to rail	0.8	–	●	◓	◓	◓

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis.

7.4 ADAPTATION IN THE TRANSPORT SECTOR

Kenya's NDC places emphasis on adaptation, and identifies priority adaptation actions for key sectors drawing on the 2015-2030 NAP. Adaptation for the transport sector in the NAP is nested within the broader framework of climate-proofing infrastructure.

RISKS AND IMPACTS

NCCAP analysis established that climate change is threatening vital infrastructure such as road and rail networks as well as water and energy systems. Depending on its location, transport infrastructure in Kenya is vulnerable to climate change such as increasing temperatures and changing rainfall patterns. Sea level rise, storms, rain and flooding, and higher temperatures pose several risks for transport infrastructure. The NCCAP identified specific risks in the transport sector and include:

- Port facilities are at risk of damage from increasingly severe storm events and sea level rise. By 2080, Mombasa's exposure to sea level rise and storm surges could grow to US$15 billion in assets, assuming the Intergovernmental Panel on Climate Change's A1B sea-level and socioeconomic scenario.[15]
- Damage to infrastructure, including roads and bridges, often results from extreme weather events. Flooding of coastal and adjacent inland areas is exacerbated due to periodic torrential rainfall, and poses a risk to maritime, road, rail and air networks.
- Higher temperatures can cause bitumen roads to soften and expand (creating rutting and potholes); and warp rail tracks, requiring track repairs or speed restrictions to avoid derailments.
- Unpredictable rainfall as a result of climate change means an additional risk to travelling in general, which calls for adoption of a culture of using weather forecasts to plan when/where to travel.
- Wading and canoeing across streams and rivers is not as common as in the past because of an expanded and improved transport network; yet people still rely on these means of transport in remote parts of Kenya, Unpredictable rainfall can cause an unexpected swelling of a river and amplify the risk of crossing. [16]

PRIORITY ADAPTATION ACTIONS IN THE TRANSPORT SECTOR

Policy and technical interventions in the transport sector are increasingly considering the impact of climate change. A representative for the Ministry of Transport, Industrialization, Housing & Urban Development (MOTIHUD) recently noted that:

- Modern bridges are raised much higher than before in anticipation of more severe floods in future.
- The Standard Gauge Railway has been raised 1.5 metres above the level of the old metre gauge railway in anticipation of more frequent flooding in the future. Some sections of the line required drainage system adjustments after washouts of the protection slope in November 2016 caused by heavy rainfall.
- Concrete is gradually replacing bitumen in road construction because of the latter's susceptibility to softening and expansion in high temperatures.[17]

These are positive measures, and more can be done to climate proof the transportsector, given the rapid growth of transportation infrastructure. As Kenya expands and modernises its transport infrastructure, it is important to design, construct and operate infrastructure in a way that accounts for anticipated climate risks and opportunities. The revision of Environmental Impact Assessment (EIA) guidelines being undertaken by the National Environment Management Authority (NEMA) could include assessment of anticipated climate change on infrastructure.

A potential action is adjusting the construction of roads to enable the roads to be used to systematically harvest water and to ward off and mitigate floods. The additional costs related to design modifications for including road water management from the start is estimated at a maximum of 5% of original investments planned for the road.[18] This cost might be supported by climate finance that is additional to the budgeted costs of the infrastructure.

Climate resilient actions in the infrastructure sector as captured in the NCCAP include improved use of weather and climate information in infrastructure development, and research to identify designs and materials that enhance the resilience of infrastructure. Regulations and codes should be revised to account for climate change impacts, and climate risk screening should be undertaken for flagship projects in the infrastructure sector. Priority adaptation actions identified in Kenya's NAP, NCCAP and through research are set out in Table 7.5.

Table 7.5. Priority Adaptation Actions in the Transport Sector

ACTION	• Enhance climate proofing of infrastructure
SHORT TERM SUB-ACTIONS	• Conduct risk and vulnerability assessments of major infrastructure and design intervention measures. • Conduct risk and vulnerability assessments of upcoming infrastructure (roads, railways, marine, aviation, buildings, ICT). • Conduct an assessment of whether existing and planned transport infrastructural assets are compatible with a low carbon climate resilient economy. • Build capacity of and train transport sector stakeholders on infrastructure climate proofing.
MEDIUM TERM SUB-ACTIONS	• Climate proof roads, railway, marine, and aviation infrastructure through use of appropriate designs/building materials. • Improve the use of weather information in the design, construction and use of transport infrastructure. • Deliver development projects (e.g. local roads and bridges) to remote areas as a way of enhancing adaptive capacity. • Introduce road water management as an adaptation action.
LONG TERM SUB-ACTIONS	• Re-assess transport infrastructure vulnerability, and upgrade infrastructure to withstand climate impacts with the latest technology. • Support for climate-resilient, safe, accessible, inclusive and affordable transport systems and policies.

ANNEX 7.1 MITIGATION OPTIONS IN THE TRANSPORT SECTOR NOT CONSIDERED IN THE ANALYSIS

Biodiesel – The transport expert group recommended removal of this option because of previous negative experiences with biofuels crops, particularly jatropha curcas. The establishment of plantations for jatropha was controversial, with suggestions that developers/investors removed farmers from their land and took control of large areas of land. Production of biofuels using jatropha is considered by some to reduce land available for food production, and to result in the destruction of woodland and scrubland. The impact of biofuels production on food security is a major concern. The potential impacts of a biofuel policy need to be carefully considered and, where possible, include a focus on pro-poor rural development.

