Kenya's Climate Change Action Plan:

Mitigation

Chapter 6: Energy Demand

Raouf Saidi (ECN), Laura Würtenberger (ECN) and Seton Stiebert (IISD)

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ASB Partnership for the Tropical Forest Margins
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Mitigation Team:

Deborah Murphy, Seton Stiebert, Dave Sawyer, Jason Dion, Scott McFatridge, International Institute for Sustainable Development

Laura Würtenberger, Lachlan Cameron, Raouf Saidi, Xander van Tilburg, Energy Research Centre of the Netherlands

Peter A. Minang, ASB Partnership for the Tropical Forest Margins at the World Agroforestry Centre

Tom Owino, ClimateCare

Peterson Olum

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ASB is the only global partnership devoted entirely to research on the tropical forest margins. ASB aims to raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services.

For further information, please contact:

Deborah Murphy, IISD
Tel: +1-613-238-2296
Email: dmurphy@iisd.ca

Laura Würtenberger, ECN
Tel: +31 88 515 49 48
Email: wuertenberger@ecn.nl

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Abbreviations

AFD	French Development Agency / Agence Française de Développement
BAU	business as usual
CDM	Clean Development Mechanism
CFL	compact fluorescent lamps
DSM	demand side management
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EU	European Union
GDP	gross domestic product
GHG	greenhouse gas
GIZ	German International Development Agency
GWh	gigawatt hour
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
KIPPRA	Kenya Institute for Public Policy Research and Analysis
LED	light emitting diode
LPG	liquefied petroleum gas
Mt	million tonnes
MW	megawatt
PV	photovoltaic
SME	small and medium sized enterprise
NAMA	nationally appropriate mitigation action
NEMA	National Environment Management Authority
REDD+	reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

6.1 Introduction

This chapter is part of a larger analysis of low-carbon development options in Kenya, which covers the six mitigation sectors set out in Article 4.1 of the United Nations Framework Convention on Climate Change (UNFCCC): energy, transport, industry, waste, forestry and agriculture. The holistic, sectoral analysis aims to inform the Kenya Climate Change Action Plan and provides the evidence base for prioritizing low-carbon development options and developing proposals for Nationally Appropriate Mitigation Actions (NAMAs) and REDD+ actions. The analysis includes a preliminary greenhouse gas (GHG) emissions inventory and reference case projecting GHG emissions to 2030 for the entire Kenyan economy and by sector. The analysis then demonstrates how low-carbon development options can bend down emissions from the proposed reference case in each sector. Recognizing Kenya's development priorities and plans, the analysis also considers how the various options can contribute to sustainable development. The overall work concludes with the identification of priority actions to enable low-carbon development.

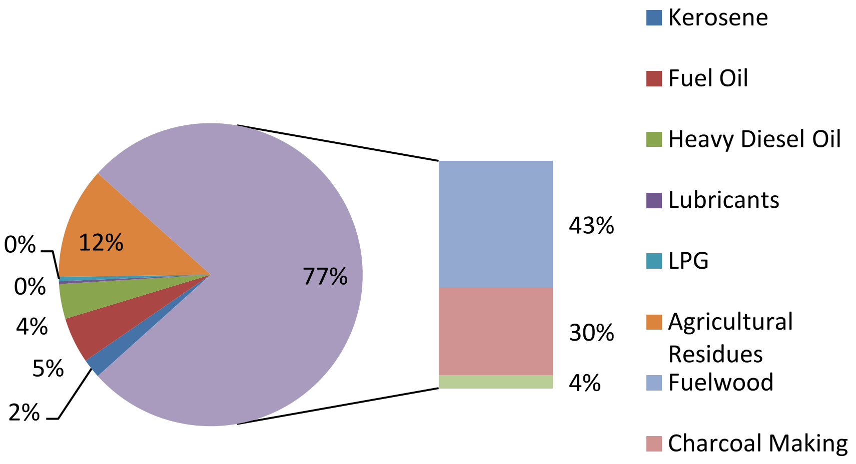
This chapter analyses low-carbon development options related to energy demand in Kenya and is one of seven sectoral chapters developed as part of the overall low-carbon scenario analysis.

6.2 Final Energy Demand: Background

6.2.1 Sector context

Energy demand in Kenya for the commercial, industrial and household sectors 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 uses in the commercial and industrial sectors and for cooking and heating purposes in the household sector. Figure 6.1 shows that biomass from wood sources accounts for 77 percent of all primary energy demand – excluding electricity and transport fuels – and is by far the most dominant fuel source.

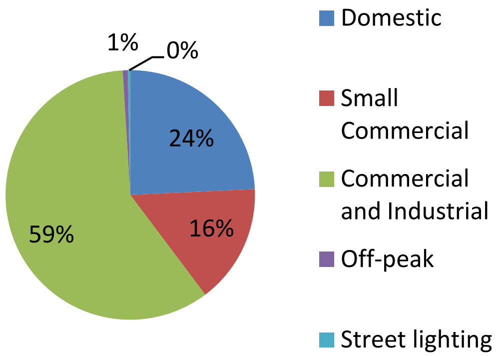
Figure 6.1: Non-transport and non-electricity fossil fuel and biomass consumption, 2009



Source: Kenya Institute for Public Policy Research and Analysis. 2010. A Comprehensive Study and Analysis on Energy Consumption Patterns in Kenya: A Synopsis of the Draft Final Report. *Nairobi: KIPPRA.*

With only 18 percent of the population – representing 1.3 million customers – connected to the grid, electricity only accounts for 10 percent of total final energy consumption, or 5,300 gigawatt hours (GWh). Roughly 60 percent of all electricity is consumed by the commercial and industrial sectors and only 24 percent is used by households (see Figure 6.2). Even though current electricity demand is relatively low, it is rapidly increasing; between 2005 to 2010 total electricity consumption increased by 27 percent, while electricity consumption in the household sector alone has risen by 35 percent. To detach GDP growth from growth in energy consumption, energy efficiency efforts are needed to reduce current consumption in households and to reduce the energy cost component in commercial and industrial services and products.

Figure 6.2: Share of electricity use per type of end-user 2010



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

6.2.2 Structure of the energy demand sector

The bodies active in the formulation of energy efficiency strategies in Kenya are:

- **The Ministry of Energy** and in particular the Division of Energy Efficiency.
- **Kenya Power (KPLC)**, the national operator, set up a Demand Side Management (DSM) unit in 2009. This unit has implemented several strategies to reduce consumption, especially at peak times. Strategies include the provision of 1.25 million free compact fluorescent lamps (CFLs) to the population and introduction of a specific tariff for peak hours.
- **The Centre for Energy efficiency and Conservation,** Kenya Association of Manufacturers is a public centre that performs energy audits mainly in industries and commercial facilities.
- **The Energy Regulatory Commission** develops technical regulations and standards that encourage energy efficiency as well as broader promotion of energy efficiency measures, for example, in buildings and for appliances. A new department for renewable energy and energy efficiency was created in the commission in 2010.

Beyond these national bodies there are many international organisations active in supporting the Government of Kenya and other stakeholders in the field of energy efficiency including the International Finance Corporation, AFD and the German International Development Agency (GIZ). The activities of these organisations target different end user groups and energy carriers.

6.2.3 Policy

Current energy efficiency policies in Kenya are aimed at providing the information and technical capacity needed to implement energy efficiency technologies, and providing regulation that mandates a certain energy performance. There is a large potential for energy savings in Kenya,[1] including many interventions that can be classified as "no-regret options," implying that the financial gains from energy savings over a reasonable payback time are greater than the needed investment.

The government has introduced regulations that promote conservation and demand management. An example is the Kenya Solar Water Heating Regulations issued by the Ministry of Energy that mandates the installation and use of solar water heating systems for all buildings with a capacity for hot water requirements of more than 100 litres a day.[2] A second example is the Draft Kenya Energy Management regulation that makes it mandatory for facilities to undergo energy audits and encourages them to implement at least 50 percent of the identified energy efficiency potential.[3]

Enforcement of these regulations remains a challenge, although some supportive policies have been launched. KPLC has provided 1.25 million free CFLs to the public and is planning to provide an additional three million units in 2012. In cooperation with the United Nations Environment Programme (UNEP), KPLC and the Ministry of Energy are researching options for standards and labelling in industry.

6.3 Development Priorities of the Government of Kenya

Energy is considered to be one of the infrastructural enablers of the three pillars of Vision 2030. The level and intensity of commercial and industrial energy use is a key indicator of the degree of economic growth and development. A key message of Vision 2030 is that Kenya must generate more energy and increase efficiency in energy consumption.[4]

Vision 2030 flagship projects focus on expanding energy infrastructure, increasing electricity generation capacity and diversifying energy sources; however, Vision 2030 does recognize that an increase in efficiency in energy consumption can complement the planned increase in energy supply. The overreliance on wood fuel is specifically mentioned as a challenge. The 2012 draft Energy Policy aims at encouraging the use of LPG by removing associated taxes to reduce the overreliance on wood fuel and at eliminating the use of kerosene in households.[5]

6.4 GHG Reference Case

This section briefly discusses the methodology, data and assumptions that were used to generate the GHG emissions baseline for the waste sector between the years 2000 and 2030. This is followed by a discussion of data availability and quality. Finally, emissions are projected out to 2030 to create the reference case against which to measure abatement potential.

6.4.1 Emissions reference case methodology

The development of the emissions reference case is aligned with the major sectors and categories of the Intergovernmental Panel on Climate Change (IPCC) that includes: Energy, Industrial Processes, Agriculture and Forestry and other land use and waste. The energy sector is further subdivided into Transportation, Electricity Supply and the household, commercial and industry energy demand sectors. Emissions associated with the consumption of electricity are included in Chapter 5, Electricity Generation, but are also shown here with reference case emissions from the household, commercial and industry energy sector so that demand side mitigation options, including fuel switching from electricity to petroleum fuels can be considered.

The methodologies, data and assumptions used to generate the GHG emissions baseline for household, commercial and industry energy use are presented in detail in Chapter 2, Preliminary Greenhouse Gas Emissions Inventory.

6.4.2 Data availability and quality

Uncertainty in the emissions reference case is relatively low for the total emissions of fossil fuels as there is a low degree of uncertainty related to the total consumption of these fuels in Kenya and the related emissions factors. The uncertainty is higher for biomass fuels as the data on total biomass fuels consumed in Kenya is based on limited surveys. It is likely that the range of uncertainty is for these types of surveys is within 30 to 60 percent.[6]

There is also significant uncertainty in the allocation of emissions to specific end-uses as this data is limited in Kenya. Future studies that allocate the total consumption of fuels in Kenya to specific energy end-uses would improve the confidence in the analysis of mitigation options.

6.4.3 Greenhouse gas emissions reference case

The emissions baseline generated from household, commercial and industrial energy consumption is summarized in Figure 6.3 by fuel type. Figure 6.3 excludes electricity emissions that are included in the corresponding report on the electricity sector, as well as carbon emissions from the unsustainable use of fuel wood and charcoal that are captured in the forestry sector.

