4) Low Carbon Growth Options in Kenya

Kenya is already implementing a range of lower carbon technologies, either because it makes existing economic sense to do so ('best technology'): reductions in GHG emissions could be considered a co-benefit, or because carbon finance is available for investing in such options. In this section of the report, an overview of the low carbon options being taken up, or potentially available, is presented, along with case studies. Information on the costs of the options is drawn from case studies or the wider literature.

Box 3. Low carbon options for Kenya

Early potential actions to reduce GHG emissions have been identified in Kenya's First National Communication (FNC, GoK 2002) and the Technology Needs Assessment (TNA, GoK 2005). The 1stNC was published in 2002. An update of relevant measures is likely to be provided in the Second National Communication, currently being compiled although not yet available. The1stNC lists a range of low carbon measures that are not explicitly focused at emission reductions but do reduce greenhouse gases. It also discusses planned measures that may not yet have been implemented.

The TNA entails the identification and evaluation of technical options. From a climate change and developmental perspective, TNA prioritises technologies, practices and policy reforms that can be implemented in different sectors of a country to reduce greenhouse gas emissions and/or to adapt to the impacts of climate change by enhancing resilience and/or contributing to sustainable development goals (Gross et al. 2004).

Gross et al (2004) state that countries may wish to take into account two distinct types of technology transfer and development opportunity:
'Win win' options that deliver both climate and other development objectives, which are available at low (even negative) costs. Special attention may need to be given to indigenous and soft (non-technical) technologies, which often represent a solution to local needs at low costs.
In the longer term, new options will become available and the relative merits and economics of different technologies and developments in different sectors may change. Technologies that are not currently 'win win' but offer particular promise for addressing climate change and other development goals in the longer term may need to be explored.

Both types of option are considered in this section of the report.

Electricity generation sector

If the LCPDP is implemented, Kenya will remain a fairly low carbon intensity system, though the gains in the next decade may start to reverse post 2020 (see previous chapter). Electrification plans will also result in a lower carbon household sector, as urban and rural electricity displaces firewood and charcoal. However, opportunities do still exist, particularly for renewables and for decentralized power generation.

There are many existing examples of low carbon options that are being implemented in this sector (as reflected in the LCPDP). Such projects are being implemented through government efforts, state corporations, NGOs and research institutions. Some of them have been developed specifically as carbon offset projects, while others are targeted at local energy needs or to meet certain development goals with carbon emission reductions as a secondary benefit.

A number of organisations are advancing low carbon technologies.

- The Kenya Electricity Generation Company (KenGen) is implementing a number of hydro, geothermal, thermal and wind power projects. Some of these projects are undergoing validation for registration under CDM carbon finance.
- Kenya Industrial Research and Development Institute (KIRDI) is a government-sponsored research body that is also developing energy efficiency as well as renewable energy projects.
- NGOs like Practical Action and GTZ are or have implemented low carbon technologies including improved biomass cookstoves and biogas.
- The Ministry of Energy has also, under its short term strategic plan, initiated a project that will see development of solar and wind technologies in various ASAL regions of Kenya.
- ICRAF (International Centre for Research in Agroforestry) is undertaking pilot projects to create carbon sinks through agroforestry projects.
- Private industries are also involved in low carbon technology. For example, Lafarge East Africa is implementing a fuel-switching project at its Bamburi factory, where the company has initiated a biofuel plantation on degraded quarry land to rehabilitate the land as well as substitute a percentage of fossil fuels used in the Kilns.

A National Task Force on Accelerated Development of Green Energy has also been proposed, and is in the process of being set-up. In this Campaign, the Government would offer attractive financing, strong fiscal incentives and/or equity investment to eligible private sector establishments to facilitate further development of renewable central generation projects (e.g. wind, geothermal), lower carbon captive generation in key industries and increased penetration of lower carbon energy using devices e.g. energy saving light bulbs.

The potential for various low carbon technologies are discussed in the following sections.

Hydropower

Hydropower plays and will continue to play a crucial role in the provision of electricity to the centralised distribution system in Kenya. The contribution of hydro in the current generation mix is the main reason that Kenya has a relatively low carbon intensity system. Hydro also has an important role to play as a decentralized or mini-grid technology.

There are three potential CDM large-scale hydro projects in Kenya (included in the LCPDP), managed by Kenya's power generator, KenGen, at the validation stage. These projects will result in emission reductions by avoiding CO_2 emissions from electricity generation by fossil fuel power plants, and will generate carbon credits for sale. The projects (with proposed funding by World Bank carbon financing through Community Development Carbon Fund in the case of Kiambere and Tana[29]) include:

- Sondu Miriu Hydro power Project (expected savings of 211,068 tonnes CO_2 eq. per annum)
- Kiambere Hydro Power Project. Expected increase in output of 20 MW with an estimated annual incremental generation of 60 GWh (and expected savings of 38,376 tonnes CO_2 eq. per annum)
- Redevelopment of Tana Hydro Power Project. Increase generation by 71.5 GWh per year (leading to expected savings of 42,258 tonnes CO_2 eq per annum)

[29] World Bank Carbon Finance site, http://wbcarbonfinance.org/Router.cfm?Page=CDCF&FID=9709&ItemID=9709&ft=Projects&ProjID=35854

Implementation of planned projects will see hydro capacity increase to over 800 MW. The Kenyan ministry of energy puts total hydro potential at 6000 MW, half of which is small-scale (<10 MW) run-of-the-river potential (GoK 2006). Small scale hydro can be successfully implemented, as illustrated by the widely cited example of Tungu-Kabri micro-hydro power project, described in Case study 1 below.

Kenya Tea Development Agency (KTDA) has also carried out several pre-feasibility studies in tea-growing zones, and through support from the Ministry of Energy carried out detailed feasibility study in 12 hydropower sites selected from the ones where pre-feasibility study had been done.

Case Study 1. Tungu-Kabri micro-hydro power project, Mt Kenya Region

Funder: UNDP
Implementation by: Practical Action / Kenyan Ministry of Environment

This is a small scale run-of-river hydro project providing clean electricity to village to meet variety of energy needs. It has the following characteristics:

Capacity: 18kW
Cost: US$3,495 per kW installed (costs of labour for construction can be saved by engaging local population). As demonstrated in later sections of the report, the costs of micro-hydro are lower than equivalent diesel generation (and hence more cost-effective in mitigation terms)
Households Served: 400 (3000 people)
Application: micro-enterprises (especially agro-processing), health, indoor lighting. Sector: commercial (agro-processing), residential

Benefits include:
Very cheap electricity once built (with low maintenance costs); skills to operate / maintain learnt by villagers who were involved in construction
Income provision through energy for micro-enterprises
Reduced use of fuelwood and local deforestation
Reduced use of kerosene for lighting
Economic time saved through reduced fuel gathering
Health risks from indoor air pollution (associated with biomass) reduced

Issues with implementation:
Requires drought resilient water source

Scale-up potential
UNDP (2006) indicate potential beneficiaries of this technology of 100,000 people, which approximates to about 110 schemes (at $90,000 each)

Source: Practical Action website, http://www.practicalaction.org/?id=micro_hydro

Wind power

The Kenyan Ministry of Energy in collaboration with UNDP and other partners produced a National Wind Atlas in 2001, which has since been improved to a high resolution Wind Atlas. This Atlas shows good wind regimes for power generation in the country. The areas identified to have high potential for wind energy generation are Marsabit, Ngong, and the Coastal region. The ministry has installed 20 wind masts and data loggers to enable collection of wind data to augment the wind atlas. Wind speeds in different areas of Kenya are shown in Figure 17 below, showing the best resource to be in the northern Marsabit region.

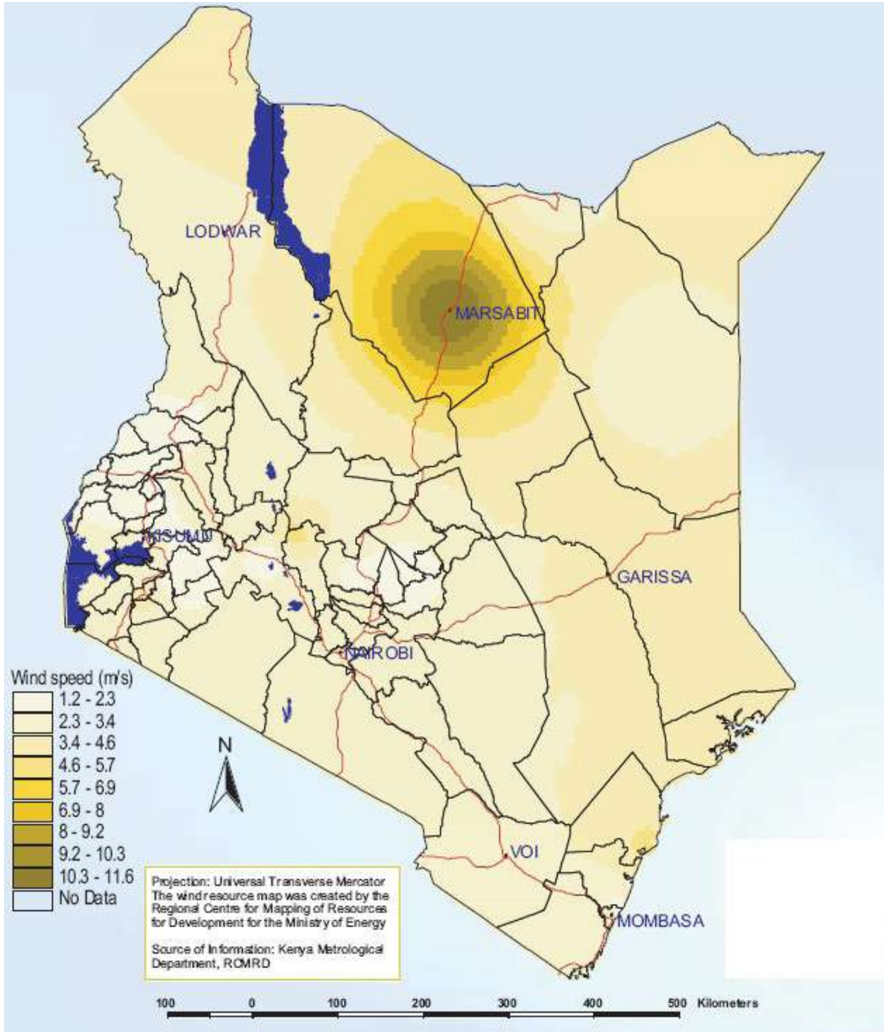

Figure 17. Wind speed map indicating potential for wind generation, particularly in Northern Kenya
(Provided by CAMCO)

The Lake Turkana Wind Power project is a large scale wind project being developed in the Marsabit region, which will have an installed capacity of 300 MW by July 2012 (widely cited as the largest wind farm in Africa). A full description of the project is provided below in Case Study 2. The government is also in the process of developing other wind energy projects in Kinangop (50MW) and Ngong (50MW). In August 2009, the first centrally supplied wind generation was provided by 6 turbine farm in Ngong Hills, providing 5.1 MW (see Figure 18 below).