Promotion of non-motorized transport (NMT) – Improving conditions for pedestrians and bicyclists are an important component of Vision 2030, Integrated National Transport Policy and Nairobi's NMT Policy. However, this option was not included in the mitigation analysis for two main reasons. First, about half of journeys in Nairobi are undertaken by NMT, primarily because of a lack of capacity in the public transport system and unaffordable costs of motorized transport. Improved conditions for NMT are important, but levels will decrease over the coming decades if the government meets its development targets. Second, there is a significant overlap with the options for mass rapid transit systems. If designed and priced well, the improved access to transport services and reduced transport inefficiencies resulting from improved transit systems will greatly reduce the number of journeys undertaken by foot.

Land use and spatial planning – Improved planning processes can be an important part of transport demand management, particularly in rapidly developing cities. However, it is very difficult to quantify the mitigation and development impacts as well as costs and benefits of the implementation of land-use and spatial planning efforts. For this reason, land-use and spatial planning has been excluded as a mitigation option. However, the option could be valuable to pursue for the associated development benefits.

Road improvements – Road improvements, which improve the flow of traffic (for example, the construction of fly-overs and dualling of roads) and lead to reductions in congestion, will lead to improved fuel economy for individual drivers. This option was not taken further in the mitigation scenario because of a lack of data and lack of clarity about net impacts of road improvements. First, while it may be possible to estimate the net impact of road improvements on emissions through analysis of data on road usage statistics before and after the improvement, this data was not available in Kenya. Some limited data was collected before the recent road improvement projects were started, but there is no on-going data collection. Second, the rebound effect (induced demand) means that improvements in road congestion, while improving the fuel economy of individual drivers, are highly likely to be offset by increases in overall traffic numbers as travel becomes less burdensome.

BRT or LRT systems in cities other than Nairobi – Nairobi, while not the only rapidly growing city in Kenya, is the largest and most advanced in terms of planning for an improved public transport system. In addition, Nairobi is the only city for which detailed studies of BRT and LRT systems are available. For this reason the current analysis is limited to Nairobi, but could be extended to other cities in the future.

Aviation – International aviation is not counted as part of national GHG emissions, as per the IPCC GHG inventory methodologies. In regard to domestic aviation, there are limited mitigation options and low associated development benefits.

REFERENCES

[1] Government of Kenya (2009). *Integrated National Transport Policy - Moving a Working Nation*. Nairobi: Ministry of Transport.

[2] Nairobi City County Government (2015). *Non-Motorized Transport Policy*. Accessed at: http://www.kara.or.ke/Nairobi%20City%20County%20Non%20Motorized%20Transport%20Policy.pdf

[3] National Transport and Safety Authority (2016). *New Motor Vehicles Statistics for the Last 10 Years.* Nairobi: National Transport and Safety Authority.

[4] National Transport and Safety Authority (2016). *New Motor Vehicles Statistics for the Last 10 Years.* Nairobi: National Transport and Safety Authority.

[5] Government of Kenya (2013). *Second Medium Term Plan 2013-17 - Transforming Kenya: Pathway to devolution, socio-economic development, equity and national unity*. Nairobi: Ministry of Devolution and Planning

[6] Kenya Airport Authority (2016). *Our Airports*. Accessed at: https://kaa.go.ke/airports/our-airports.

[7] Nairobi City County Government (2015).

[8] Government of Kenya (2013).

[9] ToPDAd (Tool-supported policy development for regional adaptation) (2015). *Adaptation and Resilience of the Transport Sector*, Policy Transport Brief of the ToPDAd project.

[10] Government of Kenya (2016). *National Adaptation Plan, 2015-2030*. Nairobi: Ministry of Environment and Natural Resources.

[11] UNEP (2011). *Kenya Case Study, Global Fuel Economy Initiative*. Nairobi: UNEP.

[12] Secorum, L. (2017). 'This is our future' – Kenya's croton tree touted as new biofuels crop. *The Guardian* (10 January). Accessed at: https://www.theguardian.com/sustainable-business/2017/jan/10/croton-oil-biofuels-kenya-food-security-farming-africa

[13] ICAO Agreement on Global Market Based Measure (GMBM) (2016). Accessed at: http://www.icao.int/Newsroom/Pages/Historic-agreement-reached-to-mitigate-international-aviation-emissions.aspx

[14] UNEP (2011). *Kenya Case study, Global Fuel Economy Initiative*.

[15] Kebede, A.S., Nicholls, R.J., Hanson, S. and Mokrech, M. (2010). Impacts of Climate Change and Sea-Level Rise: A Preliminary Case Study of Mombasa, Kenya. *J. Coastal Research* (volume 28, issue 1A) pp. 8–19.

[16] Government of Kenya (2013). *Mainstreaming Kenya's National Climate Change Action Plan into the Infrastructure Sector*, a Briefing Note developed for Kenya's NCCAP. Accessed at: http://www.kccap.info.

[17] Ministry of Environment and Natural Resources (2016). *National Climate Change Coordination Strategy Workshop, 5-7 December 2016: Meeting Report - Draft.*

[18] Garcia-Landare Puertas, D., Woldearegay, K., Mehta, L., Van Beusekom, M., Agujetas Perez, M., and Van Steenbergen, F. (2014). Roads for water: the unused potential. *Waterlines* (volume 33, number 2), pp. 120-137. See also: http://www.roadsforwater.org.