Figure 6.3: Total household, commercial and industrial energy emissions ($MtCO_2e$) excluding electricity

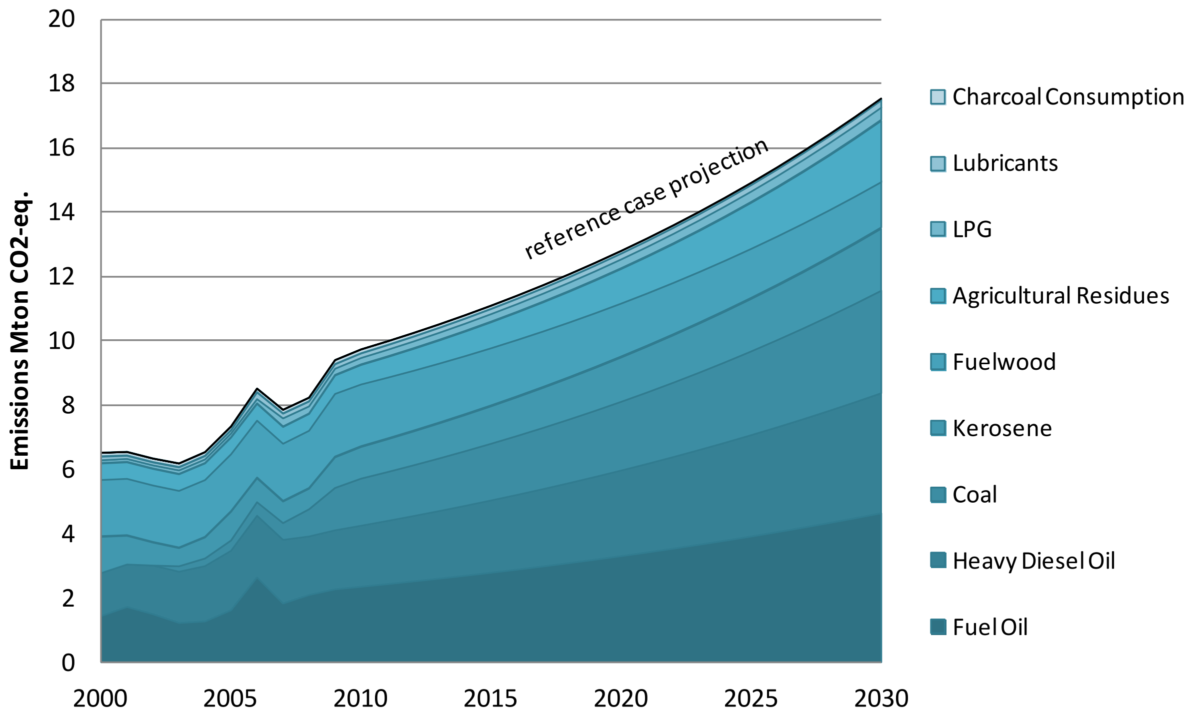
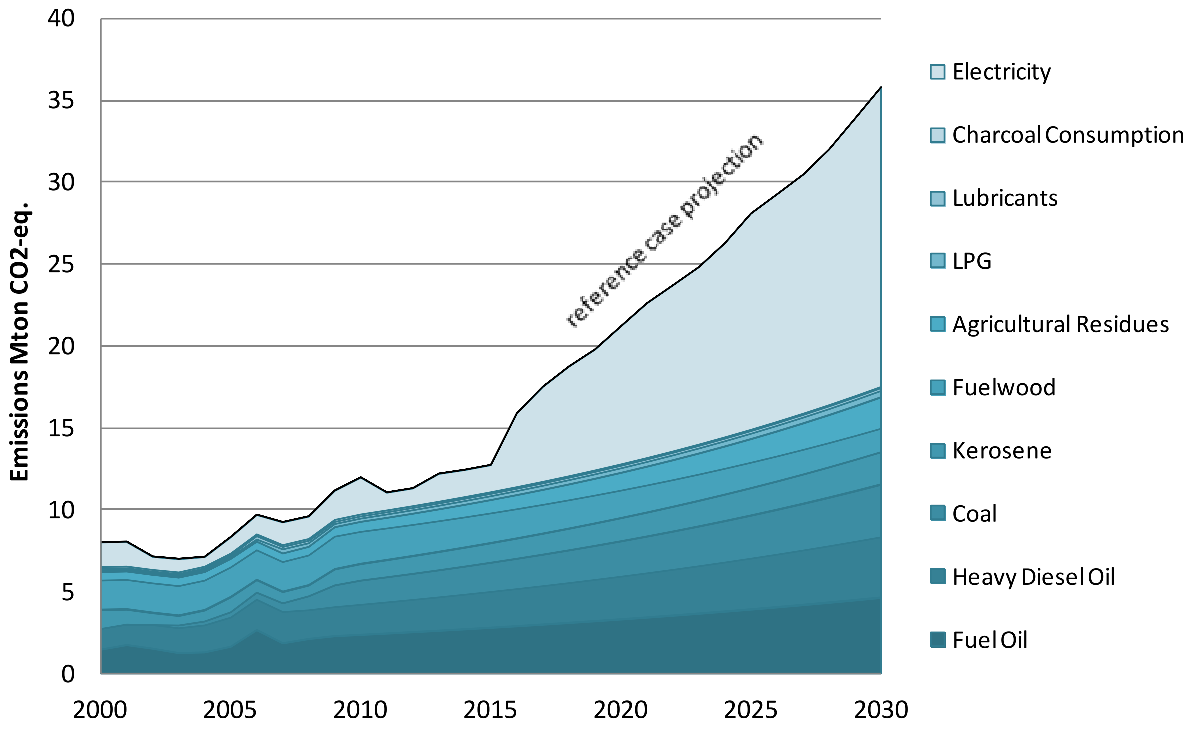


Table 6.1: Total household, commercial and industrial energy emissions (MtCO₂e)

Source	2000	2010	2015	2020	2025	2030
Fuel Oil	1.46	1.65	2.82	3.33	3.94	4.67
Heavy Diesel Oil	1.34	1.86	2.25	2.67	3.15	3.73
Coal	0.00	0.32	1.77	2.14	2.61	3.19
Kerosene	1.13	0.89	1.17	1.38	1.63	1.93
Fuelwood	1.77	1.79	1.81	1.68	1.56	1.45
Agricultural Residues	0.51	0.52	0.81	1.07	1.43	1.91
LPG	0.08	0.11	0.24	0.28	0.33	0.39
Lubricants	0.11	0.10	0.16	0.18	0.20	0.23
Charcoal Consumption	0.11	0.12	0.10	0.08	0.07	0.06

Figure 6.4 includes electricity emissions so the analysis can consider demand side mitigation options that would impact the demand for electricity. Including electricity emissions increases total emissions from the household, commercial and industrial energy sector by 23 percent in 2010; but as demand for electricity expands and gas, coal and diesel plants are added, GHGs rise significantly to 2030.

Figure 6.4: Total household, commercial and industrial energy emissions (MtCO₂e) including electricity



6.5 Low-carbon Scenario Analysis

The low-carbon scenario analysis consists of identifying low-carbon development options, and calculating the mitigation potential against the reference case. The resulting wedge analysis demonstrates the emission reduction potential by low-carbon technology in the sector.

6.5.1 Choice of abatement options

The identification of low-carbon options for in-depth analysis followed a participatory multi-step approach that is described in Chapter 1. Seven low-carbon development options were identified in the energy demand sector:

- Improved cook stoves;
- Renewable lamps replacing kerosene lamps;
- Solar thermal water heating;
- Energy efficiency light bulbs;
- Energy efficient electric appliances;
- Energy efficiency improvements in industry;
- Emission reductions (energy emissions) in the cement industry; and
- Co-generation in agriculture.

These options and the preliminary results were presented at local validation meetings in May and June 2012 for review by and input from Kenyan experts. Box 6.1 discusses options that were suggested by Kenyan experts and the rationale for not including in the low-carbon scenario.

6.5.2 Calculation of abatement potentials

Much of the mitigation options mentioned are linked to energy efficiency improvements in the household, commercial and industrial sectors. These options do not represent technologies that are adopted by a few large actors such as utilities and Independent Power Producers (IPPs) in the case of electricity generation. These options will have to be adopted by the end-users, and this has implications for the calculation of the abatement potentials. The choices of end-users in three different sectors need to be quantified, which are further fragmented by differences in income, size, market or location. This is very challenging and requires extensive data availability.

Available data was limited to supply-side data on fuel and electricity consumption, rather than end-user data on appliance use and consumption behaviour. To circumvent this lack of demand-side data, scenarios were created which estimate the potential for low-carbon demand side technologies based on the estimates for the following:

- Possible cost reductions of the low-carbon technologies for the purchase, installation and maintenance of the technology; and
- The likely future price behaviour of the underlying, or business-as-usual, energy carrier.

In addition to these estimates of future developments, information on current technical potentials, target sectors and investment characteristics was used to develop current adoption rates of technologies, which were then validated in stakeholder consultation sessions.

Box 6.1: Low-carbon options in the energy demand sector not considered in the analysis

Energy demand options proposed at local validation meetings but excluded after further analysis are discussed below.

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 most 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. The Ministry of Livestock in conjunction with the Kenya National Federation of Agricultural Producers, is promoting biogas in Bungoma county.

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 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 liquefied propane gas (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 6, Transportation, which also discusses the potential negative impacts of biofuel production on food security).

The **implications of the oil discovery** in Turkana County in early 2012 could not be analysed, but could be taken up in a future revision of the analysis when more information about the size of oil reserves and timing of eventual production are better known.

For efficiency improvements in the household sector – improved cook stoves, energy-efficient light bulbs and appliances, and solar water heating – the necessary upfront investment cost was a leading characteristic in establishing current and future adoption rates. Households are unlikely to invest in energy efficiency measures that have payback times of longer than one to three years. An intervention in the form of a subsidy can reduce the payback time of an investment, but the efficiency improvement will still not be affordable for large parts of the population.

For the industrial and commercial sector, the upfront investment cost was also considered, but it was assumed that companies would have a higher ability and willingness to make upfront investments, and accept payback times longer than one to three years. In addition, the complexity of implementation, and the availability and knowledge of the technologies, was considered to be an important consideration when estimating potential future uptake of technologies.

In this way, for each of the technology options, an efficiency improvement in terms of percentage or amount of saved energy compared to the baseline option was developed. This was then multiplied by the emission factor of the energy end use to determine the final abated GHG emissions.

Establishing the emissions factor for biomass was slightly more complicated as emissions from biomass are dependent on what percentage of the feedstock is renewable, which is difficult to predict for the future. Through the validation sessions it was established that for projects in Kenya, generally 35 percent of non-renewable biomass is assumed. This share was used for all biomass-based options in each of the reports in this low-carbon analysis (see Forestry Chapter for more detail) .

6.5.3 Calculation of abatement costs

Where it was possible to calculate marginal abatement costs, current marginal abatement costs were calculated. Thus current prices of the low-carbon technologies were used and no potential future price developments in costs for biomass or fossil fuel energy carriers were taken into account. Where options are analysed on an aggregated level, e.g. efficiency improvements across industries, the costs for low-carbon technologies are very situation specific and it was not possible to determine average costs. Marginal abatement costs were hence not calculated for the options analysed on an aggregated level.

6.5.4 Data availability and uncertainties

The available data was limited to supply side data on fuel and electricity consumption, rather than end-user data on energy consumption behaviour and appliance use. A detailed study on end-use energy consumption is being undertaken with support from AFD, and could inform future low-carbon analyses.

The current rates of adoption were not necessarily the easiest starting point for the low-carbon scenario. For many options, it was easier to make an estimate of potential future adoption rates of the low-carbon technologies based on the assumptions discussed under Section 4.2.2, stakeholder consultation and experiences in other countries. For example, it is easier to assume that by 2030 all conventional non-fluorescent light bulbs in Kenya could be replaced by CFLs, than to determine today's ratio of CFL use in rural areas in the country.

Kenya's industrial sector is very fragmented with a large portion of small and medium enterprises (SMEs) meaning limited available information on the type of technologies used in the sector and their energy-use characteristics. The analysis aggregated different potential approaches for improving industrial energy efficiency into one option, rather than analysing them separately. This approach reduced error margins by avoiding uncertainties associated with the adoption rates of specific technologies.

6.6 Low-carbon Development Options

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

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

6.6.1 Context

Improved cookstoves

In 2009, Kenya used a total of 12,000 ktoe of woody biomass, directly as fuel wood or through conversion into charcoal, representing 77 percent of total primary energy demand. The households sector is the largest end-user group, mainly for cooking and heating purposes. In urban areas – where over 60 percent still use cookstoves – simple manufactured cook stoves dominate, while rural areas primarily use the traditional open "three stone" fires. Use of these cookstoves produces considerable negative environmental, social and health effects because of the partial or incomplete combustion of feedstock. Incomplete combustion leads to increased carbon monoxide, methane, particulate matter and nitrous oxide emissions causing severe respiratory damage especially among women and children.[7]

The use of improved cookstoves partially alleviates these effects through improved isolation and air intake designs, improving combustion and reducing the emission of poisonous gases. In addition, an improved cookstove reduces the amount of feedstock necessary for cooking, relieving pressure on woodlots and the time consumed in collecting fuelwood. The use of improved cookstoves also reduces associated GHG emissions; this is done through improved combustion reducing the emissions of potent GHGs such as methane and nitrous oxide, and by reducing the amount of feedstock required. The latter provides the largest potential savings if woody biomass is not harvested in a sustainable manner. Thus GHG emission savings from improved cookstoves are directly related to the degree of renewable or sustainably produced feedstock used. Expert consultation determined that the woody biomass used to produce charcoal or to be directly used as fuel wood would consist of 35 percent of non-sustainably harvested or non-renewable biomass.