Figure 18. Vestas V52 Wind Turbines in Ngong Hills, Kenya

Case Study 2: Lake Turkana Wind Power Project

The Lake Turkana Wind Power project is a 310 Megawatt (MW) wind power farm in Loyiangalani, Laisami District, Northeastern province of Kenya. It will consist of 365 turbines each with a capacity of 850 kilowatts (kW). Each turbine will be mounted on a tower and powered by a three-bladed rotor.

The plant will add approximately 25% to the current existing capacity of Kenya and will supply up to 1,500 GWh of electricity per year. The electricity generated will be purchased by the Kenya Power & Lighting Company (KPLC) and distributed to consumers in Kenya.

The project concession area covers approximately 150 square km (66,000 ha), which has been leased from the Marsabit County Council for 33 years, twice renewable. The project area has unique geographical conditions in which daily temperature fluctuations generate strong predictable wind streams. Wind speeds have been measured during a full year at a 43, 62, 81 and 83 meters high. The average monthly wind speed is 11 m/sec (as compared with a high average in Europe of 7 m/s).


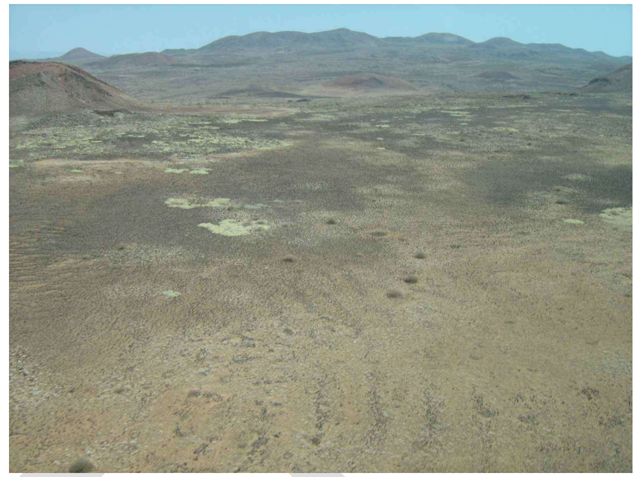

Figure 19. Lake Turkana (left) and the project site

The project will be connected to the national grid near Longonot, with a 400 kV transmission line of approximately 428km in length. As the turbines have to be transported from Mombasa to Loiyangalani a number of road adjustments, upgrades and constructions will be needed for the safe passage of the wind power units.

The wind power project is expected to start production in June 2011 and reach full production of 300 MW by July 2012.

Economics

The total project cost (including transmission line and road construction) is estimated at 780 million USD. The project will be financed through equity and commercial loans. No ODA or grants are involved. Note that economics of the project are not fully published as the developers are in negotiation over various aspects. It is expected that levelised generation costs will be around 6 USD cent/kWh based on a discount rate of 16.4% and a capacity factor of 53% (although capacity factor could be higher or lower).

The project will benefit from carbon revenue by replacing electricity generated by fossil fuel fired power plants connected to the national grid (The grid emission factor for Kenya was roughly 0.62 tCO2/kWh in 2008). It is expected that the project will generate average emission reductions of 919,060 tCO_2 per year which at current market prices amounts to roughly 12 million euro per year (based on the current price of 17 USD /tCO2 which equates to 1 USD cent/kWh generated).[30]

Difficulties

Apart from the rather general barriers (financing and approval processes) which every infrastructure project experiences, the project has revealed a number of potential barriers . These are:

Data Availability and site selection:
Wind potential assessments are site specific and time consuming. Wind energy developments require a large initial investment for careful wind prospecting which can take up to two years. Good equipment and quality work is needed, which is expensive.

Negotiating a good tariff
The key to the success of any grid-connected energy project is the retail tariff. According to a survey carried out by the World Bank, the retail tariff level is reported by leading investors as the most important reason why power sector investments in developing countries succeed with 66% of investors surveyed reporting that this is critically important for the success of an investment. The same survey also provides an insight into reasons why a power sector investment

[30] The project has not yet entered into any Emission Reduction Purchase Agreement so the credit figure is based on the current market price.

fails. An inadequate tariff level tops the list, followed by a lack of government responsiveness and weak contract enforcement.[31]

Currently, the Kenya Power and Lighting Company (KPLC) is the only licensed public electricity distributor in Kenya. The industry structure in place is therefore of the single buyer model, with KPLC undertaking transmission, dispatch, distribution and supply. KPLC buys the electricity from a power producer based on a Power Purchasing Agreement. Fifty-one percent of the shares of KPLC are government-owned.

In 2008, the Ministry of Energy adopted a *Feed-in Tariffs Policy on Wind, Biomass and Small Hydro Resource Generated Electricity*. Even though the Feed-in Tariffs Policy is considered an important step towards attracting more investment in renewable energy projects, many project developers consider them to be too low for the policy to serve its purpose. In terms of wind energy, the Feed-in Tariffs Policy only provides a tariff for wind projects of 50MW and lower. Because of the lack of a guaranteed tariff for wind projects larger than 50MW, the project activity had to negotiate its own tariffs with KPLC.

Key barrier in negotiating an attractive tariff with KPLC is the fact that the country has historically relied on hydropower, which is a relatively cheap form of energy (4 USD cent/kWh). Because of the increased (periodic) occurrence of droughts in the region, hydropower has become less reliable and there is a realisation that there needs to be enegy diversification. However, the mindset is still very much focused on the 4 USD cent/kWh, which is highly insufficient for a wind energy project.

As one of the elements of negotiating an attractive tariff with KPLC, the project has agreed with KPLC to transfer part of the carbon credit revenue to KPLC.

[31] Brandtzaeg, B. and S. Hansen (2005) *Barrier to Investment in the Power Sector in Developing Countries.* ECON Analysis/Nordic Consulting Group

Geographical Coordinates of the Project Area		
	North (N)	East (E)
A	2º 45' 53"	36º 42' 20"
B	2º 32' 22"	36º 59' 22"
C	2º 25' 11"	36º 47' 44"
D	2º 30' 57"	36º 45' 29"
E	2º 30' 43"	36º 42' 01"

Figure 20. LTW project location and coordinates

Transmission line

The project has exceptional wind conditions – the key factor in its selection. The main disadvantage of the area is that there is no transmission infrastructure in place that can easily connect the project to the national grid. In fact, the lack of transmission infrastructure is increasingly seen as a major barrier to the implementation of renewable energy projects such as wind and solar.

To overcome this barrier, the project activity has to establish a 428km transmission line connecting the project to the national grid.

Lack of understanding of technology

Wind energy is a relatively new form of energy in the region. Only on 21 August 2009, the first 5.1 MW of wind generated electricity was commissioned in Kenya. Because of the recent introduction, there is still a general lack of understanding about the technology. People tend to be skeptical about the potential of wind energy as a reliable source of energy.

The lack of familiarity with the technology has meant that the negotiations and approval processes has taken longer than for other projects and external support was needed to facilitate parts of the discussions.

Potential for similar projects

The topography of Kenya (channelling and hill effects due to the presence of the Rift Valley and various mountain and highland areas) have endowed the country with some excellent wind regime areas. The North West of the country (Marsabit and Turkana districts) and the edges of the Rift Valley are the two large windiest areas (average wind speeds above 9m/s at 50 m high). The coast is also a place of interest though the wind resource is expected to be lower (about

5-7 m/s at 50 m high). Many other local mountain spots offer good local wind conditions. Due to the monsoon influence, some seasonal variations on wind resource are expected (low winds between May and August in Southern Kenya). It is expected that about 25% of the country is compatible with current wind technology.

Currently there are already a number of other large-scale wind projects under consideration in Kenya including in Malindi, Kinangop, Ngong and Marsabit. The pioneering work done by the Lake Turkana Wind Power project will greatly facilitate the further development of those projects and increase confidence of investors and financers. The potential is certainly there but until the deal is finalised, the focus will be on the Lake Turkana Wind Project outcome.

Co-benefits

The implementation of the Lake Turkana Wind Power Project is expected to contribute to the sustainable development of Kenya in various ways:

- The provision of a reliable source of energy to Kenya's growing economy
- To open the way for the further expansion of wind power projects in Kenya and the region
- To generate local employment opportunities during the construction and operation phase
- To upgrade the road system in the project area
- To contribute to Kenya's fiscal revenues through the payment of taxes.
- To improve the hydrocarbon trade balance through reduction of oil imports used for electricity generation.
- To reduce the consumer price of electricity which is currently very high due to high fuel costs

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Photovoltaic (PV) systems

Kenya has one of the most commercial PV system market in the developing world, with an estimated installed PV capacity in the range of 4 MW. 120,000 rural households have solar home systems, using average sized systems of 25 watts. Annual PV sales in Kenya are around 25,000 units; growth has been 170% in 8 yrs, with limited government intervention (ESD 2005). This market development has been more successful than the Rural Electrification Programme, which has been running for considerably longer. Despite high upfront costs, these technologies can offer the most cost-effective means of providing electricity in very remote and rural areas. Larger institutions have also been taking up solar as means of hot water heating.