8.1 THE WASTE SECTOR IN KENYA

Municipal solid waste (MSW) generation rates are influenced by economic development, the degree of industrialisation, public habits and local climate. Generally, the higher the level of economic development and rate of urbanization, the greater the amount of solid waste produced. This is linked to disposable incomes and living standards. As these two rise, consumption of goods and services correspondingly increases, and consequently does the amount of waste generated. Further, urban residents produce about twice as much waste as their rural counterparts.[1] As an example, the volume of solid waste generated across Kenyan urban centres increased from 4,95o tonnes per day in 2011 to 5,990 tonnes per day in 2014; a rate faster than the country's urbanisation rate.[2] The amount of wastewater generated is also expected to increase with increased urbanisation and improved access to piped water. This is against a backdrop of inadequate waste handling facilities as well as unsustainable waste management practices.

The need for adequate waste treatment is accentuated by growing industrialization of the Kenyan economy, as well as lack of or inadequate enforcement of existing waste management laws and regulations. Significant quantities of solid waste generated in urban centres are not collected and disposed of at designated sites. In rural areas, waste is mainly burned or disposed of in an unregulated fashion.[3] Sewerage coverage was estimated to be only 12% in 2010, with only 5% of the national sewerage treated effectively.[4]

The percentage of waste collected daily (but not necessarily disposed of at designated sites) varies from one urban centre to another. The National Solid Waste Management Strategy, citing historical data from different sources, provides the following percentages of solid waste collection: Kisumu – 20%, Nakuru - 45%, Eldoret – 55%, Thika – 60%, Mombasa – 65%, and Nairobi – 80%. The strategy notes that work is needed to establish the actual rates of collection and disposal as these figures do not reflect the physical reality, which the Strategy considers an "eyesore". About 61% of the waste is residential and non-hazardous, with the rest being industrial and hospital/pharmaceutical waste, which is hazardous.[5]

Poorly managed and inappropriately disposed of solid waste and wastewater pollutes air, water and soil, causing significant health and environmental problems. This is especially true in slums and other low-income areas, where high population density and lack of infrastructure and service provision aggravates these problems. About 70% of Nairobi's 3.5 million inhabitants live in slums.[6] Slum residents in Nairobi have a higher mortality burden than even rural dwellers from preventable and treatable conditions associated with among other factors, lack of or inadequate water and sanitation facilities, lack of garbage collection and overcrowding.[7]

Waste management is a devolved function, that is regulated at the national level by the Environmental Management and Co-ordination (Waste Management) Regulations 2006.[8] The regulations stipulate measures and standards that counties are to comply with in managing waste. Several counties have adopted appropriate waste transportation trucks to comply with the regulations, according to the National Solid Waste Management Strategy.[9]

The National Solid Waste Management strategy has a short-term goal of 30% waste recovery and 70% controlled dumping by 2020. To work toward the strategy's goal, the National Environment Management Authority (NEMA) launched the 100 days Rapid Results Initiative on solid waste management in August 2016 for the implementation of various standards and requirements by the County Governments. The initiative included media campaigns, and improved compliance and enforcement.[10] In March 2017, the Ministry of Environment and Natural Resources (MENR) introduced a ban on the manufacture, use and importation of plastic bags use for commercial and household packaging. The ban will be in effect from September 2017 onward, but several players in the plastic packaging industry (manufacturers and supermarkets) have started to comply with the regulation.

The Kenya Environmental Sanitation and Hygiene Policy 2016-2030 complemented the solid waste management strategy. The Ministry of Health policy focused on strategies to ensure universal access to improved sanitation and a clean and healthy environment. The policy recognized the devolution of most sanitation functions and

Figure 8.1. Baseline Waste Sector GHG Emissions Projections (MtCO2e)

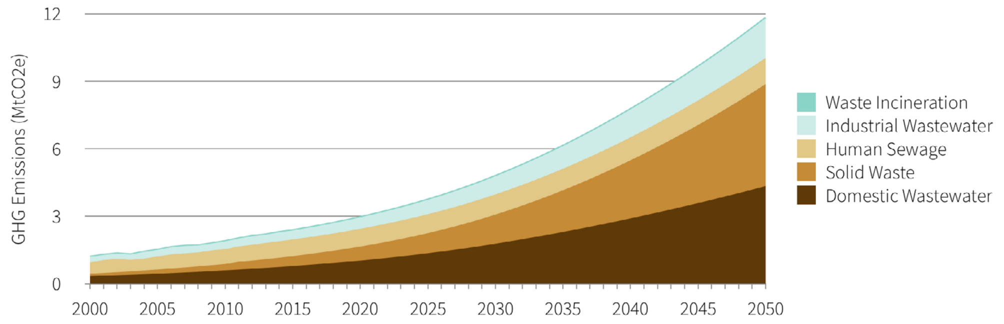


Figure 8.2. Comparison of 2030 Baseline Emissions and NDC Target Emission Reductions (MtCO2e)