The Jiko stove is an example of an improved cookstove and is currently utilised in urban and rural households. The stove can be manufactured in Kenya and therefore has the additional co-benefit of providing increased employment opportunities. This stove can lead to emission reductions of roughly 30 to 50 percent per stove and contributes to substantial GHG emissions savings (if biomass is sourced in an unsustainable manner). Policies that increase the share of sustainable, GHG-neutral biomass lead to a reduction of the emission reduction potential of this option.

Improved fuelwood and charcoal stoves were emphasized as a potential low-carbon development options in the county consultations, indicating that many Kenyans are familiar with the technology.

LPG stove substitution

Similar to the use of improved cookstoves, substituting woody biomass with liquefied petroleum gas (LPG) for cooking can reduce the negative health and environmental effects associated with the use of woody biomass. The health impacts are almost completely mitigated as LPG burns more efficiently and contains a fraction of the particulate matter or harmful gases, such as methane and carbon monoxide, of solid biomass. LPG is a fossil fuel, and the degree of renewable or sustainably produced feedstock used is the key factor in determining GHG emission savings. Again, an assumption of 35 percent of non-sustainably harvested or non-renewable biomass was used.

Although it is unclear how much LPG is currently used for cooking in Kenya, the share of fuel consumption in Figure 6.1 indicates that it is minimal. Kenya has a refinery that produces LPG, but its production capabilities are limited. However, increased LPG consumption is a priority in Kenya, and the latest national energy policy draft aims to support both the demand side – through zero tax policies, and the supply side – through the construction of a LPG import handling, storage and distribution facility, expected to open in Mombasa in late 2012.[8]

Renewable lamps replacing kerosene lamps

Kerosene is the ubiquitous fuel used for lighting in off-grid rural communities. When used in simple kerosene lamps, kerosene leads to high indoor air pollution as well as to an increased risk of burns, fires and poisonings.[9,10] Kenya – being a net fossil fuel importer – also experiences negative macroeconomic effects, both foreign exchange and balance of trade, related to the import of kerosene.

Replacing kerosene with a combination of light emitting diode (LED) lanterns in combination with compact renewable energy sources, such as solar photovoltaic (PV), can reduce these negative effects. Currently these products are available in the market, and have experienced considerable price decreases over the past five years. However, negative experiences have been attributed to cheap products, mainly produced in Asia, as the performance of both the LED bulb and the solar PV panel may be less than stated by the manufacturer and the equipment is not as durable as expected.[11] There is a lack of standardisation for renewable lighting products in Kenya.

Solar thermal water heating

With an average solar radiance of 4.5 kilowatt hour per square metre per day (KWh/m^2/day) and fairly constant temperatures, Kenya can take advantage of the benefits of solar water heating. Currently, there is a trend towards using direct electric devices with heating elements between 2.5 and 5 KW to heat hot water for the use in showers.[12] This poses a challenge to electricity demand management, as they tend to be used during morning and afternoon times when there is peak demand for hot water.

Solar water heaters are currently available in Kenya and are primarily used by larger hotels, as their large demand for hot water warrants the solar water heater's relatively high upfront cost. In addition, most hotels do not share their building with other businesses so they can easily place the systems on their roof. For households, in particular those in apartment complexes, this may not be an option. Currently, a typical 100 litre solar water heating system in Kenya costs about US$1,500, which means it is unaffordable for many households.[13]

Energy efficient light bulbs

Replacing incandescent bulbs with compact fluorescent lamps (CFLs) decreases energy consumption by 80 percent per bulb, and CFL bulbs last roughly ten times longer. the longer life time of CFLs alone justifies the higher investment cost. When energy savings are taken into account the payback period falls and CFLs usually pay back within one year.

The exact share of CFLs in Kenya is unknown, but it can be safely assumed penetration rates are relatively high, especially in urban areas. The lack of a labelling scheme and the entry of low quality, less efficient CFLs do not allow consumers to properly assess the options. Incandescent light bulbs may be prominent in rural areas, but the low level of rural electrification would limit the potential for large energy savings.

Energy efficient appliances

Replacing appliances such as refrigerators, air conditioners and televisions in households and commercial facilities with more modern efficient units can lead to substantial energy savings. The high prices for new appliances in Kenya, combined with the large influx of older, cheaper second-hand appliances from the European Union (EU) makes it unattractive to purchase a new model. In addition, lack of labelling means that consumers are not informed about the possible cost savings associated with choosing newer, more efficient products. Old inefficient refrigerators are estimated to make up a substantial share of household energy demand. The use of air conditioning units is still limited, but expected to grow significantly in the future in line with a growing middle class.

The economics of energy-efficient appliances often contrast with the earlier example of CFL lighting, where the investment is returned within one year and the cost of a bulb is relatively low. There can be a larger difference in upfront costs for energy-efficient and less-efficient appliances, especially when second-hand equipment is involved. In addition, payback times for the additional up-front investment are generally longer than a year. A combination of regulation and supportive policies can stimulate the adoption of more energy efficient appliances. A standardization and labelling project carried out by the Kenya Bureau of Standards, Ministry of Industrialization and the UNDP is researching options.

Energy efficiency improvements across industries

The industrial and commercial sector in Kenya is dominated by SMEs and includes the agriculture and food, pulp and paper, information and communications technology, textile and tourism industry. These industries all use a wide variety of equipment and appliances typical to the product or service offered – unlike the previous example that focussed on general appliances. Low-carbon options exist for each subsector, such as variable speed drives and improved boilers. However, the upfront costs often present a barrier to adoption.

Access to finance for these options is difficult in Kenya. Banks prefer providing loans to larger enterprises, impose high collateral demands that are often difficult for SMEs, or engage in short-term consumer lending where high interest rates are charged (for example, for the purchase of private vehicles). National adoption of a “soft” loan (a loan with a below-market interest rate usually guaranteed by government or development banks) in combination with audits and technical training could provide the necessary stimulus for increased adoption of energy efficiency matters.

Emission reductions (energy emissions) in the cement industry

The cement industry is the largest single emitting industry in Kenya. Emissions result from direct energy-related emissions (40 percent of emissions) from fossil fuel combustion used to heat the kiln; indirect energy-related emissions (5 to 10 percent of emissions) from electricity consumption used to power machinery; and process-related emissions (50 percent of emissions) due to calcination, whereby limestone releases CO_2 as it is heated in the kiln and transformed into clinker, the main component of cement.[14] This option looks at a reduction of indirect energy-related emissions by introducing:

- High efficiency motors and drives;
- Variable speed drives;
- High efficiency classifiers; and
- Efficient grinding technologies.

Moreover, it is assumed that increasing the overall efficiency of the plant can also lead to efficiency improvements of direct energy use for heating the kiln. The option does not assume a major fuel switch to renewable fuels such as biomass or using large proportions of waste as fuel.

Co-generation in agriculture

Biogas is a predominantly methane gaseous mixture that is generated during anaerobic digestion processes using wastewater, solid waste (for example, at landfills), organic waste (such as animal manure) and other sources of biomass.[15] This mitigation option considers the production of biogas from agricultural residues (with biogas production from solid waste considered in the waste sector discussed in Chapter 9, Waste). Specific farming of energy crops as a feedstock for biogas digesters is not considered due to its potential implication for food security and the large overlap with the biofuels options considered in the transport sector.

Biogas can be used as a source of energy, both in small-scale rural applications (such as cooking) and industrial-scale applications such as the generation of electricity and heat. This low-carbon option focuses on industrial-scale applications, and in particular cogeneration using biogas. Agricultural residues are collected in one place during the processing of the agricultural product, offering several advantages:

- Transport costs for the feedstock are minimized;
- Electricity and waste heat can be used directly for processing;

- Additional electricity can be fed into the national grid; and
- Biogas plant effluent can be used on the farm as organic fertilizer.[16]

The advantages of biogas production can make agricultural production more efficient and sustainable. The value-added remains in the local market and additional employment opportunities are created.

As noted above, for companies where agricultural residues accrue during processing, the installation of biogas plants could, initially, help satisfy their own energy consumption. Other options include the direct sale of biogas electricity to bulk consumers and export to the grid while taking advantage of the revised feed-in tariff that includes biogas installations from 500 kW to 40 megawatts (MW) in size.[17]

Little data is available on biomass potentials, but a 2010 study used a bottom-up approach to estimate the potential for cogeneration using agricultural residues in Kenya.[18] Fisher *et al.* determined that up to 50 MW of installed capacity could be achieved using available residues, but noted this is a conservative figure as it represents part of the total agro-industrial sector and does not include future investments and growth.

6.6.2 Scenarios

The assumptions underlying the abatement options in the low-carbon scenario are described below.

Improved cook stoves – The low-carbon scenario assumes a 100 percent penetration of improved cookstoves by 2030, with the cookstoves having a 50 percent efficiency improvement over equipment in 2012. This is an optimistic assumption in the sense that 100 percent penetration of improved stoves may not be fully achievable by 2030; however, a Jiko stove currently achieves up to 50 percent efficiency improvements at relatively low costs.[19] Therefore, by 2030, stoves with more than 50 percent efficiency improvements versus 2012 business-as-usual may compensate for less than 10 percent penetration. The low-carbon scenario assumes a linear increase in the penetration of improved stoves until 2030.

LPG stove substitution – Aggressive policies have increased the uptake of LPG very significantly in a short time span in some countries, such as Indonesia. The scenario for Kenya takes a more conservative approach, assuming that in 2020 almost all urban households, representing 30 percent of the total population, use LPG as a cooking fuel. Reaching the remote rural population could prove to be more challenging. Cooking on LPG requires an upfront investment in a new stove and spending money to purchase LPG during operation; which makes it much more expensive than fuelwood collection. Therefore it is assumed that the overall country-wide penetration rate of LPG will increase by 10 percent every 5 years from 2020 to 50 percent in 2050. The emission reductions used for LPG are 30 percent, which is the average reduction when compared to charcoal and fuelwood stoves and therefore does not account users of fuelwood in ‘open’ fires due to a lack of data.[20]

Renewable lamps replacing kerosene lamps – One hundred percent adoption of renewable lighting technologies is assumed (for off-grid applications[21]) by 2030, completely replacing kerosene lamps. This is a result of decreasing prices for renewable lighting technologies, such as solar lanterns, which have dropped significantly over the past few years, and the a decrease in the negative health effects of kerosene use. Given the short payback times for a solar lantern (or similar equipment), a rapid increase in penetration to reach 65 percent of the population by 2020 is assumed, further increasing to 100 percent by 2030. This leads to the elimination of the import 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.

To simplify the calculation, it is assumed that the solar thermal water heating systems would not use fossil fuel based or electricity-run back-up systems. Thus by 2030, GHG emissions from water heating are assumed to be 20 percent lower than in the reference case. Although a regulation is in place mandating solar thermal water heaters in all new buildings of a certain size, significant additional support is needed to achieve more than 20 percent total penetration by 2030.

Energy efficient light bulbs – The low investment cost of CFL and further cost reductions can lead to high adoption rates in the short term. 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.

Energy efficient electric appliances – The relatively high investment cost and the influx of second-hand appliances from the EU has led to conservative assumptions. The introduction of a labelling scheme is expected to slightly increase adoption of energy efficient appliances, but the necessary regulation of imported second hand goods is more politically challenging and difficult to enforce. Furthermore, many of the appliances have long lifetimes and replacing the current stock of products could go beyond 2030. For these reasons, an emission reduction of 30 percent is assumed in 2030.