The solar resources are of course very good, helping make such a technology attractive economically; Kenya receives high insolation rates with an average of 5 peak sunshine hours (The equivalent number of hours per day when solar irradiance averages 1,000 W/m2) (ESD 2005).

As part of the Rural Electrification Programme, the ministry of energy has implemented a programme to install PV systems in boarding schools, public dispensaries and health centres in the country's Arid and Semi-Arid Lands (ASALs). The programme has criteria for determining the institutions to benefit from the programmes which include that it should be a public institution in the ASAL region, 15 kilometres away from the National Grid and if near a trading centre, then the centre should be 15 kilometres away from the institution. The programme begun in 2005/2006 financial year and to date has installed solar power in 134 institutions with a capacity of 0.4MW. A further 54 institutions benefited in 2008 and as a result of the success of the programme, the government intends to provide annual funding for the installation of PV systems in schools.

The high levels of solar radiance are shown in Figure 21 below, illustrating the significant potential for such technologies in Kenya.

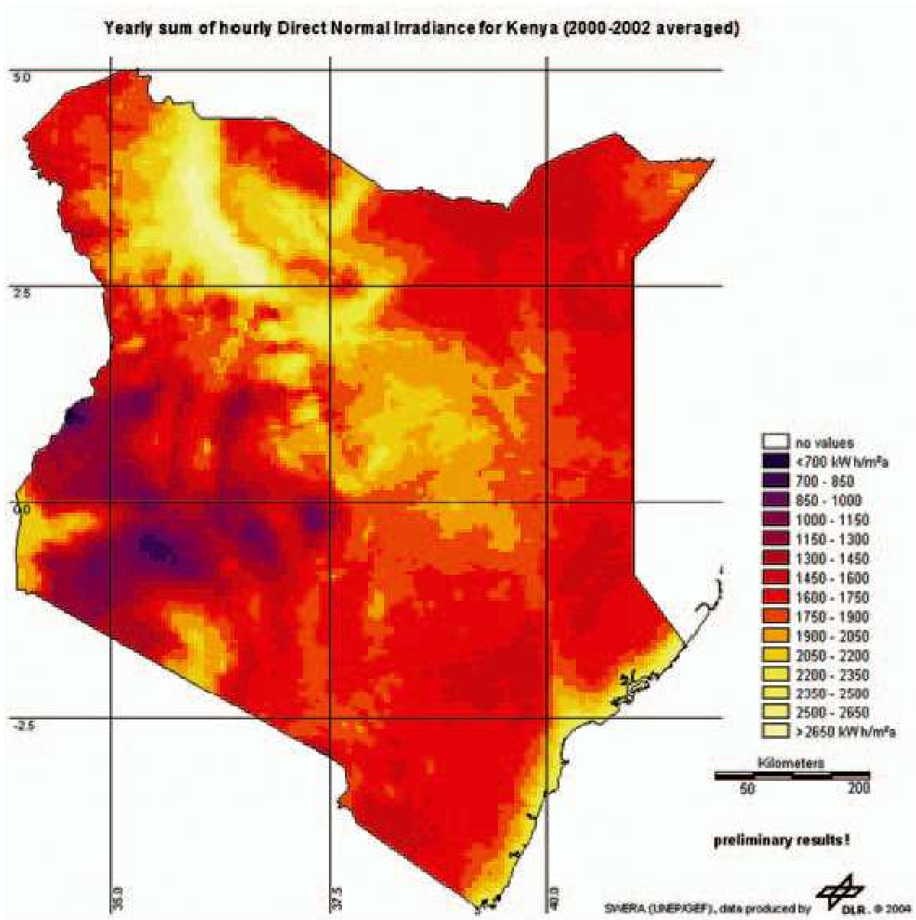


Figure 21. Irradiance levels for Kenya (2000-2002 average) (Provided by CAMCO)

Geothermal

Currently, geothermal accounts for 10% of electricity generation capacity, or 128 MW. The LCPDP illustrates the importance of geothermal for electricity generation in future years, with the ambition to increase geothermal capacity to near 3000 MW by 2030.

Surveying activities of resources are being supported by Africa Rift Valley Geothermal Development Facility (ARGeo), a GEF funded project with support from UNEP / World Bank totaling $18 million. Promising initial surveying activities have suggested significant potential, of up to 4000 MW in the Rift Valley area, much of which is in Kenya.[32] This project is very important as it is reducing the significant risks involved in geothermal development, which involve the high costs of drilling without finding good steam resources.

Two KenGen projects (existing plant expansion) are at the CDM validation stage (with proposed funding by World Bank carbon financing through Community Development Carbon Fund)[33]:

[32] See UNEP website for latest news - http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=553&ArticleID=6017&l=en

[33] See World Bank Carbon Finance website - http://wbcarbonfinance.org/Router.cfm?Page=Projport&ProjID=30583

- Olkaria II Geothermal Expansion Project. The purpose of the project is to increase the capacity at the existing plant from 70 to 105 MW, with an estimated additional annual generation of 276 GW. The project's estimated annual emissions reduction is 171,026 tonnes CO_2 eq. per annum
- Olkaria III Geothermal Expansion Project in Kenya. The objective of this project is to increase the electricity generation capacity from 12 MW to 48 MW. The estimated annual emissions reduction is 171,265 tonnes CO_2 eq. per annum.

<u>Options appraisal for low carbon electricity generation options</u>

A summary of the characteristics of renewable options is provided in Table 3 below.

Table 3. Low carbon electricity generation options

Option	Cost-effective?*	Adaptation synergies	Other benefits	Barriers
Centralised				
Hydro	Yes. Long plant lifetime / no fuel costs relative to fossil generation incurring high fuel costs	May lower climate resilience of system if changes in pattern of average or extreme precipitation	For all renewables: Reduced reliance on fossil fuels, with - Air quality	Capital intensive Sustainability issues Competing with irrigation demand
Geothermal	Yes as baseload plant. More C-E in Kenya due to drilling risks offset by ArcGeo project.	Resilient to future climate impacts	improvements. - Reduced fuel imports - Reduced sensitivity to fuel price shocks	Capital intensive
Wind	Depends on wind speed and consistency of resource. In NW Kenya, probably C-E although high costs of connection due to remote area	Likely to be resilient to future climate impacts (though estimates of climate change on future wind speeds are highly uncertain)	- Greater energy diversity and security	Capital intensive Tariff certainty required Grid infrastructure costs (due to remote location) Intermittent
Decentralised (Micro / Small grid)				
Hydro	Yes, if reasonable annual availability (reliable flow)	May not be as resilient to climate impacts (due to potential changes in average and extremes) as other options	As above. Reduced reliance on biomass gathering due to alternative energy source Low maintenance requirements	Need reliable hydro source
Solar PV	Not generally as PV costs currently very high		However, cost-effective relative to other options in remote areas – due to high solar resource and very expensive alternative	High costs
Wind	Not generally unless extremely good wind resource			High costs, Intermittent

* Cost-effective means 'no regrets / negative cost, or very low cost (<$10/tCO_2$). Cost-effectiveness will be dependent on the alternative option. In Kenya, we have tended to compare options against diesel generation, which has relatively high fuel costs.

Further analysis of the cost-effectiveness of these options in the Kenyan context can be found in section 5 of this report.

In conclusion:

- Kenya has abundant low carbon potential for electricity generation, with enough resources to meet demand forecasts with limited need for fossil fuel (though noting fossil fuel may have a role in peaking or reserve plant).

- There is large potential for hydro-power, which can generate electricity at lower cost than conventional diesel powered generation. This also includes harnessing regional resources, such as hydro power from Ethiopia, as discussed in the previous section (3). However, there are risks to a high hydro-based future due to climate impacts affecting water availability; this issue is further discussed in section 5.
- There is a large wind resource, particularly in the north of the country, which could power a large increase in generation capacity. The costs are higher than hydro generation, but it offers energy diversity.
- Decentralised options continue to be very important due to the demographics / geographical situation of Kenya, with many communities living in remote areas, far removed from the grid network. Of particular importance in arid areas are solar home systems. Small hydro may also have an important role to play, although this will depend on the water resource availability / reliability. A detailed case study analysis by Kirubi et al. (2008) of a community-based electric micro-grid in rural Kenya demonstrates that access to electricity enables is very important for development. The use of electric equipment and tools by small and micro enterprises can result in significant improvement in productivity per worker (100–200% depending on the task at hand) and in a corresponding growth in income levels in the order of 20–70%, depending on the product made.

Households, small-scale commercial and public sector (buildings)

The projections in the previous chapter suggest that biomass for heating and cooking will remain an important energy source for households in future years but that electricity will become increasingly important. Due to the low carbon electricity generation predicted in future years, this sector will remain relatively low carbon. However, there remain significant opportunities for further reducing emissions particularly through more efficient use of biomass, and increased uptake of renewable technology to meet all energy needs.

The main mitigation options identified for this sector are listed in Table 4 below. Note that small-scale technologies for electricity generation are discussed in the previous section.