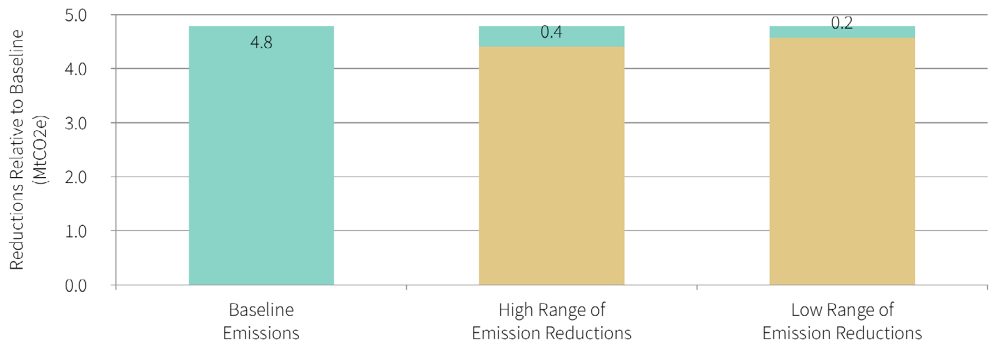
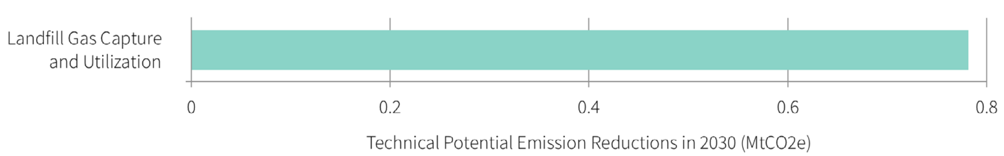


Figure 8.3. Technical Potential Emission Reductions in 2030 of Mitigation Option



services to the 47 County Governments. It spelled out the needed national and county government actions to increase access to improved sanitation, and included actions to address solid waste management and increase wastewater treatment.[11]

Many county governments are taking action on solid waste and wastewater management. An example is the Nairobi County Government that in 2015 enacted a waste management law. The Nairobi City County Solid Waste Management Act 2015 provides for the establishment, demarcation and fencing of a waste disposal site that conforms to internationally recognized standards.[12] However, much still needs to be done particularly across major urban centres to ensure sustainable waste management.

8.2 CLIMATE CHANGE AND THE WASTE SECTOR

Waste - through the processes of disposal, treatment, recycling and incineration - produces GHG emissions. The organic waste material in a landfill, such as food residues, paper and biomass, is decomposed by microbes which generate a mixture of methane, carbon dioxide and traces of other gases. The gaseous mixture is referred to as landfill gas. In a wastewater treatment plant, methane is generated as organic matter as the wastewater is decomposed under anaerobic conditions by methane-forming microorganisms.

Waste incineration, like other forms of combustion, generates CO_2 as well as smaller amounts of methane and nitrous oxide emissions, depending on the composition of the waste. The breakdown of human sewage can also lead to significant amounts of indirect nitrous oxide emissions.[13] Methane and nitrous oxide are more potent greenhouse gases than CO_2 with global warming potentials, respectively, 25 and 265–298 times that of CO_2 for a 100-year timescale.

Solid waste disposal on land generally represents the main source of GHG emissions in the sector. Methane emissions from wastewater treatment plants are generally considered to be the second largest source of GHG emissions in the waste sector.[14] Globally the waste sector contributes less than 5% of GHG emissions.[15] In Kenya, the waste sector was estimated account for about 3% of total national GHG emissions in 2015, an insignificant contribution in comparison to other sectors such as agriculture, land-use, land use change and forestry (LULUCF) and energy.

Building resilience to climate change impacts on waste disposal systems and facilities is of greater importance. Improperly managed solid waste can accumulate in areas otherwise intended for water runoff and flood control, and such conditions make cities and towns vulnerable to floods and contaminated water – from moderate rainfall, let alone intense and heavy rain expected with climate change. Areas of uncontrolled and improperly disposed of waste can be sources of environmental pollution and health hazards.

In addition, poor waste management, as is the case in Nairobi and other urban areas, increases the burden of diseases that are not necessarily climate change-related, but which affect the less affluent, who are also the most vulnerable to climate change. For instance, respiratory ailments linked to air pollution are most likely to affect those living near sources of pollution such as dumpsites. Secondly, heavy rainfall can increase sewage runoff into drinking water sources and increase exposure to cholera and other diarrheal diseases in informal settlements with substandard sanitation facilities. The latter is a climate change challenge discussed in detail in the 2010 NCCRS.[16]

8.3 MITIGATION IN THE WASTE SECTOR

Waste emissions currently account for approximately 3% of total national emissions and this contribution is expected to remain relatively constant in the future to 2030.[17] This contribution is low compared to other sectors in Kenya (such as forestry, energy and transport).

The baseline emissions projection out to 2050 for the Waste sector is illustrated in Figure 8.1 below. Greenhouse gas emissions are projected to increase from 2.4 $MtCO_2e$ in 2015 to 4.8 $MtCO_2e$ in 2030, an increase of 100%.

NDC TARGET FOR THE WASTE SECTOR

Kenya's NDC "seeks to abate its overall greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario." However, this does not necessarily translate into a 30% emission reduction target for the waste sector equivalent to 1.4 $MtCO_2e$ reductions, from baseline emissions in 2030 of 4.8 $MtCO_2e$.