Energy efficiency improvements across industries – Results from energy audits undertaken in different commercial and industrial facilities in Kenya show that with measures of payback times of less than two years, savings in electricity consumption of between eight percent (for a tourist resort) and 26 percent (for a tea factory) could be achieved through measures such as the use of more efficient pumps and motors. Fuel efficiency improvements of more than 9 percent could be achieved for a boiler in a tea factory by, for example, an adjustment of the oxygen for combustion – a measure with a payback time of about half a year.[22] Longer payback times of up to five years would mean a significantly higher level of savings. However, it is difficult to encourage SMEs, which form a significant part of Kenya's commercial and manufacturing sector, to invest in energy efficiency without interventions or support programs. Taking all these factors into consideration, a 15 percent energy efficiency improvement by 2030 is assumed.

Emission reductions (energy emissions) in the cement industry – The low-carbon scenario assumes a 10 percent improvement in total energy efficiency, assuming that all possible reductions in indirect energy use are fully realized, leading to 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. However, the recent developments in the Kenyan cement sector show coal as a preferred substitute, which lowers prices but increases emissions.

Co-generation in agriculture – The low-carbon scenario for biogas based cogeneration assumes that the mean potential from a GTZ study[23] is utilised 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 agricultural output is assumed to 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[24]). Note that costs are reported separately for small- and large-scale plants, as the scale of a biogas cogeneration plant makes a big difference to its costs.

6.6.3 Mitigation potentials

Given the dominant role of biomass as energy carrier in Kenya, total GHG emissions from energy use depend to a large extent on the assumption of the percentage of woodfuel used is renewable or harvested sustainably. Figures 6.5 and 6.6 shows the baseline scenario for the energy-use sector, including and excluding the assumption non-unsustainable biomass, which clearly shows the large effect on the emissions. The emission baseline chosen for this analysis assumes that all the biomass used between the 2000 and 2030 consist of 35 percent unsustainable biomass. As a consequence emissions from woodfuel dominate total energy use emissions.

Figure 6.5 shows the abatement potentials for options in the energy demand sector assuming 100 percent sustainable woodfuel use. The largest emission reductions are realised by renewable lighting replacing kerosene lamps with 1.8 $MtCO_2e$, followed by co-generation in agriculture with 1.6 $MtCO_2e$ per year, energy efficient light bulbs with 1 $MtCO_2e$, and energy efficiency improvements in industry and improved cookstoves with 0.9 and 0.8 $MtCO_2e$ per year respectively. The abatement potential for the remaining options lie between 0.1 $MtCO_2e$ and 0.4 $MtCO_2e$.

The wedge analysis does not consider interactions between the options, but represents a simple addition of separate bottom-up analyses. Simply adding up the emission reduction potentials of the different options does not necessarily give a good indication of the total potential. For example, the options of improved cookstoves or stoves using LPG exclude each other: a household either switched to LPG or uses an improved woodfuel cookstove. There are fewer interactions for other options, for example a household can use solar lanterns and cook on LPG.

Kenya is still experiencing deforestation, meaning that it is not realistic to assume 100 percent sustainable woodfuel use. Although it is very difficult to make a conclusive statement on the percentage of wood sourced unsustainably, 35 percent seems to be a realistic assumption. This assumption is further discussed in Chapter 2, Forestry.

Figure 6.6 shows the abatement potentials for options in the energy demand sector assuming 35 percent unsustainable woodfuel use Under this assumption total emissions increase significantly by about 10 $MtCO_2e$ per year. The emission reduction potential of improved cookstoves amounts to 5.6 $MtCO_2e$ per year. The potential for the use of LPG for cooking would be 1.7 $MtCO_2e$ per year.

The factsheets in Annex 1 show each of the wedges separately and give further information on the various low-carbon development options.

Improved cookstoves and renewable lighting show the largest potential in the short term, as the adoption scenarios used assume that the current availability of the products, maturity of the markets and economic attractiveness of the options will rapidly react to supportive national policies, regulations or other types of interventions such as access to (micro-finance) capital for households. Energy efficiency options will be slower in realising their abatement potential as the low-carbon scenarios often involve the replacement of appliances or machinery, and end-users are usually reluctant to replace these before the end of their lifetime.

Figure 6.5: Low-carbon option mitigation wedges in the energy demand sector (MtCO$_2$e) assuming 100 percent sustainable woodfuel use

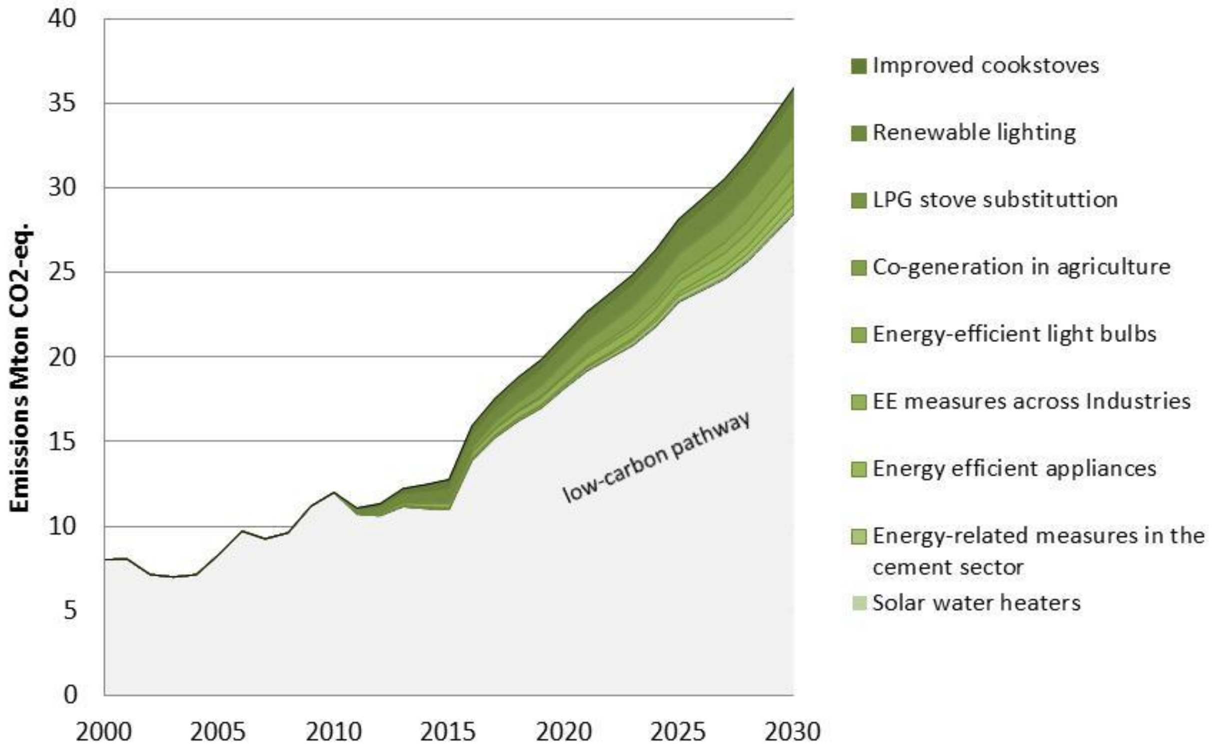
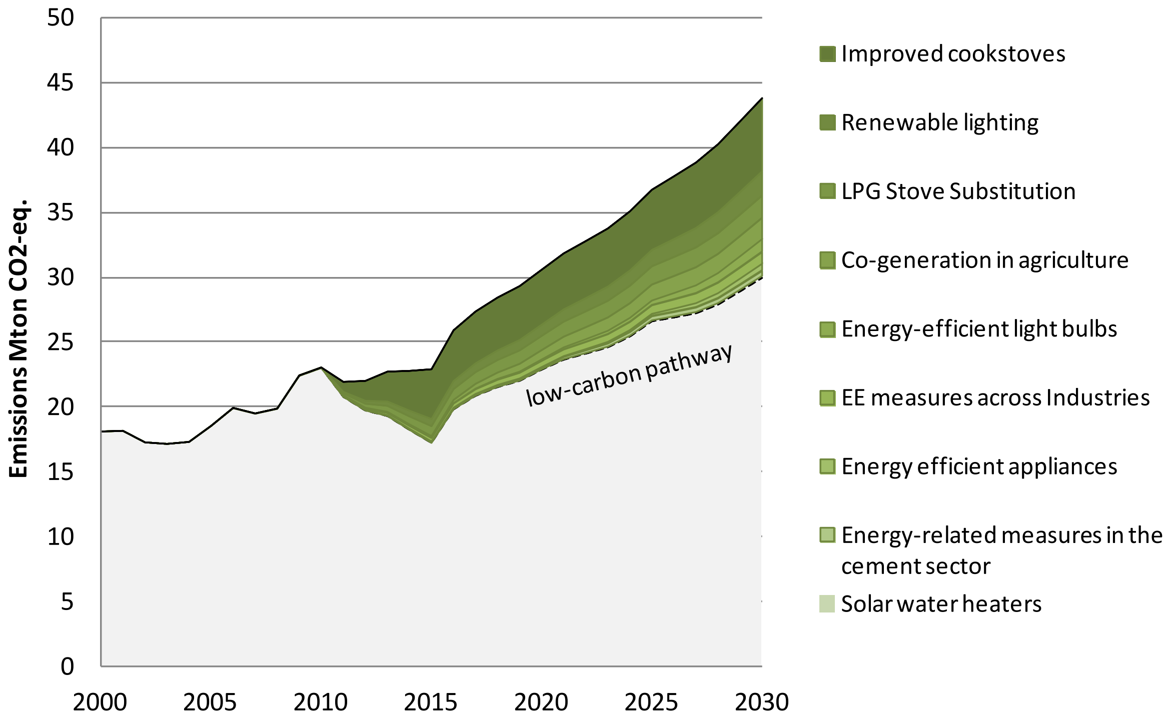


Figure 6.6: Low carbon option mitigation wedges in the energy demand sector (MtCO$_2$e) assuming 35 percent unsustainable woodfuel use



6.6.4 Costs

The aggregated nature of the assumptions related to adoption of the technologies and mitigation potentials translates to high uncertainties for abatement costs. The grouping of several possible low-carbon technologies in one sector, for example grouping energy efficiency across industry, even makes it impossible to quantify costs because the abatement options are spread across a large number of commercial activities.

Table 6.1 below shows the abatement costs, where available, for the options. For most of the options where costs could be calculated, abatement costs are negative. This implies that all of these options should be economically attractive to end-users. Indeed, most options such as the use of renewable lighting technologies and CFLs have very short pay-back times.

Table 6.1: Marginal abatement cost per option as calculated in this study

Low-carbon option	Abatement cost (\$/tCO$_2$e)
Improved cook stoves	-25
LPG stove substitutions	N/A
Renewable lamps replacing kerosene lamps	-230
Solar thermal water heating	N/A
Energy efficient light bulbs	-153
Energy efficient electric appliances	N/A, technology dependant
Energy efficiency improvements across industries	N/A, technology dependant
Emission reductions (energy emissions) in the cement industry	N/A, technology dependant
Co-generation in agriculture (small/large scale)	47 / -18

Note: due to the uncertainties associated with estimating developments in costs of technologies and fossil fuel costs until 2030, the calculation of marginal abatement costs assumes 2012 costs, but 2030 mitigation potentials. Cost should thus be interpreted with a high level of caution. Marginal abatement costs assume a discount rate of 12 percent.

Even if abatement costs are negative, an option does not necessarily happen by itself under a business-as-usual scenario because of barriers. Lack of access to capital for the initial investment and a lack of knowledge could prevent uptake. For a more detailed description of the barriers, please see Section 6.4.7, Feasibility of implementation.

For improved cook stoves, the calculation of abatement costs assumes that charcoal or fuel-wood need to be purchased. If fuelwood is collected, it is likely that the time savings related to the lower time requirements caused by the lower amount of fuel wood required for cooking cannot be monetized. In this situation, marginal abatement costs for improved cook-stoves would be positive, as the higher investment costs for the efficient stove cannot be compensated with any associated cost savings.

6.6.5 Development impacts

Some of the energy demand low-carbon development options have very significant development benefits. Figures 6.7 and 6.8 present an overview of the sustainable development benefits for household and industrial energy demand respectively.

The benefits fall under the following categories:

- Cost savings for households or companies;
- Effects on standard of living and health;
- Energy security; and
- Decreased deforestation.