Table 4. Mitigation options for household, small-scale commercial and public sector (excluding electricity generating technologies)

Option	Cost-effective? *	Adaptation synergies	Co-benefits	Barriers
Improved efficiency of stoves	Yes (high)	Lower reliance on increasingly scarce or stressed resource	Reduced fuel costs Improved combustion – lower indoor air pollution levels (health benefits) Less pressure on local forestry Increase economic time	Initial investment Lack of information / awareness
Improved efficiency of charcoal production	Yes	Lower reliance on increasingly scarce or stressed resource	Less pressure on local forestry Reduced costs	Initial investment Lack of information / awareness
Switching to alternative fuels (away from biomass)	Fuel / technology dependent	Lower reliance on increasingly scarce or stressed resource	Lower indoor air pollution levels (health benefits) Less pressure on local forestry More convenient	No access to electricity Investment and higher fuel costs
Solar cookers / lighting	For lighting, yes compared to kerosene; for cookers, yes	Lower reliance on increasingly scarce or stressed resource (for cookers)	Lower indoor air pollution levels (health benefits) Reduced fuel costs Reduced fuel wood use (cookers)	Initial investment Cultural resistance (solar cookers)
Biogas	Fuel / technology dependent	Lower reliance on increasingly scarce or	Lower indoor air pollution levels (health benefits)	Upfront costs Require livestock

		stressed resource	Less pressure on local forestry More convenient Slurry by-product has high nutrient content, used for fertiliser	Lack of awareness
More efficient lighting (electric)	Yes		Reduced energy costs Reduced pressure on electricity system	Lack of information / awareness
More efficient appliances (electric)	Yes		Reduced energy costs Reduced pressure on electricity system	Cheap price of less efficient appliances

* Cost-effective means 'no regrets / negative cost, or very low cost (<$10/t$CO_2$).

As with low carbon options discussed throughout this report, where private individuals are required to make decisions, affordability for many socio-economic groups is a crucial factor. In the case of the household choice of energy, the cost of alternative clean energy options (to biomass) is too high for most poor households to afford. Until incomes increase, a large proportion of the population will continue to source fuel wood from the local area of residence. This has been reflected in the projections analysis.

Based on Kenya's energy situation for the buildings sector, where biomass use dominates and will continue to do so, the focus is on two specific options, driven by energy policy but where climate and other policy co-benefits are strong, as are synergies with adaptation:

- Efficiency improvements in biomass stoves
- Switching to alternative renewable sources

Efficiency improvements in stoves

During the 1990's, there was significant intervention by government agencies and NGOs[34] in provision of improved stoves – KCJ for charcoal burning (1.6 million without subsidy), and Maendeleo (also known as Upesi) known as for wood burning (400,000 by end of 1996) (GoK 2002).[35] According to GEF (2005), the Kenya Ceramic Jiko (KCJ) initiative was Africa's most successful fuel-efficient stove programme. However, there remain many inefficient stoves and other cooking methods, particularly for wood fuel in rural areas, such as the 3-stone open fire. In addition, the production of charcoal is highly inefficient; efficient kilns with potential recoveries of 30-45% are not well known. Over 95% of the kilns used in the country are inefficient, with 8-20% conversion efficiency (UNEP 2006).

The Government recognizes that biomass will continue to play a very important role and therefore improving the efficiency of use is critical. It stated in the 2004 White Paper on Energy Policy that *the Government recognizes that biomass energy will continue to be the primary source of energy for the rural population and urban poor for as long it takes to transform the rural economy and the informal sector from subsistence economy to a high income economy capable of paying for modern energy, education, health, food, and decent shelter*.

In the White Paper, the Government provided the following policy statements on the use of biomass (GEF 2005), which have been reflected in the projections:

- Increasing efficient charcoal stove take-up from 47% currently to 80% in urban areas by 2010 and to 100% by 2020. This would translate to a reduction in demand of fuelwood for charcoal production by 3.36 million tonnes;

[34] GTZ and Practical Action have been particularly active in the provision of improved stoves in Kenya to rural communities. Between 2005-08, GTZ provided +700,000 stoves, particularly Jiko and Rocket models. Practical Action have been particularly active in providing and enable local manufacture of clay Upesi stoves.

[35] A useful overview of stoves types can be found on the GTZ website at http://www.gtz.de/en/themen/umwelt-infrastruktur/energie/14577.htm

- Increase the take-up of efficient fuelwood stoves from 4% currently to 30% by 2020 in both rural and urban areas. This would reduce the overall demand for fuel wood by 15.4 million tonnes;
- Rehabilitate and strengthen the 10 agroforestry centres country wide and increase them to 20 in order to act as demonstration centres on issues of efficiency and conservation.
- Promote energy conservation measures including drying of wood before burning, soaking of long-cooking grains, adoption of fireless cookers etc.

Improving efficiency not only leads to reduction in GHG emissions but has many other benefits:

- Improvements in indoor air pollution, a major health problem
- Reduce fuel costs (where wood / charcoal is purchased)
- Reduced time gathering an increasingly scarce resource
- Reduced pressure on forestry resources

A number of initiatives have been implemented in Kenya to date (as illustrated by the KCJ example). Examples are described below, including a Case Study example of an ongoing GEF co-funded stove programme for public institutions (see Case Study 3).

Case Study 3. Market transformation for efficient biomass stoves for institutions and small and medium-scale enterprises in Kenya

Funder: GEF / UNDP (USD 1 million, Overall cost USD 6.6 million)
Implementation by: Rural Energy Technology Assistance Programme (RETAP)

The GEF Biomass Energy Project aims to transform markets for highly efficient biomass stoves for institutions (schools and hospitals) and medium-scale enterprises (restaurants, hotels) in Kenya by:
Promoting highly efficient improved stoves;
Establishing woodlots owned and managed by the institutions and private sector; and
Removing policy and financial barriers to the widespread adoption of stoves.

This is a four year project of the Ministry of Energy being implemented by RETAP under supervision from the UNDP Kenya country office.

Key issue: Over 95% of about 20,000 institutions (schools, colleges, hospitals) in Kenya are relying on fuel wood as the main source of energy for cooking and hot water purposes. While the high additional costs of buying appliances that run on electricity and gas are prohibitive, the unreliable supply of electricity and gas, and high running costs are the major deterrents. Such institutions using biomass put significant pressures on local biomass resources.

Objectives: Selling of 5000 improved stoves (against a baseline of 1500 stoves during the project period, i.e. the project will result in the selling of an additional 3500 improved stoves during the 4-year project). This is a penetration rate of 16% against a baseline of 5%. Plus 15 million tree seedlings planted within the project.

Baseline data below (for 2006) illustrates the low levels of improved stove use.

SectorNumber using biomass% biomass usageTraditional stoves usedImproved stoves usedRestaurants6,00050%100%0%**Hotels, Lodgings**7,00050%100%0%**Schools Primary**19,00095%80%20%**Schools Secondary**4,00095%50%50%**Health institutions**4,00050%100%0%

Case Study 3. (Cont'd)

GHG Benefits: An improved institutional stove reduces greenhouse gas emissions through:
Improved efficiency means 70% less wood is required for the same cooking task,
Reduced emissions of products of incomplete combustion which have higher global warming potentials than CO_2, and
When introduced together with a sustainably managed woodlot the cycle becomes closed and therefore 100% renewable.

Other cited benefits include:

Environmental benefitsReduced deforestation and forest degradation, increased trees on farmsReduced air pollution indoors (and outdoors)Improved school / SME environments through proximity of wood-lotsSocial benefitsImproved respiratory and general health of cooksReduced eye irritation of cooksReduced cooking timesLess time spent gathering fuel, more time available for cookingCleaner kitchensProtection for community forestsEconomic benefitsReduced fuel costs*Income generation for stove producers and tree producersIncreased time for income generating activities for stove users
* Stoves will be sold at USD 1300 (20% less than current price due to scale of production). RETAP have shown payback on investment is fast due to fuel savings. Schools with the improved stoves spend 60% less on fuel costs. A school with an average of 300 students therefore saves $1,025 per year.**

Barriers to overcome:
Policies insufficient or not providing required support
Financial investment
Poor marketing and business management from retailers
Lack of information and awareness from consumers
Costs of production high unless scaled

Key source: GEF (2005)
** GEF SGP, Energy-Saving Institutional Stoves in the Mt. Kenya Region, Kenya, GEF Small Grants Programme, http://sgp.undp.org/

RETAP have long been involved in promotion of improved stoves. In 2001, a part-GEF funded project (through their small grants programme) introduced improved efficiency stoves (for cooking / water heating) in 100 schools in the Mt. Kenya Region (20 resulting from SGP funding), and a total of 150 schools nationally, including non-SGP funded areas. Such stoves lead to 60-70% fuel savings. This project was also recognised by the Ashden Awards in the UK.[36] Scaling up potential for such technologies is significant with 90% of Kenya's 20,000 educational institutions using wood fuel to prepare meals, as reflected by further action described in the above case study.

A significant co-benefit of using improved stoves is the reduction in indoor air pollution due to improved design and better combustion. Box 4 below discusses some of the issues in relation to health benefits of improved stove use.

[36] Ashden Awards, http://www.ashdenawards.org/winners/retap

Box 4. Improved stove technology for reducing indoor air pollution and impacts on health

The World Health Organization (2006) estimates that 396,000 people died from diseases caused by indoor air pollution in 2002 in sub-Saharan Africa. The primary cause of these deaths is exposure to particulate matter, emitted into the home as a result of wood fuel and charcoal burning. The effects are not evenly distributed in society, with poorer households more exposed due to greater reliance on biomass fuels and less advanced technology, and women and children most exposed due to being in the home for longer periods and engaged in cooking activities.

Switching to moderns fuels such as LPG and biogas brings about the greatest reductions in indoor air pollution, whilst reducing GHGs, although the costs may well be prohibitive without additional financial help.

Cost benefit analysis has been conducted by the WHO that demonstrates that fuel switching and improving stoves results in benefits far exceeding the costs (WHO 2006).

> *Making improved stoves available, by 2015, to half of those still burning biomass fuels and coal on traditional stoves, would result in a negative intervention cost of US$ 34 billion a year as the fuel cost savings due to greater stove efficiency exceed the investment costs. This generates an economic return of US$ 105 billion a year over a ten-year period (Table 5). Time gains from reduced illness, fewer deaths, less fuel collection and shorter cooking times, valued at Gross National Income (GNI) per capita, account for more than 95% of the benefits. When time gains are conservatively valued at 30% of GNI per capita for adults and 0% of GNI for children, the economic payback decreases to US$ 33 billion a year for improved stoves.*

This analysis shows the important of full policy appraisal to identify the full benefits and costs of an option, particularly for a measure such as this that has such multi-policy

Fuel switching

A move away from biomass to other fuels is already projected to happen as Kenya's access to electricity increases. Much of this switching is premised on the rise in incomes. The same is true for other modern energy forms, as illustrated by Figure 22, showing income versus fuel of choice.