Significant work conducted for Kenya's 2013-2017 NCCAP examined the technical potential of emission reductions related to all sectors (energy, waste, LULUCF, agriculture and industrial processes). This technical potential provided a basis for determining the overall 30% target for Kenya, but each sector had widely differentiated potential as well as costs. With this view in mind, the waste sector

Box 1. Mitigation Options in the Waste sector not considered in the Emissions Reduction Analysis

Waste technologies proposed at NDC sector expert and NCCAP validation meetings but excluded after further analysis are described below.

WASTE TO ENERGY INCINERATION

Bamburi cement operates a waste to energy incinerator in Mombasa. Geocycle collects, segregates and incinerates waste – including biomass, waste oil and waste tyres – in the Bamburi kiln, in place of imported coal. The firm reports that it uses international waste management standards that leave no residue after disposal. Lafarge, Bamburi's parent company, states that scrap tires used for thermal energy in a cement kiln can reduce GHG emissions by roughly 30% for every tonne of coal replaced, along with an expected 10 to 15% reduction in nitrogen oxide, but work is needed to determine GHG emission reductions in the Kenyan context.

ANAEROBIC COMPOSTING

Anaerobic composting involves a two-stage process of anaerobic digestion and composting. It can treat organic waste to recover energy in the form of biogas, and compost in the form of a liquid residual. Both would reduce methane emissions and may produce a soil conditioner. In addition, the biogas can generate electricity via gas engines. However, it needs a feed stream of source-separated organic wastes, typically in the form of animal manure (which is not readily collected in Kenya) or municipal organic wastes (which are not collected in Kenya). Agricultural residues are considered as a cogeneration option in the energy chapter.

WASTE-TO-ENERGY GENERATION

Waste-to-energy generation is often better suited to areas with a scarcity of space for landfill (because of the lower costs of using landfill) and waste with a lower moisture and higher energy content (less likely in Kenya because of a high organic waste content). Although incineration can still prove beneficial under these conditions, there is a significant overlap with the option of electricity generation from landfill gas without appropriate waste separation practices, which are not currently found in Kenya.

LANDFILL GAS FLARING

Landfill gas flaring is similar to the landfill gas methane capture option, but the captured methane is simply burnt to avoid its release to the atmosphere. It is a second-best option – because no electricity is produced – and not considered further in the mitigation scenario. Its mitigation potential would be similar to that calculated for landfill gas generation if modern high efficiency flare technology were used; with older candle flares up to 10 percent of the methane might be released un-burnt.

WASTEWATER TREATMENT

Wastewater treatment is a potentially feasible solution that could be considered in a future analysis. A 2010 study on agro-industrial wastewater suggested that the potential for methane capture and utilisation is relatively low because the methane potentials per cubic metre of wastewater are much lower than solid substrates due to the low content in organic material and high water content.

emission reduction target must be less than the technical potential of individual mitigation options identified, while also contributing to the overall 30% emission reduction target.

Figure 8.2 identifies a reasonable low and high range for a 2030 target for emission reductions in the Waste sector. The low target is aligned with the proportional contribution that the sector would need to make for there to be a high level of certainty that the overall target will be achieved if all other sectors also meet their low target reduction. The high target is intended to guide responsible ministries and agencies in terms of what they should objectively plan and prepare for should the sector require additional emission reductions. The overall NDC target and how the individual Waste sector target was calculated is discussed in Chapter 2 of this NDC sector report.

Figure 8.2 illustrates a low (minimum) target emission reduction of 0.2 $MtCO_2e$ for the Waste Sector. This is equivalent to a 5% reduction in 2030 baseline Waste emissions. A proportionately lower target in the waste sector may make sense because of the high cost of mitigation (i.e., $/tonne reduced) in the waste sector relative to other sectors.

MITIGATION OPTIONS IDENTIFIED IN KENYA'S SECOND NATIONAL COMMUNICATION

Only one mitigation option, landfill gas capture and utilization was developed and presented for the Waste sector in Kenya's NCCAP and SNC. The level of GHG emissions in the sector is low compared to other sectors, and this option has the largest potential for short-term GHG emission reductions. The technical mitigation potential of the landfill gas generation option in 2030 is presented in Figure 8.3.

This mitigation potential was calculated based on the estimated amount of municipal solid waste generated in Nairobi, about 996,450 tonnes per year. Limited data was available on the amounts of waste in other cities, meaning that a higher mitigation potential could be expected. The amount of methane captured is based on conservative assumptions from a study that determined that 11 to 64 MW of municipal solid waste biogas electricity could be installed in Nairobi, based on 2009 waste levels.[18]

A Nationally Appropriate Mitigation Action (NAMA) proposal for a Circular Economy Solid Waste Management Approach for Urban Areas in Kenya was developed by the MENR in 2016.[19] The project concept included the creation of recycling points for waste sorting and subsequent recycling, and composting facilities for organic waste treatment. The recycling and reuse would substantially reduce the amount of disposed waste and the related GHG emissions. The NAMA would support the recycling of up to 600 tonnes of waste each day, thereby reducing GHG emissions by more than 800,000 tonnes of CO_2e over the 15-year project period. If implemented successfully and scaled up to other cities, it has the potential to be a NDC mitigation option.