Cost savings for households or companies

Many of the low-carbon development options in the energy demand sector have the potential to lead to significant cost savings for households and companies. Distributed solar lanterns and energy-efficient light bulbs have the potential to lead to very significant savings in relation to the initial investment costs required for the technology. A family that requires 80 litres of kerosene a year for lighting their home with a kerosene lantern, has (undiscounted) cost savings of about US$53 in the first year, assuming that they buy a solar lantern for US$27 and pay US$1 per litre of petrol, and US$80 in all following years, depending on the lifetime of the solar lantern. Solar thermal water heaters and some of the efficiency improvements in industry have longer payback times on the initial investment required, but can still lead to significant cost savings for the involved households or companies. For improved cookstoves, direct cost savings can only be realized in cases where a household or institution pays for fuelwood or charcoal, rather than collects fuel wood.

Effects on standard of living and health

Improved cookstoves, the use of LPG and distributed renewable lanterns have significant positive impacts on health, as 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. Indoor smoke from cooking with biomass fuels is estimated to cause over 1.5 million premature deaths each year globally. Acute respiratory infections are responsible for nearly one-fifth of child mortality worldwide and poor indoor air quality is recognized as a risk factor for for these infections in children.[25] Illnesses resulting from cooking and lighting fuel are estimated to cause the deaths of more women in rural Kenya than both malaria and tuberculosis.[26] In addition, the use of kerosene lanterns frequently leads to accidents where houses burn down after a lamp falls down or is knocked over.

Renewable lanterns can also raise general standards of living as the light these lanterns give is usually much brighter and better suited for productive uses or for children's homework 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.

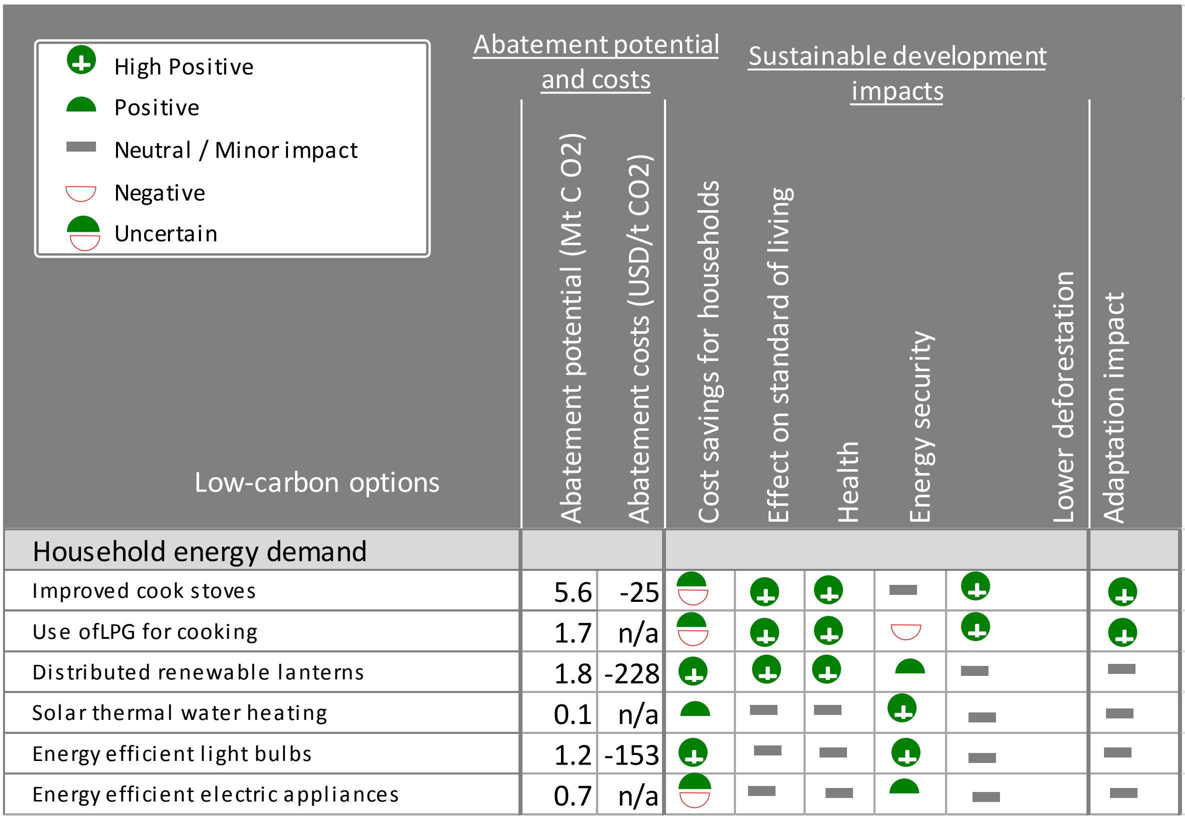
Energy security

The low-carbon development options that decrease electricity use or the need to import fossil fuels improve energy security in Kenya.

Decreased deforestation

Improved cookstoves and substituting woodfuels with LPG stoves has the potential to significantly reduce rates of deforestation. An improved stove with an improved efficiency of 50 percent requires 50 percent less wood fuel and LPG stoves totally mitigate the need for biomass resources. This reduces pressure on the country's wood biomass resources or makes allows the saved woodfuel for other purposes.

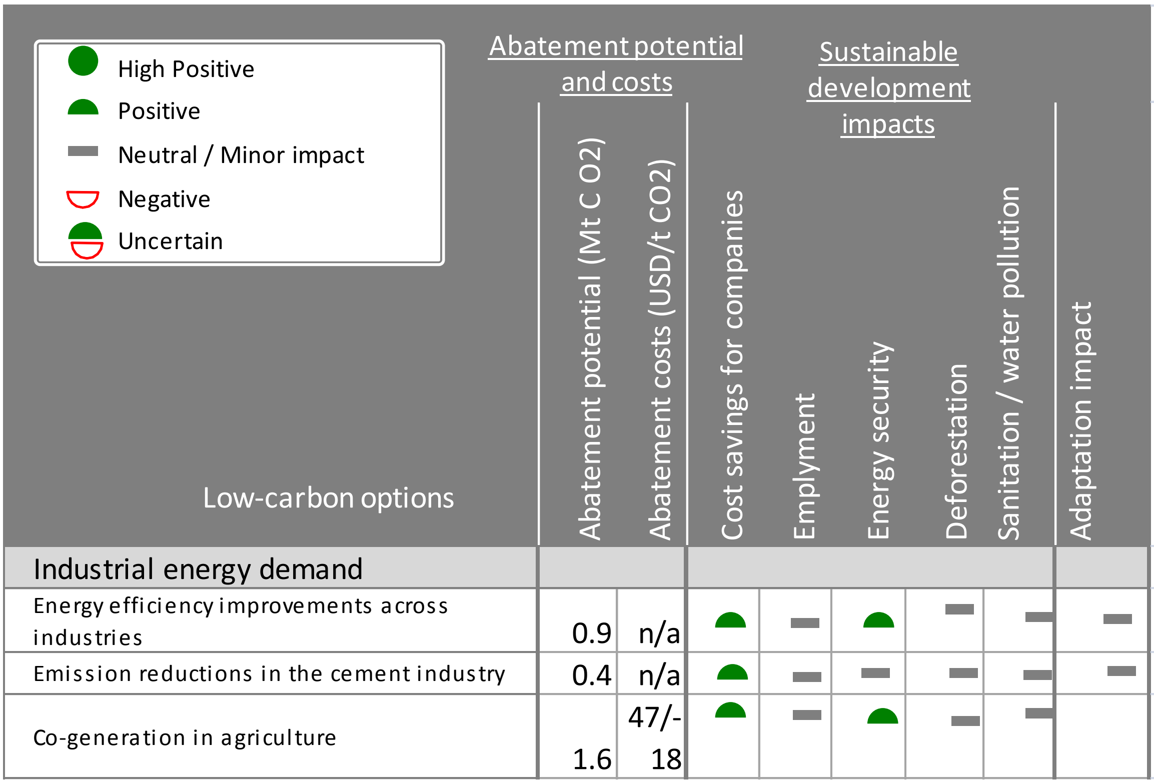
Figure 6.7: Visualization of development impacts of household energy demand options



⊕ High Positive
◠ Positive
▬ Neutral / Minor impact
◡ Negative
◓ Uncertain

Low-carbon options	Abatement potential and costs		Sustainable development impacts					
	Abatement potential (Mt C O2)	Abatement costs (USD/t CO2)	Cost savings for households	Effect on standard of living	Health	Energy security	Lower deforestation	Adaptation impact
Household energy demand								
Improved cook stoves	5.6	-25	◓	⊕	⊕	▬	⊕	⊕
Use ofLPG for cooking	1.7	n/a	◓	⊕	⊕	◡	⊕	⊕
Distributed renewable lanterns	1.8	-228	⊕	⊕	⊕	◠	▬	▬
Solar thermal water heating	0.1	n/a	◠	▬	▬	⊕	▬	▬
Energy efficient light bulbs	1.2	-153	⊕	▬	▬	⊕	▬	▬
Energy efficient electric appliances	0.7	n/a	◓	▬	▬	◠	▬	▬

Figure 6.8: Visualization of development impacts of industrial energy demand options



● High Positive
◠ Positive
▬ Neutral / Minor impact
◡ Negative
◓ Uncertain

Low-carbon options	Abatement potential and costs		Sustainable development impacts					
	Abatement potential (Mt C O2)	Abatement costs (USD/t CO2)	Cost savings for companies	Emplyment	Energy security	Deforestation	Sanitation / water pollution	Adaptation impact
Industrial energy demand								
Energy efficiency improvements across industries	0.9	n/a	◠	▬	◠	▬	▬	▬
Emission reductions in the cement industry	0.4	n/a	◠	▬	▬	▬	▬	▬
Co-generation in agriculture	1.6	47/-18	◠	▬	◠	▬	▬	

6.6.6 Climate resilience impacts of low-carbon options

The abatement options dealt with in this energy demand chapter 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 low-carbon option. For example, continuous drought would have a large impact on the agricultural sector, limiting the available income and biomass necessary for co-generation. Improved cookstoves could be impacted by increased levels of desertification, which would increase pressure on available woodlots.

Two of the options, improved cookstoves and using LPG for cooking, are expected to increase climate resilience as they reduce fuelwood requirements, and thus deforestation. The link between reduced deforestation and increased climate resilience is explained in Chapter 2, Forestry.

6.6.7 Feasibility of implementation

The abatement options for energy demand face several barriers to implementation. These barriers can be related to the option, such as the upfront investment need, technological complexity and operation; or to external factors such as energy costs, the regulatory environment and the national energy policy framework. The main barriers discussed below are:

- Available upfront investment and access to finance;
- Lack of knowledge and understanding of low-carbon options;
- Lack of standardization and enforcement of regulations; and
- Technological or logistical limitations to implementation.

Available upfront investment and access to finance

Although most of the energy efficiency-related options can lead to overall cost savings for energy consumers, both for households and for commercial energy-users; the upfront investment requirements and access to finance pose a major barrier to deployment.

For poor households, even relatively modest investment requirements for a solar lantern or improved cookstove may pose a significant barrier. Often such households have a very low disposable income and no access to loans, even if the purchase of the lantern or cookstove could be used for income generating activities, which would enable repayment of a loan. In situations where households collect fuelwood, rather than purchase wood or charcoal, cooking on LPG also leads to higher operational costs through the purchase of LPG, posing an additional barrier to deployment.

The investment costs of more than $1,000[27] required for the installation of a solar thermal water heater pose a barrier to deployment for urban households. Energy-efficiency improvements and co-generation in agriculture require significant upfront investment. SMEs may have access to loans at attractive interest rates to undertake such investments, especially as the energy savings realised through these options do not always pay back in one to three years. Moreover, SMEs usually do not possess the collateral required by banks.