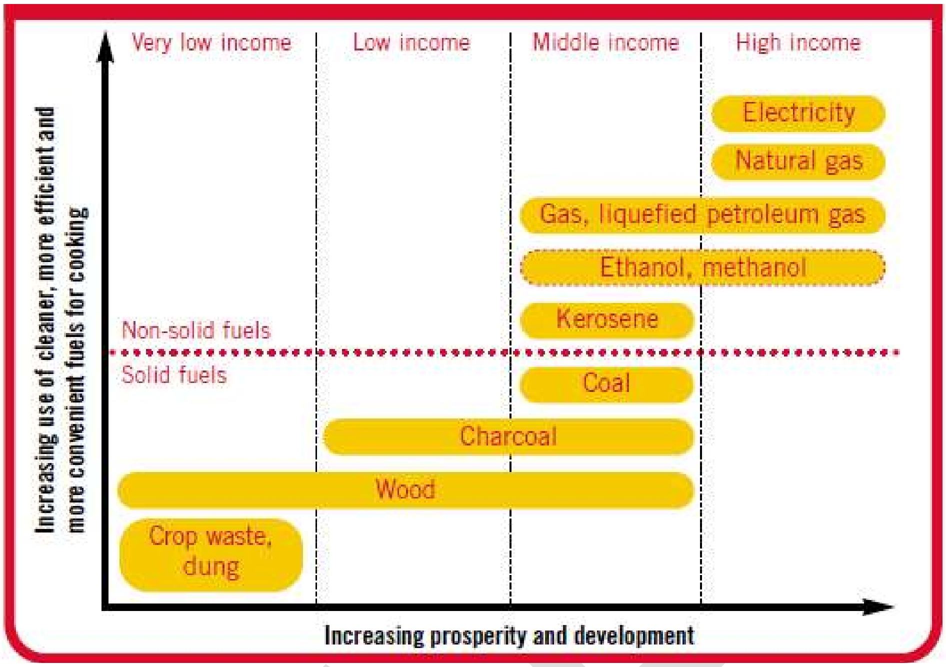


Figure 22. The energy ladder: household energy and development inextricably linked (WHO 2006)

In addition, there is a range of example of non-fossil alternatives, or options that reduce energy demand. Some examples are outlined in Table 5 below

Table 5. Examples of technologies to enable fuel switching or reduce energy requirements in Kenya

Technology	*Example project*	*Additional comments*
Solar cookers	Solar Cookers International (SCI) have been distributing a solar cooker (named CooKit) which provides an alternative energy source for cooking, and can also pasteurise water, reducing water-borne diseases. The project in Kenya to disseminate this technology in refugee camps was recognized by the Ashden Awards in the UK.[37]	There does not appear to be a consensus that this has been an effective technology in the main in Kenya, with limited uptake
Solar WLED lighting	Lighting the "Bottom of the Pyramid". GEF funded project to help move away from the polluting fuel-based lighting to less polluting and higher quality modern lighting sources, such as WLEDs (white light emitting diodes)[38]	Practical Action have teamed up with a company called Sollatek UK Limited to provide this technology[39]
Biogas	Kenya Biogas feasibility study (ETC 2007), to assess the strategic and operational feasibility of implementing a biogas promotion programme in the south-western region of Kenya. Assessing barriers and key target groups for technology. Objective of the programme to install 6000 systems in five years with 30 companies and 120 technicians in 5 districts in Western Kenya	Mwirigi et al (2009) note the poor take up rate of this technology in recent years, and the various scoio-economic factors affecting this

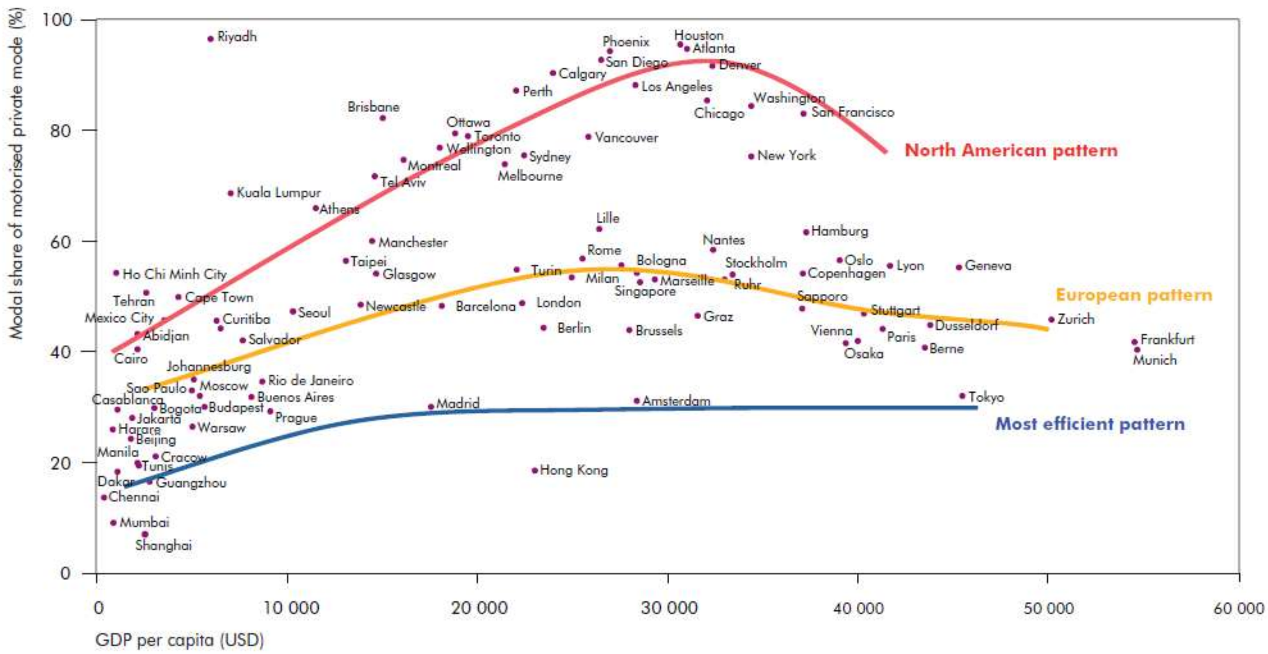
[37] Ashden Awards, Porject summary http://www.ashdenawards.org/winners/sci#

[38] See GEF project brief for additional information at http://www.gefonline.org/projectDetailsSQL.cfm?projID=2950

[39] See http://practicalaction.org/energy/solar_power?id=solar_power

Transport

The transport sector, as shown in the projections, is likely to be the main driver of increasing GHG emissions in future years. As incomes increase through economic growth, demand for private vehicle transportation increases significantly (Kahn Ribeiro et al. 2007). Figure 23 shows the relationship between private motoring and GDP in different urban areas of the world. Those cities with relatively low shares indicate high density cities with good public transport systems.



Source: UITP, 2006 (Courtesy of SYSTRA).

Figure 23. Share of private motoring journeys as % of total journeys relative to GDP / capita (cited in IEA 2008)

Kenya has the opportunity to try and plan for the increased demand for transportation in a sustainable way, but this will require stronger policy with a mix of integrated urban planning, public transport provision and efficient and low carbon vehicle options. In a rapidly urbanizing country, such a strategy is extremely challenging to implement, but is essential to ensure effective and efficient transport systems, particularly in such urban areas. Within the Vision 2030, there is a 50 year spatial and transport plan, which will be key to this.

Sperling and Salon (2002) capture the problem facing many developing countries:

> *Rapid motorization is creating major challenges in the expanding "megacities" of the developing world. These cities face stifling traffic congestion, huge expenses for road infrastructure and worsening air pollution. Many have much more severe traffic congestion and air pollution than U.S. cities. Bangkok, Thailand is the best known example, but there are numerous others. What is surprising and troubling is that these car-induced problems occur even though vehicle ownership rates are still far lower than those in more developed cities.*

The importance of an integrated approach for mobilisation is critical, and Kenya needs to implement modern urban transport systems, provide adequate transport infrastructure and ensure quality of urban environments. This can be advanced with lower carbon options. Low carbon approaches offer many benefits in reducing the social and economic costs of congestion and reducing pollution and noise from transport, as well as having potential benefits through reducing the levels of oil use and imports.

There are a number of specific challenges associated with Kenyan transport system (UNEP 2006), not untypical of rapidly urbanising and developing countries, resulting in inefficiency (and higher per vehicle emissions):

- Traffic congestion, which translates into loss of time, increased fuel use and higher emissions (GHG and air pollution), is particularly acute in urban areas. The infrastructure is in poor condition, with the roads now carrying over ten times the amount of traffic they were designed for. It has been estimated that an hour spent in traffic jams in Nairobi wasted 1.26 litres of fuel per car.
- Prevalence of old vehicles with poor fuel efficiencies. The influx of cheap second hand vehicles onto Kenyan roads (mainly from Japan and United Arab Emirates) is attributed to economic policy reforms in the early 1990s, where many aspects of international trade were liberalised. Most new car registrations are for reconditioned vehicles.

Addressing these problems is not easy, and would have important implications in respect of investment needed, distributional effects, etc. However, any progress would result in a more efficient transportation system, an improved urban environment and improved efficiency of fuel use and lower GHG emissions.

On improving infrastructure and reducing congestion, the current energy policy has provisions to promote mass transportation but nothing on improving roads, building new relief roads or promoting non-motorised transport. On efficiency, the Government has plans to reduce inefficient imports from the market (although implementation appears weak (GoK 2005)) but nothing on removing very old vehicles or improving vehicle maintenance and better driving practices (UNEP 2006).