Other potential interventions examined in the NCCAP (landfill gas flaring, wastewater treatment, waste-to-energy generation, and anaerobic composting) and described in Box 8.1, were not considered for the following reasons:

The use of human waste for methane generation: This faces social acceptability challenges, despite its large potential. Such projects have for instance, been successfully implemented in prisons.

Waste incineration: Current incineration technologies in Kenya do not meet the minimum threshold incineration temperatures, and end up generating toxins and creating unintended health concerns. The other reason is that waste is scattered all over and collecting it for incineration would present additional cost barriers.

Industrial waste: Requires significant investment by the private sector that is difficult to incentivize. The use of industrial effluent in methane gas capture and energy generation has been identified as a potential opportunity for attracting climate financing. Such a project is being conceptualised to help address Kisumu's effluent problem.

Composting: Higher costs (i.e., $/tonne reduced) than for mitigation options in other sectors. As noted, this could be scaled up to an NDC mitigation option if successfully piloted through the NAMA project.

KEY MITIGATION TECHNOLOGIES IN THE WASTE SECTOR

Implementation of the landfill gas capture and utilisation (for energy) mitigation option consists of several hard and soft technologies. Hard technologies include landfill gas recovery systems that are employed in recovering/collecting the landfill gas (which consists primarily of methane and carbon dioxide in an almost equal ratio) for combustion; and compaction systems that compact the waste to increase a landfill's carrying capacity.

Other technologies are leachate systems that collect leachate to prevent it from percolating into and polluting ground water resources and energy generation and utilisation facilities. The main

Table 8.1. Key Mitigation Technologies in the Waste Sector

MITIGATION OPTION	KEY TECHNOLOGIES REQUIRED
Landfill gas capture and utilization	Landfill gas recovery systems, improved rates of collection and disposal, improved management of landfills including daily cover, leachate systems, compaction, waste depth, regulatory framework for rights to landfill gas, incentives to install methane capture and energy utilization facilities, feed-in tariff, MRV programme

Table 8.2. Linkages between priority mitigation actions in the Waste Sector and SDGs

MITIGATION ACTION	SDG GOAL	TARGET	INDICATOR
Landfill methane capture	Goal 7 - Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 - By 2030, increase substantially the share of renewable energy in the global energy mix	Renewable energy share in the total final energy consumption
	Goal 11 - Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 - By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities
	Goal 12- Ensure sustainable consumption and production patterns	12.5 - By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	National recycling rate, tons of material recycled
	Goal 3 - Ensure healthy lives and promote well-being for all at all ages	3.9 - By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Mortality rate attributed to household and ambient air pollution Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)

Source: United Nations (2017). Revised list of global Sustainable Development Goal indicators.

Table 8.3. Overview of Development Benefits of Mitigation Options in the Waste Sector

	CLIMATE		LINKS TO SDG	
	Abatement Potential ($MtCO_2$)	Adaptation Impact	SDG 7: Renewable Energy	SDG 12: Improved Waste Management Job Creation
Landfill methane capture	0.78	◓	◓	●

Adapted from the Development Impact Tables developed for the NCCAP mitigation analysis, and updated to include the SDGs.

soft technology for Kenya is appropriate institutional and regulatory framework. Table 8.1 below summarises technology options for landfill gas capture and utilisation for energy generation.

DEVELOPMENT IMPACTS OF MITIGATION ACTIONS

Adaptation actions – such as climate proofing landfill sites – should be prioritized because the actions reduce vulnerability to climate change and create sustainable development benefits, particularly those pertaining to human health. As noted earlier, mitigation benefits are insignificant compared to other sectors. That said, mitigation actions to reduce GHG emissions in the waste sector can have positive development impacts that are linked to the Sustainable Development Goals (SDGs).

Sustainable waste management is not considered in a specific SDG. Rather, it cuts across several goals and targets. For instance, wastewater treatment as a potential mitigation action in the waste sector (see Annex 1 of this Chapter) could contribute to the achievement of SDG 6 (ensure availability and sustainable management of water and sanitation for all) and Target 6.3 (by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally).

Table 8.2 below illustrates how the priority mitigation action (landfill methane capture) coupled with other waste solid waste management measures such as waste prevention, reduction, recycling and re-use could contribute to SDG goals and targets. This strategy consisting of waste prevention, reduction, recycling, re-use and sanitary landfilling is the recommended approach of the Solid Waste Nationally Appropriate Mitigation Action (NAMA) for which Kenya is seeking climate finance.[20]

Table 8.3 includes the development and adaptation benefits assessment undertaken for Kenya's NCCAP mitigation analysis, which has been updated and aligned with the SDGs.

DEVELOPMENT IMPACTS

Poorly managed municipal solid waste is associated with an array of health challenges, which have been the subject of several research initiatives. One study has, for instance, documented higher than recommended levels of lead, mercury and cadmium from the Dandora dumpsite's leachate. Exposure to high concentrations of these heavy metals is associated with adverse health implications such as impairment of neurological system development, gastro-intestinal disorders, irritation of the lungs, and damage of kidneys, among a host of other health problems.[21]

Another study on the dumpsite undertaken for a Clean Development Mechanism (CDM) project concluded that replacing such dumpsites with sanitary landfills with facilities for methane landfill gas capture and utilisation could generate the following socio-development benefits:

Improved groundwater quality if the management of the site is combined with leachate collection and disposal action. This is linked to SDG 3 and SDG 11.