Lack of knowledge and understanding of low-carbon options

A limited understanding of the benefits of low-carbon options holds back their implementation. There is little understanding among households of the cost savings that more efficient equipment could yield, contribute to by a lack of labelling of appliances and light-bulbs. Industry, especially SMEs, demonstrate limited understanding of the potential for cost-effective energy efficiency improvements. Despite efforts to promote the health benefits (and potential cost savings) of improved stoves), there is no widespread trust in these new technologies. The lack of trust may also be partly related to cultural factors and habits with respect to methods of cooking and differences in the taste of food cooked on traditional versus improved cookstoves.

Lack of standardization and enforcement of regulations

Some low-carbon technologies have suffered setbacks in terms of acceptance and penetration because cheap equipment of sub-standard quality had entered the market. The resulting lack of trust in the new technologies can only slowly be regained. Such incidents have happened with renewable lighting technologies, improved cookstoves and CFLs and often result from a lack of quality standards and enforcement of standards.

Standards and related energy labelling have not yet been developed in Kenya for energy-efficient appliances. For energy-efficient light bulbs to reach 100 percent adoption in 2030, regulations phasing out incandescent bulbs will need to be introduced. Effective enforcement can be challenging.

Other barriers to implementation

For improved cookstoves the informal or unregulated nature of the market does not reflect the true cost of fuelwood or charcoal, and reduces the incentive to adopt new technologies.

Finally, there are technical and logistical limits to the implementation of solar water heaters and agricultural co-generation. Solar water heaters, for example, require access to rooftops to place the heat collector and water reservoir (for passive systems), and investment in the rearrangement of the water system in the building. These features often exclude apartments or businesses established in shared buildings, and households or businesses that do not own the property. For co-generation the necessary investments are only economically viable for larger producers with large amounts of agricultural waste. To include smaller-scale farmers will require a logistical transport network and agreed prices for the feedstock, adding further complexity to the option.

6.7 Potential Policy Measures and Instruments

As discussed in the above section on feasibility of implementation, the policy framework is a crucial element in realising many low-carbon development options. The main instruments that can lead to increased adoption are:

- Regulatory policies and their enforcement;
- Supportive policies and programmes; and
- Capacity building and information.

Regulation would be required to phase out incandescent light bulbs, create a labelling scheme for electrical appliances, and provide standards and codes for the use of solar water heating. The ability of these regulations to be enforced is critical to their success. The difficulty in enforcing the regulation on solar water heating is an example of the challenges encountered in policy enforcement.

For the deployment of other options, supportive policies and programmes can be very valuable, especially if these facilitate access to capital. Steps could be taken to use the energy audits generated over the last decade in large- and medium-sized commercial and industrial facilities in Kenya to identify concrete low-cost follow-up actions for larger end-users. These end-uses could be supported with access to capital and technical assistance in implementing the required investments. Such an approach is currently successfully implemented by the Regional Technical Assistance Program aimed at providing support for the financing of selected investments in renewable energy and energy efficiency projects, especially in the agricultural and hospitality sectors. AFD and the Kenya Association of Manufacturers implement the program and funds totalling Ksh 3.3 billion are available through CFC Stanbic and Co-op banks.[28] The program not only provides loans but also carries out audits that help commercial end-users identify energy efficiency options.

Capacity building and information is necessary to provide users with the knowledge to identify efficiency opportunities. Appliance labelling is an example of a measure that provides users with the energy performance of appliances on an annual basis, and can lead to increased adoption of efficient appliances. Further technical capacity building for the commercial sector on energy management also leads to increased identification of efficiency options, and is often facilitated by industry associations.

6.8 Conclusion

The analysis in this report demonstrates how low-carbon development options related to energy demand in Kenya can lower GHG emissions compared to a reference case. In addition, all of the analysed low-carbon development options have substantial sustainable development benefits, and can help contribute to Kenya's development goals.

A few options stand out as potential priority actions. **Improved cookstoves and the use of LPG for cooking increase climate resilience due to lower fuelwood requirements and decreased pressure on forests.** The use of LPG and improved fuelwood and charcoal stoves for cooking have significant health benefits because reduced indoor air pollution decreases the incidence of respiratory diseases. Moreover, both options can lead to cost savings, depending on whether fuelwood is collected or purchased, and the price for LPG. **Similarly, the replacement of kerosene lamps through distributed renewable lanterns, such as solar lanterns, can lead to large cost savings for households not connected to the electricity grid and significant health and safety benefits as the indoor burning of kerosene becomes obsolete**. These three options were mentioned as important in the county consultations, and confirmed as potential priorities in stakeholder consultations.

Annex 1: Low-Carbon Development Option Fact Sheets

Improved Cookstoves

In Kenya, biomass from wood sources accounts for 77 percent of all primary energy demand, excluding electricity and transport fuels, and is by far the most dominant fuel source. Cooking is primarily based on wood fuels in the form of fuelwood or charcoal. Improved cookstoves are characterized by higher fuel efficiency, which results in less time required to gather wood or in cost savings when fuelwood or charcoal are purchased, as well as in lower indoor air pollution.

The Kenyan Ceramic Jiko stove is an example of an improved cookstove using charcoal and is among the most widely used improved cookstoves models.

Current situation: Simple cookstoves currently dominate, and in rural areas open three-stone fires are predominantly used. These cookstoves produce considerable negative environmental, social and health effects due to the incomplete combustion of feedstock. This leads to indoor air pollution with carbon monoxide, methane, particulate matter and nitrous oxide emissions causing severe respiratory damage especially amongst women and children.[29]

Low-carbon scenario: The low-carbon scenario assumes that by 2030 a 100 percent penetration of improved cookstoves with 50 percent efficiency improvement over today's equipment will be achieved.[30]

Development benefits and priorities

Development benefits:

- Reduces the amount of feedstock required, saving time (to collect firewood) or income (to buy charcoal).
- Reduces indoor air pollution.
- Potentially creates additional employment opportunities through stove manufacturing.
- Reduces the pressure on woodlots.

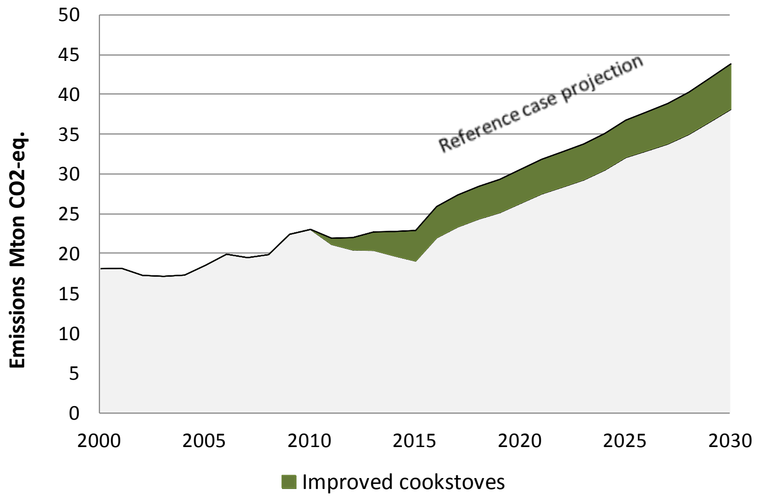
Alignment with Government of Kenya priorities: The overreliance on wood fuel is specifically mentioned as a challenge the country faces in Vision 2030, which is reiterated in the Ministry of Energy's Scaling Up Renewable Energy Plan.

Links to adaptation: Not directly affected by climate change, but indirectly, increased levels of desertification could place even higher pressures on available woodlots, forcing a shift to a substitute fuel. The use of improved cookstoves increases climate resilience as it decreases pressure on forests.

Abatement potential and costs

Greenhouse gas abatement: Assuming that 35 percent of the feedstock is non-renewable, a total abatement potential of 5.6 $MtCO_2$/year in 2030 could be realised.

Costs: The unit costs of mitigation are expected to be favourable, with a marginal abatement cost of US$-24 /$tCO_2$, assuming upfront investment cost of US$ 20 for the improved stove.



Scenario	2010	2015	2020	2025	2030
Adoption rate	40%	60%	70%	80%	100%
Abatement potential ($ktCO_2e$)	-	3.835	4.237	4.639	5.642

Feasibility of implementation

The required upfront investment for the improved stoves poses a barrier to deployment of improved stoves. Additional barriers include the lack of standardization of stoves, which has led to the sale of low-quality products in the past. In addition, there is a lack of regulation in the fuelwood sector. It is especially the latter that will need to be tackled as the informal or unregulated nature of the market means that the true cost of fuelwood or charcoal is not reflected in the price. This reduces the stimulation for efficient behaviour. Cultural issues may also play a role in limiting the uptake of efficient cookstoves, as improved stoves may not reflect cultural preferences for how the cooking is done.

LPG Stove Substitution

Support for an increase in the adoption of LPG cookstoves can contribute to the reduction of woody biomass used and mitigate almost all the negative health effects related to indoor air pollution.

Current situation: Cookstoves using fuelwood or charcoal currently dominate, and in rural areas open ‘three stone’ fires are predominantly used. The use of these cookstoves produces considerable negative environmental, social and health effects due to the incomplete combustion of feedstock. This leads to increased carbon monoxide, methane, particulate matter and nitrous oxide emissions causing severe respiratory damage especially amongst women and children.[31]

Low-carbon scenario: The low-carbon scenario assumes that by 2030 a 50 percent penetration of LPG cookstoves with a 30 percent emission reduction over 2012 equipment will be achieved.[32]

Development benefits and priorities

Development benefits:

- Reduces pressures on forests and woodlots.
- Almost completely reduces the emission of particulate matter, methane and carbon monoxide.
- Can lead to further employment opportunities through LPG handling and distribution activities.

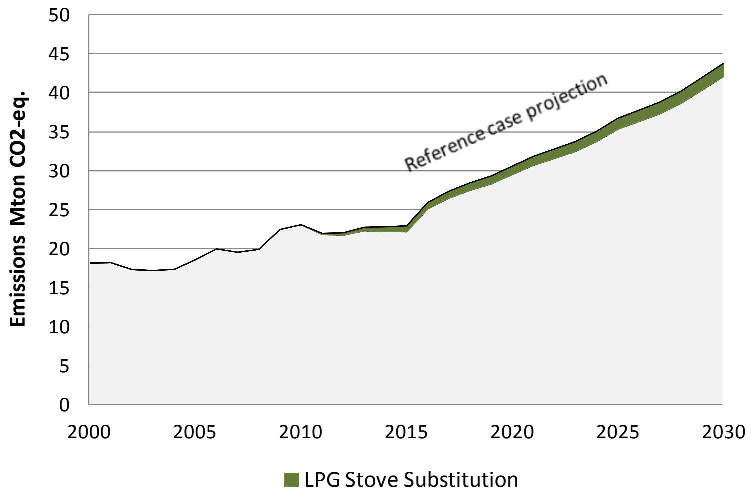
Alignment with Government of Kenya priorities: The overreliance on wood fuel is specifically mentioned as a challenge the country faces. (Vision2030, SREP). Furthermore, Kenya is aiming to build a LPG handling and distribution facility for this purpose.

Links to adaptation: Not directly affected by climate change.

Abatement potential and costs

Greenhouse gas abatement: Assuming 35 percent of the feedstock is non-renewable the low carbon scenario indicates a total abatement potential of 1.7 $MtCO_2$/year in 2030. Note: this wedge includes emissions from biomass of which 35 percent is non-renewable.

Costs: Not available.



Scenario	2010	2015	2020	2025	2030
Adoption rate	-	20%	30%	40%	50%
Abatement potential ($ktCO_2e$)	-	767	1,089	1,392	1,693

Feasibility of implementation

Barriers are the availability of upfront investment for poorer rural communities, and the need to regulate the fuelwood sector in order for LPG to be competitive without over subsidizing the costs to users. Distribution is also a key issue, as it is likely that urban areas are far more easily reached than remote rural areas.

Renewable Lamps Replacing Kerosene Lamps

Distributed renewable lanterns can provide a cost-efficient and practical alternative to kerosene-fire lamps in non-electrified, off-grid areas. In contrast to larger solar PV systems, such lighting systems are stand-alone rechargeable electric lighting appliances and can be installed by a typical user without having to rely on the services of a technician.[33] The most common distributed renewable lamps are solar lanterns, but there are also other alternatives, such as efficient LED lights powered by a stationary bicycle.[34]

Current situation: Kerosene is the ubiquitous fuel used for lighting in off-grid rural communities. Kerosene leads to high indoor air pollution when used in simple lamps as well as to an increased risk of burns, fires and poisoning from the fumes produced.[35,36] Kenya – being a net fossil fuel importer – also experiences negative macroeconomic effects related to foreign exchange and balance of trade, from the import of kerosene.