If existing provisions of the current policy were implemented in a specific way, emission savings could be significant, as reported in UNEP (2006). This could be done through development of Nairobi's public transport system and greater control and enforcement on imported vehicle standards. In addition to reducing GHG emissions, such measures are particularly important for their other benefits:

- Reduced costs to the economy of poor transport systems
- Increased employment / productivity in the sector
- Reduced reliance on foreign imported petroleum
- Reduced congestion, noise pollution and air pollution in urban areas

As part of implementing the Vision for the transport sector, the Ministry of Transport (2009) has developed a Transport Sector Plan. Many of the measures cited in the plan are about increasing capacity of the existing system, particularly through developing ports to take larger vessels, increasing airport capacity, upgrading the rail network (from narrow to standard gauge), and developing / enhancing transport corridors (e.g. Mombasa to North West Sudanese border, and up east coast to Lamu).

An important planned project is a Mass Rapid Transit System (MRTS) for Nairobi, which would consist of a Bus Rapid Transit System and a Light Rail System. This is planned to be in place by 2015. It is needed to provide services for a rapidly expanding Nairobi Metropolitan area, the growth of which is characterized to some extent by growth in satellite towns and areas outside the city proper (peri-urban). The Transport Plan quotes growth of 6.76 million in 2005 (Metropolitan area) to 20.6 million[40] in 2030. Vehicle congestion is already severe and transport systems are being used at levels significantly exceeding capacity. Of particular concern is that 22% of passengers are in private vehicles accounting for 64% of traffic volume. The private car use is also increasing by 6.4% per annum.

[40] Note this population projection is different to the Vision document because it considers the wider metropolitan area of Nairobi.

Preliminary feasibility studies have put the costs for the bus system at around $US 497 million, whilst a single line on the light rail system from the airport to city centre could cost around $US 190 million. An estimate of how many commuters this scheme will cater for is not included in the Transport Plan. However, the Vision 2030 document states that the light rail system would carry 150,000 people per day to meet 5% of future public transport demand (GoK 2007).

In the following section, we concentrate on the two priority options for Kenya to reduce emissions significantly in the transport sector– improving the efficiency of the road vehicle fleet and by introducing efficient public transport systems. Both of these options are considered in the following section. Emission reductions are likely to be co-benefits of effective and sustainable urban planning, meeting urban transport needs through public transport, and reducing oil consumption.

In broader mitigation terms, there are a range of options for the transport sector. Sperling and Salon (2002) suggest that there are three main ways of reducing emissions in developing countries:

- Restrain vehicle demand and use
- Employ new technology now available in developed countries;
- Employ 'leapfrog' technology.

Restraining vehicle demand and use focuses on changing behavior through various different mechanisms (increasing costs of road use through tolls, higher taxes on fuels, improving public transport alternatives, parking constraints) but have many barriers. New technology available in developed countries focuses primarily on improving efficiency of vehicles by restricting low efficiency vehicles on the market or subsidizing higher efficiency vehicles. This could also include use of cleaner fuels e.g. biofuels. 'Leapfrog' technology are emerging technologies (e.g. electric vehicles) that would help developing countries avoid the high fossil transportation sector that the developed world experiences, and has been locked into.

The main mitigation measures listed by the IPCC (Kahn Ribeiro et al. 2007) are shown in Table 6 below.

Table 6. Mitigation options for transportation sector

Option	Cost-effective?	Adaptation synergies	Co-benefits	Barriers
More fuel efficient vehicles	Yes		Reduced fuel costs Energy security benefits Lower AQ pollution (per vehicle) Reduced accidents as modern vehicles	Price differential versus less efficient vehicle Effective enforcement
Advanced technology vehicles e.g. hybrids[41]	Not currently		Reduced fuel costs Lower AQ pollution (per vehicle)	Investment per the alternative Maintenance of newer technologies
Use of biofuels	Dependent on feedstock – and use levels	Land security may be affected by climate impacts	Energy security benefit due to less petroleum use	Conflict with crop production

[41] Kenya has a fleet of green-coloured Toyota Prius taxis. Eco Cabs, the company that owns the taxis, says the hybrid cars produce 60% less emissions than normal vehicles.

Modal shifts from road transport to rail and public transport systems	Situation specific		Improved urban environment (AQ, noise, safety) Reduced accidents	Very high capital investment
Non-motorized transport (cycling, walking)	Yes		Reduced vehicles on road Exercise	Higher incomes drive demand for private vehicles
Driving behaviour	Yes		Reduced fuel costs Reduce accidents	Difficult message to promote Difficult to enforce
Road charging			Funding for infrastructure	Lack of public support
Traffic management systems			Reduce congestion	

Box 6. The use of biofuels in Kenya's transport sector?

There are plans for the introduction of bio-diesel in the refinery/blending of public transport fuels in Kenya. *Jatropha Curcas*, locally known as "mbariki", is a plant whose seeds have the potential to produce bio-diesel. This form of diesel has been around for a while and is being used by small firms/enterprises for different purposes. Attempts on biofuel in the past by the Agro-chemical and Food Complex in Muhoroni and the Kisumu Molasses plant were not successful. By then, the government was subsidizing operations of the former to produce gasohol (10% alcohol, 25% regular petrol and 65% super petrol). As the price of petrol became cheaper, it was no longer viable. The two plants still produce power alcohol, which is exported.

Different initiatives are being undertaken by many organizations to promote the production of biofuel in the country, such as Green Africa foundation, Vanila Jatropha Development Foundation, and Energy for Sustainable Development Africa Ltd, among others. The government has pledged to support all initiatives geared towards the production of bio-diesel. In this regard, the Department of Renewable Energy, with the collaboration of stakeholders, is developing a biofuel strategy.

However, despite the exciting prospects for biofuel, many important questions remain unresolved about its implications for the poor, food security, the environment and international trade. For instance, an increase in the production of biofuel could imply putting more productive land under oil crops. This may have negative repercussions to the environment and also food security. Besides, in areas with insecure land tenure, the poor may be dispossessed of land, with the result that poverty and food insecurity may increase. Use of maize as a source of biofuel may lead to a rise in maize prices, which is major staple food in the country.

Industry

Different sectors of manufacturing are going to drive Kenya's economic growth in future years, as the economy move away from primarily agrarian. An important problem facing this sector is high energy costs (GoK 2007); energy efficiency savings are therefore an important means for becoming more competitive, and would of course have positive impacts on reducing carbon emissions.

In 2000, Kenya had fairly inefficient production relative to other countries such as India and China (Kirai 2008), reflected in a high energy intensity per GDP indicator. Energy use is not very efficient among SMEs, with surveys estimating that wastage of energy ranges between 10% and 30% of primary energy input. In the past, investment in energy efficiency has been impeded by the historically low power tariffs and price control on petroleum products. This situation is being helped to some extent by a new tariff policy, power subsector reorganization and the newly liberalized petroleum market (GoK 2005).

The main mitigation options for industry are listed in Table 7 below. These are generic options for industry, with limited large-scale energy intensive industries in Kenya (with the exception of cement sector).

Table 7. Mitigation options for industry sector

Option		Co-benefits
Improved management systems, incl. benchmarking	Auditing Inventory reporting GHG management systems Benchmarking	Reduced fuel costs Reduced susceptibility to price shocks due to imports Lower air pollution emissions
Improvements to energy efficiency	Housekeeping and general maintenance on older, less-efficient plants - 10–20% savings. Low-cost/minor capital measures (combustion efficiency optimisation, recovery and use of exhaust gases, use of correctly sized, high efficiency electric motors and insulation, etc.) 20–30% savings. Higher capital expenditure measures (automatic combustion control, improved design features for optimisation of piping sizing, and air intake sizing, and use of variable speed drive motors, automatic load control systems and process residuals) - 40–50% savings	Reduced fuel costs Reduced susceptibility to price shocks due to imports Lower air pollution emissions
Switch to lower carbon fuels	Such as to natural gas	Lower air pollution emissions Reduced susceptibility to price shocks due to imports
Heat and power recovery, including cogeneration		Reduced fuel costs Additional finance through sale of surplus ELC to grid Lower air pollution emissions
Renewable energy	Biomass, or provision of electricity needs from renewable sources	Reduced fuel costs Reduced susceptibility to price shocks due to imports Lower air pollution emissions
Carbon capture and storage (CCS)		Potential for carbon financing

Source: IPCC 4th Assessment Report – mitigation (Bernstein et al. 2007)

For Kenya, possible mitigation options listed in the TNA (GoK 2005) and the First National Communication (GoK 2005) include:

- Improving energy efficiency
- Change from wet to dry process in cement production
- Fuel switching
- Offsetting through afforestation
- Co-generation e.g. tea sector
- Use of CO_2 in industry from natural instead of manufactured sources

Energy efficiency measures could be implemented on the basis that they are economically rational, i.e. they are 'no regret' options that should actually lead to cost savings compared to the inefficient measures they displace. However, many barriers exist that prevent or inhibit uptake including:

- Limited demand not rewarded by the market or government
- Slow rate of capital stock turnover (illustrating issues of 'lock-in')
- Financial constraints (with limited access to carbon financing for this sector in Kenya)
- Slow rate of technology transfer
- Poor awareness of options, and skills / capacity to implement

- Up front capital expenditure

From the perspective of introducing new technology, the TNA (GoK 2005) lists the numerous barriers in Box 7.