Improvement of local air and safety (fewer emissions of sulphur oxide, nitrogen oxide and particulates) through burning less coal for electricity generation and reduction of landfill gas released into the air. This is linked to SDG 3 and SDG 11.

Reduced risk of dangerous methane gas concentrations in landfills and reduced exposure of residential areas to odour.

Small increase in local employment. The process of designing, constructing and operating landfill gas capture plants could create jobs, however the technology used and local content are important factors in determining the local economic impact.

In some cases, additional payment by the project sponsor to support community programmes for stakeholders, including support for people living nearby the sites and who are affected by the project.

ADAPTATION AND CLIMATE RESILIENCE IMPACTS

Sanitary landfills can be vulnerable to climate change-related floods, depending on their design and construction. Climate proofed sanitary landfills are designed to limit exposure to climate extremes, as well as address negative impacts improper waste management, such as impacts on health.

8.4 ADAPTATION IN THE WASTE SECTOR

Kenya's NDC places emphasis on adaptation and resilience because of the country's high vulnerability to climate change and climate variability. The approach is to mainstream adaptation actions into the planning, budgeting and implementation process at both the national and county levels of government. The country's

Table 8.4. Potential Climate Change Impacts Across the Solid Waste Sector

CLIMATE VARIABLE	POTENTIAL CHANGE	POTENTIAL IMPACTS ON SOLID WASTE MANAGEMENT
Temperature	Annual warming	Increased risk of combustion at open sites and composting
	Increase in sea level	Flooding of facilities and basement/underground equipment Floating waste may wash up with high rainfall or storm surges
Precipitation	Increased rainfall More intense rainfall events	Saturated soil and decreased stability of slopes and landfill linings at waste management sites Flooding in areas with untreated, dumped waste carries risk of groundwater contamination Disruptions in the removal and transport of solid waste

Table 8.5. Potential Climate Change Impacts on Specific Solid Waste Components

INFRASTRUCTURE/ COMPONENT	CLIMATE VARIABLE	POTENTIAL CHANGE	POTENTIAL IMPACTS ON WASTE MANAGEMENT
Closed and open disposal sites	Temperature	Increase or decrease	Altered chemical composition of contaminants below the surface, changes in evaporation rates
	Precipitation	Increase	Unexpected leaching of contaminants in surface areas of closed landfills
Marine transfer stations	Sea level rise	Increase	Impacts on coastal docking and transfer facilities.
Path or roadside refuse	Precipitation	Increase or decrease	Damage to waste releases contaminants to waterways, pathways, and low-lying areas. Potential for pools of standing contaminated water that promote waters and vector-borne diseases.
	Storm surges	Increase	

Source: Zimmerman and Faris (2010), in World Bank, 2017, Guide to Climate Change Adaptation in Cities – Web Toolkit.

Table 8.6. Priority Adaptation Actions in the Waste Sector

ACTION	Enhance climate proofing of infrastructure
SHORT TERM SUB-ACTIONS	Enhance capacity of institutions and bodies responsible to water and sanitation, and waste management, on climate impacts. Conduct risk and vulnerability assessments of existing and upcoming infrastructure. Conduct capacity building on infrastructure climate proofing.
MEDIUM TERM SUB-ACTIONS	Strengthen the capacity of national and county institutions responsible for coordinating climate change adaptation. Climate proof infrastructure though use of appropriate design and construction materials.
LONG TERM SUB-ACTIONS	Re-assess infrastructure vulnerability and update infrastructure to withstand climate impacts.

Source: Government of Kenya (2016). National Adaptation Plan, 2015-2030, pages 27, 32 and 33.

vulnerability to climate change is documented in its 2010 NCCRS, the Strategy's 2013-17 NCCAP, and the 2015-2030 NAP.[22]

RISKS AND IMPACTS

Climate change poses risks to the solid waste sector and has potential impacts on the solid waste infrastructure, described Tables 8.4 and 8.5 below.

Climate change impacts on the waste sector are exacerbated by lack of or inadequate sanitary handling of wastes. The climate risks include:

- Flooding of waste handling facilities is a climate change risk associated with more frequent and severe weather events. Other impacts may include reduced capacity to cope with large volumes of waste generated by flood events; possible increase in waste dispersed by high and strong winds; and increased rates of decay of putrescent waste potentially necessitating in some areas more frequent collections of food waste to avoid negative impacts such as odour.
- Water stress, which may be caused by drought or reduced rainfall, is linked to higher incidences of cholera and other diarrheal diseases in areas with substandard sanitation facilities. These risks can be compounded by sudden precipitation increases, due to increased sewage run off into drinking water sources.
- The disposal of wastes in unsanitary landfill without containment technology such as the Dandora dumpsite leads to surface and groundwater pollution, and negative impacts on health of adjacent populations. Excessive precipitation may increase the rates of leaching of the chemicals and the distance they travel, thereby affecting more people
- Populations adjacent to dump sites (often poor and living in informal settlements) are at disproportionately greater risk to pollution from the dumpsites. A UNEP study listed a range of heavy metals and persistent organic pollutants from the Dandora dumpsite that could be potentially linked to skin disorders, respiratory abnormalities, and abdominal and intestinal disorders, amongst other ailments that are afflicting the adjacent communities.[23]

PRIORITY ADAPTATION ACTIONS IN THE WASTE SECTOR

The NDC's adaptation goal is enhanced resilience to climate change towards the attainment of Vision 2030. This is to be achieved by mainstreaming climate change adaptation into MTPs and implementing adaptation actions. While the NAP does not identify specific adaptation actions in the waste sector, actions under the water and sanitation sector and the infrastructure sector have applicability to the waste sector. These actions, set out in Table 8.6 are generally concerned with climate proofing waste infrastructure. The waste sector a devolved function requiring close collaboration between the national and county governments to ensure that national aspirations and goals in the sector are reflected in CIDPs and county budgets.