Low-carbon scenario: The low-carbon scenario assumes that by 2030 all kerosene lamps will be replaced by distributed renewable lanterns.

Development benefits and priorities

Development benefits:

- Improved energy security through lowered kerosene imports.
- Reduced household expenditure on energy.
- Reduced indoor air pollution and thus positive health impacts, lowering the incidence of chronic illnesses
- Improved safety by reducing the risk of domestic fires. (Note that kerosene lamps lead to frequent accidents when lamps topple, often burning down houses.)
- Renewable lanterns can support income-generating activities, for example through extension of productive hours. Moreover, they may have a positive effect on education since proper lighting means that children can spend more time learning.
- Some renewable lanterns can also provide power to mobile devices.

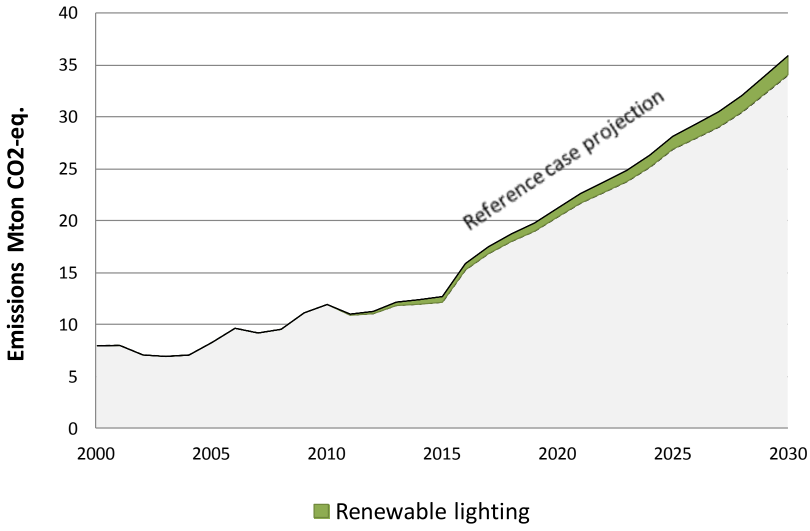
Alignment with Government of Kenya priorities: There are various government- and donor-initiated programmes supporting the replacement of kerosene lanterns.

Links to adaptation: Neither renewable lanterns, nor the kerosene it displaces have obvious exposure to climate variability and little impact on increasing climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Light powered by renewable energy sources can replace the emissions from simple kerosene lamps. On this basis, the mitigation potential is in the order of 1.8 $MtCO_2$/year in 2030. (Note that in the graph on the right hand side “total energy emissions after implementation of low-carbon option” does not take into consideration unsustainable biomass use.)

Costs: Marginal abatement costs are highly negative US$ -228 /tCO_2, assuming that investment costs for a solar lantern are US$ 27.5, with a lifetime of five years, and yearly energy cost savings of US$80 (equivalent to using 80 litres of kerosene/year). Payback times of the initial investment are very short (less than six months).



Scenario	**2010**	**2015**	**2020**	**2025**	**2030**
Penetration rate	-	50%	65%	80%	100%
Abatement potential (ktCO_2e)	-	550	845	1,231	1,822

Feasibility of implementation

Barriers include the lack of standardization, which can lead to the performance of LED bulb and the solar PV panel being less than that stated by the manufacturer and breaking faster.[37] Such incidences have led to a decrease in the trust in the technology in Kenya. In addition, the upfront investment costs for a renewable lantern may be a barrier to poor households in spite of the significant cost savings that can be achieved over the lifetime of the equipment. Access to the technology in remote locations may be another barrier to deployment.

Solar Thermal Water Heating

Solar thermal water heating systems can be used to provide hot water for domestic or industrial uses. For *domestic uses,* solar thermal water heating systems are generally installed on the roof of a house. The installation includes solar collectors that can either be flat plates or evacuated tubes (which have efficiencies of 30 percent and 40 percent, respectively). The solar collectors are coupled to a storage tank to provide hot water.[38]

Current situation: With an average solar radiance of 4.5 KWh/m^2/day and fairly constant temperatures, Kenya can take advantage of the benefits of solar water heating. Currently, there is a trend in many Kenyan households to use direct electric devices with heating elements between 2.5 and 5 KW for heating water for the use in showers.[39] Solar water heaters are currently available in Kenya and are primarily being used by larger hotels, as their large demand for hot water warrants the solar water heater's relatively high upfront cost.

Low-carbon scenario: The penetration of solar thermal water heating systems is assumed to increase by 5percent a year, reaching 20 percent in 2030.

Development benefits and priorities

Development benefits:

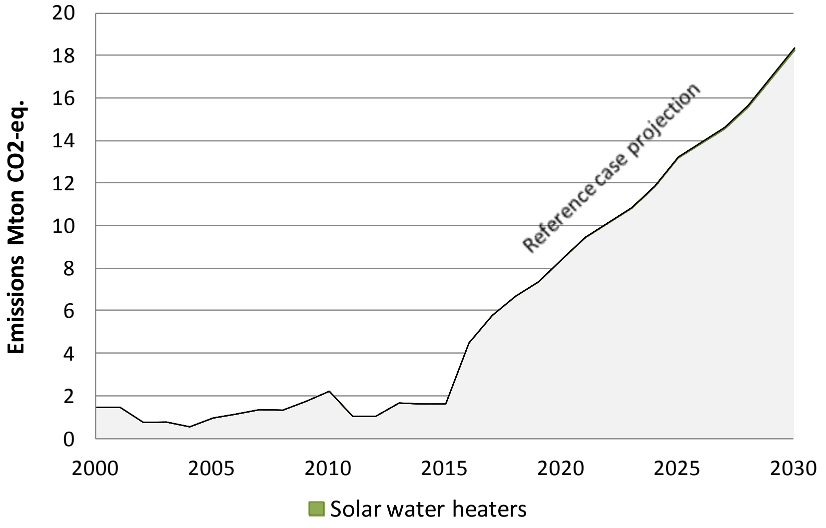
- Improved energy security through lower oil/coal imports (related to electricity generation).
- Cost savings to households and the commercial sector, especially hotels.
- Reduced peak load electricity demand.

Alignment with GoK priorities: Vision 2030 states that Kenya should increase electricity generation as well as efficiency in energy consumption. The Kenya Solar Water Heating Regulations issued by the Ministry of Energy mandate the installation and use of a solar water heating systems for all buildings with hot water requirements of more than 100 litres a day.[40]

Links to adaptation: not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Solar water heaters reduce electricity consumption. It is assumed that the solar thermal water heating systems would be used without fossil-fuel based or electricity-run back-up systems. On this basis the mitigation potential is in the order of 115 $ktCO_2$/year in 2030. (Note that the abatement potential is sensitive to the assumption of how much electricity is being used for water heating in Kenya today and in 2030. The percentage of electricity used for water heating is based on assumptions in a 2010 study by the Kenya Institute for Public Policy Research and Analysis.[41]



Costs: Currently, costs of a typical 100-litre Solar Water Heating System in Kenya are about US$1,500,[42] which renders them unaffordable for many households.

Scenario	2010	2015	2020	2025	2030
Penetration rate	-	5%	10%	15%	20%
Abatement potential (ktCO_2e)	-	2	16	47	115

Feasibility of implementation

Solar water heaters have high upfront investment costs (including the cost to rearrange the water system in the building) and require access to rooftops to place the heat collector and water reservoir (for passive systems). These barriers mean that the use of solar water heaters is not feasible in apartments or businesses established in shared buildings, and households or businesses that do not own the property.

Energy Efficient Light Bulbs

Compact Fluorescent Lamp (CFL) light bulbs provide an energy efficient alternative to traditional Tungsten filament light bulbs.

Current situation: Replacing incandescent bulbs with CFLs decreases energy consumption by 80 percent per bulb, and CFL bulbs last roughly ten times longer. In Kenya there is no detailed data on the current uptake of CFL, but it can be safely assumed that, especially in urban areas, the penetration rates are relatively high already. Incandescent light bulbs may be prominent in rural areas, but the low level of rural electrification limits the potential for large energy savings.

Low-carbon scenario: It is assumed that by phasing out incandescent bulbs, an adoption rate of 100 percent will be achieved in 2030.

Development benefits and priorities

Development impacts:

- Improved energy security through lower fossil fuel imports (related to electricity generation).
- Cost savings for households due to reduction in electricity use.
- Most CFLs in use today contain mercury vapour that has negative environmental impacts when old CFLs are not disposed of properly. Large-scale use of CFLs should be accompanied by a proper waste recovery programme. This may pose a challenge in developing countries.[43]

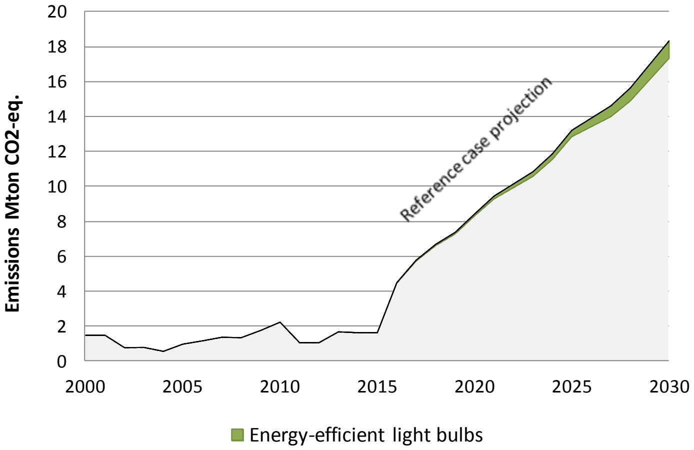
Alignment with Government of Kenya priorities: Efficient energy use is a stated goal of Vision 2030.

Links to adaptation: Not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Reduces emissions from electricity generation. On this basis the mitigation potential is in the order of 1,000 ktCO$_2$/year in 2030.

Costs: Energy efficient light bulbs have negative abatement costs of US$ -153 /tCO$_2$ (assuming costs for an efficient light bulb of US$4 and a 12 percent discount rate). Marginal abatement cost would decrease further with further fall in costs. Under these assumptions, payback times for households are short (less than a year).



Scenario	2010	2015	2020	2025	2030
Penetration rate	-	25%	50%	75%	100%
Abatement potential (ktCO$_2$e)	-	11	112	366	1,000

Feasibility of implementation

Barriers include the lack of standardization and labelling, which reduce the awareness of the cost savings that more efficient equipment could yield among households. A regulation to phase out incandescent bulbs will need to be enforced in order to realize the low-carbon scenario above.

Energy Efficient Appliances

Large differences exist in the energy efficiency of electric appliances. Over the past two decades, there have been major improvements in the energy performance of most appliances. In the United States, for example, refrigerators in 2012 use about 60 percent less energy than 20-year old models.[44] In Mexico, refrigerators sold between 1995 and 2000 were estimated to consume 30 percent more electricity than those of the same size sold between 2001 and 2007.[45] In developing countries, energy efficiency of electric appliances is often lower than in developed countries, especially if there is a significant market for second hand inefficient models or if efficient models are not available or significantly more expensive. Second hand, energy inefficient refrigerators from Europe have traditionally been exported in large numbers to Africa.

Current situation: Replacing appliances such as refrigerators, air conditioners and televisions in households and commercial facilities with more modern efficient units can lead to substantial energy savings. The high prices of new appliances in Kenya, combined with the large influx of older cheaper second-hand appliances from the EU, mean it often unattractive to purchase new models.

Low-carbon scenario: The low carbon scenario assumes that by 2030, electricity consumption from appliances could be reduced by 30 percent through a combination of standards, labelling programmes and support for the phasing out of very inefficient appliances, especially inefficient refrigerators.

Development benefits and priorities

Development benefits:
- Improved energy security through lower fossil fuel imports (related to electricity generation).
- Cost savings to households.