Box 7. Barriers to new technology take-up

Policies and national strategies
High import duties on industrial equipment and material.
Bureaucratic procedure in authorizing investments
Political situation/Poor governance.
High interest rates on borrowed money
No explicit technology development policy
Subsidies that reduce viability of investments in the energy sector
Inadequate funds for Research and Development in clean energy technologies from both the government and donor
Financial
Poor access to capital funds for investments in technology improvements
High interest rates on borrowed money
High bank transaction costs
Information and awareness
Poor access to capital funds for investments in technology improvements
Poor participation and representation Industry in Energy and Environmental matters
Little knowledge on the new Environment Act and its implications to industry
Weak information exchange mechanisms amongst stakeholders
Limited institutional capacity to facilitate take-up
Lack of benchmarking in industry to estimate benefits of new technology

Source: GoK (2005)

In terms of key measures for this assessment, the most important option lies in improving energy efficiency, particularly as this tend to be cost-effective (with higher fuel savings due to significant use of petroleum based products). In addition, fuel switching (to renewable energy) and cogeneration also have potential.

Energy efficiency

There is significant potential for energy efficiency improvement in Kenyan industry, particularly in small and medium size industries. A good example of an initiative to improve energy efficiency in Kenya's industry is the GEF-KAM programme (see Case Study 4).

Fuel switching

Options for fuel switching can also reduce reliance on fossil fuels, leading to reduced GHG emissions and other co-benefits. Two examples for Kenya are described below.

Lafarge Bamburi Biomass energy project
Lafarge Bamburi[42] cement has adopted a project to use alternative fuels in the process of cement manufacturing and are reducing estimated emissions in their Kenya and Uganda industries by 132,000 tonnes by 2010, through the use of biomass from trees, coffee, rice and coconut husks to fire its kilns instead of coal. The company currently uses 300 tonnes of coal daily and the latest plans will see use of fossil fuels reduced by 20% at its Mombasa plant and 50% at the Ugandan plant. The biomass will include wood from

[42] The Bamburi plant also converted from a wet to dry clinker production in 2000, significantly reducing energy needs per unit of output.

the company's own plantations (the company has also planted over 2.5 million trees so far) as well as coffee, rice and coconut husks bought from local farmers. The switch from coal to biomass will cost about Ksh1.4 billion ($20 million), with a significant part of the investment going towards upgrading equipment. [CAMCO – Ref]

Case study 4. GEF-KAM Energy Efficiency Programme

Funder: GEF / UNDP (Total project cost incl. co-financing USD 8.6 million)
Implementation by: Kenyan Association of Manufacturers (KAM) for the Ministry of Industrial Development

Many of the manufacturing sectors use old and inefficient technology, providing significant potential for energy efficiency savings. This initiative started in the year 2000 to target energy efficiency in medium to small-scale industries. Objectives include:

Removal of barriers to energy efficiency and conservation (information, technical, financial, institutional)

Enhance energy efficiency in SMEs, and enable investments in energy efficiency

Reduce CO_2 emissions

Industry to produce high quality products at lower cost

Increase the institutional capability to implement energy efficiency projects

Specific activities undertaken as part of initiative include awareness raising, training, energy auditing, financial barrier assessment, demonstration projects, Industrial Energy Efficiency Network, and a energy award scheme (to reward good practice)

Kirai (2008) estimates potential savings to be significant across all sectors, in particularly food, tea, textiles and paper. The potential is estimated as follows:
108,200 toe per annum
14% of industrial energy consumption
602,000 tCO_2 / year

Cumulative savings of 115,000 toe have been realized between 2001-06. This is equivalent to 580,000 ton CO_2 @ $5.50 per tonne in 5yrs.

2003 study on the project impact revealed that it had a significant impact in raising awareness on the economic benefits of implementing energy efficiency programs. Total annual savings of approximately USD 1 million were realized by ten of the companies surveyed, with an estimated capital cost of USD 1.1 million, yielding a simple investment payback period of 1.1 years. 37 of the industries surveyed in the study reduced CO_2 emissions by an estimated 8.1 thousand tons. The amount of savings and CO_2 avoided is expected to rise over the project period involving over 500 local industries. The project is developing an energy efficiency database for reference by industry and energy consultants (GoK 2005).

Chandaria Industries Ltd (CIL) runs a converting plant and a cotton plant. The main products are paper and tissue. There are 3 main production processes, which include manufacture of paper and its conversion into paper products and surgical cotton manufacture. A range of measures implemented resulted in energy savings of 10% (GoK 2005) including waste heat recovery from boiler flue gas, paper machine flash steam recovery by modification of the existing system and efficiency improvement of back water pumps by installation of high efficiency pumps (SAN website).

Greening the Tea Industry in East Africa (GEF 2006b)
This GEF supported regional project aims to promote the use of small-scale hydropower across the tea industry in Eastern and Southern Africa, under the East Africa Tea Trade Association (EATTA). Benefits include reduction in GHGs, improved reliability of supply, cheaper electricity, and provision of electricity to wider community. There may also be benefits from sale of surplus electricity to the grid. The project is considered important for removing barriers, including lack of confidence in the small hydro sector, limited experience and knowledge of the technology, unclear government policies to promote small hydropower rural electrification through public private partnership, and ambivalence on the part of utilities to purchase excess energy produced by small renewable energy projects.

Over the 4 year project, it is envisaged that at least six small hydropower plants will be constructed, producing a total of around 10 MW of power. Avoided GHG emissions are anticipated to be around 42,000 tons of CO_2 per annum. Over a 20 year life time, schemes are expected to reduce 765,600 tons of CO_2 emissions cumulatively (relative to alternative diesel power generation). It is anticipated that the replication potential of the project could be 82 MW of small hydropower within a twenty year period within the tea sector.

Co-generation

Co-generation could have an important role to play in improving the efficiency of plant, and meeting electricity needs of both the industry but also wider distribution network. Examples include the tea and sugar sectors (GoK 2005):

- Through a study undertaken under the GEF-KAM Industrial Energy Efficiency Project, it was estimated that Kenya would save emission of 240,000 tonnes of CO_2 emitted annually by simply applying the co-generation technology in the tea sub-sector.

- Kenya has not fully exploited the co-generation capacity that exists in the sugar factories. Though Kenyan sugar industries can produce up to 56 MW the majority of the sugar factories actually import electricity from the national grid. Currently, it is only Mumias Sugar Company that supplies 2MW to the national grid (as reflected in the LCPDP). Co-generation would reduce the use of thermal power stations in western Kenya and make sugar production cheaper in the local and international market. Mwakubo et al. (2007) states that the potential for electricity generation from bagasse has been estimated at 300 MW for the seven existing sugar companies at the current capacity.

Cogen for Africa is a regional initiative funded by the Global Environment Facility (GEF) designed to support industries in Africa to develop their cogeneration potential (GEF 2006). Kenya is covered by this project. The target is to install a capacity of 40 MW during the project and 20 MW post-project, reducing greenhouse gas emissions directly by approximately 3.26 million tons of CO_2 equivalent over 20 years. The project is being implemented by The Energy, Environment and Development Network for Africa (AFREPREN/FWD).

Agriculture

The agriculture sector is the largest of the economy, and constitutes the single largest source sector of GHGs, particularly CH_4 from enteric fermentation and N_2O emissions from soil cultivation. There are a range of mitigation measures that could be considered to address these sources.

Table 8. Mitigation options for the agricultural sector

Option category	Option
Cropland management	Nutrient management, particularly with respect to method and timing of fertiliser application, to improve N use efficiency
	Reducing or no tillage farming practices. Soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion; reduced tillage can avoid / reduce losses
	Water management. Increased or more effective irrigation can enhance carbon storage in soils through increased yields and residue returns [-ve: potential gains offset by energy for pumping, increased emissions from fertilisers]
	Rice management. Reduce CH_4 emissions through various practices including draining and using alternative rice varieties.
	Agro-forestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. [+ve: strong synergies forest protection, and adaptation; -ve: lower intensity of yields]
	Returning cropland to another land cover, increasing the carbon storage in soils / vegetation
Grazing land management and pasture improvement	Grazing intensity (and timing) can influence the removal, growth, carbon allocation, and flora of grasslands, and therefore affecting level of carbon accrual in soils
	Increasing productivity e.g. fertilisers. Application can increase yields and carbon storage. However, it can also lead to N_2O emissions thereby offsetting some of the benefits.
	Nutrient management – as mentioned above for croplands
	Reducing biomass burning, as this can lead to CH_4 emissions from combustion, reduce the albedo of the land surface, plus contribute to climate change through different indirect ways.
	Species introduction: Introducing grass species with higher productivity, or carbon allocation to deeper roots, has been shown to increase soil carbon.
Livestock management	Improved feeding practices, for example, feeding more concentrates, normally replacing forages. Although concentrates may increase daily methane emissions per animal, emissions per kg feed intake and per kg-product are almost invariably reduced.
	Specific agents and dietary additives. A wide range of specific agents, mostly aimed at suppressing methanogenesis, has been proposed as dietary additives to reduce CH4 emissions.
	Longer-term management changes and animal breeding. Increasing productivity through breeding and better management practices, such as a reduction in the number of replacement heifers, often reduces methane output per unit of animal product.
Other	Management of organic/peaty soils. Due to the high storage of carbon in such soils, use of these soils for agriculture can lead to CO_2 / N_2O emissions in particular. This is because soils are drained, which aerates the soil, favouring decomposition. Emissions can be reduced by practices such as avoiding row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table. The most important mitigation practice is avoiding the drainage of these soils in the first place or re-establishing a high water table
	Restoration of degraded lands, which may lead to enhanced carbon storage. Such measures have strong synergies with adaptation.
	Manure management. Animal manures can release significant amounts of N_2O and CH_4 during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling, use of solid covers, mechanically separating solids from slurry, or by capturing the CH4 emitted. The manures can also be digested anaerobically to maximize CH_4 retrieval as a renewable.

NB. Primarily sourced from the IPCC 4th Assessment Report WG3 (Smith et al. 2007)

Whilst measures on the whole are low or negative cost; Mckinsey (2009) analysis suggests that over 90% of abatement potential in 2030 for the sector globally could be achieved at a cost of less than $10 /t$CO_2$ eq. However, there are issues with implementation, particular across a sector that is often fragmented, with many smaller farms and small-holdings. This inevitably makes policy implementation more problematic.