Adaptation options related to waste management include protecting critical infrastructure, limiting the demand for SWM facilities through recycling and demand management, and requiring waste treatment facilities to prepare adaptation plans. Proper siting of landfills is a low-cost adaptation option. Landfills should be sited where there is reliable access, but away from bodies of water and areas with high water tables. A USAID report on addressing climate change impacts on solid waste management infrastructure provides a screening process to guide decision making. The assessment considers four key factors:

- **Criticality** – How important is the infrastructure to the community or region? How large is the population served by the waste management system? Are backup services available?
- **Likelihood** – Given climate projections, what is the probability that the collection, processing, or disposal infrastructure will be affected?
- **Consequences** – How significant is the impact? Will the impacts complicate solid waste management? Will the impacts have health implications?
- **Resources available** – Can changes be made to collection, processing, or disposal using a reallocation of existing time and resources? Are additional resources, such as additional workers, required?[24]

Counties are expected to prepare waste management action plans (linked to the CIDPs) to meet the targets of the National Solid Waste Management Strategy 2015, which include achieving approximately 80% waste recovery (recycling, composting and waste to energy) and 20% landfilling in a sanitary landfill (inert material) by 2030.[25] These plans offer opportunity to introduce climate proofing of infrastructure and to ensure that systems are climate resilient.

REFERENCES

[1] The World Bank (undated). *Waste Generation*. Urban Development Series-Knowledge Papers. Washington DC: The World Bank. Accessed at: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap3.pdf

[2] Soezer, A. and Owino, T. (2015). *A Circular Economy Solid Waste Management Approach for Urban Areas in Kenya*. Nairobi: UNDP

[3] National Environment Management Authority (2015). *National Solid Waste Management Strategy*. Nairobi: NEMA.

[4] Government of Kenya (2016). *Kenya Environmental Sanitation and Hygiene Policy, 2016-2030*. Nairobi: Ministry of Health, page 8.

[5] Government of Kenya (2016). *National Adaptation Plan, 2015-2030*. Nairobi: Ministry of Environment and Natural Resources. page 10.

[6] United Nations Human Settlement Programme (2003). *Slums of the World: The face of Urban Poverty in the New Millennium?* Nairobi: Global Urban Observatory.

[7] Kyobutungi, C., Kasiira Ziraba, A., Ezeh, A. and Ye, Y. (2008). *The burden of disease profile of residents of Nairobi's slums: Results from a Demographic Surveillance System*. Population Health Metrics.

[8] NEMA (2006). *Waste Management Regulations, 2006*. Accessed at: https://www.nema.go.ke/images/Docs/Regulations/Waste%20Management%20Regulations-1.pdf

[9] NEMA (2015).

[10] KEPSA (2016). *Launch of Rapid Result Initiative (RRI) on Solid Waste Management. Accessed at:* http://kepsa.or.ke/2016/08/18/launch-of-rapid-result-initiative-rri-on-solid-waste-management/

[11] Government of Kenya (2016). *Kenya Environmental Sanitation and Hygiene Policy, 2016-2030*. Nairobi: Ministry of Health.

[12] Nairobi City County Government (2015). *The Nairobi City County Solid Waste Management Act 2015*. Nairobi: Nairobi City County Government.

[13] Government of Kenya (2015). *Second National Communication to the UNFCCC*. Nairobi: NEMA.

[14] United Nations Environment Programme (2010). *Waste and Climate Change - Global Trends and Strategy Framework*. Accessed at: http://www.unep.or.jp/ietc/Publications/ spc/Waste&ClimateChange/Waste&ClimateChange.pdf

[15] Bogner, J., M. Abdelra e Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, T. Zhang (2007). Waste Management, In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer [eds]). Cambridge: Cambridge University Press.

[16] Government of Kenya (2010). *National Climate Change Response Strategy*. Nairobi: Ministry of Environment and Mineral Resources.

[17] Based on the updated baseline, and developed building on calculations undertaken for the National Climate Change Action Plan, 2013-17, and updated for the Second National Communication.

[18] 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: German International Cooperation (GIZ).

[19] Soezer A. and Owino T. (2015).

[20] Soezer A. and Owino T. (2015).

[21] United National Environment Programme (UNEP) (2007). *Environmental Pollution and Impacts on Public Health - Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya*. Nairobi: UNEP.

[22] Government of Kenya (2010), *National Climate Change Response Strategy*; Government of Kenya (2013), *National Climate Change Action Plan, 2013-2017*; and Government of Kenya (2016) *National Adaptation Plan, 2015-2030*.

[23] UNEP (2007).

[24] USAID (2012). *Solid Waste Management: Addressing Climate Change Impacts on Infrastructure.* Fact Sheet.

[25] NEMA (2015). *National Solid Waste Management Strategy.* Page 42-43.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