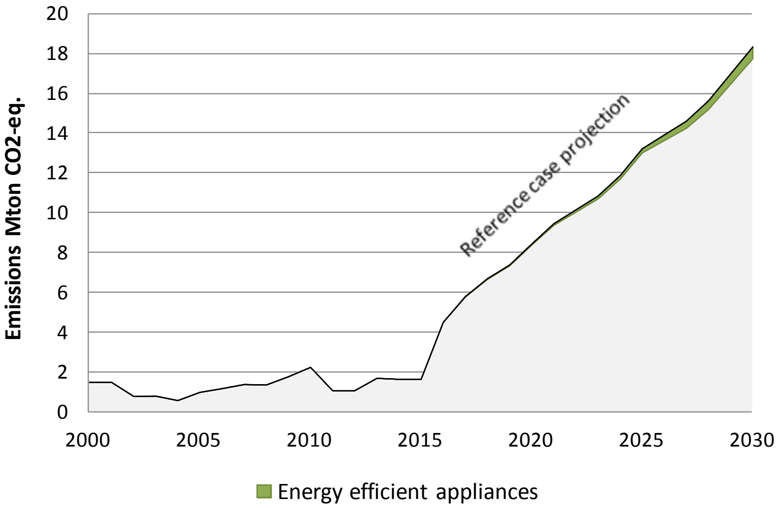
Alignment with Government of Kenya priorities: Efficient energy use is a stated goal of Vision 2030.

Links to adaptation: Not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Reduces emissions from electricity generation. On this basis the mitigation potential is in the order of 590 $ktCO_2$/year in 2030.

Costs: Not available due to the variety of equipment falling under this low-carbon option including different sizes and types of refrigerators, televisions and air conditioners.



Scenario	2010	2015	2020	2025	2030
Improvement in the energy efficiency of electric appliances	-	5%	10%	20%	30%
Abatement potential ($ktCO_2e$)	-	6	54	213	590

Feasibility of implementation

There may be large differences between the upfront costs for energy-efficient and less-efficient appliances, especially when second-hand equipment is considered. Payback times for the additional upfront investment are generally longer than a year. The lack of labelling means that consumers are not informed about the possible cost savings associated with choosing newer and more efficient products.

Energy Efficiency Improvements across Industries

Current situation: The industrial and commercial sector in Kenya is dominated by SMEs 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. Low-carbon options exist for each subsector, such as motors with variable speed drives, more efficient boilers and general improvements in energy demand management. Results from energy audits undertaken in different commercial and industrial facilities in Kenya show that there is a clear perspective 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 eight percent (for a tourist resort) and 26 percent (for a tea factory) could be achieved. Fuel efficiency improvements of more than nine percent 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.[46] If longer payback times of up to five years would be acceptable, the level of savings would be significantly higher.

Low-carbon scenario: A conservative assumption of improving the energy efficiency by 15 percent by 2030 was used for this option.

Development benefits and priorities

Development benefits:

- Reduced energy cost in commercial and industrial facilities.
- Improved energy security through lower fossil fuel imports (related to electricity generation).
- Decouple economic growth and energy consumption.

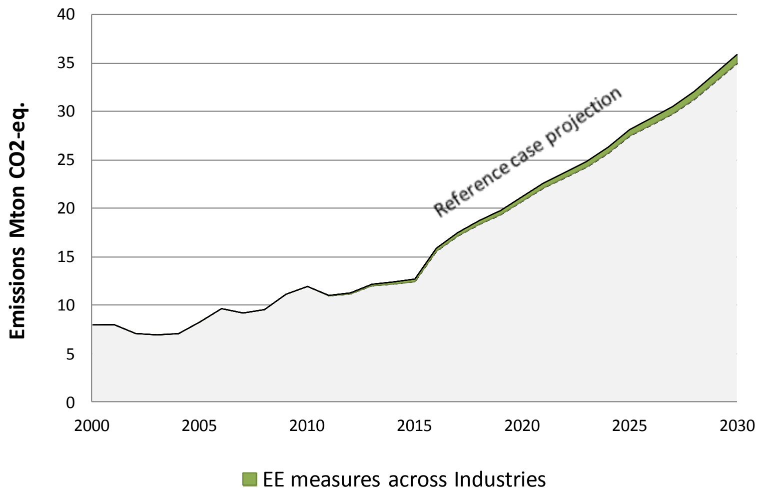
Alignment with Government of Kenya priorities: Efficient energy use is a stated goal of Vision 2030. A modern and efficient industry can provide the basis for economic growth.

Links to adaptation: Not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Reduces emissions from electricity and fuel consumption. On this basis the mitigation potential is in the order of 898 $ktCO_2$/year in 2030. (Note that in the graph on the right hand side “total energy emissions after implementation of low-carbon option” does not take into consideration unsustainable biomass use.)

Costs: Technology and sector dependent, hence not available on a general level. The description under “current situation” gives an indication of payback times encountered in different sectors in Kenya.



Scenario	2010	2015	2020	2025	2030
Efficiency improvement	-	10%	10%	15%	15%
Abatement potential ($ktCO_2e$)		278	472	657	898

Feasibility of implementation

Access to finance for these options is an issue for this sector dominated by SMEs. Banks prefer providing loans to larger enterprises with high collateral demands or engaging in short-term consumer lending, for example, for the purchase of private vehicles, where high interest rates are charged. SMEs often have difficulty meeting such demands. National adoption of a ‘soft’ loan in combination with audits and technical training could provide the necessary stimulus to increase the adoption rate of energy efficient technology.

Emission Reductions (Energy Emissions) in the Cement Industry

Current situation: The cement industry is the largest single emitting industry in Kenya. This option looks at the reduction of energy-related emissions by introducing, high efficiency motors and drives, variable speed drives, high efficiency classifiers, efficient grinding technologies and a limited amount of emission improvements by fuel switching.

Low-carbon scenario: The assumption, 10 percent improvement in the emissions intensity (only energy related emissions) per tonne of cement produced by 2030 was used for this option.

Development benefits and priorities

Development benefits:

- Reduced energy cost in commercial and industrial facilities.
- Improved energy security through lower oil/coal imports (related to electricity generation).
- Decouples economic growth and energy consumption.

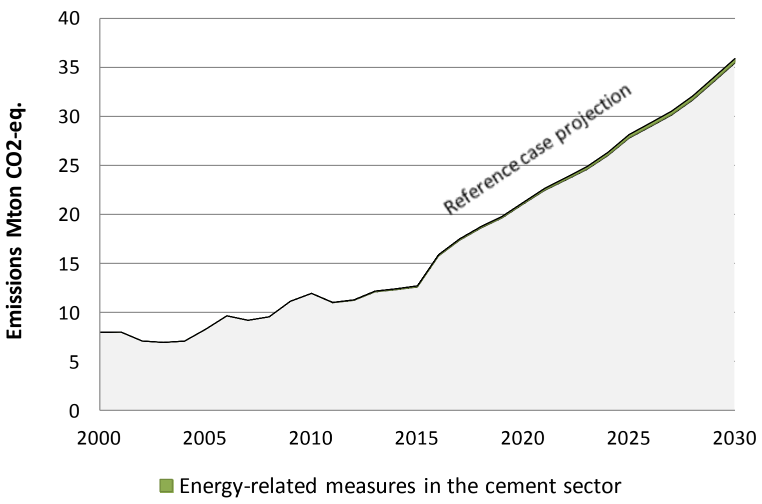
Alignment with Government of Kenya priorities: Efficient energy use is a stated goal of Vision 2030. A modern and efficient industry can provide the basis for economic growth.

Links to adaptation: Not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Reduces energy-demand related emissions. On this basis the mitigation potential is in the order of 381 ktCO$_2$/year in 2030. (Note that in the graph on the right hand side "total energy emissions after implementation of low-carbon option" does not take into consideration unsustainable biomass use.)

Costs: Not available.



Scenario	2010	2015	2020	2025	2030
Improvement in energy-related emissions intensities	-	5%	5%	10%	10%
Abatement potential (ktCO$_2$e)	-	105	128	312	381

Feasibility of implementation

This is quite an ambitious assumption and would require any new cement manufacturing capacity becoming operational until 2030 to deploy best-available technologies and operating them according to best practices. To mitigate emissions beyond this figure would require a large-scale fuel switch from heavy fuel oil to renewable biomass or waste to heat the kiln. The most recent developments in the Kenyan cement sector show coal as a preferred substitute to lower prices, but this would increase emissions. Regulation and standards could demand manufacturers to adhere to lower emissions, but it may damage competitiveness.

Cogeneration in Agriculture

Cogeneration, also known as "combined heat and power" is the simultaneous production of heat (usually in the form of hot water or steam) and power, through utilizing one primary fuel. Biogas is a gaseous mixture that is predominantly methane that is generated during anaerobic digestion processes using wastewater, solid waste (for example, at landfills), organic waste (for example, animal manure) and other sources of biomass.[47] This mitigation option considers the production of biogas from agricultural residues. This biogas can be used as a source of energy, both in small-scale rural applications (such as cooking) and industrial-scale applications such as the generation of electricity and heat. The low-carbon option in consideration focuses on industrial- scale applications, and in particular cogeneration using biogas.

Current situation: Cogeneration is already deployed in agro-industries in Kenya, especially in the sugar industry. However, the full potential of the technology is not yet exploited.

Low-carbon scenario: The low-carbon scenario assumes that the mean potential from Fischer *et al*. is utilised in 2020 (42 MW), which increases to 80MW by 2030.[48] This is a relatively ambitious assumption, as it is 50 percent higher than the estimated maximum potential in 2012. However, agricultural output is assumed to have grown to cover this by 2030. It is also assumed that 25 percent of installed capacity is small scale and 75 percent is large (as per the 'industrial' scenario of the GIZ study).[49] In addition, it is assumed that there will be an additional 100 MW of bagasse-based cogeneration by 2030. In total, it is assumed that 187 MW of additional cogeneration plants are in place by 2030.

Development benefits and priorities

Development benefits:

- Reduced energy cost in commercial and industrial facilities.
- Improved energy security through lower oil/coal imports.
- Decouples economic growth and energy consumption.

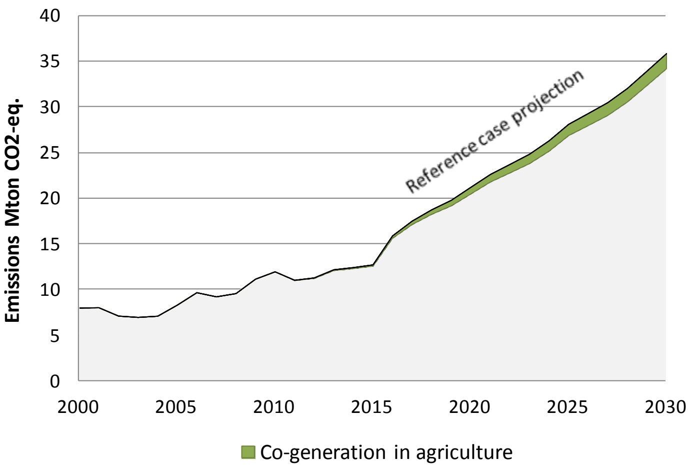
Alignment with Government of Kenya priorities: Efficient energy use is a stated goal of Vision 2030. A modern and efficient industry can provide the basis for economic growth.

Links to adaptation: Not affected by climate change / little impact on improving climate resilience.

Abatement potential and costs

Greenhouse gas abatement: Reduces energy-demand related emissions. On this basis the mitigation potential is in the order of 381 $ktCO_2$/year in 2030. (Note that in the graph on the right hand side "total energy emissions after implementation of low-carbon option" does not take into consideration unsustainable biomass use.)

Costs: Marginal abatement costs taken from Fischer (2010) are US $42 /$tCO_2$ for small-scale applications and US$ -15 /tCO_2 for large-scale applications in 2030.[50]



Scenario	2010	2015	2020	2025	2030
MW installed (in addition to the reference case)	-	15	82	140	187
Abatement potential ($ktCO_2$-eq)		132	720	1,229	1,641

Feasibility of implementation

Requires significant up-front investments. Cogeneration is most economical when there is demand for the full heat and electricity production. Ideally, electricity can be fed into the grid.

Endnotes

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