The First National Communication (GoK 2002) stated that the Government had *adopted wide ranging measures and policy instruments that also address GHG emissions* in this sector. The type of options include:

- Methane reduction in rice cultivation through use of different rice varieties and better irrigation control
- Recovery and use of methane from livestock through biogas technologies
- Animal breeding and genetic improvements to reduce methane emissions
- Improved or reduced application of inorganic fertilisers
- Increased or maintained soil carbon in cultivated land through recycling agricultural wastes, mulching, better tilling, reduced burning, reducing soil runoff / erosion and returning marginal land to natural plant coverage.

The TNA (GoK 2005) highlights the different opportunities for synergies between adaptation and mitigation to climate change in the agricultural sector. Mitigation is important given that the sector is the largest source of GHG emissions. Carbon sequestration projects involve activities that increase carbon stores in terrestrial ecosystems, including agro-ecosystems. Activities such as tree growing, reduced tillage farming, improved tilling techniques, ecosystem restoration, and soil conservation all increase carbon stores in ecosystems.

The major constraints to the implementation of mitigation options in the agriculture sector include financial costs, lack of quality data and information, inadequate extension services, inappropriate technologies, inadequate policies and lack of economic incentives.

It is clear that the agriculture sector is significant emitter of emissions. Mitigation options exist that are low cost but often difficult to implement. It is not clear what strategies Kenya has in place specifically to deal with this issue; however, it is clear that to address emissions from the sector, such options are going to have to complement other significant priorities such as food security, improving land productivity and adapting to increasing climate impacts.

Of course, agriculture is a very climate sensitive sector, and will be affected by climate change, though this may involve positive and negative effects. The consideration of any mitigation in the sector must be undertaken alongside consideration of the potential effects of temperature, CO_2 fertilisation, water availability, extreme events, pests and diseases, and complex interactions with other key sectors, e.g. water availability for irrigation, under a changing climate. The analysis of the impacts of climate change on agriculture is assessed in the climate change impacts section of the main report.

Forestry

Maintaining and expanding the forests of Kenya is critical for ensuring that natural resources are safeguarded. MEMR (2009) list the importance of forests for:

- Conserving biological diversity and wildlife habitats (also important for tourism)
- Water catchments
- Conserving and protecting soils
- Products such as timber and fuel wood, and non-wood products e.g. medicines

They estimate that the forest contributes in excess of KSh 20 billion directly to the economy annually and employs 50,000 people directly and another 300,000 indirectly. In addition, over one million households living within a radius of five kilometers from the forest reserves depend on forests for basic living needs.

Forests also play an essential role in both climate change mitigation (acting as sinks) but also an important role in adaptation (e.g. water catchment management and soil protection). Given the importance of forests outlined above, protecting and expanding forest cover as part of a low carbon strategy would be supported by a range of other equally important sustainability drivers. Agro-forestry can also be an important sustainable and integrated way of protecting forests whilst maintaining small-scale agriculture, and has strong links to adaptation strategies (see SCC-Vi Agroforestry project in Kisumu case study in adaptation section of this study).

Key mitigation options listed by the IPCC are shown in Table 9 below.

Table 9. Mitigation options for the forestry sector

Option	Co-benefits	Barriers
Reducing deforestation and degradation	Maintain livelihoods using forest resource Biodiversity preserved Maintain ecosystem services	Pressures for alternative land uses e.g. agriculture Domestics energy needs Timber export market
Afforestation / reforestation	Reduce soil erosion Improve water and soil quality Enhance biodiversity and wildlife habitat improve the aesthetic / amenity value of the area New economic resource	Pressures for alternative land uses e.g. agriculture
Forest management to increase stand- and landscape-level carbon density		
Increasing off-site carbon stocks in wood products and enhancing product and fuel substitution	Energy conservation through the use of bioenergy	

Source: IPCC 4th Assessment Report – mitigation (Nabuurs et al. 2007)

In Africa, options for mitigation are viewed as relatively cost effective. The IPCC's 4th Assessment report (Nabuurs et al. 2007) cites estimates from forestry modeling that indicate that 70% of the mitigation potential can be undertaken at \$1-20 /tCO_2, and near 90% between \$20-50/tCO_2. The McKinsey cost curve analyses that have been done for Brazil and Indonesia, which focus on forestry, support this finding – although debates continue as to the opportunity cost of foregoing the use of land for non-forestry activities.

As set out in the Vision 2030, the Government is committed to increasing forest cover from the current 3% to 10% (additional 4.1 million hectares) by 2030. This requires 384 million seedlings to be grown per year, at a substantial annual cost of KSh 7.6 billion (MEMR 2009). Importantly, the success of this initiative will depend on a number of other factors – fuelwood demand, value of forestry assets to tourism, access to carbon finance, agriculture sector needs and other landuse pressures.

Two important carbon finance opportunities in the forestry sector to fund activities such as those outlined above include:

- The creation of carbon sinks through afforestation / reforestation activities. Carbon offsets may be sold either to compliance or voluntary markets. However, there are still very few registered A/R projects under the CDM (for compliance markets) due to technological barriers, high transaction and MRV costs and challenges with project viability. Projects developed using voluntary standards (e.g. Voluntary Carbon Standard, CCB, Carbon Fix, Plan Vivo) are limited in number to date but include; Forest Again Kakamega Forest in Western Kenya using the CCB standard, Bushenyi project in Uganda and Trees Sustain Life project in Tanzania using the Plan Vivo standard, the Kikonda project in Uganda using the Carbon Fix standard, the Green Belt Movement on Mount Kenya (as described in the case study below).

Case study 5. Green Belt Movement Reforestation

Funder: World Bank Carbon Finance Unit (through BioCarbon Fund)
Implementation by: Green Belt Movement

Sources: http://wbcarbonfinance.org/Router.cfm?Page=Projport&ProjID=9635,
http://greenbeltmovement.org/index.php

Description: The project proposes to reforest 1,876 ha of degraded public land and private land with high community access in the Aberdare Range and Mount Kenya watersheds. The project will pay local communities and provide them with the technology and knowledge to reforest, and manage the new forest. Communities will be organised in Community Forest Associations (CFAs) that will participate to each step of the project and develop management plans. The long term goal is to use the re-grown forest in a sustainable manner for a variety of products including fuel wood, charcoal, timber, medicinal and other uses.

Benefits:
Sequester around 0.1 Mt CO_2e by 2012 and 0.38 Mt CO_2e by 2017
The project is targeting specifically denuded steep sloped lands in important water catchment areas, and will therefore bring benefits including reducing the erosion process, protecting the water sources, and regulating water flows.
Increase biodiversity due to re-introduction of natural tree species
Farmers income increased through the payments for environmental services
Social benefits include sustainable provision of forest products and improved social organization and capacities

- The protection and expanding of existing carbon sinks in forests and other valuable habitats through activities that result in reduced rates of deforestation and forest degradation. This is referred to as REDD (Reduced Emissions from Deforestation and forest Degradation). So far funds have been established for activities that result in REDD in six Congo Basin countries and Tanzania. Kenya is about to begin the process of preparing its REDD Readiness Plan (funded through Forest Carbon Partnership Facility).

Synergies with adaptation are strong, as shown by the adaptation / mitigation matrix in Table 10, sourced from the IPCC 4th Assessment report (Nabuurs 2007). This illustrates the vulnerability of forests to climate impacts, and the need to integrate mitigation and adaptation strategies. It also illustrates that there are limited conflicts between adaptation and mitigation measures.

Mitigation option	*Vulnerability of the mitigation option to climate change*	*Adaptation options*	*Implications for GHG emissions due to adaptation*
A. Increasing or maintaining the forest area			
Reducing deforestation and forest degradation	Vulnerable to changes in rainfall, higher temperatures (native forest dieback, pest attack, fire and, droughts)	Fire and pest management Protected area management Linking corridors of protected areas	No or marginal implications for GHG emissions, positive if the effect of perturbations induced by climate change can be reduced
Afforestation / Reforestation	Vulnerable to changes in rainfall, and higher temperatures (increase of forest fires, pests, dieback due to drought)	Species mix at different scales Fire and pest management Increase biodiversity in plantations by multi-species plantations. Introduction of irrigation and fertilisation Soil conservation	No or marginal implications for GHG emissions, positive if the effect of perturbations induced by climate change can be reduced May lead to increase in emissions from soils or use of machinery and fertilizer
B. Changing forest management: increasing carbon density at plot and landscape level			
Forest management in plantations	Vulnerable to changes in rainfall, and higher temperatures (i.e. managed forest dieback due to pest or droughts)	Pest and forest fire management. Adjust rotation periods Species mix at different scales	Marginal implications on GHGs. May lead to increase in emissions from soils or use of machinery or fertilizer use
Forest management in native forest	Vulnerable to changes in rainfall, and higher temperatures (i.e. managed forest dieback due to pest, or droughts)	Pest and fire management Species mix at different scales	No or marginal
C. Substitution of energy intensive materials			
Increasing substitution of fossil energy intensive products by wood products	Stocks in products not vulnerable to climate change		No implications in GHGs emissions
D. Bio-energy			
Bio-energy production from forestry	An intensively managed plantation from where biomass feedstock comes is vulnerable to pests, drought and fire occurrence, but the activity of substitution is not.	Suitable selection of species to cope with changing climate Pest and fire management	No implications for GHG emissions except from fertilizer or machinery use

Table 10. Synergies with adaptation for different mitigation options for forestry (Nabuurs 2007)

Note, however, that the forest and forestry sector are potentially vulnerable to the future effects of climate change. Forestry is a sector with long life-times: stands established now are likely to be situ for decades and will therefore be exposed to the more significant climate signals. Projections of the net effects of climate change on forestry are complex. Tree growth may be enhanced by some processes but might be negatively affected by others However, there is a need for any mitigation options in the forests sector to be considered alongside these potential impacts. The analysis of the impacts of climate change on forest is assessed in the climate change impacts section of the main report.